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Essential oils of the ginger plants *Meistera caudata* and *Conamomum vietnamense*: chemical compositions, antimicrobial, and mosquito larvicidal activities

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Abstract: The current study describes the chemical identification, antimicrobial, and mosquito larvicidal activities of essential oils from *Meistera caudata* and *Conamomum vietnamense*, growing in Vietnam. Essential oils were extracted from the leaves and rhizomes, and characterized by the GC-FID/MS (gas chromatography-flame ionization detection/mass spectrometry) analysis. Monoterpenes (33.1–89.2 %) were the main chemical class found in these oils. *β*-Pinene (30.8 %) and *α*-pinene (23.8 %) were two major compounds in *M. caudata* leaf oil. *C. vietnamense* leaf and rhizome essential oils were dominated by 1,8-cineole (47.9–62.0 %) and limonene (10.3–16.2 %). With the same MIC (minimum inhibitory concentration) value of 25 μg/mL, *C. vietnamense* leaf and rhizome essential oils strongly inhibited the growth of Gram-positive bacteria *Staphylococcus aureus* ATCC 29213 and *Bacillus subtilis* ATCC 6501, respectively. For 24 and 48-h treatments, *C. vietnamense* leaf essential oil strongly controlled the growth of mosquito *Aedes aegypti* with the respective LC_{50} values of 7.67 and 6.73 μg/mL, and the respective LC_{90} values of 13.37 and 10.83 μg/mL. In the same manner, *C. vietnamense* rhizome essential oil also showed strong mosquito larvicidal activity against *Aedes albopictus* with the LC_{50} values of 12.37 and 12.00 μg/mL, and the LC_{90} values of 20.56 and 18.58 μg/mL, respectively. *C. vietnamense* essential essential oils containing a high amount of 1,8-cineole are generally better than *M. caudata* essential essential oils in both two biological assays.

Keywords: antimicrobial; *Conamomum vietnamense*; essential oil; *Meistera caudata*; mosquito larvicidal.

1 Introduction

Zingiberaceae (the ginger family) is a big family of small to large herbaceous plants made up of 53 genera and more than 1600 species [1]. The plants of this family are widely distributed in tropical and subtropical areas of Asia, Africa, Australia, and America [2]. Importantly, many ginger species established great economic value as flavors, spices, beverages, cosmetic and pharmacological products [3]. Accumulative evidence has shown that Zingiberaceae plants are a rich resource of phytochemicals type essential oils. Therewith, ginger essential oils include phenolics, ketones, and aliphatic compounds, especially in terms of terpenoids, as well as they have a variety of pharmacological activities such as antimicrobial, anticancer, antioxidative, anti-inflammatory, analgetic, larvicidal activities, and slimming aromatherapy [4–6].

Meistera is an Asian genus of flowering plants in the ginger family [7]. About 10 species were recorded, and plants of this genus are native to Sri Lanka, India, New Guinea, Australia, and Indochina [7]. *Conamomum* is a small genus of 11 flowering plants in the tribe Alpinieae of the ginger family [8]. Its native range is Indochina, Peninsular Malaysia, Singapore, Sumatra, and Borneo [8]. It should be noted that *Meistera* and *Conamomum* have previously been classified in the genus *Amomum* [7, 8]. Recently, *Meistera caudata* Šída f. & Škorničk. and *Conamomum vietnamense* N.S.Lý & T.S. Hoang, two endemic Vietnamese ginger plants, were collected and namely identified as new species [7–9].

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To date, there have not yet been studies on essential oils of the plants of these two genera *Meistera* and *Conamomum*. Our current study wishes to provide new information on chemical compositions of essential oils in the leaves and rhizomes of *M. caudata* and *C. vietnamense*, collected from the Central Highland region of Vietnam. The obtained essential oils were further screened for antimicrobial and mosquito larvicidal activities.

2 Materials and methods

2.1 Plant materials

The fresh leaves and rhizomes of *M. caudata* were collected from Bidoup Nui Ba National Park, Lac Duong, Lamdong, Vietnam in 04/2022, whereas the fresh leaves and rhizomes of *C. vietnamense* were collected from Loc Bac Commune, Bao Lam, Lamdong Vietnam in 04/2022. Their Latin names were identified by the co-author Ly Ngoc Sam. The voucher specimens Ly-1627 (*M. caudata* leaves and rhizomes) and Ly-1621 (*C. vietnamense* leaves and rhizomes) were deposited in the VNM herbarium, Institute of Tropical Biology. The obtained samples (3.0 kg each) were immediately cut into pieces, and hydro-distilled using a Clevenger apparatus for 4.0 h to give the yellowish essential oils. The yields of extraction, which were calculated following fresh materials, reached a range of 0.2–0.25 %.

