

Chemical profiles and antibacterial activities of acetone extracts of *Globba macrocarpa*

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Abstract

Globba macrocarpa Gagnep. is a rare species of *Globba* genus (Zingiberaceae family). The present study reported the chemical compositions and antibacterial effects of acetone extracts obtained from the *G. macrocarpa* rhizomes and aerial parts. By using Gas Chromatography Mass Spectrometry (GC/MS) assay, fifty and thirty-two chemical compounds were identified from rhizomes and aerial parts of the species, respectively. Of those, germacrene D (15.25 %), 1H-indole, 4-(3-methyl-2-butenyl)- (14.33 %), (E)- β -farnesene (11.28 %), and 2-biphenylamine, 3-methyl (10.27 %) were the major constituents in the rhizome extract while the aerial part extract was characterized by the predominance of linolenic acid (19.89 %), palmitic acid (13.05 %), phytol (7.52 %), and neophytadiene (4.76 %). In addition, the rhizome extract had antibacterial activities against five 5 out of 6 oral bacteria, including *Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Salmonella typhimurium*, *Bacillus cereus*, and *Staphylococcus aureus*. Meanwhile, the aerial part extract was active against 4 out of 6 test bacteria, except for *Escherichia coli* and *S. typhimurium*.

Introduction

Globba L. is a third largest genus belonging to Zingiberaceae with over 100 species. This genus is distributed widely throughout tropical and subtropical of Asia such as India, southern China, New Guinea and Southeast Asia. *Globba* plants are small perennial herbs, reaching to a height of 1 m, except for *G. racemosa* (about 3 m) (Williams *et al.* 2004). Members of *Globba* consist of a large number of useful plants. For instance, the *G. bulbifera* rhizomes have been used to cure

cough, asthma, and snakebite. *G. multiflora* was used to treat headache and rheumatic inflammation (Jain 1995). The anti-inflammatory, antioxidant, and antipyretic activities were recorded as the biological activities of *G. malaccensis* (Ngamrojanavanich *et al.* 2005). In addition, previous studies showed the phytochemical composition and bioactivities of several *Globba* species (Andila and Tirt 2019; Raj *et al.* 2020). *Globba macrocarpa* Gagnep. is a rare species of *Globba* genus. This species was described for the first time by Gagnepain (1901) and mainly

distributed in Cambodia, Thailand and Vietnam (Pham 2000; Nguyen 2017). In 2020, we conducted some field trips to the Binh Chau-Phuoc Buu Nature Reserve, Bung Rieng ward, Xuyen Moc District, Ba Ria-Vung Tau Province, and encountered a flowering population of *G. macrocarpa*. To date, the chemical compositions and bioactivities of *G. macrocarpa* are still unknown. The present study, thus, firstly reported the chemical constituents and antibacterial effects of acetone extracts from the *G. macrocarpa* rhizomes and aerial parts.

Experimental

Plant materials

The samples of *G. macrocarpa* were collected from Binh Chau-Phuoc Buu Nature Reserve, Bung Rieng Ward, Xuyen Moc District, Ba Ria-Vung Tau Province, Vietnam, location of about 10°32'19.4"E 107°26'57.4"N, 18 m in elevation (Fig. 1).

