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Chemical Composition of the Essential Oils from *Goniothalamus tortilipetalus* M.R.Hend. and Their Antioxidant and Antibacterial Activities

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Abstract: This work was the first investigation of the essential oil composition of *Goniothalamus tortilipetalus* M.R.Hend. The aim of this study is to investigate the essential oil composition extracted from different parts of *Goniothalamus tortilipetalus* M.R.Hend., including flowers, leaves, and twigs, and to evaluate their antioxidant and antibacterial activities. The Clevenger apparatus was used for hydrodistillation to prepare the essential oils. The essential oils were investigated using gas chromatography–mass spectrometry (GC-MS). The three major compounds of the flowers were bicyclogermacrene (15.81%), selin-11-en-4-α-ol (14.68%), and *E*-caryophyllene (7.02%), whereas the leaves were *p*-cymene (39.57%), ascaridole (9.39%), and α-copaene (9.12%). In the case of the twigs, *α*-copaene (10.34%), selin-11-en-4-*α*-ol (8.85%), and *p*-cymene (7.76%) were the major compounds. The flower essential oil showed antioxidant activities with IC_{50} values of 725.21 µg/mL and 123.06 µg/mL for DPPH and ABTS assays, respectively. The flower essential oil also displayed antibacterial activity against *Bacillus subtilis*, *Staphylococcus aureus*, *Micrococcus luteus*, *Salmonella typhimurium*, and *Shigella flexneri*, with the same MIC value of 640 µg/mL.

Keywords: *Goniothalamus tortilipetalus*; essential oil; antioxidant activity; antibacterial activity

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1. Introduction

Plants have been known for their use in traditional medicines for centuries [1], and many of them have been reported for biological activities with potential therapeutic applications. The genus of *Goniothalamus* is one of the largest genera of the family of Annonaceae, and over 150 species were discovered worldwide [2]. Different parts of *Goniothalamus* species have been used for the treatment of fever, scabies, edema, typhoid fever [3], asthma, malaria, stomachache [4], and also as a mosquito repellent [5]. *Goniothalamus* species produced diverse types of chemical constituents, including styryl lactones [6], alkaloids [3], flavonoids [7,8], steroids, terpenoids [7], and acetogenins [9]. Many of these compounds showed various biological activities such as antimicrobial [10], antioxidant [7], anti-inflammatory [11,12], and cytotoxicity [5,7,9]. In the case of essential oils, many *Goniothalamus* species have been widely reported for their chemical compositions, including *G. malayanus* [13,14], *G. uvariodes* [14,15], *G. macrophyllus* [14,16], *G. andersonii* [14], *G. cardiopetalus* [17], *G. clemensii* [4], *G. tapis* [18], *G. takhtajanii* [19], and *G. multiovulatus* [19]. Nevertheless, the essential oil compositions and their biological activities have not been reported from *Goniothalamus tortilipetalus* M.R. Hend, according to the SciFinder Scholar database (Chemical Abstracts Service, Columbus, OH, USA). This information led us to

investigate the essential oil compositions and their antioxidant and antibacterial activities from the flower, leaf, and twig essential oils of *G. tortilipetalus*. This work was the first investigation of essential oils compositions and their antioxidant and antibacterial activities in regard to *G. tortilipetalus*.

2. Materials and Methods

2.1. Plant Material

The flowers, leaves, and twigs of *G. tortilipetalus* were collected in April 2021 from Narathiwat Province, Thailand. The plant was identified by Mr. Abdulromae Baka, Independent Research Group on Plant Diversity in Thailand, Sichon, Nakhon Si Thammarat, Thailand. Specimens of this plant (MFU-NPR0214) have been deposited in the Natural Products Research Laboratory at the Mae Fah Luang University under specimen number MFU-NPR0214.

2.2. Extraction of the Essential Oils

The flowers, leaves, and twigs of *G. tortilipetalus* were washed and crushed with a grinder before being hydrodistilled. The materials were immersed in 500 mL distilled water and subjected to hydrodistillation at 100 °C for 4 h using Clevenger apparatus to obtain the volatile oils, which were dried over anhydrous sodium sulfate (Na_2SO_4). The % yields of the extracts were calculated using the material weights.

