© 2017
Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas 16 (1): 26 - 33
ISSN 0717 7917
www.blacpma.usach.cl

Artículo Original | Original Article

Constituents of essential oils from the leaf, stem, root, fruit and flower of *Alpinia macroura* K. Schum

[Constituyentes de los aceites esenciales de las hojas, tallo, raíz y flores de *Alpinia macroura* K. Schum]

Le T Huong[1], Do N Dai[2], Mai V Chung1, Doan M Dung[3] & Isiaka A Ogunwande[4]

[1]*Faculty of Biology, Vinh University, 182-Le Duan, Vinh City, Nghe An Province, Vietnam*
[2]*Faculty of Agriculture, Forestry & Fishery, Nghe An College of Economics, 51-Ly Tu Trong, Vinh City, Nghe An Province, Vietnam*
[3]*Faculty of Chemistry, Vinh University, 182-Le Duan, Vinh City, Nghe An Province, Vietnam*
[4]*Natural Products Research Unit, Department of Chemistry, Faculty of Science, Lagos State University, Badagry Expressway Ojo, P. M. B. 0001, Lasu Post Office, Ojo, Lagos, Nigeria*
Contactos | Contacts: **Do N DAI - *E-mail address:* daidn23@gmail.com**
Contactos | Contacts: Isiaka A OGUNWANDE - E-mail address: isiaka.ogunwande@lasu.edu.ng

Abstract: This paper reports the chemical constituents of essential oils from the various parts of *Alpinia macroura* K. Schum (Zingiberaceae) from Vietnam. The essential oils were obtained by hydrodistillation and analysed by means of gas chromatography coupled to Flame ionization detector (GC-FID) and gas chromatography coupled to mass spectrometry (GC/MS). The main constituents of the oils were β-pinene (8.8%-16.4%), 1,8-cineole (5.5%-17.7%), γ-terpinene (5.9%-16.9%), α-pinene (4.5%-8.4%) and β-caryophyllene (1.4%-18.6%). Sabinene (9.0%) was identified only in the fruit. Overall, nineteen of the identified compounds are coming to all the essential oils. The chemical constituents of essential oils from the leaf, stem, root, fruit and flower of *A. macroura* are being reported for the first time and were found to be different from those of other *Alpinia* oils.

Keywords: *Alpinia macroura*, hydrodistillation, essential oil, monoterpenes, sesquiterpenes

Resumen: En este trabajo se presentan los componentes químicos de los aceites esenciales de las distintas partes de *Alpinia macroura* K. Schum (Zingiberaceae) de Vietnam. Los aceites esenciales se obtuvieron por hidrodestilación y se analizaron por medio de cromatografía de gases acoplada a detector de ionización de llama (GC-FID) y cromatografía de gases acoplada a espectrometría de masas (GC/MS). Los principales constituyentes de los aceites fueron β-pineno (8,8% -16,4%), 1,8-cineol (5,5% -17,7%), γ-terpineno (5,9% -16,9%), α-pineno (4,5% -8,4 %) y β-cariofileno (1,4% -18,6%). Sabineno (9,0%) fue identificado solamente en la fruta. En general, diecinueve de los compuestos identificados están llegando a todos los aceites esenciales. Los componentes químicos de los aceites esenciales de la hoja, tallo, raíz, frutas y flores de *A. macroura* están siendo reportados por primera vez y se encontró que eran diferentes de las de otros aceites de *Alpinia*.

Palabras clave: *Alpinia macroura*, hidrodestilación, aceite esencial, monoterpenos, sesquiterpenos.

Recibido | Received: June 4, 2016
Aceptado | Accepted: July 2, 2016
Aceptado en versión corregida | Accepted in revised form: July 24, 2016
Publicado en línea | Published online: January 30, 2017
Declaración de intereses | Declaration of interests: The authors wish to thank National Foundation for Science and Technology Development, Vietnam (NAFOSTED) for financial support of this study through the Project Nr. 106-NN.03-2014.23..
Este artículo puede ser citado como / This article must be cited as: LT Huong, DN Dai, MV Chung, DM Dung, IA Ogunwande. 2017. Constituents of essential oils from the leaf, stem, root, fruit and flower of *Alpinia macroura* K. Schum. **Bol Latinoam Caribe Plant Med Aromat** 16 (1): 26 - 33.

