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Chemical Compostions of Essential Oils and Antimicrobial Activity of *Hyptis suaveolens* (L.) Poit. (Lamiaceae) from Vietnam

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Authors' contributions

This work was carried out in collaboration among all authors. Authors LTH and DND designed the study and wrote the protocol. Author IAO performed the statistical analysis while author NTC managed the analysis of the study. Author IAO wrote the first and final drafts of the manuscript. Authors IAO and DND managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This present study described the chemical constituents and antimicrobial activity of essential oils hydrodistiled from the leaves and flowers of *Hyptis suaveolens* (L.) Poit.
Study Design: This research was designed to accommodate different stages such as collection of authentic sample of *Hyptis suaveolens,* obtain essential oil by hydrodistillation, chemical analysis of the oil samples by gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC/MS) and screening of the essential oils for antimicrobial activity.

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Place and Duration of Study: School of Natural Science, Vinh University, Vinh City, Nghệ An Province, Vietnam, between August and December 2018.
Methodology: The leaves and flowers of *H. suaveolens* used for this study were gotten from Đồng Văn Commune, Pù Hoạt Nature Reserve, Vietnam. The collection was done in December 2018. Essential oils were distilled off using hydrodistillation method according to established procedure. The determination of antimicrobial efficacy of essential oils of *H. suaveolens* will be achieved by the method of microdilution broth susceptibility assay. The minimum inhibitory concentration (MIC) and IC_{50} were evaluated accordingly.
Results: The major compounds in the oil were β-caryophyllene (31.1% and 33.7%), caryophyllene oxide (17.6% and 3.9%), phytol (9.9% and 2.7%) and α-humulene (6.7% and 6.6%), respectively. The leaf oil displayed strong antimicrobial activity against *Enterococcus faecalis* ATCC299212, *Bacillus cereus* ATCC14579 and *Candida albican*s ATCC10231 with minimum inhibitory concentrations (MIC) of 16.0, 32.0 and 16.0 µg/mL respectively, while the IC_{50} values were 5.78, 9.35 and 6.78 µg/mL, respectively. The flower oil showed activity towards the same organisms with MIC values of 64.0, 64.0 and 16.0 µg/mL, respectively; with IC_{50} values of 20.45, 26.78 and 6.78 µg/mL, respectively. Both essential oils exhibited moderate activity towards *Staphylococcus aureus* ATCC25923 with MIC of 256.0 µg/mL.
Conclusion: The results are indication of the potential of *H. suaveolens* essential oils as source of antimicrobial agents.

Keywords: Hyptis suaveolens; leaves; flowers; essential oil; terpenes; antimicrobial activity.

1. INTRODUCTION

Plants are part of our daily life and their essential oils have been extracted from over 3000 different species that have domestic, industrial and medicinal uses [1]. Essential oils as part of natural products are well known for their various biological and pharmacological effects. These activities are normally related to the chemical substances mostly terpenes and non-terpenes present in the essential oils [2]. In recent years, greater attention has been paid to the screening of antimicrobial activity from essential oil as source of developing new antimicrobial agents to combat microbial resistance. Review articles describing the antimicrobial potentials of essentials from other parts of the world have been published [3]. The potency of essential oils derived from plants grown world over including Vietnam as antimicrobial agents have been documented. For example, in Vietnam essential oils from the rhizome oil of *Amomum rubidium* Lamxay & N. S. Lý exhibited antimicrobial activity against *Escherichia coli* (ATCC 25922) and *Fusarium oxysporum* (ATCC 48112) with MIC of 50 µg/mL [4]. The antimicrobial activity of essential oils from the leaf [5] and rhizome [6] of *Zingiber zerumbet* (L.), Smith, the leaf and wood of *Taxus chinensis* (Rehder & EH Wilson) Rehder [7], the rhizomes of *Alpinia tonkinensis* Gagnep and *Alpinia globosa* Hour [8] and the pseudo-stem of *Zingiber castaneum* Škorničk. & Q.B. [9] were recently evaluated and reported.