2.3. Analysis by GC/MS

The essential oils were characterized through GC/MS using Agilent Technologies, HP 6890 gas chromatography with the HP 5973 mass selective detector (Agilent Technologies, Santa Clara, CA, USA). An HP-5 ms (5% phenylpolymethylsiloxane) capillary column (30 m length × 0.25 mm id × 0.25 µm film thickness, Agilent Technologies, CA, USA) was used. Helium (99.9% purity) was used as carrier gas with a flow rate of 1 mL/min and injection in split mode 1:70. The oven temperature was set at 60 °C and was increased at 3 °C/min to 220 °C. The injector and detector temperatures were set at 250 °C and 280 °C, respectively. The mass spectrometer operated in Electron Impact mode at 70 eV, and the electron multiplier voltage was 1150 V. MS data were acquired in scan mode in the range of m/z 29–300. The ion source and quadrupole temperatures were set at 230 °C and 150 °C, respectively [20]. Furthermore, for the identification of the isolated compounds, the retention indices (RIs) were compared relative to a series of C_8–C_{20} *n*-alkanes standard and the mass spectra of individual components with the reference mass spectra via the National Institute of Standards and Technology (NIST) mass spectral library. Also, their mass spectra were compared with their Kovats index (KI) [21] with that determined by the host lab. The chemical compositions of essential oils were summarized as a percent relative peak area, as shown in Table 1.

Table 1. Chemical composition (relative area percentage) of the essential oils from flowers, leaves, and twigs of *G. tortilipetalus* by GC–MS.

No	Compound Name	RI [1]	RI [2]	Flowers	Leaves	Twigs
1	*α*-Pinene	934	932	0.58 ± 0.04	1.50 ± 0.06	0.18 ± 0.02
2	Myrcene	991	988		2.47 ± 0.05	0.35 ± 0.00
3	*δ*-2-Carene	1003	1001		1.18 ± 0.03	
4	*α*-Phellandrene	1006	1002		1.77 ± 0.03	1.68 ± 0.00
5	*α*-Terpinene	1022	1014	0.82 ± 0.04	3.05 ± 0.05	7.08 ± 0.03
6	*p*-Cymene	1026	1020		39.57 ± 0.65	7.76 ± 0.11
7	*o*-Cymene	1029	1022			4.14 ± 0.08
8	*β*-Phellandrene	1029	1025		6.04 ± 0.08	
9	*γ*-Terpinene	1058	1054		1.30 ± 0.01	1.59 ± 0.01
10	*p*-Cymenene	1089	1089			0.44 ± 0.00
11	Linalool	1100	1095	0.54 ± 0.02	2.77 ± 0.01	2.37 ± 0.02
12	(*Z*)-*p*-Menth-2-en-1-ol	1122	1118		1.47 ± 0.01	0.21 ± 0.00
13	(*E*)-*p*-Menth-2-en-1-ol	1139	1136		1.37 ± 0.00	
14	*β*-Pinene oxide	1156	1154		0.79 ± 0.01	
15	Terpinen-4-ol	1177	1174	0.94 ± 0.01	1.64 ± 0.00	1.25 ± 0.01