Abbreviation List: v/w- volume by weight; GC-FID Gas chromatography coupled to Flame Ionization Detector; GC-MS- Gas chromatography coupled to mass spectrometry.

INTRODUCTION

The genus *Alpinia* from the Zingiberaceae family of plants consists of more than 230 species (Krees *et al*., 2005). *Alpinia macroura* is pseudostem plant of about 2-2.5 m high with oblong leaf blades. The labellium are red with yellow margin. The globular fruits are white and are about 2-2.5 cm long. Flowering takes place in August to December while fruiting occurs in November to March of later year. It is native to Vietnam, Thailand, Mianma, Laos and Cambodia (Binh, 2011). The plant is used ethnomedically in the treatment of sores, fever and intestinal infections (Huong, 2016). The authors are not aware of any information on the biological potentials and non-volatile phytochemical constituents on this plant.

There are no previous references in literature about the chemical composition of essential oil of this plant from Vietnam or elsewhere and this prompted the present investigation of the volatile constituents of *A. macruora*. In continuation of an extensive study into the chemical constituents of underutilized flora of Vietnam (Chau *et al*., 2015; Dai *et al*., 2016), we report the compounds identified in the essential oils obtained by hydrodistillation of the leaf, stem, root, fruit and flower of *A. macruora*.

MATERIALS AND METHOD

Plants collection

Leaves, stems, roots, fruits and flowers of *A. macroura* were collected from Pù Mát National Park, Nghệ An Province, Vietnam, in May 2014. Voucher specimen DND 389 was deposited at the Botany Museum, Vinh University, Vietnam. Plant samples were air-dried prior to hudrodistillation.

Hydrodistillation of the essential oils

Briefly, 500 g of each of the pulverized sample were carefully introduced into a 5 L flask and distilled water was added until it covers the sample completely. Hydrodistillation was carried out in an all glass Clevenger-type distillation unit for 3 h, according to established procedure (Vietnamese Pharmacopoeia, 1997), at normal pressure. The volatile oils distilled over water and were collected separately in the receiver arm of the apparatus into a clean and previously weighed sample bottles. The oils were kept under refrigeration until the moment of analyses.

Analysis of the essential oils

Gas chromatography (GC) analyses of essential oils were carried on Agilent Technologies HP 6890 Plus Gas Chromatograph which was equipped with a flame ionization detector and HP-5MS column. The dimension of the column is 30 m x 0.25 mm (film thickness 0.25 μm). The GC operating parameters based on temperature programming were as follows oven temperature 40º C, injection port 250º C while the detector temperature was 260º C. Oven temperature programming: 40º C for 2 min, and then raise to 220º C (and held isothermally for 10 min) at 4º C/min. The carrier gas used was H_2 at a flow rate of 1 mL/min. The split ratio was 10:1 while 1.0 μL of the diluted essential oil in hexane was injected into the GC at inlet pressure was 6.1 kPa. Each analysis was performed in triplicate. Retention indices (RI) value of each component was determined relative to the retention times of a homologous n-alkane series with linear interpolation on the HP-5MS column. The relative amounts of individual components were calculated based on the GC peak area (FID response) without using correction factors.

An Agilent Technologies HP 6890N Plus Chromatograph fitted with a fused silica capillary HP-5MS column (30 m x 0.25 mm, film thickness 0.25 μm) and interfaced with a mass spectrometer HP 5973 MSD was used for the gas chromatography-mass spectrometry (GC/MS) analyses, under the same conditions as those used for GC analysis. The conditions were the same as described above with He (1 mL/min) as carrier gas. The MS conditions were as follows: ionization voltage 70 eV; emission current 40 mA; acquisitions scan mass range of 35-350 amu at a sampling rate of 1.0 scan/s.

Identification of the constituents

The identification of constituents was performed on the basis of retention indices (RI) determined by co-injection with reference to a homologous series of *n*-alkanes, under identical experimental conditions. Further identification was performed by comparison of their mass spectra with those from NIST (NIST, 2011) and the home-made MS library built up from pure substances and components of known essential oils, as well as by comparison of their retention indices with literature (Adams, 2007).