Hyptis suaveolens (L.) Poit is one of the important traditional medicinal plants belonging to family Lamiaceae. It is commonly called Bush mint, Bush tea, Pignut, or Chan. The plant is native to the tropics of America and now considered as a weed worldwide. *H. suaveolens* is a fast-growing perennial and aromatic herb, 0.4-2 m tall with hairy stems and leaves, having branches and usually woody at the base. The leaves are weak, oval in outline, tip and broadly pointed [10]. Phytochemical analysis of the plant led to the characterization of quercetin 3-*O*-*β*-D-glucopyranoside, apigenin, sorbifolin, quercetin, kaempferol, genkwanin, rosmarinic acid, methyl rosmarinate, podophyllotoxin and picropodophyllotoxin [11].

The chemical constituents of essential oil from *H. suaveolens* have been reported from a different origin. However, the oils from *H. suaveolens* differ in composition according to the geographic origin (genotype) of the plants. Different terpene compounds have been described from the essential oils analyzed fromm various parts of *H. suaveolens*. There are oil samples in which caryophyllene features as the main component along with other terpenes. The main components of the fresh leaf oil from Tanzania were [12] β-caryophyllene (26.0%) and β-elemene (10.4%).

The constituents of a sample oil of *H. suavelens* from Nigeria [13] were carryophyllene (20.643%) and sabinene (16.711%). The oil composition of immature leaf of *H. suaveolens* [14] revealed the abundance of β-caryophyllene (22.3%), α-phellandrene (10.6%) and caryophyllene oxide (10.3%). β-Caryophyllene (34.65%) and germacrene-D (10.32%) were the main compounds from Indonesia sample [15]. A sample of *H. suaveolens* described from India [16] contains β-Caryophyllene (25.18%) and sabinene (14.68%).

There are some compositional pattern in which caryophyllene, although present, was not the predominant constituents. The stem of oil of *H. suavelens* from Nigeria [17] was dominated by β-pinene (20.9%), estragole (16.3%) and β-caryophyllene (11.1%). The main components of sample from Brazil [18] were identified as sabinene (7.3-31.3%), eucalyptol (14.0-24.6%), β-caryophyllene (6.9-12.7%), 1,8-cineole (11.5%) and β-phellandrene (10.2%). The major identified compounds of sample from Benin Republic [19] were 1,8-cineole (14.0%) and β-caryophyllene (9.8%). The *H. suaveolens* oil from Italy contains sabinene (34%), β-caryophyllene (11.2%), terpinolene (10.7%) [20].

Essential oils from *H. suaveolens* containing low contents or near absence of caryophyllene have been defined. The fruits oil of *H. suavelens* from Nigeria [17] contained high amounts of 1, 8-cineole (29.5%) and fenchone (17.2%). Previously, the composition of essential oil the aerial parts of *H. suaveolens* from Vietnam were eugenol (68.2%) and germacrene D (11.0%) were the major constituents of the oil [21]. The main constituents of essential oils obtained from the leaves and flowers of *H. suaveolens* collected from Venezuela [22] were 1,8-cineole (19.1% leaves, flowers 13.3%), fenchone (18.5% leaves, flowers 16.1%), bicyclogermacrene (12.7% leaves, flowers 18.8%), D-germacrene (6.3% leaves, flowers 10.0%). Another analysis reported the abundance of β-elemene (39.71%), γ-elemene (8.82%) and bicyclogermacrene (8.52%) in the essential oil of *H. suaveolens* [23]. The sample from Brazil (24) contained low amount of β-caryophyllene (4.69%) and high content of eucalyptol (47.64%). There are several other minor constituents which differ from one another depending on the origin of the sample being analyzed.

Essential oils from *H. suaveolens* have previously displayed antimicrobial activities against a number of pathogens including *Mucor* sp. [12], *Aspergillus* sp. [24], among others. The essential oil from Venezuela displayed antibacterial activity against *Escherichia coli* ATCC 25922, *Klebsiella pneumoneae* ATCC 23357, and *Salmonella typhi* CDC 57, with minimun inhibitory concentration (MIC) ranging between 300 µL/mL and 450 µL/mL (22). The essential oil from the leaves of *H. suaveolens* was effective on *Staphylococcus aureus* Meti-R and *S. aureus* ATCC 25923 with MIC values of 5.37 mg/mL [25]. The essential oil of *H. suaveolens* also showed anti-mycobacterium activity when tested on strain 7H9/ADC with MIC of 3.13% [26]. The MIC range of between 0.5 mL/mm and 0.125 mL/mm were reported for essential oil *H. suaveolens* [23]. Essential oils of *H. suaveolens* showed mortality towards *Trypanasoma congoles* [13], *Tenebroides mauritanicus* (L.) [19], *Sitophilus granaries* [20], *Callosobruchus maculatus* [23] and *Anopheles gambiae* [27]. The antioxidant and antimicrobial activities of essential oil from *H. suaveolens* have been reported [28].

