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CHEMICAL DIVERSITY OF ESSENTIAL OILS FROM AERIAL PARTS OF EIGHT SPECIES OF ZINGIBERACEAE FAMILY FROM VIETNAM

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Abstract

The objective of this work was to analyze the content and the chemical diversity of the essential oils from the aerial parts of eight species belonging to Zingiberaceae family collected in Binh Chau-Phuoc Buu Nature Reserve, Vietnam. The essential oils were isolated by hydrodistillation and their constituents were investigated by gas chromatography-mass spectrometry. The essential oils from the aerial parts of eight studied species, including *Zingiber zerumbet, Zingiber pellitum, Curcuma pierreana, Globba macrocarpa, Globba globulifera, Alpinia conchigera, Stahlianthus campanulatus* and *Amomum* sp. were obtained in a yield of 0.01%, 0.008%, 0.01%, 0.012%, 0.012%, 0.02%, 0.015 and 0.3%, respectively. There were a total of 75 compounds identified from the essential oils obtained from eight studied species. Four main clusters and three subclusters were formed by the cluster analysis. Cluster I consisted of *A. conchigera* with the presence of β-elemene (51.76%) and caryophyllene (28.1%). Cluster II contained five species, including *Z. zerumbet, Z. pellitum, C. pierreana, G. globulifera* and *S. campanulatus* with high concentration of β-pinene (11.81%, 5.32%, 4.43%, 25.42% and 1.57%), caryophyllene (13.61%, 23.45%, 19.78%, 34.26% and 18.72%), caryophyllene oxide (4.66%, 4.00%, 13.65%, 8.15% and 24.69%). Cluster III consisted of *G. macrocarpa,* and presented 4-isobutylquinoline (24.43%), β-copaene (21.69%), α-farnesene (20.73%), 2-tert-butylquinoline (6.05%), 3-Dihydroxydiphenylamine (5.47%), β-panasinsene (5.13%) as major compounds. Cluster IV contained *Amomum* sp. and had eucalyptol (25.22%), camphor (24.51%), camphene (14.57%), β-pinene (13.45%), Isoborneol (9.17%), α-Selinene (6.21%) as main constituents.

Keywords: Zingiberaceae, GC-MS, essential oils, Binh Chau-Phuoc Buu Nature Reserve

INTRODUCTION

For thousands of years, plants have been used to flavor, food, medicines, in which medicinal plants are rich sources of antimicrobial agents, potential and powerful drugs. Many chemical constituents which isolated from medicinal plants are usually responsible for the biological properties including treatment of infectious diseases (Silva and Fernandes, 2010; Vashist and Jindal, 2012; Awad and Abdelwahab, 2016). The potential of vascular plants as a source for new medicine is still largely unexplored. However, only a small percentage have been recorded phytochemically among the estimated about 500,000 species (Mahesh and Satish, 2008) in which the medicinal aspects, chemical constituents and bioactivities of Zingiberaceae plants were investigated by some previous studies (Jantan *et al.,* 2003; Jatoi *et al.,* 2007; Koga *et al.,* 2016).