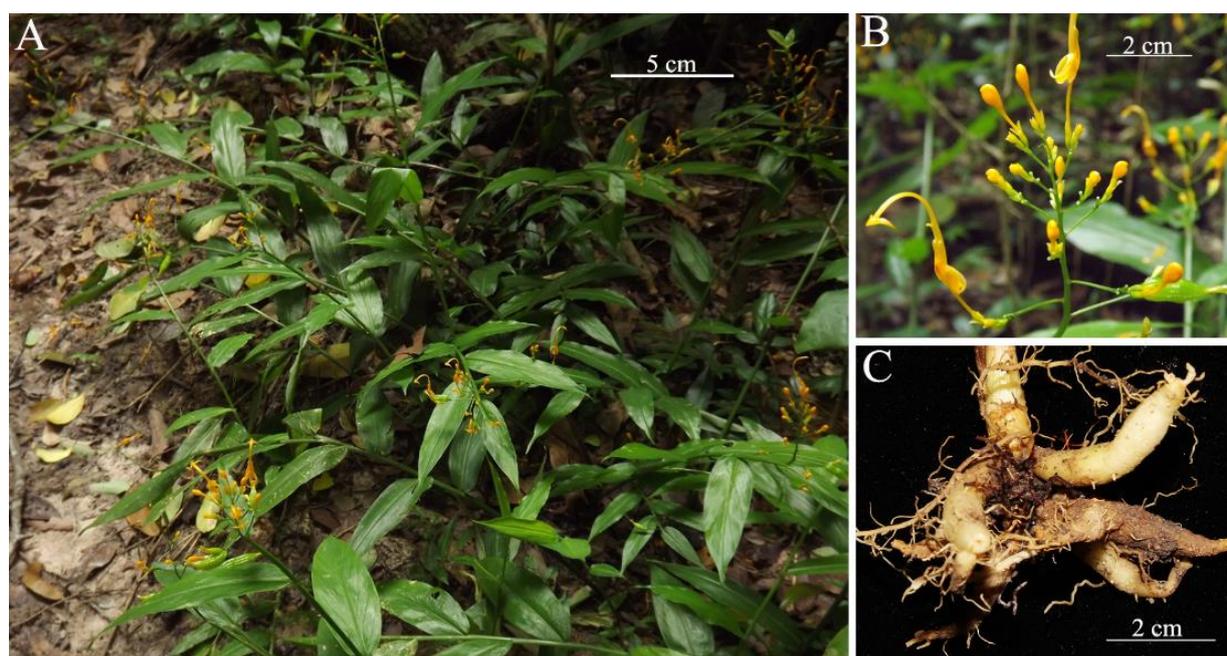


Fig.1. *Globba macrocarpa*. **A** – Species in habitat, **B** – Flowers, **C** – Rhizome.

Bacterial strains

In this study, the antibacterial properties of acetone extracts of the *G. macrocarpa* rhizome and aerial parts were investigated by using six bacterial strains such as *Salmonella typhimurium*-ATCC 13311, *Salmonella enteritidis*-ATCC 13976, *Pseudomonas aeruginosa*-ATCC 27853, *Escherichia coli*-ATCC 25922, *Staphylococcus aureus*-ATCC 25923, and *Bacillus cereus*-ATCC 11774.

Extraction procedures

The rhizome and aerial parts of *G. macrocarpa* were dried at 50 °C until constant weight. The dried samples were pulverized. 250 mL of acetone 99 %

solution was used to macerate 50 g of the dried powders at ambient temperature for three days. The studied samples were then filtered through the Whatman paper. The process was repeated twice and filtrates were concentrated under the reduced pressure at 60 °C to obtain the brown extracts. The final extracts were subjected to sublimation drying to completely remove the remaining acetone (Bobinaité et al. 2013).

Gas chromatography/mass spectrometry (GC/MS) assay

The TRACE 1310 Gas Chromatograph (Thermo Fisher Scientific, Waltham, USA) and ISQ 7000 single quadrupole mass spectrometer was used to identify the chemical compositions in the acetone

extract. GC column DB-5MS 30 m, 0.25 mm, 0.25 μm (Agilent Technologies, Santa Clara, USA) was used and carrier gas was helium with the column flow rate of 1.2 mL.min⁻¹. The specimen was added into the system with the split ratio of 30 : 1, the splitless mode of 1 min, and the split flow of 36 mL.min⁻¹, the inlet temperature of 250 °C. The initial temperature was set for 5 min at 80 °C. The temperature was then raised to 280 °C at the rate of 20 °C.min⁻¹ and hold for 10 min. The electron ionization mode and the ion source temperature were 70 eV and 250 °C, respectively. The mass scan range was 29 – 650 m/z. The NIST 2017 library version 2.3 (NIST 2017) was used to identify the chemical constituents of studied samples.

Antibacterial assay

The antibacterial properties of the acetone extract of the *G. macrocarpa* were conducted by Disc diffusion assay following the CLSI guideline (CLSI 2010). Luria-Bertani Broth was used to activate the bacterial strains until their turbidity was equivalent to 0.5 McFarland. Mueller Hinton Agar plate was inoculated with 0.1 mL of the bacterial culture by spread – plate technique before sterile paper discs containing 10 μL of the extract solution were placed on its surface. Gentamycin antibiotic discs (10 $\mu\text{g.mL}^{-1}$) (Nam Khoa Biotek, Ho Chi Minh City, Vietnam) were used as the positive control. The plates were incubated at 37 °C for 18 – 24 h. The antibacterial effects of the studied samples were identified by recording the size of the zone of inhibition.

Three biological replicates were used for the experiment, and results were expressed as mean \pm standard deviation (SD). Differences between means groups were calculated by LSD procedure using the Statgraphics Centurion XV software (Statgraphics Technologies, Inc., The Plains, USA) with $P < 0.05$.