RESULTS AND DISCUSSION

The yield of essential oils were 0.21% (v/w, leaf), 0.15% (v/w, stem), 0.24% (v/w, root), 0.18% (v/w, fruit) and 0.30% (v/w, flower), calculated on a dry weight basis. Oil samples were light yellow (leaf and root), yellow (stem) and colourless (fruit and flower). Table 1 indicates the chemical constituents present in the oils, their percentages as well as retention indices on HP-5MS column. Monoterpenes hydrocarbons (59.9%) and the oxygenated counterparts (27.2%) represent the main classes of compounds present in the leaf oil. Sesquiterpenes are less common (ca. 5.7%). 1,8-Cineole (17.7%), γ-terpinene (13.3%) and β-pinene (11.4%) were the compounds occurring in higher quantity. There are significant amounts of α-phellandrene (8.5%), α-pinene (7.8%), α-terpinene (6.4%) and terpinen-4-ol (5.9%). On the other hand, monoterpenes hydrocarbons (71.9%) and oxygenated counterparts (13.6%) were the main classes of compounds identified in the stem, of which the main compounds were γ-terpinene (16.9%), β-pinene (16.4%), 1,8-cineole (11.2%) and α-terpinene (9.4%). α-Pinene (8.4%) and α-phellandrene (5.9%) were also present in sizeable quantity.

Table 1
Chemical constituents of *A. macruora* oils[a]

Compounds[b]	RI[c]	RI[d]	MI[e]	L	S	R	Fr	Fl
α-Thujene	930	921	f	1.6	2.0	1.9	0.4	0.6
α-Pinene	939	932	g	7.8	8.4	6.5	5.8	4.5
Camphene	953	946	f	1.2	2.1	2.9	1.3	0.8
Sabinene	976	969	g	-	-	-	-	9.0
β-Pinene	980	976	g	11.4	16.4	12.5	11.1	8.8
β-Myrcene	990	988	g	1.3	1.6	1.4	1.3	1.1
α-Phellandrene	1006	1004	g	8.5	5.9	1.9	3.7	1.5
δ-3-Carene	1011	1008	f	-	-	0.2	-	-
α-Terpinene	1017	1014	g	6.4	9.4	8.5	3.2	4.7
o-Cymene	1024	1022	f	4.5	3.8	2.1	1.2	0.6
β-Phellandrene	1028		f	-	-	-	-	3.4
1,8-Cineole	1034	1032	g	17.7	11.2	8.7	11.1	5.5
(*E*)-β-Ocimene	1052	1044	f	0.6	1.0	0.7	0.6	0.6
γ-Terpinene	1061	1054	f	13.3	16.9	13.9	5.9	7.9
cis-Sabinene hydrate	1073	1065	f	0.1	-	-	-	-
α-Terpinolene	1090	1089	f	3.3	4.4	3.7	1.4	1.3
Linalool	1100	1095	f	1.6	0.3	0.4	-	0.5
Nonanal	1106	1100	f	-	-	-	0.3	-
Fenchyl alcohol	1120	1118	f	0.1	-	0.1	-	-
allo-Ocimene	1128	1128	f	-	-	0.1	-	-
Camphor	1145	1141	f	0.1	-	0.2	0.1	0.3
Borneol	1167	1167	f	0.5	0.1	0.5	0.1	-
Terpinen-4-ol	1177	1177	f	5.9	1.1	2.3	0.6	4.4
α-Terpineol	1189	1187	f	0.7	0.1	0.2	0.3	1.5
Myrtenal	1207	1195	f	-	-	0.1	-	-
trans-Piperitol	1209	1207	f	0.2	-	-	-	-
Fenchyl acetate	1222	1229	f	0.1	0.3	7.8	0.3	-
4-Phenyl-2-butanol[i]	1241	1243	f	2.2	-	-	-	-
Geraniol	1253	1249	f	-	-	0.4	0.3	3.5
Bornyl acetate	1289	1287	g	0.2	0.3	1.0	5.0	7.2
Bicycloelemene	1327	1337	f	-	-	0.5	-	1.5
Neryl acetate	1362	1359	f	-	-	-	0.1	-
α-Copaene	1377	1374	f	0.1	0.2	0.7	0.2	0.5