Although the chemical constituents of *H. Suaveolens* grown in Vietnam were previously reported, there is no information about the antimicrobial of *H. suaveolens,* analyzed from Vietnam. As part of our on-going research aimed at the identification of the chemical constituents and biological activities of essential oils from plants grown in Vietnam [4-8] aimed at sourcing for potentials chemicals for control of diseases, we obtained essential oils from leaf and flowers of *H. suaveolens,* analysed the compounds present therein and examined the antimicrobial activity.

2. MATERIALS AND METHODS

2.1 The Leaves and Flowers of *H. suaveolens*

The leaves and flowers of *H. suaveolens* used for this study were gotten from Đồng Văn Commune, Pù Hoạt Nature Reserve, Vietnam. The samples were collected in the month of December 2018. About 1.5 kg of each of the leaf and flower samples was collected from the mature plants planted in the park. The identification of the sample was done by Dr. Dai DN of the Faculty of Agriculture, Nghe An College of Economics, Vinh City, Vietnam. For the future reference, a voucher specimen coded NTC 742 was deposited at the Botany Museum, NghệAn College of Economics, Vietnam.

2.2 Hydrodistillation of the Essential Oils from the Leaves and Flowers of *H. suaveolens*

To obtain essential oil, the leaves and flowers of *H. suaveolens* were air-dried under the laboratory for few days. Thereafter the samples were grinded to reduce the surface area for easy volatilization of the oil. For the hydrodistillation experiment, 1.2 kg of each of the leaf and flower was subjected to hydrodistillation according to specification [29], using a Clevenger-type apparatus. The samples were carefully packed inside a 5 L flask to which distilled water was added and ensured that the sample was completely covered. The time used for distillation was 3 h and at normal pressure. The essential oil was stored in weighed sample bottle and kept refrigerated (4°C) until the time of chemical and biological analyses. The hydrodistillation process was done in triplicates.

2.3 Chemical Analysis of Essential Oils

The techniques of gas chromatography (GC) and gas chromatography-mass spectrometry (GC/MS) were used to analyze the constituents of the essential oils. In the GC analysis, an HP 7890A Plus Gas chromatograph (Agilent Technologies) having a flame ionization detector (FID) and fitted with HP-5MS column of dimension 30 m x 0.25 mm and a film thickness of 0.25 μm was used. The analytical conditions used for the GC include H_2 as the carrier gas at a flow rate of 1 mL/min, injector temperature of 250°C and a detector temperature of 260°C. The column was temperature programmed from 60°C (held for 2 min) to 220°C (10 min hold isothermally) at 4°C/min. Essential oil (1.0 μL) was injected by splitting at ratio of 10:1 using inlet pressure of 6.1 kPa. Quantification was done by external standard method using calibration curves generated by running GC analysis of representative compounds.

The GC/MS analysis was conducted with the same GC used above interfaced with a mass spectrometer HP 5973 MSD. The GC conditions were as described above except that He (1 mL/min) was used as the carrier gas. The mass spectrometer was operated by using ionization voltage of 70eV and emission current of 40 mA. The mass spectral was obtained with acquisition scan mass range of 35-350 amu and at a sampling rate of 1.0 scan/s.

The constituents of the essential oils were identified from the GC/MS spectral obtained from *H. suaveolens*. This was made possible by comparison of their retention indices (RI) with homologous series of *n*-alkanes. For few of the constituents, the method of co-injection with known compounds which were run with the same GC conditions was employed. The identity of the mass fragmentation patterns of each compound was checked and compared with known essential oil composition [30]. Moreover, the fragmentation patterns were also compared with literature data as described in previous studies [4-8].