Table 1. *Cont.*

No	Compound Name	RI [1]	RI [2]	Flowers	Leaves	Twigs
16	*p*-Cymen-8-ol	1185	1179			0.25 ± 0.01
17	α-Terpineol	1191	1186	0.32 ± 0.01		0.36 ± 0.01
18	Ascaridole	1239	1234		9.39 ± 0.09	
19	Cumin aldehyde	1240	1238			0.17 ± 0.01
20	Piperitone	1254	1249		1.30 ± 0.02	0.56 ± 0.01
21	Bornyl acetate	1286	1287	0.95 ± 0.02		
22	Thymol	1293	1289			0.17 ± 0.01
23	Carvacrol	1302	1298		0.65 ± 0.01	0.69 ± 0.01
24	α-Cubebene	1350	1345			0.22 ± 0.03
25	Engenol	1358	1356			0.25 ± 0.01
26	α-Copaene	1376	1374	2.88 ± 0.03	9.12 ± 0.15	10.34 ± 0.09
27	β-Elemene	1393	1389	5.68 ± 0.03	1.34 ± 0.03	3.82 ± 0.04
28	Cyperene	1401	1398			1.47 ± 0.01
29	*E*-Caryophyllene	1422	1417	7.02 ± 0.05		4.85 ± 0.04
30	α-Bergamotene	1436	1432	0.75 ± 0.04		
31	Aromadendrene	1440	1439	0.38 ± 0.02		
32	α-Guaiene	1440	1437			0.18 ± 0.01
33	α-Humulene	1454	1452	1.14 ± 0.08		0.99 ± 0.04
34	β-Chamigrene	1476	1476	2.50 ± 0.04		
35	γ-Gurjunene	1476	1475			2.03 ± 0.03
36	β-Selinene	1487	1489	6.89 ± 0.04	1.31 ± 0.03	3.26 ± 0.03
37	Viridiflorene	1496	1496		1.72 ± 0.05	
38	α-Selinene	1497	1498			3.82 ± 0.03
39	Bicyclogermacrene	1497	1500	15.81 ± 0.47		
40	α-Muurolene	1501	1500			0.39 ± 0.01
41	Germacrene A	1506	1508	5.23 ± 0.13		
42	δ-Cadinene	1524	1522	0.85 ± 0.01		2.99 ± 0.04
43	Zonarene	1527	1528			0.30 ± 0.01
44	α-Calacorene	1544	1544			0.22 ± 0.01
45	Elemol	1551	1548			0.41 ± 0.01
46	*E*-Nerolidol	1565	1561	3.24 ± 0.32		0.46 ± 0.00
47	Maalilo	1569	1566			0.30 ± 0.03
48	Spathulenol	1579	1577	4.18 ± 0.07	7.22 ± 0.19	2.32 ± 0.03
49	Caryophyllene oxide	1584	1582	5.86 ± 0.08		
50	Thujopsan-2-α-ol	1586	1586			2.70 ± 0.02
51	β-Copaen-4-α-ol	1589	1590			0.42 ± 0.45
52	Viridiflorol	1592	1592	1.63 ± 0.03		
53	Globulol	1593	1590			1.11 ± 0.30
54	Cubeban-11-ol	1594	1595	0.50 ± 0.11		
55	Guaiol	1599	1600			1.32 ± 0.21
56	Rosifoliol	1603	1600	0.88 ± 0.03		
57	Rosifoliol	1604	1600			1.05 ± 0.06
58	Cubenol (1-epi)	1629	1627	0.35 ± 0.13		
59	1-epi-Cubenol	1631	1627			2.97 ± 0.10
60	γ-Eudesmol	1634	1630			1.27 ± 0.09
61	Caryophylla-4(12),8(13)-dien-5α-ol	1639	1639			0.32 ± 0.01
62	Aromadendrene epoxide	1639	1639	1.65 ± 0.06		
63	α-Muurolol	1643	1644	0.34 ± 0.13		
64	Cubenol	1645	1645			1.82 ± 0.08
65	α-Muurolol	1649	1644			0.41 ± 0.05
66	β-Eudesmol	1653	1650			1.37 ± 0.05
67	Selin-11-en-4-α-ol	1657	1658	14.68 ± 0.16		8.85 ± 0.07
68	Intermedeol (neo-)	1660	1658	0.57 ± 0.07		
69	Intermedeol	1662	1665			0.47 ± 0.04
70	Bulnesol	1670	1670	0.90 ± 0.02		2.55 ± 0.05
71	(Z)-α-Santalol	1672	1674	1.77 ± 0.07		0.61 ± 0.02
72	Guaiol acetate	1722	1725	0.96 ± 0.05		
73	Hexadecanoic acid	1959	1959	0.41 ± 0.03		
	Number of compounds identified			32	21	51
	Total identified (%)			91.18	96.97	95.10
	Monoterpene hydrocarbons (%)			3.61	71.36	25.81
	Oxygenated monoterpenes (%)			0.54	4.24	2.75
	Sesquiterpene hydrocarbons (%)			49.12	13.49	34.67
	Oxygenated sesquiterpenes (%)			37.91	7.22	30.73

Values are the mean percentage of peak areas ± standard deviation (SD), $n = 3$. [1] Experimentally determined retention indices. [2] Retention indices from the literature [21].

2.4. Antioxidant Activity by DPPH Free Radical Scavenging Assay

The antioxidant activity of the flower, leaf, and twig essential oils of *G. tortilipetalus* was assessed based on the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method, as described previously [20]. DPPH (Sigma Aldrich, St. Louis, MI, USA) radical scavenging

methanolic solution (6×10^{-5} M, 100 µL) was prepared. The essential oils were prepared in methanol at serially diluted concentrations of 100, 250, 500, 1000, 2000, and 3000 µg/mL. A mixture of diluted essential oils (100 µL) and DPPH methanolic solution (100 µL) was prepared in a 96-well microplate. The solution was incubated at room temperature in darkness for 30 min. The absorbance of the reaction solution was measured at 517 nm using the microplate reader (Biochrom Asys UVM 340 Microplate Reader, Biochrom, Cambridge, UK). Ascorbic acid was used as the positive control at serially diluted concentrations (1, 2, 5, 10, and 15 µg/mL in methanol). The DPPH radical scavenging activity was expressed as the inhibitory concentration at 50% (IC_{50}).