2.2 GC-FID/MS analysis

The GC-FID analysis was carried out following the conditions [10–12]: Agilent Technologies HP-5 MS column (30 m × 0.25 mm, film thickness 0.25 µm), Helium carrier gas (1.1 mL/min), injector temperature of 260 °C, detector temperature of 270 °C, column temperature program: 65 °C (3 min hold), increase to 230 °C (4 °C/min), 230 °C (10 min hold), inlet pressure of 6.0 kPa, split mode injection (split ratio, 10:1), 1.1 µL injection volume.

The GC-MS analysis was performed in the same manner: Agilent Technologies HP 7890A Plus Chromatograph (Santa Clara, CA, USA), HP-5 MS (30 m × 0.25 mm, film thickness 0.25 µm) column, HP 5973 MSD mass detector, Helium carrier gas (1.1 mL/min), MS ionization voltage of 70 eV, emission current of 40 mA, acquisitions range of 40–400 amu, a sampling rate of 1.0 scan/s. The GC was operated under the same circumstances as GC-FID. The retention indices (RI) based on a series of C_7-C_{30} *n*-alkanes, co-injection with pure compounds (Sigma-Aldrich, St. Louis, MO, USA) or identified essential oil components, MS library search (NIST 17 and Wiley Version 10), and comparison with the literature MS fragmentation were used to identify the chemical components of the essential oils [13, 14]. Based solely on the GC peak area (FID response) and without the use of correction factors, the relative concentrations (%) of the constituents were computed. The measurements were made three times.

2.3 Antimicrobial assay

Antimicrobial activity of essential oils was evaluated against eight strains [15], including Gram-positive [*Bacillus subtilis* ATCC 6501 and *Staphylococcus aureus* ATCC 29213], Gram-negative [*Escherichia coli* ATCC 11775 and *Pseudomonas aeruginosa* ATCC 27853], filamentous fungi [*Aspergillus niger* ATCC 10404 and *Fusarium oxysporum* ATCC10960], and yeasts [*Candida albicans* ATCC 14053 and *Saccharomyces cerevisiae* ATCC 18824]. All strains were acquired from American Type Culture Collection (ATCC). Each strain was sub-cultured for 24 h on tryptic soil agar at 37 °C (bacteria) and on potato dextrose agar at 35 °C (yeasts). The assays were performed in Mueller–Hinton broth (bacteria) and RPMI 1640 culture medium (yeasts). The inoculum was adjusted to 5×10^5 CFU/mL for bacteria and 2.5×10^3 CFU/mL for yeasts.

The tested oil samples were dissolved in DMSO and diluted in a culture medium to achieve concentrations from 400 µg/mL to 4 µg/mL. Inoculated wells with and without antimicrobial agents were assayed to control the adequacy of the broth for microorganism growth and medium sterility, respectively. The final concentration of DMSO (5 %) was also evaluated. The microplates were incubated at 37 °C (bacteria) or 35 °C (yeasts) for 24 h. After that, resazurin (aqueous solution 0.02 %) was added to the microplates to indicate the microorganism viability. Before that, aliquots were aseptically removed from each well, plated onto an adequate culture medium, and incubated. The lowest concentration that allowed no discernible growth of the tested microorganism was identified as the minimum inhibitory concentration (MIC). Streptomycin and tetracycline severed as the standards for Gram-positive and negative bacteria, respectively, while nystatin was used as the standard for fungi and yeasts. DMSO at 5 % was used as a negative control. Each experiment was performed 3 times.