Results and Discussion

Constituents of *G. macrocarpa* extracts

The acetone extracts isolated from rhizomes and aerial parts of *G. macrocarpa* in this study

contained a total of 50 and 32 components, respectively (Table 1 and 2). Accordingly, the rhizome extract was characterized by the predominance of germacrene D (15.25 %), 1H-indole, 4-(3-methyl-2-butenyl)- (14.33 %), (*E*)- β -farnesene (11.28 %) and 2-biphenylamine, 3-methyl- (10.27 %) (Fig. 2A). Meanwhile, the aerial part extract was found to be rich of linolenic acid (19.89 %), palmitic acid (13.05 %), phytol (7.52 %) and neophytadiene (4.76 %).

Previous studies have been reported the biological properties of some compounds obtained from the acetone extracts of *G. macrocarpa* rhizomes and aerial parts in this study. For instance, germacrene D, a major component from both rhizome and aerial part extracts, possessed the strong insecticidal activities against *Acyrtosiphon pisum*, *Sitobion avenae*, and *Myzus persicae* (Bruce *et al.* 2005). Similarly, germacrene D had also potent larvicidal effects against three mosquitos such as *Anopheles gambiae*, *Culex quinquefasciatus*, and *Aedes aegypti* with LD₅₀ values of 1.8, 2.1 and 2.8 mg.cm⁻³ (Ravi and Sita 2007). Recently, Schepetkin *et al.* (2020) demonstrated that germacrene D possessed the immunomodulatory activities. Accordingly, germacrene D could inhibit neutrophil Ca²⁺ mobilization, chemotaxis, and reactive oxygen species production with IC₅₀ values of 0.51, 5.4 and 9.9 $\mu\text{g.mL}^{-1}$ (Schepetkin *et al.* 2020). In addition, (*E*)- β -farnesene, another component from both rhizome and aerial part acetone extracts of *G. macrocarpa*, showed the effects on natural enemies to cabbage aphid (*Brevicoryne brassicae*) control in Chinese cabbage fields (Cui *et al.* 2012). Also, this compound has been reported to possessed other biological activities, including repellent and aphicidal activities against *Myzus persicae* (Qin *et al.* 2016). Furthermore, α -pinene and β -pinene, two bioactive compounds found in the rhizome and aerial part extracts, has been suggested as the larvicidal and insecticidal agents against *Aedes aegypti*, *Lasioderma serricorne*, and *Rhodnius nasutus* (Aparna *et al.* 2012; Wu *et al.* 2015; Carta *et al.* 2017). Palmitic acid, a compound from both rhizome and aerial part acetone extracts of *G. macrocarpa*, possessed the anti-inflammatory activities (Aparna *et al.* 2012), physiological role,

metabolism and nutritional implications in human (Carta *et al.* 2017).

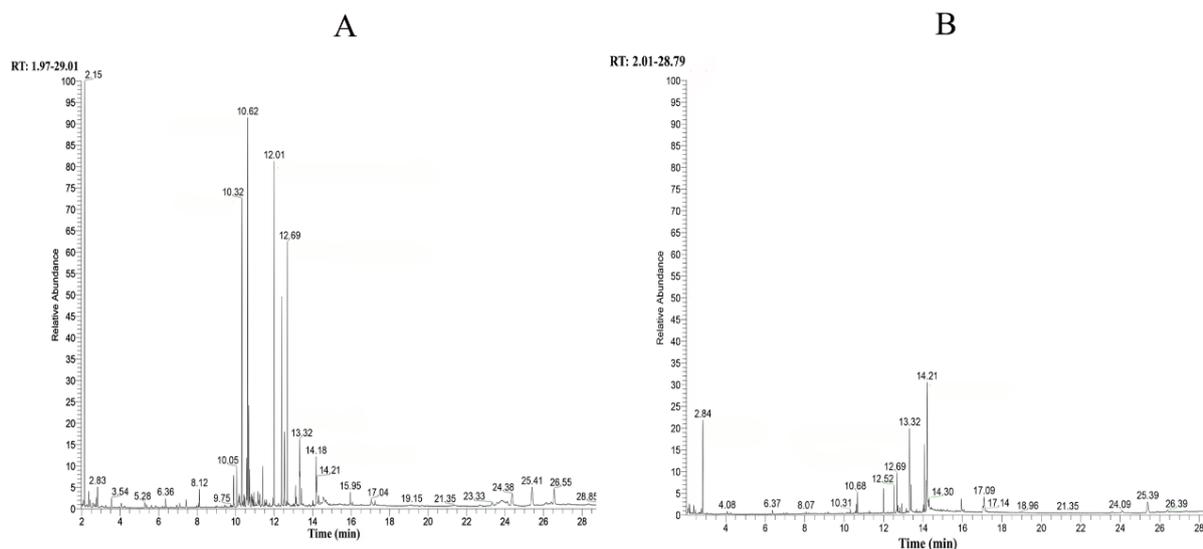


Fig. 2. GC/MS chromatograms of studied extracts from *G. macrocarpa* rhizomes (A) and aerial parts (B) with major components.