2.5. Antioxidant Activity Using ABTS Radical Cation Scavenging Assay

The 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid (ABTS) radical cation scavenging assay was performed as previously described [22]. In brief, the working solution of ABTS radical cation ($ABTS^{\bullet+}$) was prepared from the reaction of equal volumes of 7 mM of ABTS with 2.45 mM of potassium persulfate in the dark at room temperature for 16 h before use. The working solution of $ABTS^{\bullet+}$ was adjusted to the absorbance of 0.70 ± 0.02 at 734 nm with ethanol. The essential oils were prepared at serially diluted concentrations of 25, 50, 100, 250, and 500 µg/mL. An aliquot of 20 µL of diluted essential oils was mixed with 180 µL of $ABTS^{\bullet+}$ solution and allowed to stand in the dark at room temperature for 5 min, then the absorbance of the reaction solution was measured at 734 nm using the microplate reader (Biochrom Asys UVM 340 Microplate Reader, Biochrom, Cambridge, UK). Serially diluted ascorbic acid concentrations (1.5, 3, 6, 12, and 25 µg/mL) were used as the positive controls. The ABTS radical cation scavenging activity of essential oils was expressed as the inhibitory concentration at 50% (IC_{50}).

2.6. Antibacterial Activity

The antibacterial activities of the essential oils from *G. tortilipetalus* were demonstrated against four Gram-positive bacteria (*Bacillus subtilis* TISTR 1248, *Listeria monocytogenes* F2369, *Staphylococcus aureus* ATCC 25923, and *Micrococcus luteus* DMST 15503), five Gram-negative bacteria (*Escherichia coli* TISTR 780, *Salmonella typhimurium* DMST 562, *Pseudomonas aeruginosa* ATCC 10145, *Shigella flexneri* DMST 4423, and *Salmonella typhi* DMST 22842). The bacterial strains were obtained from the Microbiological Resources Centre of the Thailand Institute of Scientific and Technological Research. Microdilution in the Mueller–Hinton broth was performed in the 96-well plates to determine the minimum inhibitory concentration (MIC) [20]. The essential oils were diluted with DMSO and then loaded in the Muller–Hinton broth microdilution with serial dilution (twofold). One hundred microliters of microbial culture, approximately 1.0×10^6 CFU/mL, was added to the 96-well plates. The negative control contained only the extraction buffer without microorganisms. The broth cultures of each strain were incubated aerobically at 37 °C for 24 h. After incubation, the MIC value was measured as the lowest concentration of the essential oils that completely inhibit the growth of microorganisms. Ampicillin, vancomycin, and gentamicin were used as positive controls.

3. Results and Discussion

3.1. Essential Oil Yield and Chemical Composition

The essential oils of the flowers, leaves, and twigs were obtained using hydrodistillation with a yield of 122.9 mg (0.06%, *w*/*w*), 167.1 mg (0.08%, *w*/*w*), and 47.0 mg (0.02%, *w*/*w*), respectively. The analyses of those essential oils by GC/MS identified 32, 21, and 51 compounds, comprising 91.18%, 96.97%, and 95.10% of the total peak areas (Figure 1) from the flowers, leaves, and twigs, respectively. The chemical compositions of those essential oils are shown in (Table 1). The percentage of monoterpenes, oxygenated monoterpenes, sesquiterpenes, and oxygenated sesquiterpenes found in the flower essential oil was 3.61%, 0.54%, 49.12%, and 37.91%, the percentage found in the leaf essential oil was 71.36%, 4.24%, 13.49%, and 7.22% and in the twig essential oil showed percentage of 25.81%, 2.75%,

34.67%, and 30.73%, respectively. The chemical constituents of leaf oil were discernibly different from those of flower and twig oils in that the former was composed almost entirely of monoterpene hydrocarbons (71.36%). In contrast, the twig oil showed similar major components but considerable variation in the percentage of individual constituents. In comparing the flower and twig oils, the percentage of sesquiterpene hydrocarbons and oxygenated sesquiterpenes were slightly similar, but the major constituents were discernibly different. The major components of the flowers were identified as bicyclogermacrene (15.81 ± 0.47%), selin-11-en-4-*α*-ol (14.68 ± 0.16%), *E*-caryophyllene (7.02 ± 0.05%), and *β*-selinene (6.89 ± 0.04%), whereas *p*-cymene (39.57 ± 0.65%), ascaridole (9.39 ± 0.09%), *α*-copaene (9.12 ± 0.15%), and spathulenol (7.22 ± 0.19%) were the main components of the leaves. In the case of the twigs, the main components were similar to those of flowers and leaves, including *α*-copaene (10.34 ± 0.09%), selin-11-en-4-*α*-ol (8.85 ± 0.07%), *p*-cymene (7.76 ± 0.11%), and *α*-terpinene (7.08 ± 0.03%).