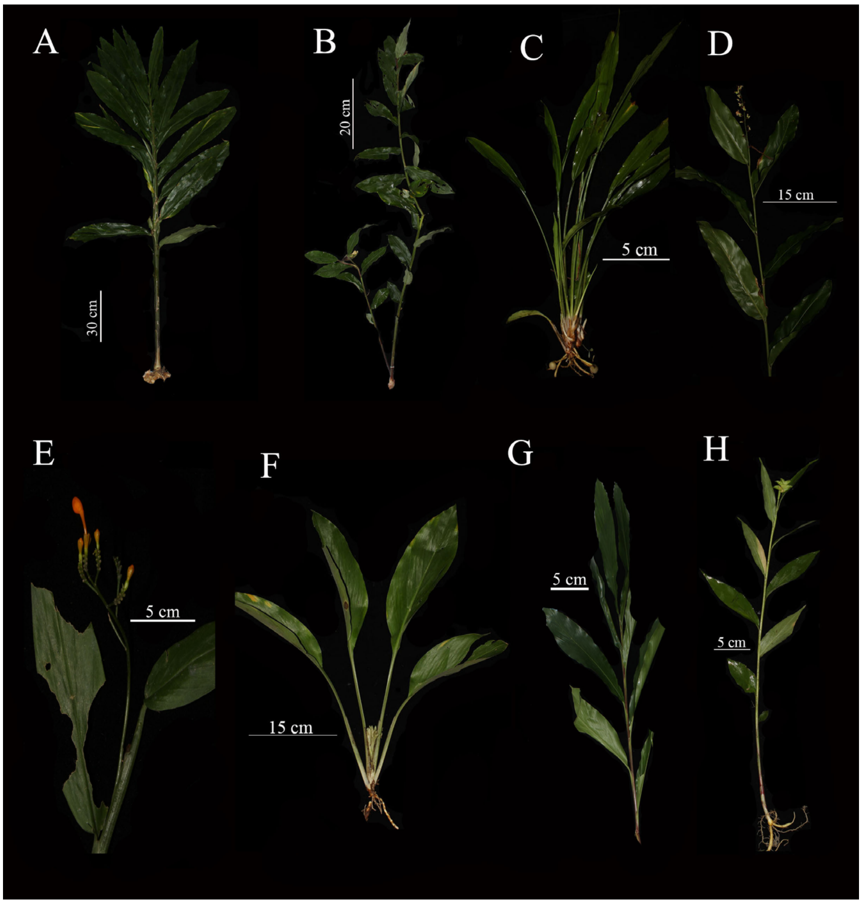
Zingiberaceae is a large family and has approximately 1400 species belonging to 53 genera which are distributed widely in Asia, especially Southeast Asia (Kress *et al.,* 2002; Leong-Škornicková and Newman, 2012; Van *et al.,* 2021; Van, 2021). In Vietnam, 129 species and 22 genera belonging to Zingiberaceae family have been recorded by previous reports (Pham, 2000; Nguyen, 2005; Leong-Škorničková and Ly, 2010; Leong-Škorničková and Tran, 2013; Leong-Škorničková and Luu, 2013; Leong-Škorničková *et al.,* 2015; Nguyen *et al.,* 2017; Nguyen, 2017). The family Zingiberaceae is well-known for its medicinal values (Jantan *et al.,* 2003). The aerial parts and rhizomes of Zingiberaceae species were used to treat cough, sore throat, improve digestion, reduce pain, heal bruises and scars (Pham, 2000; Jantan *et al.,* 2003). Members of Gingers provided many useful products for medicines, spices, cosmetics, and essential oil as important natural resources (Jantan *et al.,* 2003; Jatoi *et al.,* 2007; Koga *et al.,* 2016; Zahara *et al.,* 2018). Furthermore, the essential oils isolated from the rhizomes and the aerial parts of Zingiberaceae species also contained many medicinal compounds, including terpenes, ketones, flavonoids and phytoestrogens (Zahara *et al.,* 2018).

In 2019, we conducted some field trips to the Binh Chau-Phuoc Buu Nature Reserve, Bung Rieng ward, Xuyen Moc District, Ba Ria-Vung Tau Province, Southern Vietnam and collected eight species belonging to Zingiberaceae family, including *Zingiber zerumbet, Zingiber pellitum, Curcuma pierreana, Globba macrocarpa, Globba globulifera, Alpinia conchigera, Stahlianthus campanulatus* and *Amomum* sp. Here, we firstly investigated and compared the chemical constituents of the essential oils isolated from the aerial parts of eight Zingiberaceae species from Binh Chau-Phuoc Buu Nature Reserve.

MATERIALS AND METHODS

Plant Materials

Specimens of eight species, including Z. *zerumbet, Z. pellitum, C. pierreana, G. macrocarpa, G. globulifera, A. conchigera, S. campanulatus* and *Amomum* sp. were collected from Binh Chau-Phuoc Buu Nature Reserve, Bung Rieng Ward, Xuyen Moc District, Ba Ria-Vung Tau Province. The vouchered specimens of these species were stored at herbarium of Binh Chau-Phuoc Buu Nature Reserve (Fig. 1 and Tab. I).