Table 1. Constituents of extract of *G. macrocarpa* rhizome.

No.	RT	Components	[%]	No.	RT	Components	[%]
1	2.15	Tyranton	0.23	26	10.83	γ -Amorphene	0.45
2	3.25	α -pinene	0.14	27	10.87	Guaia-10(14),11-diene	0.40
3	3.54	Camphene	0.69	28	10.91	α -Bulnesene	0.22
4	4.06	Sabinen	0.38	29	10.95	Epicubebol	0.48
5	5.28	Isosylvestrene	0.42	30	11.17	Germacrene B	0.53
6	5.38	Orthodene	0.28	31	11.21	Tricyclo[5.1.0.0(2,4)]oct-5-ene-5-propanoic acid, 3,3,8,8-tetramethyl-	0.34
7	5.63	β -Ocimene	0.21	32	11.27	Isoaromadendrene epoxide	0.59
8	6.36	3-(pyrrolidin-1-yl)cyclopent-2-en-1-one	0.56	33	11.40	1H-indole, 4-(3-methyl-2-butenyl)-	1.65
9	6.93	Triacetoneamin	0.14	34	11.51	1-epi-cubenol	0.24
10	7.10	4(1H)-quinolinone, octahydro-1-methyl-	0.39	35	11.56	Aromadendrene oxide-(1)	0.12
11	7.42	Alcanfor	0.51	36	11.60	Benzeneacetonitrile, α -cyclopentyl-	0.21
12	7.97	Methyl salicylate	0.11	37	12.01	1H-indole, 4-(3-methyl-2-butenyl)-	14.33
13	8.12	Dihydroanethole	0.77	38	12.38	3-(2-methylbut-3-enyl)-1H-indole	8.01
14	9.89	β -elemen	1.33	39	12.53	Quinoline, 2-ter-butyl-	2.57
15	10.06	α -gurjunene	1.60	40	12.69	2-biphenylamine, 3-methyl-	10.27
16	10.17	Caryophyllene	0.49	41	13.11	3-Methyldiphenylamine	0.73
17	10.20	γ -elemene	0.43	42	13.32	Palmitic acid	2.52
18	10.32	(E)- β -farnesene	11.28	43	13.41	Benzenamine, 4-methyl-N-phenyl-	0.61
19	10.38	Aristolene	0.13	44	14.18	9(E),11(E)-conuated linoleic acid	2.0
20	10.44	Humulene	0.43	45	14.21	Linolenic acid	1.44
21	10.55	Isogermacrene D	0.40	46	15.95	Palmitin, 2-mono-	0.63
22	10.58	(Z)- α -farnesene	1.93	47	17.04	9,12-octadecadienoic acid (,),2,3-dihydroxypropyl ester	0.93
23	10.62	Germacrene D	15.25	48	17.23	Stearin, 2-mono-	0.44
24	10.72	Bicylogermacrene	1.35	49	24.13	Stigmasterol	3.08
25	10.75	β -bisabolene	0.36	50	25.42	γ -Sitosterol	0.94

Table 2. Constituents of extract of *G. macrocarpa* aerial part.

No.	RT	Components	[%]	No.	RT	Components	[%]
1	4.07	β -Pinene	0.70	17	12.69	Neophytadiene	4.76
2	4.24	Cyclohexane, 1,2,4-trimethyl	0.38	18	12.72	3,7,11,15-Tetramethylhexadec-2-ene	1.05
3	6.37	3-(pyrrolidin-1-yl)cyclopent-2-en-1-one	0.77	19	12.82	Phytol	0.57
4	6.93	Triacetamin	0.21	20	12.69	Neophytadiene	1.13
5	7.01	Isophorone	1.62	21	13.32	Palmitic acid	13.05
6	7.10	(5R,8aR)-5-Propyloctahydroindolizine	0.22	22	13.41	2-biphenylamine, 3-methyl-	3.17
7	8.07	Pyrazine, 3-butyl-2,5-dimethyl	0.24	23	14.08	Phytol	7.52
8	9.02	5H-1-pyridine	0.12	24	14.18	Linoleic acid	4.36
9	9.17	2-methoxy-4-vinylphenol	0.20	25	14.21	Linolenic acid	19.89
10	10.31	(E)- β -farnesene	0.41	26	14.30	Octadecanoic acid	1.48
11	10.57	trans- α -bergamotene	0.24	27	15.94	Palmitin, 2-mono-	1.94
12	10.61	Germacrene D	1.06	28	17.08	2-Monolinolenin	3.93
13	10.68	α -farnesene	2.17	29	23.58	Campesterol	0.55
14	11.26	(-)-Spathulenol	0.30	30	24.10	Stigmasterol	1.04
15	11.99	1H-indole, 4-(3-methyl-2-butenyl)-	2.84	31	25.39	β -Sitosterol	5.80
16	12.52	3-(2-methylbut-3-enyl)-1H-indole	2.91	32	26.37	Cholesteryl formate	0.70