2.4 Screening of the Essential Oils for Antimicrobial Activity

The antimicrobial activity of the essential oils of the leaves and flowers of *H. suaveolens* was evaluated using three strains of Gram-positive test bacteria, *Enterococcus faecalis* (ATCC299212), *Staphylococcus aureus* (ATCC25923), *Bacillus cereus* (ATCC14579), three strains of Gram-negative test bacteria, *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC27853), *Salmonella enterica* (ATCC13076) and one strain of yeast, *Candida albicans* (ATCC 10231). The minimum inhibitory concentration (MIC) and median inhibitory concentration (IC_{50}) values were measured by the microdilution broth susceptibility assay [31] by preparing the stock solutions of the oils in dimethylsulfoxide (DMSO). Dilution series were prepared from 16,384 to 2 μg/mL (2^{14}, 2^{13}, 2^{12}, 2^{11}, 2^{10}, 2^{9}, 2^{7}, 2^{5}, 2^{3} and 2^{1} μg/ mL) in sterile distilled water in micro-test tubes from where they were transferred to 96-well microtiter plates. Bacteria grown in double-strength Mueller-Hinton broth or double-strength tryptic soy broth, and fungi grown in double-strength Sabouraud dextrose broth were standardized to 5×10^5 and 1×10^3 CFU/mL, respectively. The last row, containing only the serial dilutions of sample without microorganisms, was used as a positive (no growth) control. Sterile distilled water and medium served as a negative (no antimicrobial agent) control. Streptomycin was used as the standard for antibacterial, while nystatin and cycloheximide were used as standards for antifungal. The plates were incubated for 24 h at 37°C. Afterwards, the MIC values were determined as the lowest concentration of essential oils of the leaf and flowers of *H. suaveolens* which completely inhibited the growth of microorganisms. The IC_{50} values were determined by the percentage of microorganisms that inhibited the growth based on the turbidity measurement data of EPOCH2C

spectrophotometer (BioTeK Instruments, Inc Highland Park Winooski, VT, USA) and Rawdata computer software (Brussels, Belgium) according to the following equations:

$$\% \text{ inhibition} = \frac{OD_{control(-)} - OD_{test\ agent}}{OD_{control(-)} - OD_{control(+)}} \times 100\%$$

$$IC_{50} = High_{conc} - \frac{(High_{inh\%} - 50\%) \times (High_{conc} - Low_{conc})}{(High_{inh\%} - Low_{inh\%})}$$

where OD is the optical density, control(–) are the cells with medium but without antimicrobial agent, test agent corresponds to a known concentration of antimicrobial agent, control(+) is the culture medium without cells, $High_{conc}$/Low_{conc} is the concentration of test agent at high concentration/low concentration and $High_{inh\%}$/ $Low_{inh\%}$ is the % inhibition at high concentration/% inhibition at low concentration).

2.4.1 Statistical analysis

The Microsoft excel program 2003 was used to evaluate the differences between mean values obtained for experimental groups. This standard deviation (SD) was calculated as a mean of four independent measurements.

3. RESULTS AND DISCUSSION

3.1 Chemical Constituents of the Essential Oil

The yields of the essential oils were 0.11% and 0.16% (v/w) respectively, calculated on a dry weight basis. Both samples of essential oil were light-yellow coloured. Table 1 depicts the identities of the compounds, percent composition and the retention indices on HP-5MS column. Thirty-six compounds accounting for 92.3% of the oil contents were identified in the leaf oil. Sesquiterpene hydrocarbons (42.6%), oxygenated sesquiterpenes (34.6%) and diterpene (9.9%) were the abundant classes of compounds present in the leaf oil. Monoterpene compounds are less common (ca. 4.4%). The main constituents of the oil were β-caryophyllene (31.1%), caryophyllene oxide (17.6%) and phytol (9.9%). There are sizeable amounts of α-humulene (6.7%), guaiol (3.8%), *ar*-turmenone (3.3%), β-bisabolene (2.8%) and humulene oxide II (2.1%). Among the forty-six compounds (90.5%) that makes up the flower oil, monoterpene hydrocarbons (22.3%), sesquiterpene hydrocarbons (46.0%), oxygenated sesquiterpenes (11.5%) and diterpenes (9.9%) were representative classes of compounds identified. The major compounds of the flower oil were β-caryophyllene, phytol (9.9%), myrcene (8.7%), α-pinene (8.3%), α-humulene (6.6%).