1: *Eight Zingiberaceae species in present study. A: Zingiber zerumbet. B: Zingiber pellitum. C: Stahlianthus campanulatus. D: Alpinia conchigera. E: Globba macrocarpa, F: Curcuma pierreana, G: Amomum sp. H: Globba globulifera.*

I: *Detailed information of collected site of eight studied species in Binh Chau-Phuoc Buu Nature Reserve*

Voucher number	Scientific names	Collected sites
VS Le 210	*C. pierreana*	N10^{0}35’41,1”; E107^{0}30’17,9”
VS Le 212	*G. macrocarpa*	N10^{0}37’14,6”; E107^{0}32’08,0”
VS Le 213	*G. globulifera*	N10^{0}32’54,7”; E107^{0}27’13,0”
VS Le 214	*Z. pellitum*	N10^{0}32’22,9”; E107^{0}28’57,5”
VS Le 215	*Z. zerumbet*	N10^{0}32’49,8”; E107^{0}27’18,0”
VS Le 216	*Amomum* sp.	N10^{0}32’20,2”; E107^{0}26’56,1”
VS Le 217	*S. campanulatus*	N10^{0}32’51,5”; E107^{0}27’08,9”
VS Le 218	*A. conchigera*	N10^{0}31’45,4”; E107^{0}27’33”

Hydrodistillation of the Essential Oils and Yield Calculation

500 g fresh aerial parts of each species were hydrodisstilled in a Clevenger-type aqqaratus for 4 h. The essential oil was dried using anhydrous sodium sulphate and (Na_2SO_4) and stored at 4 ºC. The experiments were performed in triplicate. The oil yields were determined using the equation $RO = M/B_m \times 100\%$, where M is the weight of the extracted oil (g) and B_m is the initial leaf biomass (g).

Gas Chromatography-mass Spectrometry (GC/MS) Analysis

The constituents of essential oil isolated from studied specimens were investigated by Gas Chromatography Mass Spectrometry GC–MS using an Agilent 7890A GC coupled to a 5975C VL MSD Triple-Axis selective Detector equipped with an ZB-5MS capillary non-polar column (30.0 m length × 0.25 mm i.d. × 0.25 µm film thickness). Helium was the carrier gas at constant pressure at 13.209 psi. The injection temperature was 250 °C; the injection volume was 0.1 µl; the split ratio was 10 : 1. The oven temperature was programmed to proceed from 60 °C to 240 °C at 3 °C/min. the chemical constituents were identified by comparing their mass spectra with internal library, NIST 2017 library and the Wiley 8th edition libraries.