Several chemical compounds obtained from *G. macrocarpa* aerial parts and rhizomes in this study have been reported to possess the antimicrobial properties by previous studies. Accordingly, Simionatto et al. demonstrated that (E)- β -farnesene had antibacterial effects against *Bacillus subtilis*, *Staphylococcus aureus*, *Salmonella setubal*, and *Pseudomonas aeruginosa* (Simionatto et al. 2007). In addition, linolenic acid showed strong bacterial activities against *Staphylococcus aureus*, and *Streptococcus pyogenes* (Zheng et al. 2005). Also, α -pinene presented the antimicrobial against a large amount of bacterial and fungal strains, including *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus faecalis*, *Candida albicans*, *Sclerotinia sclerotiorum*, *Mycobacterium smegmatis*, *Cylindrocarpon mali*, *Aspergillus niger*, and *Stereum purpureum* (Prudent et al. 1993). In another report, α -pinene has been also reported to possess the antibacterial activities against *Staphylococcus aureus*, *S. epidermidis*, *Streptococcus pyogenes*, and *S. pneumonia*. Moreover, β -pinene had the antibacterial activity against gram-positive bacteria causing potential infectious endocarditis such as *Staphylococcus*

aureus, *S. epidermidis*, *Streptococcus pyogenes*, and *S. pneumonia* (Medeiros et al. 2007).

As mentioned above, *G. macrocarpa* is a rare species. The phytochemicals and biological properties of this plant are limited. However, there are some publications for chemical compositions and antimicrobial effects of other member of the *Globba* species using GS/MS assay. For instance, the major components of ethanol extracts isolated from *G. candida* rhizomes grown in Indonesia included levoglucosan (19.07 %), allylhydrazone acetaldehyde (5.52 %), *trans*-2,3-epoxybutane (6.30 %), butan-3-enoic acid methyl ester (4.36 %) while the leaf extract has been reported to contain pinostrobin chalcone (75.63 %), 1-(1-(hydroxyphenyl-methyl)-cyclopropyl)-2-phenyl-ethano (2.4 %), benzenepentanal (2.08 %) as the major compounds (Andila and Tirta 2019). In addition, the chemical profiles of the essential oil extracted from the rhizomes of *G. pendula* from Vietnam were found to be rich in δ -selinen (36.45 %) and ishwarane (10.76 %) (Ngo et al. 2020). Furthermore, the chemical compositions of rhizome essential oils of three *Globba* species collected from India, including *G. cernua*, *G. marantina*, and *G. ophioglossa* have been reported (Menon and Dan 2009). As a result, caryophyllene was the most

components in the oils (19.3 – 24.2 %), followed by α -humulene, (Z)-nerolidol, and (Z,Z)-farnesol (Menon and Dan 2009).

Antibacterial activities of G. macrocarpa extracts

The extracts of *G. macrocarpa* rhizomes were found to be effective against five oral bacteria, except for *E. coli* (Fig. 3 and Table 3). As a result, the rhizome extract showed potent antibacterial effects against *P. aeruginosa* and *S. aureus* with the zone of inhibition of 19.0 ± 1.7 and 14.7 ± 2.5 mm, respectively which higher than that of positive control (Table 3). Also, the rhizome extract possessed moderate effects against *B. cereus*

(14.2 ± 0.8 mm), *S. enteritidis* (11.2 ± 1.2 mm), and *S. typhimurium* (10.8 ± 1.1 mm).

The data in Table 3 and Fig. 3 presented the antimicrobial effects of aerial part extracts of *G. macrocarpa*. Among 6 tested bacteria, the extract was found to be effective against four studied bacteria, including *P. aeruginosa*, *B. cereus*, *S. enteritidis*, and *S. aureus*. Generally, the aerial part extract possessed antibacterial effects weaker than that of rhizome extract. This extract only possessed the moderate effects against *S. enteritidis* with the zone of inhibition of 13.5 ± 1.3 mm while this sample presented the weak antibacterial activities against *B. cereus* (9.3 ± 0.3 mm), *S. aureus* (9.3 ± 0.3 mm), and *P. aeruginosa* (7.2 ± 0.3 mm).