Geranyl acetate	**1381**	**1379**	**f**	**-**	**-**	**-**	**0.1**	**-**
β-Elemene	**1391**	**1389**	**f**	**1.7**	**1.3**	**0.8**	**3.4**	**0.7**
α-Gurjunene	**1412**	**1409**	**f**	**1.1**	**1.0**	**1.5**	**1.2**	**-**
β-Caryophyllene	**1419**	**1417**	**g**	**1.4**	**2.4**	**2.3**	**18.6**	**12.6**
Widdrene	**1431**	**1432**	**f**	**-**	**-**	**-**	**-**	**0.7**
γ-Elemene	**1437**	**1434**	**f**	**-**	**0.1**	**0.4**	**0.3**	**3.6**
α-Guaiene	**1440**	**1437**	**f**	**0.4**	**-**	**-**	**-**	**1.8**
Aromadendrene	**1441**	**1439**	**f**	**-**	**0.2**	**0.1**	**0.3**	**0.6**
α-Humulene	**1454**	**1452**	**f**	**0.2**	**0.5**	**0.8**	**3.1**	**1.0**
Selina-4(15),7(11)-diene	**1475**	**1470**	**g**	**-**	**-**	**0.4**	**-**	**-**
γ-Gurjunene	**1477**	**1475**	**f**	**-**	**-**	**-**	**0.1**	**1.0**
γ-Muurolene	**1480**	**1478**	**f**	**-**	**-**	**-**	**0.2**	**-**
Germacrene D	**1485**	**1484**	**f**	**-**	**0.2**	**0.6**	**0.5**	**3.3**
α-Amorphene	**1485**	**1485**	**f**	**-**	**-**	**0.2**	**0.2**	**-**
β-Selinene	**1486**	**1488**	**f**	**-**	**0.4**	**0.6**	**1.1**	**-**
α-Selinene	**1493**	**1498**	**f**	**0.3**	**0.7**	**-**	**-**	**-**
Bicyclogermacrene	**1500**	**1500**	**g**	**-**	**-**	**0.9**	**0.7**	**0.9**
α-Muurolene	**1500**	**1500**	**f**	**-**	**-**	**0.1**	**-**	**-**
β-Bisabolene	**1506**	**1505**	**f**	**-**	**-**	**0.1**	**-**	**-**
(*E*,*E*)-α-Farnesene	**1508**	**1507**	**g**	**-**	**-**	**-**	**0.1**	**-**
δ-Cadinene	**1525**	**1522**	**f**	**0.2**	**0.4**	**0.7**	**0.5**	**-**
(*E*)-Nerolidol	**1563**	**1561**	**f**	**0.2**	**0.3**	**0.8**	**0.3**	**-**
Spathulenol	**1578**	**1577**	**f**	**-**	**-**	**0.3**	**-**	**0.7**
Caryophyllene oxide	**1583**	**1581**	**g**	**0.3**	**0.4**	**0.6**	**7.1**	**0.7**
τ-Muurolol	**1646**	**1640**	**f**	**-**	**-**	**1.0**	**-**	**-**
α-Cadinol	**1654**	**1652**	**f**	**-**	**0.2**	**-**	**0.8**	**-**
(*E*,*E*)-Farnesol	**1718**	**1722**	**f**	**-**	**-**	**0.4**	**0.5**	**0.4**
Phytol	**2125**	**2119**	**g**	**-**	**-**	**0.2**	**0.1**	**-**
Total				**95.2**	**93.6**	**92.0**	**93.5**	**97.7**
Monoterpene hydrocarbons				**59.9**	**71.9**	**56.3**	**35.9**	**44.8**
Oxygenated monoterpenes				**27.2**	**13.6**	**21.7**	**18.0**	**22.9**
Sesquiterpene hydrocarbons				**5.4**	**7.2**	**10.7**	**30.5**	**28.2**
Oxygenated monoterpenes				**0.5**	**0.9**	**3.1**	**8.7**	**1.8**
Diterpenes				**-**	**-**	**0.2**	**0.1**	**-**
Non-terpenes				**2.2**	**-**	**-**	**0.3**	**-**

[a] SD, values were insignificant and excluded from the Table to avoid congestion; [b] Elution order from HP-5MS column; [c] Retention indices on HP-5MS column; [d] Literature retention indices; [e] Mode of Identification; [f] Identification by mass spectra and GC retention indices; [g] Identification by mass spectra, column retention indices and co-injection with authentic compound; [i] tentative identification; - Not found; L leaf; S stem; r root; Fr fruit; Fl flower