A comparative analysis of the present study with data reported for the essential oils of *H. suaveolens* from other parts of the world plants revealed some quantitative and qualitative variations. The abundant of β-caryophyllene in the present leaf and flower oils of *H. suaveolens* confer similarity with data obtained from samples analyzed from Tanzania [12], Nigeria [13,14], Indonesia [15] and India [16] among others. The present oil samples belong to the group in which β-caryophyllene along with other terpene were the major compounds. However, the compositions of essential oils were different from a previous sample analyzed from Vietnam [21]. The major constituents of the aerial parts of *H. suaveolens* previously from Vietnam, namely eugenol was conspicuously absent in the present oil samples. In addition, the content of germacrene D in the present investigated flower oil sample was much lower than reported earlier for the aerial part, while germacrene D was not identified in the leaf oil under study. The oil samples of *H. suaveolens* from Vietnam could be assumed to belong to different chemotypes. The amount and the composition of the bioactive substances may vary among the same or different plant species, and according to different factors such as the extraction methods, the geographic and the growing conditions, the harvest time etc. [32].

3.2 Antimicrobial Activity of the Oil

The results of the antimicrobial study are presented in Table 2. Both essential oils exhibited antivity towards the gram-positive pathogens. The essential oil from the leaf oil of *H. suaveolens* displayed stronger antimicrobial activity against *Enterococcus faecalis* ATCC299212 (MIC of 16.0 µg/mL), *Candida albican*s ATCC10231 (MIC of 16.0 µg/mL) and *Bacillus cereus* ATCC14579 (MIC 32.0 µg/mL respectively). The IC_{50} values of 5.78, 6.78 and 9.35 µg/mL, respectively were recorded by the same organisms. The flower oil on the other hand, exhibited activity towards the same organisms with MIC values of 64.0, 16.0 and 64.0 µg/mL, respectively, while the IC_{50} values were 20.45, 6.78 and 26.78 µg/mL, respectively.