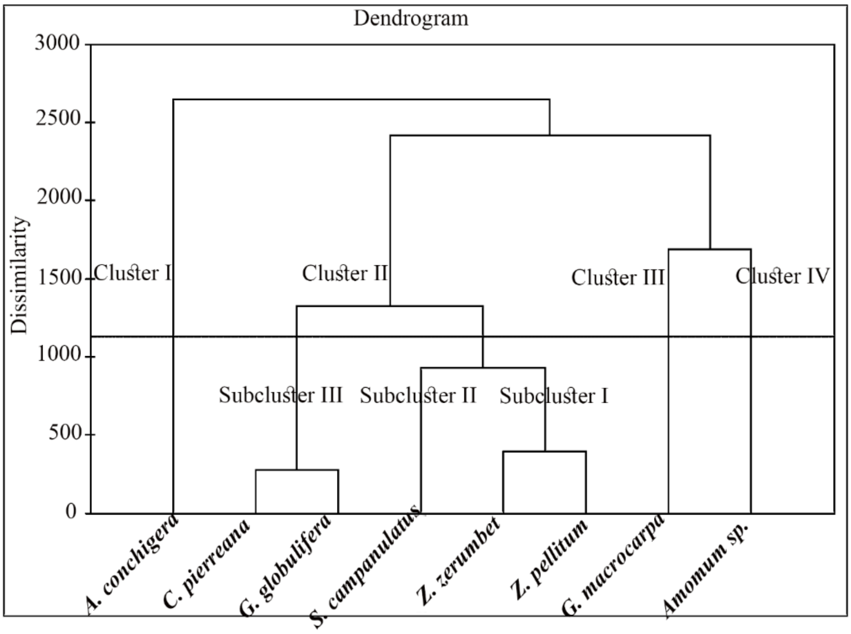
Data Analysis

The essential oils were classified into clusters based on their similarities in volatile compound constituents by Agglomerative Hierarchical Clustering (AHC). Besides, the volatile constituents were subjected to Principal Component Analysis (PCA) using covariance matrix to identify the typical constituents of each essential oil. All analyses were performed using XLSTAT Sensory (Addinsoft, Boston, USA).

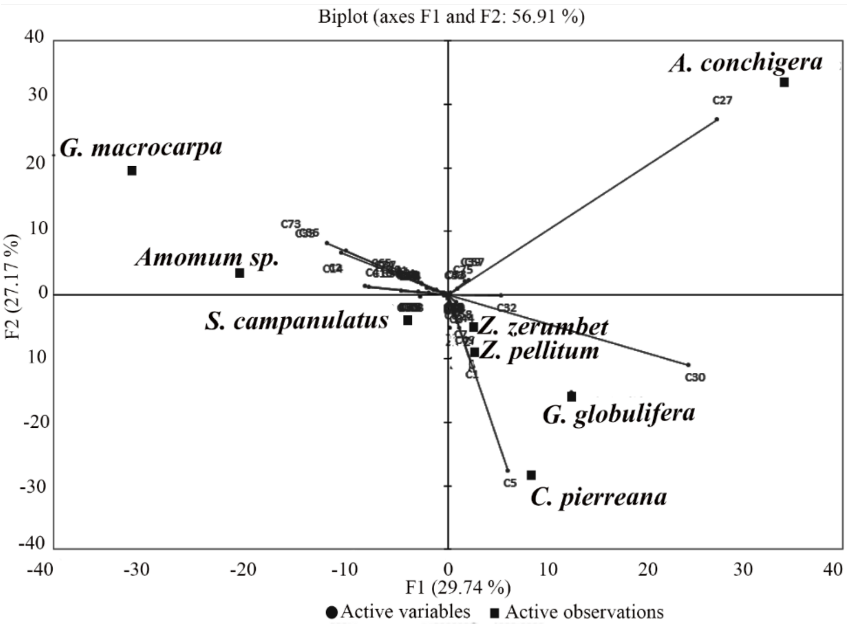
RESULTS AND DISCUSSION

The average of aerial parts oil yields of eight studied specimens, including *Z. zerumbet, Z. pellitum, C. pierreana, G. macrocarpa, G. globulifera, A. conchigera, S. campanulatus* and *Amomum* sp. presented highly significant differences, on average 0.01%, 0.008%, 0.01%, 0.012%, 0.012%, 0.02%, 0.015 and 0.3%, respectively.