2.4 Mosquito larvicidal activity

Eggs of *Aedes aegypti* and *Aedes albopictus* were purchased from Institute of Biotechnology, VAST, and maintained at the Laboratory of Department of Pharmacy of Duy Tan University, Da Nang, Vietnam. For the assay [16], aliquots of the studied essential oils, dissolved in DMSO (1 % stock solution), were placed in a 300-mL beaker and added to water, containing 20 larvae (third and fourth instar larvae). In each experiment, a set of controls using DMSO was also run for comparison. Mortality was calculated after 24 and 48 h of exposure during which no nutritional supplement was added. The experiments have been carried out at room temperature. Each test was carried out with 3 replicates with several concentrations (100, 50, 25, 12.5, 6.0, 3.0, 1.5, and 0.75 µg/mL). Permethrin was used as a positive control. The acute mosquito larvicidal effects on *Ae. aegypti* and *Ae. albopictus* were recorded after 24 h and 48 h treatments. The data obtained were subjected to log-probit analysis to obtain LC_{50} (50 % lethal concentration), LC_{90} (90 % lethal concentration), and 95 % confidence limits using XLSTAT v. 2018.5 (Addinsoft, Paris, France).

3 Results and discussion

Hydrodistillation of *M. caudata* fresh leaves resulted in a yellow oil with a 0.25 % yield. A total of 35 compounds were identified, accounting for 92.0 % (Table 1). The main chemical classes were monoterpenes (65.7 %), and sesquiterpenes (21.7 %), whereas monoterpenoids (3.5 %), sesquiterpenoids (0.7 %), and non-terpenic compounds (0.4 %) presented as minor compounds. Two monoterpenes β-pinene (30.8 %),

Table 1: The identified compounds (%) in essential oils of two Zingiberaceae plants.

R_t	RI_E	RI_L	Constituents	*M. caudata* leaf oil	*M. caudata* rhizome oil	*C. vietnamense* leaf oil	*C. vietnamense* rhizome oil
10.21	930	924	*α*-Thujene	0.3	0.4		
10.52	940	932	*α*-Pinene	23.8	4.9	3.9	2.8
10.99	955	946	Camphene	2.2	10.7	0.6	2.0
11.70	978	969	Sabinene	0.2	0.1		
11.91	985	974	*β*-Pinene	30.8	6.2	1.0	0.8
12.08	991	988	Myrcene	0.2	0.2	1.9	0.8
12.49	1010	1002	α-Phellandrene			0.8	0.4
12.90	1016	1008	*δ*-3-Carene	0.2	0.3	0.2	0.3
13.34	1029	1022	*p*-Cymene	0.3	0.8	2.3	3.0
13.50	1033	1024	Limonene	0.9	1.6	16.2	10.3
13.65	1038	1026	1,8-Cineole	6.8	7.7	62.0	47.9
14.01	1048	1044	*β*-(*E*)-Ocimene		0.2	0.3	0.3
15.31	1093	1087	2-Nonanone			0.2	
15.66	1101	1088	Fenchone		0.3		
15.75	1099	1097	2-Nonanol	0.3		0.4	
15.81	1101	1095	Linalool	0.6	0.4	1.5	5.2
16.33	1122	1114	*endo*-Fenchol			0.3	0.6
17.48	1148	1137	*trans*-Sabinol	0.3			
17.61	1152	1140	*p*-Methylacetophenone	0.1			
17.71	1155	1141	Camphor	1.5	2.4		0.3
18.18	1174	1162	*δ*-Terpineol			0.2	
18.42	1175	1165	Borneol		1.1	0.9	3.1
18.59	1185	1174	Terpinen-4-ol			0.7	0.6
18.78	1186	1177	Santalone	0.3	0.4		
18.94	1196	1183	Cryptone				0.9
19.21	1197	1186	*α*-Terpineol	0.2	0.1	2.6	2.3
19.44	1204	1194	Myrtenol	0.2			
19.51	1206	1195	Myrtenal	0.2			
20.25	1227	1229	Fenchyl acetate		4.0		1.1
20.43	1239	1232	Thymor methyl ether				0.1
20.79	1249	1238	Cumaldehyde				0.2
21.06	1257	1253	Linalyl acetate				0.9
22.53	1293	1284	Bornyl acetate	0.2	**5.0**		3.4
22.36	1295	1293	2-Undecanone			0.2	
24.34	1348	1335	*δ*-Elemene		0.7		
24.59	1356	1346	*α*-Terpinyl acetate		0.3		
25.33	1285	1379	Geranyl acetate				0.2
25.69	1389	1382	*α*-Copaene	0.5	0.9		0.6
26.16	1404	1389	*cis*-*β*-Elemene	4.4	5.2		
26.85	1432	1412	*α*-Santalene				0.3
26.88	1426	1415	2,5-Dimethoxy-*p*-cymene		0.2		
27.21	1437	1417	*β*-Caryophyllene	0.3	0.8	0.5	0.3
27.48	1446	1432	*α*-*trans*-Bergamotene		0.2		
27.83	1457	1439	Aromadendrene		0.2		
28.29	1471	1452	*α*-Humulene	0.2	0.4		
28.53	1479	1464	9-*epi*-(*E*)-Caryophyllene	0.9	1.5		
28.86	1489	1476	*β*-Chamigrene	0.3			
28.90	1491	1478	*γ*-Muurolene	0.3	1.6		0.4
28.92	1498	1481	2-Tridecanone			0.2	
29.04	1498	1484	Aristolochene				0.2
29.12	1502	1487	Germacrene D	0.8	3.4		
29.35	1505	1491	*β*-Selinene	5.7	3.0		0.2
29.29	1513	1492	α-Muurolene				0.2
29.48	1510	1495	*α*-(*Z*)-Bisabolene	0.1	0.7		