Table 1. Volatile constituents of the leaves and flowers of *H. suaveolens*

Sr. no	Compounds[a]	RI[b]	RI[c]	Leaves	Flowers
1	α-Thujene	930	926	-	0.2
2	α-Pinene	939	932	0.9	8.3
3	Camphene	955	946	0.3	0.5
4	Sabinene	978	972	0.5	0.7
5	β-Pinene	984	980	0.6	2.0
6	Myrcene	992	988	0.3	8.7
7	δ-3-Carene	1016	1014	0.2	-
8	o-Cymene	1029	1022	0.8	0.7
9	Limonene	1034	1032	0.3	0.7
10	γ-Terpinene	1063	1060	-	0.2
11	Terpinolene	1094	1089	-	0.3
12	(*E*)-4,8-Dimethylnona-1,3,7-triene	1118	1118	0.2	0.3
13	Fenchyl acetate	1228	1228	0.2	0.1
14	Bornyl acetate	1294	1292	0.3	0.2
15	δ-Elemene	1348	1348	0.2	0.3
16	α-Copaene	1389	1387	0.2	0.7
17	*cis*-β-Elemene	1403	1402	0.9	1.1
18	β-Caryophyllene	1438	1437	31.1	33.7
19	Aromadendrene	1457	1457	-	0.2
20	(*Z*)-β-Farnesene	1461	1461	-	0.1
21	α-Humulene	1471	1470	6.7	6.6
22	*ar*-Curcumene	1493	1494	0.2	0.1
23	Germacrene D	1499	1498	-	0.8
24	β-Selinene	1505	1506	0.2	0.2
25	(*E,E*)-Farnesene	1513	1510	-	0.5
26	α-Selinene	1514	1413	0.3	-
27	Bicyclogermacrene	1514	1515	-	0.7
28	β-Bisabolene	1518	1520	2.8	0.5
29	β-Sesquiphellandrene	1534	1534	-	0.1
30	δ-Cadinene	1537	1535	-	0.4
31	(*E*)-Nerolidol	1571	1572	0.9	0.7
32	Spathulenol	1598	1598	0.8	0.4
33	Caryophyllene oxide	1605	1606	17.6	3.9
34	Guaiol	1612	1612	3.8	-
35	Humulene oxide I	1620	1620	0.3	-
36	Humulene oxide II	1632	1632	2.1	0.4
37	1-*epi*-Cubenol	1648	1648	1.7	0.4
38	Caryophylla-3(15),7(14)-dien-6-ol	1659	1660	0.8	0.2
39	α-Cadinol	1673	1675	0.4	0.4
40	*ar*-Turmenone	1678	1678	3.3	3.4
41	14-Hydroxy-9-*epi*-(*E*)-caryophyllene	1692	1690	0.5	-
42	Curlone	1716	1714	0.4	1.2
43	1-Phenyl-hepta-1,3,5-triyne	1744	1746	0.6	-
44	α-Oxobisabolene	1762	1762	0.2	0.1
45	6,10,14-Trimethylpentadecan-2-one	1849	1851	0.8	0.4
46	Isopimara-8,15-diene	2044	2044	-	0.4
47	Manool	2084	2082	-	1.0
48	Abietatriene	2086	2086	-	0.9
49	Heneicosane	2100	2100	-	0.2
50	Abietadiene	2116	2118	-	4.7
51	Phytol	2119	2119	9.9	2.7
52	Abieta-8(14),13(15)-diene	2186	2186	-	0.2
Total				92.3	90.5
Monoterpene hydrocarbons (Sr. No. 1-11)				3.9	22.3
Oxygenated monoterpenes (Sr. No. 13, 14)				0.5	0.3
Sesquiterpene hydrocarbons (Sr. No. 5-30)				42.6	46.0
Oxygenated sesquiterpenes (Sr. No. 31-45)				34.6	11.5
Diterpenes (Sr. No. 46-52)				9.9	9.9
Non-terpenes (Sr. No. 12, 49)				0.6	0.5

[a] Elution order on HP-5MS column; [b] Retention indices on HP-5 column; [c] Literature retention indices (NIST, 2018); Identification included co-injection with authentic compounds; S/N, Serial Number; - Not identified

Table 2. Antimicrobial activity of *H. suaveolens* leaves and flowers oils

Microorganisms	MIC (µg/mL)		IC_{50} (µg/mL)	
	Leaves	Flowers	Leaves	Flowers
E. faecalis ATCC299212	16.0 ± 0.00*	64.0 ± 0.10	5.78 ± 0.00	20.45 ± 0.00
S. aureus ATCC25923	256.0 ± 0.00	256.0 ± 0.00	68.98 ± 0.00	100.56 ± 0.50
B. cereus ATCC14579	32.0 ± 0.00	64.0 ± 0.50	9.35 ± 0.50	26.78 ± 0.50
C. albicans ATCC10231	16.0 ± 0.00	16.0 ± 0.50	6.78 ± 0.50	6.78 ± 0.10

Means ± SD (n = 3)

However, both essential oils showed moderate activity towards *Staphylococcus aureus* ATCC25923 with MIC of 256.0 µg/mL. The oil samples, however, did not inhibit the growth of gram-negative bacteria, *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC27853) and *Salmonella enterica* (ATCC13076). The antimicrobial activity of the present oil samples competes favorably with data reported for *H. suaveolens* essential oil samples from other parts of the world screened for their activities through inhibition of the growth of some tested microorganisms.

The antimicrobial activities of essential oils of some *H. suaveolens* species were reported previously. A notable observation was that the oils under investigation were ineffective against the strain of *E. coli* ATCC 25922 contrary to the data reported for Venezuela sample [22]. In addition, the oil samples displayed a lesser activity against *S. aureus* ATCC 25923 compared with sample from Benin Republic [25] tested for antimicrobial activity.