Tab. II presented the chemical compositions of essential oil from the aerial parts of eight studied species. A total of seventy-five chemical constituents have been identified in which the essential oils of eight studied specimens contained about monoterpene hydrocarbons (0.81%–62.19%), oxygenated monoterpenes (0.12%–59.3%), sesquiterpene hydrocarbons (10.65%–90.3%), oxygenated sesquiterpenes (0.17%–34.2%), non-terpenes (0.24%–30.58%) and others (0.31%–6.83%). Furthermore, Fig. 2 and 3 showed the results derived from clustering analysis and PCA. The chemical constituents of essential oils divided into 4 clusters. Accordingly, cluster I contained *A. conchigera* with the high presence of β-elemene (51.76%) and caryophyllene (28.1%). Cluster II, consisting of five plants, including *Z. zerumbet, Z. pellitum, C. pierreana, G. globulifera* and *S. campanulatus* had β-pinene (11.81%, 5.32%, 4.43%, 25.42% and 1.57%), caryophyllene (13.61%, 23.45%, 19.78%, 34.26% and 18.72%) and caryophyllene oxide (4.66%, 4.00%, 13.65%, 8.15% and 24.69%) as major compounds. Because it was characterized by a number of distinct constituents, cluster II was divided into three subclusters. Consequently, subcluster I consisted of *Z. zerumbet* and *Z. pellitum* with β-Pinene (11.818% and 5.32%) as a main constituent while *S. campanulatus* belonged to the second subcluster which was characterized by the following compounds: alloaromadendrene (9.74%), β-pinene (1.57%) and D-limonene (1.33%). Subcluster III contained two species (*C. pierreana* and *G. globulifera*) with concentration of α-pinene (11.72% and 1.9%), D-limonene (1.20% and 1.80%), humulene (1.87% and 9.56%). Furthermore, cluster III contained *G. macrocarpa* with the presence of 4-isobutylquinoline (24.43%), β-copaene (21.69%), α-farnesene (20.73%), 2-tert-butylquinoline (6.05%), 3-dihydroxydiphenylamine (5.47%) and β-panasinsene (5.13%) as major compounds. Finally, cluster IV, consisting of *Amomum* sp. had eucalyptol (25.22%), camphor (24.51%), camphene (14.57%), β-pinene (13.45%), isoborneol (9.17%), α-selinene (6.21%) as major constituents.



2: *The AHC tree diagram presenting the four clusters of the essential oils of eight studied species*



3: *PCA biplot presenting the main constituents of the essential oils of eight studied species*

The chemical constituents of the essential oils of eight studied specimens showed significant difference. Among eight studied species, two species belonging to *Zingiber* genus, including *Z. zerumbet* and *Z. pellitum* were classified into subcluster I whereas two *Globba* species (*G. macrocarpa* and *G. globulifera*) belonged to two different clusters (Fig. 2 and 3). The chemical diversity of essential oils of some species belonging to the same genus has been investigated by previous studies (Wong *et al.,* 2005; Kurup *et al.,* 2018). For instance, the chemical constituents of the essential oils of two *Alpinia* species, such as *A. conchigera* and *A. latilabris* were high different. Accordingly, *A. conchigera* consisted of the following major compounds: β-bisabolene (28.9%), 1,8-cineole (15.3%), β-caryophyllene (10.0%), β-pinene (9.5%) whereas methyl (*E*)-cinnamate (89.5%) was the main constituent in essential oil of *A. latilabris* (Wong *et al.,* 2005). Similary, *A. agastyamalayanum* and *A. newmanii,* two species belonging to *Amomum* genus, had the diversity in the chemical constituents of the essential oils. For instance, *A. agastyamalayanum* oils contained allo-aromadendrene (16.23%), II: *Chemical compositions in the essential oils from aerial parts of eight species of Zingiberaceae family in Binh Chau-Phuoc Buu Nature Reserve*