Table 3. Zone of inhibition of acetone extracts from *G. macrocarpa* against six oral bacteria.

Microorganism	Size of zone of inhibition [mm]		
	Rhizome	Aerial part	Gentamycin
<i>B. cereus</i>	14.2 ± 0.8^b	9.3 ± 0.3^a	22.3 ± 0.6^c
<i>E. coli</i>	-	-	21.3 ± 1.5
<i>P. aeruginosa</i>	19.0 ± 1.7^c	7.2 ± 0.3^a	13.5 ± 1.8^c
<i>S. enteritidis</i>	11.2 ± 1.2^a	13.5 ± 1.3^a	20.3 ± 1.5^b
<i>S. typhimurium</i>	10.8 ± 1.1^a	-	14.8 ± 1.1^b
<i>S. aureus</i>	14.7 ± 2.5^b	9.3 ± 0.3^a	12.3 ± 2.1^{ab}

^{a,b,c}The notable variation ($P < 0.05$) was represented by distinct superscript lower-case letters in the same row.

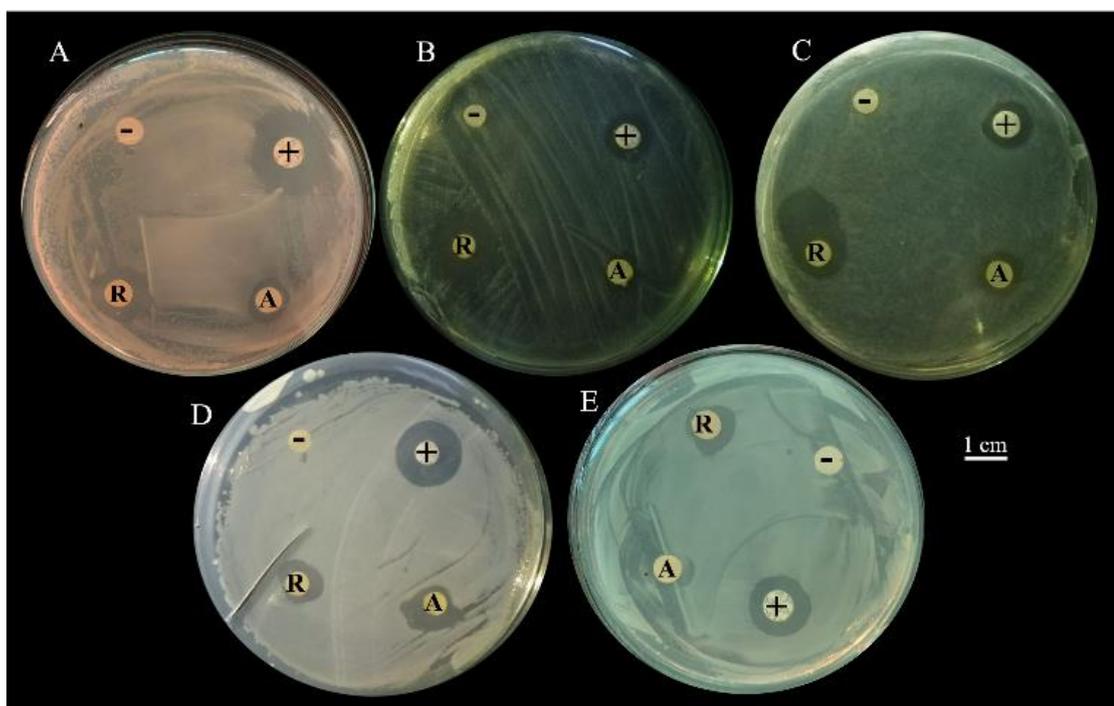


Fig. 3. Antibacterial effects of the rhizome (R) and aerial part (A) extracts of *G. macrocarpa*. **A** – *B. cereus*; **B** – *P. aeruginosa*; **C** – *S. aureus*; **D** – *S. enteritidis*; **E** – *S. typhimurium*. (-) – Negative control, (+) – Positive control.