Table 1: (continued)

R_t	RI_E	RI_L	Constituents	*M. caudata* leaf oil	*M. caudata* rhizome oil	*C. vietnamense* leaf oil	*C. vietnamense* rhizome oil
29.60	1514	1498	*α*-Selinene	5.9			
29.64	1515	1500	Bicyclogermacrene		13.3		
29.71	1517	1505	*β*-Bisabolene	1.7	1.6		
29.83	1521	1511	*δ*-Amorphene		0.2		
30.08	1530	1513	*γ*-Cadinene	0.4	2.8	0.2	0.3
30.15	1539	1521	*trans*-Calamenene				0.6
30.28	1537	1522	*δ*-Cadinene	0.2	0.9		
30.44	1542	1529	*γ*-(*E*)-Bisabolene		0.2		
31.06	1563	1548	Elemol		0.2		
31.25	1569	1561	(*E*)-Nerolidol	0.7	0.7	2.7	2.4
31.96	1593	1569	Scapanol		0.2		
31.98	1597	1575	Axenol				0.1
32.08	1600	1577	Spathulenol		2.1		
32.12	1605	1582	Caryophyllene oxide			0.3	1.0
32.78	1622	1600	Rosifoliol		0.2		
32.88	1632	1608	Humulene epoxide II				0.2
33.12	1634	1618	1,10-*di*-*epi*-Cubenol		0.4		
33.31	1647	1627	1-*epi*-Cubenol				0.2
33.43	1651	1630	*γ*-Eudesmol				1.1
33.77	1657	1635	Cadina-1(10),4-dien-8*α*-ol		1.1		
33.84	1659	1638	*epi*-*α*-Cadinol		0.6		0.4
33.94	1663	1644	*α*-Muurolol		0.3		0.3
34.04	1673	1649	*β*-Eudesmol				1.7
34.10	1672	1652	*α*-Eudesmol				0.8
34.22	1675	1652	*α*-Cadinol		1.4		
34.32	1676	1660	*neo*-Intermedeol		1.2		0.8
Total				92.0	93.1	99.7	99.3
Monoterpenes				65.7	33.1	89.2	68.6
Monoterpenoids				3.5	14.0	6.2	17.7
Sesquiterpenes				21.7	37.6	0.7	2.9
Sesquiterpenoids				0.7	8.4	3.0	9.0
Non-terpenic compounds				0.4		0.6	1.1
Compounds were identified based on their RI and MS data							

R_t, retention time; RI_E, retention indices relative to *n*-alkanes (C7-C30) on HP-5 MS column; RI_L, retention indices from Adams book [13] and the NIST standard database [14].

and *α*-pinene (23.8 %) were the principal compounds, followed by several significant compounds 1,8-cineole (6.8 %), *α*-selinene (5.9 %), *β*-selinene (5.7 %), *cis*-*β*-elemene (4.4 %).

The obtained essential oil from *M. caudata* rhizomes was yellow with a 0.2 % yield. This essential oil sample was characterized by the presence of 50 compounds, corresponding to 93.1 %. All identified compounds belong to terpenoids, in which sesquiterpene, monoterpenes, monoterpenoids, and sesquiterpenoids reached 37.6, 33.1, 14.0, and 8.4 %, respectively.