Compounds	RT	Code	The amount percentage in samples (%)							
			Z. zerumbet	*Z. pellitum*	*C. pierreana*	*G. globulifera*	*G. macrocarpa*	*Amomum* sp.	*A. conchigera*	*S. campanulatus*
α-Pinene	9.55	C1	29.30	15.95	11.72	1.9	-	-	0.13	0.16
Eucalyptol	9.60	C2	-	-	-	-	0.23	25.22	-	-
4-Carene	9.70	C3	-	-	0.63	-	0.43	-	-	-
Camphene	9. 72	C4	-	0.18	-	0.39	-	14.57	-	-
β-Pinene	10.10	C5	11.81	5.32	41.04	25.42	-	13.45	-	1.57
Cyclofenchene	10.10	C6	-	11.31	-	-	-	-	-	-
3-Carene	10.50	C7	2.30	6.21	6.99	-	-	-	-	-
D-Limonene	10.61	C8	10.18	-	1.2	1.8	-	-	-	1.33
Sylvestrene	10.68	C9	-	5.35	-	-	-	-	-	-
β-Ocimene	10.78	C10	2.67	-	-	-	-	-	-	-
γ-Terpinene	10.87	C11	0.25	-	-	-	-	-	-	-
1,6-Octadien-3-ol, 3,7-dimethyl-	11.15	C12	-	-	-	0.6	-	-	-	-
Cyclopropane, 1,1-dimethyl-2- (3-methyl-1, 3-butadienyl)-	11.20	C13	-	4.43	-	-	-	-	-	-
Camphor	11.48	C14	-	-	-	-	-	24.51	-	-
2-Octanol, acetate	12.01	C15	-	-	-	0.51	-	-	-	-
Isoborneol	12.28	C16	-	-	-	-	-	9.17	-	-
4-Ethyl-2-hexynal	12.46	C17	-	-	-	-	-	1.09	-	-
Bornyl acetate	12.48	C18	-	-	-	-	-	-	-	0.14
Isobornyl acetate	12.55	C19	-	-	-	-	-	0.4	-	-
Dihydroedulan II	12.61	C20	0.14	-	-	-	-	-	-	-
Tetracyclo[3.3.1.1(1,8).0(2,4)]Decane	12.75	C21	0.12	-	-	-	-	-	-	-
γ-Elemene	12.89	C22	0.20	-	-	-	-	-	-	-
α-Cubebene	12.95	C23	-	-	-	-	-	-	-	0.22
Aciphyllene	13.04	C24	-	-	-	-	-	-	-	0.23
γ-Pyronene	13.08	C25	-	-	-	-	-	0.25	-	-
α-Copaene	13.19	C26	-	-	-	-	-	-	-	7.28
β-Elemene	13.22	C27	7.59	-	-	4.44	-	3.15	51.76	-
Germacrene D	13.26	C28	-	-	-	-	0.53	-	-	-
β-Bourbonene	13.33	C29	-	-	-	-	0.46	-	-	-
Caryophyllene	13.58	C30	13.61	23.45	29.11	34.26	-	1.29	28.1	18.72
β-Cadinene	13.77	C31	-	-	-	-	2.37	-	-	-
Humulene	13.84	C32	2.92	-	1.87	9.56	-	-	6.24	-
2-Norpinene	13.86	C33	-	-	-	-	-	-	0.49	-
α-Curcumene	13.89	C34	-	-	-	-	-	0.24	-	-
β-copaene	13.98	C35	6.38	-	-	-	21.69	-	-	-
α-Farnesene	14.00	C36	-	-	-	-	20.73	-	-	-