The chemical components of hexane and dichloromethane extracts obtained from different parts of *G. schomburgkii* collected from Thailand have been reported. Accordingly, hexane extract of rhizomes was characterized by the predominance of β -patchoulene (9.8 %), 3-acetoxy-5-pregnene (7.8 %), and γ -bicyclohomofarnesal (6.4 %) while phytol was the most abundant components in the hexane extract of stalks (13.8 %) and leaves (34.6 %). The major constituents in the hexane extract of flowers were β -caryophyllene (16.5 %) and γ -bicyclohomofarnesal (14.6 %). Meanwhile, the most major constituent the dichloromethane extracts of rhizomes, stalks, leaves, and flowers were α -gurjunene (16.3 %), β -caryophyllene (11 %), phytol (19 %), and caryophyllene oxide (15.8 %), respective (Doungchawee *et al.* 2019). In addition, the antimicrobial activities of the hexane, dichloromethane, and methanol extracts from four plant parts of *G. schomburgkii* have been investigated. All twelve extracts had an inhibitory effect on *Streptococcus sobrinus*. The hexane and dichloromethane extracts displayed activity against *Streptococcus mutans*, *Salmonella typhimurium*, and *Staphylococcus aureus* whereas *Aspergillus flavus* was inhibited by the dichloromethane extracts (leaves, stalks, and flowers) and the methanol extracts of leaves (Doungchawee *et al.* 2019). Similarly, the dichloromethane extract and its fractions and sub-fractions obtained from *G. schomburgkii* rhizomes were mainly composed of γ -bicyclohomofarnesal (4.1 – 20.8 %), (*E*)-15,16-dinorlabda-8(17),12-dien-14-one (7.6 – 58.2 %). Moreover, crude dichloromethane extract and its fractions were found to be effective against four pathogenic bacteria, including *S. aureus*, *M. luteus*, *E. coli*, and *P. aeruginosa* (Suekaew *et al.* 2020).

Conclusion

This study identified 50 and 32 chemical compositions in the acetone extracts of *G. macrocarpa* rhizomes and aerial parts, in which some components have been reported to possess many biological properties. The rhizome extract was demonstrated to be active against 5 bacterial strains with the diameter of inhibition zones of *P. aeruginosa* (19.0 ± 1.7 mm), *S. aureus* (14.7 ± 2.5 mm), *B. cereus* (14.2 ± 0.8 mm), *S. enteritidis*

(11.2 ± 1.2 mm) and *S. typhimurium* (10.8 ± 1.1 mm) while the aerial part extract showed antibacterial effects *S. enteritidis* (13.5 ± 1.3 mm), *S. aureus* (9.3 ± 0.3 mm), *B. cereus* (9.3 ± 0.3 mm) and *P. aeruginosa* (7.2 ± 0.3 mm). The results from the present study can be used as reference for pharmaceutical products and relative fields from *G. macrocarpa* which could increase the economic valuation of this species.

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Conflict of Interest

The authors declare that they have no conflict of interest.

References

- Andila P, Tirta I (2019) Distribution and phytochemical component in the ethanol extract of *Globba candida* Gagnep. (Zingiberaceae) by GC-MS Analysis. *J. Trop. Life Sci.* 9: 43-51.
- Aparna V, Dileep KV, Mandal PK, Karthe P, Sadasivan C, Haridas M (2012) Anti-Inflammatory property of n-hexadecanoic acid: structural evidence and kinetic assessment. *Chem. Biol. Drug Des.* 80: 434-439.
- Bobinaite R, Viškelis P, Šarkinas A, Venskutonis PR (2013) Phytochemical composition, antioxidant and antimicrobial properties of raspberry fruit, pulp, and marc extracts. *CyTA-J. Food.* 11: 334-342.
- Bruce TJA, Birkett MA, Blande J, Hooper AM, Martin JL, Khambay B (2005) Response of economically important aphids to components of *Hemizygia petiolata* essential oil. *Pest Manag. Sci.* 61: 1115-1121.
- Carta G., Murru E., Banni S., Manca C (2017) Palmitic acid: Physiological role, metabolism and nutritional implications. *Front. Physiol.* 8: 2-14.
- CLSI document M45-A2 (2010) Methods for Antimicrobial Dilution and Disk Susceptibility of Infrequently Isolated or Fastidious Bacteria. Clinical and Laboratory Standards Institute Approved Guideline – Second Edition, 950 West Valley Roadn Suite 1400, Wayne, Pennsylvania, USA, 2010, 100 p.
- Cui LL, Francis F, Heuskin S, Lognay G, Liu YJ, Dong J (2012) The functional significance of E- β -Farnesene: Does it influence the populations of aphid natural enemies in the fields? *Biol. Control* 60: 108-112.
- Doungchawee J, Kulsing C, Suekaew N, Pombjra SN, Chavasiri W, Plabutong N (2019) Volatile chemical composition, antibacterial and antifungal activities of