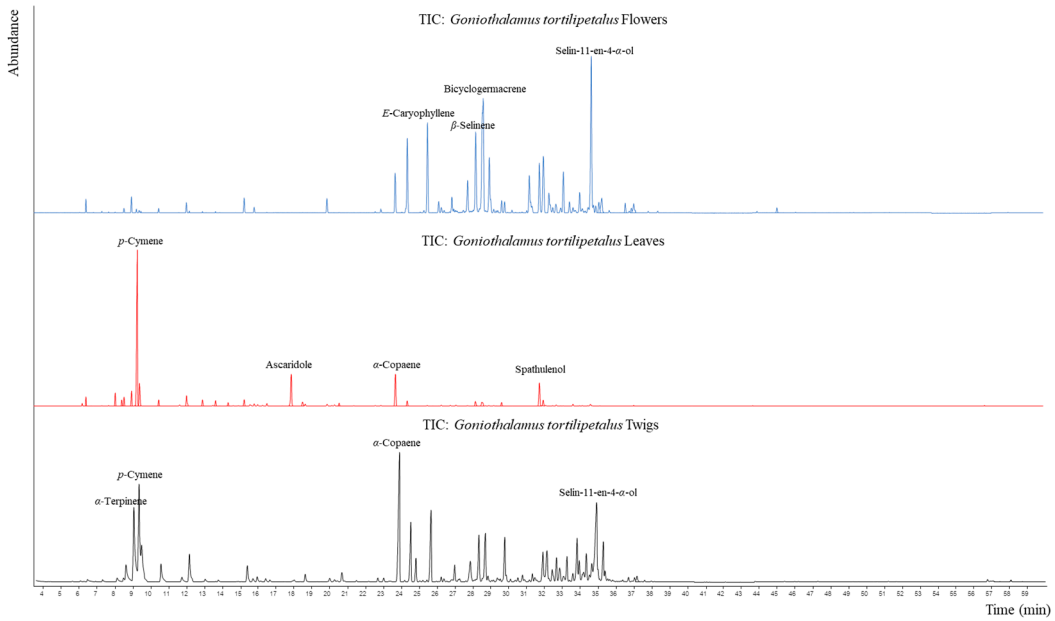

Figure 1. GC–MS chromatogram of flower, leaf, and twig essential oils from *G. tortilipetalus*.

Previous chemical composition investigations of the leaf essential oils from *Goniothalamus* species found that the different species will produce different major compositions. For example, the *G. uvariodes* revealed 51 components, mainly comprising *β*-cubebene (15.2%), elemol (9.7%), epi-*α*-cadinol (6.2%), and *α*-muurolene (4.8%) [15]. The leaf essential oils of *G. malayanus* and *G. andersonii* consisted of 43 and 25 components, respectively. The major compounds of *G. malayanus* were *β*-selinene (33.6%), varidifloral (13.1%), epiglobulol (7.7%), and *E*-nerolidol (4.4%). In comparison, the major components present in *G. andersonii* were guaiol (28.6%), elemol (19.6%), *β*-caryophyllene (7.7%), and *Z*-nerolidol (3.7%) [13]. In addition, the leaf essential oils from *G. tapis* and *G. tapisoides* have been reported and the presence of 29 and 28 compounds, respectively, was revealed. The major components of *G. tapis* were *α*-copaene (23.8%), linalool (18.5%), *β*-caryophyllene (14.4%), and 1,8-cineole (7.6%), whereas *G. tapisoides* showed 1,8-cineole (79.0%), *α*-pinene (9.6%), *α*-terpineol (4.4%), and terpinene-4-ol (2.3%) as major compounds [18]. In another study, the chemical constituents of essential oils obtained from the leaf of *G. takhtajanii*, *G. multiovulatus*, and *G. wightii* were reported [19]. The major constituents of *G. takhtajanii* were linalool (17.6%), *α*-phellandrene (16.7%), bicycloelemene (8.3%), and bicyclogermacrene (8.0%) [19]. The *G. multiovulatus* mainly comprised *β*-caryophyllene (32.0%), *α*-humulene (21.2%), caryophyllene oxide (5.6%), and spathulenol (5.2%) [19]. The major constituents of *G. wightii* mainly comprised linalool (18.9%), *δ*-cadinene (15.5%), bicyclogermacrene (15.3%), and bicycloelemene (12.7%) [19]. Previous studies revealed that leaf oils from

different *Goniothalamus* species showed variations in their major components, with variable quantities of percentage constituents. However, linalool and *β*-caryophyllene were identified as common major compounds in the leaves across this genus. A comparison of the leaf oil from *G. tortilipetalus* revealed a similarity to other species regarding *α*-copaene being one of the main components.