Compounds	RT	Code	The amount percentage in samples (%)							
			Z. zerumbet	*Z. pellitum*	*C. pierreana*	*G. globulifera*	*G. macrocarpa*	*Amomum* sp.	*A. conchigera*	*S. campanulatus*
β-Panasinsene	14.08	C37	-	-	-	-	5.13	-	-	-
α-Selinene	14.09	C38	-	-	-	-	-	6.21	0.15	-
Alloaromadendrene	14.11	C39	-	0.56	-	-	-	-	4.05	9.74
γ-muurolene	14.14	C40	0.84	3.02	-	-	4.30	-	-	-
δ-Cadinene	14.24	C41	-	-	-	-	2.56	-	-	2.71
1,3-Bis-(2-cyclopropyl, 2-methylcyclopropyl)-but-2-en-1-one	14.25	C42	-	-	-	-	-	0.22	0.31	-
α-Elemene	14.27	C43	-	-	-	-	-	-	-	2.1
Nerolidol	14.30	C44	0.62	-	0.42	5.55	-	0.17	-	-
1,1,5-Trimethyl-1, 2-dihydronaphthalene	14.35	C45	-	-	-	-	-	-	-	2.6
Arachidonic acid	14.37	C46	-	-	0.14	-	-	-	-	-
2,2-Dichloro-1-phenyl-1,3-propanediol	14.38	C47	-	-	-	-	0.78	-	-	-
Aromadendrene	14.40	C48	0.18	-	-	-	-	-	-	-
Caryophyllene oxide	14.66	C49	4.66	4.00	4.38	8.15	-	-	-	24.69
cis-Thujopsene	14.67	C50	-	3.68	-	-	-	-	-	-
3-Cyclohexen-1-carboxaldehyde, 3,4-dimethyl-	14.77	C51	0.41	-	-	-	-	-	-	5.23
Carvone Epoxide	14.83	C52	-	-	-	-	0.24	-	-	-
Isooctadecane	14.87	C53	-	-	-	-	-	-	0.27	-
Adamantane	14.89	C54	-	-	0.61	-	-	-	0.19	-
Bicyclo[3.2.2]non-6-en-3-one	14.96	C55	-	-	-	-	-	-	-	5.45
4-hydroxymethylbenzaldehyde	14.98	C56	-	-	-	-	0.35	-	-	-
Epiglobulol	15.01	C57	-	-	-	-	-	-	4.04	-
Caryophylla-4(12),8(13)-dien-5.beta.-ol	15.03	C58	-	-	-	4.36	-	-	-	-
Longifolene	15.04	C59	0.43	-	-	-	-	-	-	-
9-Tetradecenol	15.06	C60	-	-	0.47	-	-	-	-	-
β-Selinene	15.09	C61	-	-	-	-	1.16	-	-	-
Isoaromadendrene epoxide	15.11	C62	0.54	-	-	-	-	-	-	9.51
Alloisolongifolene	15.29	C63	-	1.79	-	-	-	-	-	-
γ-Cadinene	15.35	C64	-	1.72	-	-	1.03	-	-	-
2-tert-Butylquinoline	15.36	C65	-	-	-	-	6.05	-	-	-
α-Cadinol	15.43	C66	-	3.02	-	-	-	-	-	-
α-Gurjunene	15.48	C67	-	3.00	-	-	-	-	-	-
Hexahydrofarnesyl acetone	15.75	C68	0.17	-	-	-	-	-	-	-
Tryptophol	15.75	C69	-	-	-	-	0.33	-	-	-
7-Methyl-3,4-octadiene	15.77	C70	-	-	0.27	-	-	-	-	-
zerumbone	15.87	C71	-	4.99	-	-	-	-	-	-
Di(1'-decahydronaphthyl)methane	15.88	C72	-	-	-	0.44	-	-	-	-
4-Isobutylquinoline	15.91	C73	-	-	-	-	24.43	-	-	-
3-Dihydroxydiphenylamine	15.97	C74	-	-	-	-	5.47	-	-	-

Compounds	RT	Code	The amount percentage in samples (%)							
			Z. zerumbet	*Z. pellitum*	*C. pierreana*	*G. globulifera*	*G. macrocarpa*	*Amomum* sp.	*A. conchigera*	*S. campanulatus*
Farnesol, acetate	15.99	C75	-	-	0.12	-	-	-	1.85	-
Monoterpene hydrocarbons:	15.99	50.47	62.19	29.51	1.46	28.27	0.81	3.06		
Oxygenated monoterpenes:	16.08	-	-	0.6	0.23	59.3	-	0.14		
Sesquiterpene hydrocarbons:	16.15	35.5	30.98	48.26	58.93	10.65	90.3	41		
Oxygenated sesquiterpenes:	5.82	12.01	5.19	18.06	-	0.17	5.89	34.2		
Non-terpenes:	0.41	-	-	0.44	30.58	0.24	-	13.28		
Others:	0.31	-	0.61	0.51	6.83	1.31	0.58	-		
Total:	95.32	97.98	98.97	97.38	98.03	99.94	97.58	91.68		

β-pinene (8.47%), (E)-caryophyllene (8.45%) as major compounds while the main constituents of *A. newmanii* oils were santolina triene (42.16%), α-pinene (17.09%), β-pinene (3.20%) and α-copaene (2.39%) (Kurup *et al.,* 2018).