Sesquiterpene bicyclogermacrene (13.3 %), and monoterpene camphene (10.7 %) were the main compounds. Some compounds have the percentages of greater than 1.0 %, such as 1,8-cineole (7.7 %) *β*-pinene (6.2 %), *cis*-*β*-elemene (5.2 %), bornyl acetate (5.0 %), *α*-pinene (4.9 %), fenchyl acetate (4.0 %), germacrene D (3.4 %), *β*-selinene (3.0 %), *γ*-cadinene (2.8 %), camphor (2.4 %), and spathulenol (2.1 %). Apparently, there is a difference between these two essential oils. The percentages of *α*-pinene and *β*-pinene drastically decreased in the rhizome. However, some compounds, especially camphene and bicyclogermacrene were not significant or absent in the leaf oil, but they appeared as the main compounds in the rhizome essential oil. Various compounds, e.g., *α*-selinene (5.9 %), appeared in the leaf essential oil, but they were absent in the rhizome essential oil, and *vice versa*.

Hydrodistilled extraction of *C. vietnamense* leaves produced a yellow oil with a 0.23 % yield. 24 compounds were identified, which accounted for (99.7 %) (Table 1). Monoterpenes (89.2 %) prevailed, whereas the percentages of monoterpenoids, sesquiterpenoids, sesquiterpenes, and

non-terpenic compounds were less than 6.2 %. Monoterpene 1,8-cineole has an impressive amount of 62.0 %, followed by limonene (16.2 %). Several compounds with more than 1.0 % included *α*-pinene (3.9 %), (*E*)-nerolidol (2.7 %), *α*-terpineol (2.6 %), *o*-cymene (2.3 %), myrcene (1.9 %), linalool (1.5 %), and *β*-pinene (1.0 %).

The last essential oil (yellow color, 0.21 % yield) derived from *C. vietnamense* rhizomes was identified, containing 43 compounds (99.3 %). Monoterpenes, at 68.6 %, were still the main chemical class, while the percentages of 17.7, 9.0, 2.9, and 1.1 % were assigned to the groups of monoterpenoids, sesquiterpenoids, sesquiterpenes, and non-terpenic compounds, respectively. Two major monoterpenes 1,8-cineole and limonene in the rhizome essential oil were lower than those in the leaf essential oil by 14.1 and 5.9 %, respectively. The rhizome essential oil was also associated with the presence of other significant compounds, such as linalool (5.2 %), *o*-cymene (3.0 %), bornyl acetate (3.4 %), and borneol (3.1 %). Various compounds were found in the rhizome essential oil, but they were absent in the leaf essential oil, and *vice versa*. For instance, bornyl acetate (3.4 %), *β*-eudesmol (1.7 %), fenchyl acetate and *γ*-eudesmol (1.1 %), cryptone and linalyl acetate (0.9 %), *α*-eudesmol and *neo*-intermedeol (0.8 %), *trans*-calamenene (0.6 %), camphor and *α*-santalene (0.3 %), cumaldehyde, aristolochene, geranyl acetate, α-muurolene, and 1-*epi*-cubenol (0.2 %), and thymor methyl ether and axenol (0.1 %) were only detected in the rhizome essential oil.

A recent publication on phytochemistry of *Amomum* essential oils also confirmed that essential oils of *A. aromaticum*, *A. compactum*, *A. kravanh*, *A. korarima*, *A. tsao-ko*, *Amomum subulatum*, and *A. verum* were rich in 1,8-cineole, while *α*-pinene and *β*-pinene are other main constituents in essential oils of various *Amomum* species [17]. Therefore, our current result suggests a close relationship between two current studied genera and *Amomum*.

Four essential oil samples have been further subjected to antimicrobial assay, and the result is outlined in Table 2. The leaf essential oil of *M. caudata* possessed the MIC value of 256 μg/mL against two Gram-positive bacteria *B. subtilis* and *S. aureus*, and yeast *S. cerevisiae*, and the MIC value of 128 μg/mL against fungus *F. oxysporum*. Meanwhile, *M. caudata* rhizome essential oil was moderately active against fungus *A. niger* and yeast *S. cerevisiae* with the MIC value of 128 μg/mL. This oil also inhibited Gram-positive bacterium *B. subtilis* and Gram-negative bacterium *E. coli* with the MIC value of 256 μg/mL. As shown in Table 2, with the same MIC value of 25 μg/mL, *C. vietnamense* leaf essential oil showed strong antimicrobial activity against Gram-positive bacterium *S. aureus*, as well as the rhizome essential oil was strongly active against Gram-positive bacterium *B. subtilis*. In general, the tested essential oils are more susceptible to Gram-positive bacteria than Gram-negative bacteria. This phenomenon can be explained that the cell wall of the Gram-negative bacteria is a complex envelope, which structurally formulated by the cytoplasmic membrane, the periplasm and outer membrane [18]. It is further observed that both these two oils controlled the growth of fungus *A. niger* and yeast *S. cervisiae* with the MIC values of 128 and 256 μg/mL, respectively. However, they failed to inhibit two studied Gram-negative bacteria.