Regarding flower and twig essential oils, 116 and 21 components were identified from the flower essential oils of *G. marcanii* [20] and the twig essential oils of *G. macrophyllus* [16], respectively. Of these, caryophyllene oxide (19.2%), *E*-caryophyllene (14.5%), *β*-copaene (4.1%), and *α*-humulene (3.6%) were found as major components in the flower essential oils of *G. marcanii* [20]. Still, geranyl acetate (45.5%), geraniol (17.0%), linalool (12.7%), and camphene (7.5%) were identified as major components of twig essential oils [16]. This study revealed that the major compounds of essential oil differed from our results, which could be attributed to the different species. To the best of our knowledge, this study was the first report on the chemical compositions of the essential oils of *G. tortilipetalus*. It was observed that each of the *Goniothalamus* essential oils has its chemical compositions, which differ from others. Our data exhibited partial similarity to those previously reported in the essential oils of some *Goniothalamus* species, with the presence of some common major and minor compounds.

3.2. Antioxidant Activity

Antioxidant activity is one of the most valuable biological activities for the cosmetics, food, and beverage industries. This work was the first investigation of the antioxidant activity of essential oil compositions from *G. tortilipetalus*. The antioxidant potential of the essential oils from *G. tortilipetalus* was assessed through the DPPH radical scavenging and ABTS radical cation assay. The concentration that inhibits 50% of the DPPH and ABTS free radical (IC_{50}) are presented in Table 2. The DPPH radical scavenging activity of the essential oils of the flowers, leaves, and twigs of *G. tortilipetalus* showed weak antioxidant activity with IC_{50} values of 725.21 μg/mL, 2017.39 μg/mL, and 2435.50 μg/mL, respectively. In the case of the ABTS radical scavenging activity, the percentage inhibitions of the ABTS radicals were similar to those of DPPH. The essential oils of flowers, leaves, and twigs showed IC_{50} values of 123.06 μg/mL, 290.63 μg/mL, and 382.17 μg/mL, respectively.

Table 2. The DPPH and ABTS radical scavenging activities of essential oils from flowers, leaves, and twigs of *G. tortilipetalus*.

Sample	Antioxidant (IC_{50}, μg/mL)	
	DPPH	**ABTS**
Flower essential oil	725.21	123.06
Leaf essential oil	2017.39	290.63
Twig essential oil	2435.50	382.17
Ascorbic Acid	5.87	6.41

3.3. Antibacterial Activity

The essential oils extracted from flowers, leaves, and twigs of *G. tortilipetalus* were evaluated for their antibacterial activities against four Gram-positive bacteria, including *B. subtilis*, *L. monocytogenes*, *S. aureus*, and *M. luteus*, and five Gram-negative bacteria, *E. coli*, *S. typhimurium*, *P. aeruginosa*, *S. flexneri*, and *S. typhi*. The minimum inhibitory concentration (MIC) values obtained from the bacterial strains tested are shown in Table 3. The flower essential oil showed antibacterial activity against the Gram-positive bacteria, *B. subtilis*, *S. aureus*, and *M. luteus*, and the Gram-negative bacteria, *S. typhimurium* and *S. flexneri*, with the same MIC value of 640 μg/mL. Whereas the leaf oils showed weak antibacterial activity against *S. aureus*, *M. luteus*, *S. typhimurium*, and *S. typhi* with an MIC value of 1280 μg/mL. In the case of the twig essential oils, only *M. luteus* was inhibited with the MIC value of 1280 μg/mL. The antimicrobial activities of the essential oils obtained

from *Goniothalamus* species have been reported. The flower essential oil from *G. marcanii* presented caryophyllene oxide (19.3%), *E*-caryophyllene (14.6%), *β*-copaene (4.2%), and *α*-humulene (3.6%) as main compounds [20]. It exhibited moderate activities against *S. agalactiae*, *S. aureus*, *S. epidermidis*, *P. mirabilis*, *S. typhimurium*, and *E. coli* with MIC values in the range of 15.62–1000 μg/mL using the paper disk diffusion method [20]. The stem bark essential oils of *G. cardiopetalus* contained linalool (11.7%), *α*-pinene (7.0%), *trans*-pinocarveol (5.2%), and caryophyllene oxide (5.0%) as major constituents and displayed antimicrobial activity with MIC values in the range of 1.0–1.5 mg/mL for the Gram-positive bacteria (*S. aureus*, *S. albus*, *S. epidermidis*, *S. mitis*, *M. luteus*, *B. subtilis*, and *B. cereu*) and 1.5–6.5 mg/mL for the Gram-negative bacteria (*E. coli*, *E. aerogenes*, *K. pneumoniae*, *S. typhi*, *P. vulgaris*, *P. aeruginosa*) [17]. In this study, the antibacterial activities of essential oils from *G. tortilipetalus* are in agreement with the previous report. Still, they are less active than essential oils from *G. marcanii* and *G. cardiopetalus*, probably due to the difference in the main chemical composition.