The observed antimicrobial activities of essential oils from *H. suaveolens* are in tandem with the antimicrobial activity of essential oils from some other plants grown in Vietnam. The leaf and flower oils of *H. suaveolens* and the leaf and wood of oils *T. chinensis* exhibited similar action against *Enterococcus faecalis* ATCC299212. The leaf oil of *T. chinensis* and the flower oil of *H. suaveolens* showed similar MIC (64.0 µg/mL) towards *Bacillus cereus* ATCC 14579, but lesser than the activity of pseudo-stem oil of *Z. zerumbet* with MIC of 50.0 µg/mL [4]. The investigated oil samples displayed lesser activity towards strains of *Staphylococcus* when compared with wood oil of *T. chinensis* [7] and the rhizome oils of *A. globosa* and *A. tonkinensis* [8]. The oils of *H. suaveolens* were more potent towards *C. albicans* ATCC10231 than the other mentioned essential oils. However, essential oils from the rhizome *A. rubidium* [4], the wood of *T. chinensis* [7] as well the rhizomes of *A. globosa* and *A. tonkinensis* [8] were more effective against *Escherichia coli* (ATCC 25922) when compared with *H. suaveolens* which showed no activity. In addition, the pseudo-stem oil of *Z. castaneum* [9] was also more potent towards *P. aeruginosa* ATCC 25923 than the oils of *H. suaveolens.* Essential oils analyzed from Vietnam have also displayed antimicrobial activity towards a number of pathogens. The rhizome oil of *A. rubidium* exhibited antimicrobial activity against *Fusarium oxysporum* (ATCC 48112) with MIC of 50 µg/mL [4]. The leaf [5] and rhizome [6] oils of *Z. zerumbet* both inhibited the growth of *Aspergillus niger* (ATCC 9763) with MIC of 50.0 µg/mL [5]. The rhizome essential oil of *A. tonkinensis* also inhibited the growth of *Saccharomyces cerevisiae* ATCC 16404 with MIC value of 25.0 µg/mL, while both *A. globosa* and *A. tonkinensis* essential oils displayed antimicrobial activity towards *Staphylococcus aureus* subsp. *aureus* ATCC 11632 and *Fusarium oxysporum* ATCC 48112 with MIC value of 50.0 µg/mL [8]. The pseudo-stem oil of *Z. castaneum* showed antimicrobial activity against *A. niger* ATCC 9763 and *F. oxysporum* ATCC 48112 with MIC values of 12.5 µg/mL and 50 µg/mL respectively [9]. In summary plant products especially essential oils from Vietnam have proven to be sources of antimicrobial agents. These essential oils can exploited further and developed as antimicrobial agents.

The qualitative and quantitative variations of chemical constituents of essential oils do greatly contribute to the variations in the activity against different species of microorganisms. The antimicrobial activity of an essential oil on may be due to the main compounds of the essential oils or a synergy between some major and minor compounds.

Some compounds previously and reported for their antimicrobial efficiency were identified in the essential oils of *H. suaveolens* investigated in this study. Such compounds include α-pinene, β-pinene, sabinene, 1,8-cineole, linalool, terpinen-4-ol, β-caryophyllene, bicyclogermacrene, germacrene D, (*E*)-nerolidol, phytol e.t.c were previously reported to inhibit significantly the growth and cell viability of

potential infectious of broad spectrum microorganisms [33]. The antibacterial activity of β-caryophyllene against *S. aureus* was reported recently [34]. Caryophyllene oxide [35] and phytol [36] are known for their biological potentials and were reported to be responsible for the antimicrobial activity of some essential oils.

4. CONCLUSION

The data presented herein showed that the compositions of essential oils of the leaf and lower of *H. suaveolens* were dominated by β-caryophyllene, caryophyllene oxide, phytol, myrcene and α-humulene. Both essential oils sample displayed activity towards *E. faecalis* ATCC299212, *B. cereus* ATCC14579, *C. albican*s ATCC10231 and *S. aureus* ATCC25923 with MIC comparable to other results. Conclusively, the study revealed the antimicrobial potentials of essential oils hydrodistilled from the leaf and flower of *H. suaveolens.*

DISCLAIMER

The sample of *H. suaveolens* used in this study, instruments and other chemicals used to achieve the desired results are common and predominantly use products in the area of natural products and essential oil research. These are readily available in Vietnam. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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