Vietnamese *Amomum* essential oils seem to be potential agents for antimicrobial activity. *Amomum cinnamomeum* leaf and rhizome oils mainly caused the inhibition of *Enterococcus faecalis*, *S. aureus*, *Bacillus cereus*, and *C. albicans* with the MIC values of 16–64 μg/mL [19]. The rhizome essential oil of *Amomum rubidium* suppressed two fungi *A. niger* and *F. oxysporum* with the same MIC value of 50 μg/mL [20]. The aerial part and rhizome essential oils of *Amomum muricarpum* containing a high amount of α-pinene (62.94–74.97 %) have induced the MIC value of 100 μg/mL

Table 2: Antimicrobial activity of the studied essential oils.

Microbial strains		Minimum inhibitory concentration (MIC: μg/mL)						
		M. caudata leaf oil	*M. caudata* rhizome oil	*C. vietnamense* leaf oil	*C. vietnamense* rhizome oil	Streptomycin	Tetracyclin	Nystatin
Gram (+)	*B. subtilis*	256	256	>400	25	6.25		
	S. aureus	256	>400	25	>400	12.5		
Gram (−)	*E. coli*	>400	256	>400	>400		6.25	
	P. aeruginosa	>400	>400	>400	>400		12.5	
Fungi	*A. niger*	>400	128	128	128			25.0
	F. oxysporum	128	>400	>400	>400			12.5
Yeasts	*C. albicans*	>400	>400	>400	>400			12.5
	S. cerevisiae	256	128	256	256			6.25

[21]. Our current result, once again, evidenced the useful values of the related *Amomum* species for pathogenic bacterial treatments.

Four oil samples were further considered mosquito larvicidal activity against *Aedes aegypti* and *Ae. albopictus* during 24 and 48-h treatments. Crude extracts exhibited strong mosquito larvicidal activity with $LC_{50} \leq 50$ μg/mL, moderate activity with $50 < LC_{50} \leq 100$ μg/mL, weak activity with $100 < LC_{50} \leq 750$ μg/mL, and inactive with $LC_{50} > 750$ μg/mL [22]. From this criterion and comparison with the results of the positive control permethrin, four studied essential oils generally exhibited strong activity against *Ae. aegypti* and *Ae. albopictus* with the LC_{50} values of 7.67–41.09 μg/mL during 24 and 48-h treatments (Table 3).

Taking *Ae. aegypti* inhibition into consideration, *C. vietnamense* leaf essential oil showed the strongest activity with LC_{50} value of 7.67 μg/mL for 24-h treatment, followed by *C. vietnamense* rhizome essential oil (LC_{50} 15.91 μg/mL), *M. caudata* leaf essential oil (LC_{50} 20.70 μg/mL), and *M. caudata* rhizome essential oil (LC_{50} 38.48 μg/mL). This phenomenon has been also observed with the LC_{90} values for 24-h treatment, as well as the LC_{50} and LC_{90} results for 24 and 48-h treatments. Regarding *Ae. albopictus* inhibition, *C. vietnamense* rhizome essential oil showed the best activity with the lowest LC_{50} and LC_{90} values for 24 and 48-h treatments. The next order of the LC_{50} and LC_{90} values was assigned as *C. vietnamense* leaf essential oil < *M. caudata* leaf essential oil < *M. caudata* rhizome essential oil (Table 3). Collectively, *C. vietnamense* essential oils are always better than *Meistera caudate* essential oils in this experiment. This result can be explained by the role of the major compound 1,8-cineole [23, 24]. Our result matches well with various studies since *Amomum* essential oils should be suitable for mosquito larvicidal activity. *A. subulatum* leaf essential oil containing a high amount of 1,8-cineole has displayed a remarkable toxic effect against *Anophelex subpictus*, *Ae. albopictus* and *Culex tritaeniorhynchus* with the LC_{50} values of 41.25–48.12 μg/mL, and the LC_{90} values of 80.29–89.30 μg/mL [24]. *A. rubidium* rhizome essential oil demonstrated mosquito larvicidal activity against *Ae. aegypti* with the LC_{50} values of about 22.0 μg/mL, and the LC_{90} values of about 31.0 μg/mL for 24 and 48-h treatments [25].