Table 3. Antibacterial activity of essential oils from flowers, leaves, and twigs of *G. tortilipetalus*.

Microorganisms	Essential Oils (μg/mL)			Antibiotics (μg/mL)		
	Flower	Leaf	Twig	Amp	Gen	Van
Gram-positive						
B. subtilis (TISTR 1248)	640	inactive	inactive	0.25	0.25	128
L. monocytogenes (F2369)	1280	inactive	inactive	1	1	1
S. aureus (ATCC 25923)	640	1280	inactive	0.5	8	64
M. luteus (DMST 15503)	640	1280	1280	0.25	0.25	0.25
Gram-negative						
E. coli (TISTR 780)	1280	inactive	inactive	8	0.5	64
S. typhimurium (DMST 562)	640	1280	inactive	1	0.5	64
P. aeruginosa (ATCC 10145)	1280	inactive	inactive	64	1	128
S. flexneri (DMST 4423)	640	inactive	inactive	128	2	128
S. typhi (DMST 22842)	1280	1280	inactive	128	1	128

Amp: ampicillin, Gen: gentamicin, Van: vancomycin.

4. Conclusions

In conclusion, the findings of the present study indicated that essential oils obtained from the flowers, leaves, and twigs of *G. tortilipetalus* were rich in monoterpene and sesquiterpene hydrocarbons. Bicyclogermacrene, *p*-cymene, and *α*-copaene were the main constituents of the total oil compositions from the flower, leaf, and twig essential oils, respectively. The DPPH and ABTS radical scavenger test of essential oils showed weak antioxidant activities. The flower essential oils showed antibacterial activity against all tested microorganisms. Meanwhile, the leaf oil showed a moderate inhibitory power towards the Gram-positive (*S. aureus* and *M. luteus*) and the Gram-negative (*S. typhimurium* and *S. typhi*) strains.