The main classes of compounds in the root oil were monoterpenes hydrocarbons (56.3%), oxygenated monoterpenes (21.7%) and sesquiterpene hydrocarbons (10.7%). Moreover, the main constituents of the oil were γ-terpinene (13.9%), β-pinene (12.5%), 1,8-cineole (8.7%), α-terpinene (8.5%), fenchyl acetate (7.8%) and α-pinene (6.5%). The authors have identified a large proportion of monoterpene hydrocarbons (35.9%), sesquiterpene hydrocarbons (30.5%) and oxygenated monoterpenes (18.0%) in the fruit. The oil was rich in β-caryophyllene (18.1%), β-pinene (11.1%) and 1,8-cineole (11.1%). In addition, caryophyllene oxide (7.1%), γ-terpinene (5.9%), α-pinene (5.8%) and bornyl acetate (5.0%) were also present in significant quantity. Moreover, monoterpene hydrocarbons

(44.8%), oxygen containing monoterpenes (22.9%) and sesquiterpene hydrocarbons (18.2%) were prominent in the flower oil. The quantitatively significant constituents of the oil were β-caryophyllene (12.6%), sabinene (9.0%), β-pinene (8.8%), γ-terpinene (7.9%) and bornyl acetate (7.2%).

The authors are unaware of any previous study on the essential oils of *A. macruora*. The present report may represent the first of its kind. However, relative information is available on the compositions of volatiles from some other *Alpinia* species growing in Vietnam. For example, the fruit oil of *A. menghaiensis* (Dai *et al*., 2016) comprised mainly of monoterpenes represented by β-pinene (40.4%) and α-pinene (11.3%). The leaf oil of *A. polyantha* has its major compounds as camphor (16.1%), α-pinene (15.2%) and β-agarofuran (12.9%), while α-pinene (12.4%), β-cubebene (10.6%) and β-agarofuran (10.3%) were present in the stem (Huong *et al*., 2015a). However, while β-cubebene (12.6%) and fenchyl acetate (10.8%) were identified in the root, the fruit was rich in δ-cadinene (10.9%), β-caryophyllene (9.1%) and β-pinene (8.7%). 1,8-Cineole was the most significant compound of rhizomes of *A. henryi* (Giang *et al.*, 2007) and *A. laosensis* (Dung *et al*., 2000). Sesquiterpenes were the dominant compounds in the essential oils of *A. chinensis*. These include β-bisabolene (47.9%) in the leaf (Dung *et al*., 1994a), caryophyllene oxide (13.2%) and β-bisabolene (10.4%) in the root (Leclerq *et al*., 1994) as well as (*E,E*)-α-farnesene (26.5%), α-humulene (22.3%), β-bisabolene (17.1%) and β-caryophyllene (13.1%) in the flower (Dung *et al*., 1994b). The composition of the flowers of *A. speciosa* (Dung *et al*., 1994c) consisted mainly of terpene hydrocarbons β-pinene (34.0%), α-pinene (14.8%) and β-caryophyllene (10.8%). A previous study reported abundance of α-pinene and β-pinene in the leaf oils of *A. malaccensis* (Huong *et al*., 2015b). In another study, while (*E,E*)-farnesol make up the oil of the seed of *A. breviligulata* (Dung, *et al*., 1994d), α-pinene and β-pinene occurred in the leaf oil (Dung *et al*., 1994f). The seed oil of *A. katsumadai* was dominated by myrcene, linalool and citronellol (Dung *et al*., 1990). Although ubiquitous terpenes predominate in the essential oils of other *Alpinia* plants and *A. macruora* from Vietnam (Dung *et al.*, 1993; Dung *et al.*, 1994e), some variation could be seen among the components of essential oils. The main compounds of other *Alpinia* essential oils from Vietnam such as myrcene, citronellol fenchyl acetate, β-cubebene, β-agarofuran, (*E,E*)-farnesol, β-cubebene, δ-cadinene, β-bisabolene, α-humulene and caryophyllene oxide were either absent or present in lower amounts in *A. macruora*.