- extracts from different parts of *Globba schomburgkii* Hook. F. Chem. Biodivers. 16: e1900057.
- Gagnepain MF (1901) Révision des genres *Mantisia* et *Globba* (Zingibérées) de l'herbier du muséum. Bull. Soc. Bot. France 48: 201-216.
- Jain SK (1995) Ethnobotanical Diversity in Zingibers of India. Ethnobotany. 7: 83-88.
- Medeiros LA, Oliveira LE, Leite SE, Fátima M, Melo DF, Nogueira TV (2007) Inhibitory effect of β -pinene, α -pinene and eugenol on the growth of potential infectious endocarditis causing Gram-positive bacteria. Rev. Bras. Cienc. Farm. 43: 121-126.
- Menon AN, Dan M (2009) Chemical composition of essential oils of *Globba* species from South India. J. Essent. Oil Res. 21: 59-60.
- National Institute of Standards and Technology (2017). The NIST Mass Spectral Search Program for the NIST/EPA/NIH EI and NIST Tandem Mass Spectral Library Version 2.3. NIST MS Search and Lib2NIST software uses InChI Library v.1.05 (Copyright © IUPAC and InChI Trust Limited, <http://www.inchi-trust.org/download/105/LICENCE.pdf>)
- Ngamrojanavanich S, Onanong S, Pornpakakul S, Muangsin M, Petsom A (2005) Cyclic AMP phosphodiesterase inhibitors from the rhizomes of *Globba malaccensis*. J. Trop. Med. Plants 6: 37-41.
- Ngo TP, Dinh TTT, Do TT, Do TTH, Le NH, Nguyen TA, Le MH (2020) Volatile compounds and biological activities of essential oil of *Globba pendula* rhizomes collected at An Giang province. Vietnam J. Sci. Technol. 58: 434-441.
- Nguyen QB (2017) Zingiberaceae-Flora of Vietnam. Publishing House for Science and Technology.
- Pham H (2000) Araceae. In Pham-hoang H (Eds.), *Cây cỏ Việt Nam: An Illustrated Flora of Vietnam*, vol. 3. Youth Publishing House, Ho Chi Minh City.
- Prudent D, Perineau F, Bessiere JM, Michel G, Bravo R (1993) Chemical analysis, bacteriostatic and fungistatic properties of the essential oil of the atoumau from martinique (*Alpinia speciosa* K. schum.). J. Essent. Oil Res. 5: 255-264.
- Qin Y, Zhang J, Song D, Duan H, Li W, Yang X (2016) Novel (E)- β -farnesene analogues containing 2-nitroimino-hexahydro-1,3,5-triazine: Synthesis and biological activity evaluation. Molecules 21: 21070825.
- Raj G, George V, Dan M, Sethuraman M G (2010) Essential oil composition of *Globba schomburgkii* Hook. f. and *Globba ophioglossa* Wight. J. Essent. Oil Res. 22: 220-222.
- Ravi KS, Sita DP (2007) Evaluation of mosquitocidal activity of essential oil and sesquiterpenes from leaves of *Chloroxylon swietenia* DC. Parasitol. Res. 101: 413-418.
- Schepetkin IA, Ozek G, Ozek T, Kirpotina LN, Khlebnikov AI, Quinn MT (2020) Chemical composition and immunomodulatory activity of hypericum perforatum essential oils. Biomolecules 10: 1-20.
- Simionatto E, Porto C, Stüker CZ, Dalcol II, Silva UF (2007) Chemical composition and antimicrobial activity of the essential oil from *Aeolanthus suaveolens* MART. ex Spreng. Quim. Nova 30: 1923-1925.
- Suekaew N, Pombejra SN, Kulsing C, Dounghawee J, Khotavivattana T (2020) Bioassay-guided fractionation, chemical compositions and antibacterial activity of extracts from rhizomes of *Globba schomburgkii* Hook.f. Chem. Biodivers. 17: e2000173.
- Williams KJ, Kress WJ, Manos PS (2004) The phylogeny, evolution, and classification of the genus *Globba* and tribe Globbeae (Zingiberaceae): appendages do matter. Am. J. Bot. 91: 100-114.
- Wu Y, Zhang WJ, Huang DY, Wang Y, Wei JY, Li ZH, Sun JS, Bai JF, Tian ZF, Wang PJ, Du SS (2015) Chemical compositions and insecticidal activities of *Alpinia kwangsiensis* essential oil against *Lasioderma serricorne*. Molecules 20: 21939-21945.
- Zheng CJ, Yoo JS, Lee TG, Cho HY, Kim YH, Kim WG (2005) Fatty acid synthesis is a target for antibacterial activity of unsaturated fatty acids. FEBS Letters 579: 5157-5162.