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References

1. Aslam, M.S.; Ahmad, M.S.; Mamat, A.S.; Ahmad, M.Z.; Salam, F. Goniothalamus: Phytochemical and ethnobotanical review. *Recent Adv. Biol. Med.* **2016**, *2*, 34–47. [CrossRef]
2. Wiart, C. Goniothalamus species: A source of drugs for the treatment of cancers and bacterial infections? *Evid. Based Complement. Altern. Med.* **2007**, *4*, 635095. [CrossRef] [PubMed]
3. Jaidee, W.; Andersen, R.J.; Patrick, B.O.; Pyne, S.G.; Muanprasat, C.; Borwornpinyo, S.; Laphookhieo, S. Alkaloids and styryllactones from Goniothalamus cheliensis. *Phytochemistry* **2019**, *157*, 8–20. [CrossRef] [PubMed]
4. Moharam, B.A.; Jantan, I.; Ahmad, F.; Jalil, J. Antiplatelet aggregation and platelet activating factor (PAF) receptor antagonistic activities of the essential oils of five Goniothalamus species. *Molecules* **2010**, *15*, 5124–5138. [CrossRef] [PubMed]
5. Surivet, J.P.; Vatèle, J.M. Total synthesis of antitumor Goniothalamus styryllactones. *Tetrahedron* **1999**, *55*, 13011–13028. [CrossRef]
6. Meesakul, P.; Jaidee, W.; Richardson, C.; Andersen, R.J.; Patrick, B.O.; Willis, A.C.; Muanprasat, C.; Wang, J.; Lei, X.; Hadsadee, S.; et al. Styryllactones from Goniothalamus tamirensis. *Phytochemistry* **2020**, *171*, 112248. [CrossRef] [PubMed]
7. Iqbal, E.; Salim, K.A.; Lim, L.B. Phytochemical screening, total phenolics and antioxidant activities of bark and leaf extracts of Goniothalamus velutinus (Airy Shaw) from Brunei Darussalam. *J. King Saud. Univ. Sci.* **2015**, *27*, 224–232. [CrossRef]
8. Trieu, Q.H.; Pham, V.C.; Retailleau, P.; Litaudon, M.; Doan, T.M.H. Rare flavonoids and sesquiterpenoids isolated from the leaves of Goniothalamus gracilipes. *Fitoterapia* **2021**, *155*, 105034. [CrossRef]
9. Tantithanaporn, S.; Wattanapiromsakul, C.; Itharat, A.; Keawpradub, N. Cytotoxic activity of acetogenins and styryl lactones isolated from Goniothalamus undulatus Ridl. root extracts against a lung cancer cell line (COR-L23). *Phytomedicine* **2011**, *18*, 486–490. [CrossRef]
10. Funnimid, N.; Pompimon, W.; Nuntasaen, N. In vitro evaluation of crude extracts and isolated compounds from Goniothalamus rongklanus and Goniothalamus latestigma for bioactive properties. *J. Nat. Remedies* **2019**, *19*, 146–152. [CrossRef]
11. Zohdi, R.M.; Kaharudin, F.A.; Mukhtar, S.M.; Sidek, H.M.; Ismail, N.H. Dichloromethane stem bark extract of Goniothalamus lanceolatus Miq. modulates inflammatory cytokines and ameliorates tissue damage in Plasmodium berghei-infected mice. *J. Appl.* Pharm. Sci. **2022**, *12*, 149–155. [CrossRef]
12. Suthiphasilp, V.; Maneerat, W.; Rujanapun, N.; Duangyod, T.; Charoensup, R.; Deachathai, S.; Andersen, R.J.; Patrick, B.O.; Pyne, S.G.; Laphookhieo, S. α-Glucosidase inhibitory and nitric oxide production inhibitory activities of alkaloids isolated from a twig extract of Polyalthia cinnamomea. *Bioorg. Med. Chem.* **2020**, *28*, 115462. [CrossRef]
13. Jantan, I.; Ahmad, F.; Ahmad, A.S. A comparative study of the essential oils of four Goniothalamus species. *Acta Hortic.* **2003**, *677*, 27–36. [CrossRef]
14. Jantan, I.B.; Ahmad, F.B.; Din, L.B. Chemical constituents of the bark oil of Goniothalamus macrophyllus Hook. f. from Malaysia. *J. Essent. Oil Res.* **2005**, *17*, 181–183. [CrossRef]
15. Ahmad, F.B.; Jantan, I.B. Chemical constituents of the essential oils of Goniothalamus uvariodes King. *Flavour. Fragr. J.* **2003**, *18*, 128–130. [CrossRef]
16. Humeirah, A.S.; Azah, M.N.; Mastura, M.; Mailina, J.; Saiful, J.A.; Muhajir, H.; Puad, A.M. Chemical constituents and antimicrobial activity of Goniothalamus macrophyllus (Annonaceae) from Pasoh Forest Reserve, Malaysia. *Afr. J. Biotechnol.* **2010**, *9*, 5511–5515.
17. Hisham, A.; Pathare, N.; Al-Saidi, S.; Jayakumar, G.; Ajitha, M.D.; Harikumar, B. The composition and antimicrobial activity of stem bark essential oil of Goniothalamus cardiopetalus (Bl.) Hook. f. et Thoms. *J. Essent. Oil Res.* **2006**, *18*, 451–454. [CrossRef]
18. Ahmad, F.B.; Moharm, B.A.; Jantan, I. A comparative study of the constituents of the essential oils of Goniothalamus tapis Miq. and G. tapisoides Mat Salleh from Borneo. *J. Essent. Oil Res.* **2010**, *22*, 499–502. [CrossRef]
19. Thang, T.D.; Dai, D.N.; Ogunwande, I.A. Identification of the volatile compounds in the leaf and stem bark of three Goniothalamus species from Vietnam. *J. Essent. Oil-Bear. Plants.* **2016**, *19*, 743–749. [CrossRef]
20. Monggoot, S.; Pripdeevech, P. Chemical composition and antibacterial activities of Goniothalamus marcanii flower essential oil. *J. Appl. Pharm. Sci.* **2017**, *7*, 144–148. [CrossRef]
21. Adams, R.P. *Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry*, 4th ed.; Allured Publ. Corp.: Carol Stream, IL, USA, 2007.
22. Dudonné, S.; Vitrac, X.; Coutiére, P.; Woillez, M.; Mérillon, J.M. Comparative study of antioxidant properties and total phenolic content of 30 plant extracts of industrial interest using DPPH, ABTS, FRAP, SOD, and ORAC assays. *J. Agric. Food Chem.* **2009**, *57*, 1768–1774. [CrossRef] [PubMed]