In present study, the aerial specimens were used to analyze the chemical composition of essential oils instead of rhizomes, as commonly used in other Zingiberaceae species. Among eight studies species, only one species belonging to *Curcuma* genus, *C. pierreana,* was investigated on chemical constituents of essential oils from the aerial parts. Accordingly, Nguyen *et al.* (1998) showed that the essential oils from the stem and leaf of *C. pierreana* contained isobornyl acetate (14.4% and 6.4%), isoborneo (12.4% and 12.8%), (2)-P-farnesene (10.8% and 8.5%), caryophyllene (10.4% and 9.1%), caryophyllene oxide (7.1% and 7.0%) whereas those of essential oils in this study were β-pinene (41.04%), caryophyllene (29.11%), α-pinene (11.72%), 3-carene (6.99%) as major constituents.

Furthermore, four of the seven remaining species, including *Z. zerumbet, Z. pellitum, A. conchigera* and *S. campanulatus* have been reported on chemical constituents of essential oils by previous studies but those of essential oils were isolated from rhizomes instead of the aerial specimens, as in this study (Sirat and Nordin, 1995; Ibrahim *et al.,* 2009; Phan *et al.,* 2011; Di *et al.,* 2017; Trinh *et al.,* 2017). The present study, therefore, was firstly investigated the essential oils isolated from the aerial parts of these species in which *Z. zerumbet* was found to be rich in α-pinene (29.3%), β-pinene (11.8%) and D-limonene (10.18%); *Z. pellitum* contained high present of caryophyllene (23.45%), α-pinene (15.95%) and cyclofenchene (11.31%); *A. conchigera* consisted of the following β-elemene (57.75%) and caryophyllene (28.1%) as major compounds; *S. campanulatus* was characterized by the following main compounds: caryophyllene oxide (24.69%), caryophyllene (18.72%) and alloaromadendrene (9.74%).

Two *Globba* species, *G. macrocarpa* and *G. globulifera*, were rare species and mainly distributed in Thailand and Cambodia. In Vietnam, these species were discovered in four locations of Vietnam, such as Son La, Dak Lak, Tay Ninh and Ba Ria-Vung Tau Provinces (Pham, 2000; Jantan *et al.,* 2003). To date, little is known about the chemical constituents of these species. Thus, in this study, the constituents of essential oils extracted from *G. macrocarpa* and *G. globulifera* were firstly investigated. Accordingly, 4-isobutylquinoline (24.43%), β-copaene (21.69) and α-farnesene (20.73) were the major compounds of *G. macrocarpa* while *G. globulifera* was found to be rich in caryophyllene (34.86%), β-pinene (25.42%), humulene (9.56%)

Finally, the essential oils of *Amomum* sp., an unknown species belonging to *Amomum* genus, were also recorded in present study. The chemical compounds of this species consisted of following compounds: eucalyptol (25.22%), camphor (25.51%), camphene (14.57%), β-pinene (13.45%) and isoborneol (9.17%).

CONCLUSION

The present study identified a total of 75 compounds of the essential oils from the aerial parts of eight species of the Zingiberaceae family collected in Binh-Chau_Phuoc-Buu Nature Reserve, Southern Vietnam. Four main clusters and three subclusters were formed by the cluster analysis. Cluster I consisted of *A. conchigera* with the presence of β-elemene (51.76%) and caryophyllene (28.1%). Cluster II contained five species, including *Z. zerumbet, Z. pellitum, C. pierreana, G. globulifera* and *S. campanulatus* with high concentration of β-pinene (11.81%, 5.32%, 4.43%, 25.42% and 1.57%), caryophyllene (13.61%, 23.45%, 19.78%, 34.26% and 18.72%), caryophyllene oxide (4.66%, 4.00%, 13.65%, 8.15% and 24.69%). Cluster III consisted of *G. macrocarpa*, and presented 4-isobutylquinoline (24.43%), β-copaene (21.69%), α-farnesene (20.73%), 2-tert-butylquinoline (6.05%), 3-dihydroxydiphenylamine (5.47%), β-Panasinsene (5.13%) as major compounds. Cluster IV contained *Amomum* sp. and had eucalyptol (25.22%), camphor (24.51%), camphene (14.57%), β-pinene (13.45%), isoborneol (9.17%), α-selinene (6.21%) as main constituents.

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