The chemical constituents of essential oils of *Alpinia* plants from some other parts of the world have been documented. The major constituents of *A. calcarata* from India were 1,8-cineole (35.9%) and β-fenchyl acetate (12.9%), while α-terpineol (15.1%), α-fenchyl acetate (12.5%), (*E*)-nerolidol (10.1%) and caryophyllene oxide (10.1%) were the main compounds of *A. smithiae* (Raji *et al*., 2013). 1,8-Cineole (17.4%) and humulene epoxide II (14.1%) are the main components of *A. allughas* from India which displayed antioxidant and antifungal activities (Sethi *et al*., 2015). An analysis from Malaysia reported the abundance of β-sesquiphellandrene (36.5%) and (*E*)-methyl cinnamate (78.2%) in the rhizomes of *A. aquatica* and *A. malaccensis* respectively (Sirat *et al*., 1995). The leaf oil of *A. purpurata* (Victório *et al*., 2010) from Brazil was rich in β-pinene (34.7%) and α-pinene (11.8%). Another report identified *trans*-caryophyllene (32.61%) in the leaf; 1,8-cineole (32.25%) and myrcene (13.63%) from the pseudostem; tetracosane (42.61%) in the rhizome and tetracosane (13.39%) from the fruit of *A. rafflesiana* grown in Malaysia (Jusoh *et al*., 2013). The major components of *A. galanga* (Suresh *et al*., 2016) were 1,8-cineole (32.9%) and α-terpineol (12.7%). The Korean specie of *A. kwangsiensis* (Wu *et al*., 2015) rhizome afforded oil whose main compounds were camphor (17.59%), eucalyptol (15.16%), β-pinene (11.15%) and α-pinene (10.50%). The major components of rhizome oil of *A. conchigera* from Malaysia (Sirat *et al*., 1995) include β-sesquiphellandrene (20.5%), β-bisabolene (12.1%) and 1,8-cineole (11.6%). The rhizome of *A. speciosa* collected from India (Akshaya *et al*., 2010) contained terpinen-4-ol (15.4%) and 1,8-cineole (11.1%). The main constituents of essential oils of *A. nutans* were sabinene (27.8%), 1,8-cineole (17.4%) and terpinen-4-ol (14.9%) in the aerial parts while terpinen-4-ol (25.1%), γ-terpinene (19.4%), sabinene (14.2%) and 1,8-cineole (10.8%) were present in the flower (Joshi *et al*., 2010).

Both inter-species and intra-species variation could be observed in the essential oils of *Alpinia* plants. For example, valencene (19.04%), calamenene (10.11%) and nootkatone (8.97%) were the main components of *A. oxyphylla* from China (Wang *et al*., 2014). In another report, myrtenal (10.25%) and α-citral (9.85%) occurred as the major

component in leaf oil of *A. oxyphylla* from another part of China (Feng *et al.*, 2012). Terpinen-7-al (40.5%) and sabinene hydrate (15.4%) were identified in *A. zerumbet* from Brazil (Victório *et al*., 2010), while, 4-terpineol (32.9%), 1,8-cineole (21.4%) and γ-terpinolene (10.0%) were the monoterpenes of *A. zerumbet* from another region of Brazil (Mendes *et al*., 2015). In addition, the major components in the oil of *A. calcarata* from India (Suresh *et al*., 2016) were α-fenchyl acetate (12.9%), cubenol (15.0 %) and 1,8-cineole (12.1 %) while another sample from India contained 1,8-cineole (35.9%) and β-fenchyl acetate (12.9%). Also, 1,8-Cineole (25.4%), β-pinene (15.1%) and camphor (15.3%) were identified in the leaf of *A. nigra* (Kanjilal *et al*., 2010), while the rhizome comprised of 1,8-cineole (34%) and α-fenchyl acetate (13.1%). Moreover, fresh leaf of *A. nigra* from Bangladesh (Islam *et al*., 2014) gave oil containing large amount of 1,5,9,9-tetramethyl-1,4,7-cycloundecatriene (24.92%), β-pinene (12.90%), 5-amino-6-(2 fluoroanilino)furazano[3,4-b] pyrazine (12.18%) and isocaryophyllene (10.76%).

It could be seen that the essential oils of *Alpinia* plants from all over the world exhibited chemical variability. In addition, the combination of the observed major compounds of the leaf, stem and root of *A. macruora* (γ-terpinene/β-pinene/1,8-cineole, β-caryophyllene/β-pinene/1,8-cineole in the fruit, as well as β-caryophyllene/sabinene in the flower, were not reported previously for any of the studied *Alpinia* essential oils from Vietnam and other parts of the world. It was well known that each plant parts contained different phytochemical composition. The variation between these results and those from other parts of the world may be due to the ecological and climatic differences between these regions; as well as the age of the plants and chemotype.