Table 3: Mosquito larvicidal activity of the studied essential oils against *Aedes aegypti* and *Aedes albopictus*.

Samples	LC_{50} (95 % confidence levels)	LC_{90} (95 % confidence levels)	χ^2	*p*
	24-h treatment (*Ae. aegypti*)			
M. caudata leaf oil	20.70 (18.78–22.79)	37.34 (32.81–44.51)	6.13433	0.189
M. caudata rhizome oil	38.48 (35.27–41.85)	59.05 (53.17–68.23)	3.0007	0.392
C. vietnamense leaf oil	7.67 (6.98–8.43)	13.37 (11.76–15.97)	1.32897	0.856
C. vietnamense rhizome oil	15.91 (14.67–17.33)	23.76 (21.27–27.85)	0.83942	0.840
Permethrin (control)	0.0094 (0.0082–0.0107)	0.0211 (0.0185–0.0249)	57.6	0.000
	48-h treatment (*Ae. aegypti*)			
M. caudata leaf oil	17.68 (16.06–19.61)	29.52 (26.62–33.58)	8.83479	0.065
M. caudata rhizome oil	36.43 (33.47–39.59)	53.57 (48.45–61.43)	4.27090	0.234
C. vietnamense leaf oil	6.73 (6.18–7.36)	10.83 (9.61–12.91)	0.55540	0.968
C. vietnamense rhizome oil	15.37 (14.17–16.78)	23.45 (20.93–27.65)	1.31903	0.725
	24-h treatment (*Ae. albopictus*)			
M. caudata leaf oil	21.41 (19.36–23.68)	40.93 (35.67–49.27)	19.6035	0.001
M. caudata rhizome oil	41.09 (37.00–44.07)	52.64 (49.20–57.89)	0.03378	0.998
C. vietnamense leaf oil	20.87 (18.84–22.33)	26.92 (25.17–29.75)	0.04836	1.000
C. vietnamense rhizome oil	12.37 (11.31–13.51)	20.56 (18.20–24.54)	0.78307	0.854
Permethrin (control)	0.0094 (0.0082–0.0107)	0.0211 (0.0185–0.0249)	57.6	0.000
	48-h treatment (*Ae. albopictus*)			
M. caudata leaf oil	19.46 (17.48–21.65)	40.21 (34.68–48.92)	28.3748	0.000
M. caudata rhizome oil	36.34 (33.33–39.44)	47.97 (43.90–53.89)	0.04569	0.997
C. vietnamense leaf oil	17.94 (16.45–19.50)	23.46 (21.43–26.42)	0.03359	1.000
C. vietnamense rhizome oil	12.00 (11.04–13.00)	18.58 (16.64–21.98)	4.46564	0.215

LC_{50}, 50 % lethal concentration; LC_{90}, 90 % lethal concentration.

4 Conclusions

For the first time, the present study provides the chemical identification, antimicrobial, and mosquito larvicidal potentials of essential oils from the leaves and rhizomes of two endemic Vietnamese ginger species *M. caudata* and *C. vietnamense*. *M. caudata* leaf essential oil was dominated by *β*-pinene (30.8 %) and *α*-pinene (23.8 %), whereas *M. caudata* rhizome essential oil was characterized by bicyclogermacrene (13.3 %) and camphene (10.7 %). 1,8-Cineole (47.9–62.0 %) and limonene (10.3–16.2 %) were the principal compounds in *C. vietnamense* leaf and rhizome essential oils. The studied essential oils showed antimicrobial activity at different levels. Especially, with the same MIC value of 25 µg/mL, *C. vietnamense* leaf and rhizome essential oils displayed strong effect against bacteria *S. aureus* and *B. subtilis*, respectively. Both four studied oils exhibited strong activity against two mosquitoes *Ae. aegypti* and *Ae. albopictus* with the LC_{50} values of 7.67–41.09 µg/mL during 24 and 48-h treatments. *C. vietnamense* essential oils are generally better than *M. caudata* essential oils in both two biological assays. More phytochemical and pharmacological studies are needed to highlight the many benefits of these two species and other ginger plants. Mechanism of biological actions should be taken into consideration.

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