The observed compositional patterns may have contributed to the biological activities of *Alpinia* essential oils such as antimicrobial (Joshi *et al*., 2010; Jusoh *et al*., 2013), antifungal (Sethi *et al*., 2015), insecticidal (Wu *et al*., 2015), modulation of the activity of aminoglycoside antibiotics (Mendes *et al*., 2015), cytotoxic (Wang *et al*., 2014), antioxidant (Joshi *et al*., 2010; Wang *et al*., 2014; Sethi *et al*., 2015) and enhances skin permeation (Feng *et al*., 2012).

CONCLUSION

The compositions of the leaf, stem, root, fruit and flower oils of *A. macruora* from Vietnam were reported. The essential oils were characterized by high contents of γ-terpinene/β-pinene/1,8-cineole in the leaf, stem and root, β-caryophyllene/β-pinene/1,8-cineole in the fruit and β-caryophyllene/sabinene in the flower. In addition, a comparative analysis of the chemical compositions of the studied oil samples with data on essential oils of other *Alpinia* plants from Vitenam and other parts of the world revealed a high chemical variation.

ACKNOWLEDGMENTS

The authors wish to thank National Foundation for Science and Technology Development, Vietnam (NAFOSTED) for financial support of this study through the Project Nr. 106-NN.03-2014.23. We also appreciated the effort of Dr. Elena Falqué López, Química Analítica, Facultad de Ciencias, España, for the translation of the abstract of the manuscript into the Spanish language.

REFERENCES

Adams RP. 2007. **Identification of essential oil components by gas chromatography/mass spectrometry**. 4th Edition, Allured Publishing, Carol Stream, Illinois, USA.

Akshaya KI, Pradeep KT, Agrawal NK. 2010. Chemical composition and antimicrobial activity of the essential oil of *Alpinia speciosa* K. Schum. rhizome from India. **J Essent Oil Res** 22: 179 - 182.

Bình NQ. 2011. **Study of the classification of the ginger family (*Zingiberaceae* Lindl.) in Vietnam**. PhD dissertation, Institute of Ecology and Biological Resources, Hanoi, Vietnam.

Chau LTM, Thang TD, Tu NTM, Dai DN, Ogunwande IA. 2015. Constituents of essential oils from the leaves, stems and roots of *Zingiber gramineum* and *Zingiber rufopilosum*. **Bol Latinoam Caribe Plant Med Aromat** 14: 449 - 455.

Dai DN, Huong LT, Thang TD, Olayiwola TO, Ogunmoye AO, Ogunwande IA. 2016. Essential oils of the fruit of *Alpinia menghaiensis*. **British Biotech J** 11: 1 - 7.

Dung NX, Phuöng DL, Leclerq PA. 1990. Constituents of the stem, leaf and seed oils of *Alpinia katsumadai* Hayata L. from Vietnam.

J Essent Oil Res 2: 259 - 261.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1993.The essential oil composition of Vietnamese *Alpinia breviligulata* Gagnep. flowers. **J Essent Oil Res** 5: 575 - 576.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994a. Chemical composition of the leaf oil of *Alpinia chinensis* Rosc, from Vietnam. **J Essent Oil Res** 6: 91 - 92.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994b. Chemical composition of the flower oil of *Alpinia chinensis* Rosc, from Vietnam. **J Essent Oil Res** 6: 637 - 638.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994c. Constituents of the flower oil of *Alpinia speciosa* K. Schum. from Vietnam. **J Essent Oil Res** 6: 433 - 434.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994d. Constituents of the seed and fruit peel oils of *Alpinia breviligulata* Gagnep. from Vietnam. **J Essent Oil Res** 6: 295 - 297.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994e. Constituents of the rhizome and root oils of *Alpinia breviligulata* Gagnep. from Vietnam. **J Essent Oil Res** 6: 499 - 501.

Dung NX, Trinh DC, Dô DR, Leclercq PA. 1994f. Chemical composition of the leaf oil of *Alpiniabreviligulata* Gagnep. from Vietnam. **J Essent Oil Res** 6: 181-182.

Dung NX, Trung HO, Văn NH, Nguyên XP, Leclercq PA. 2000. Volatile constituents of the rhizome oil of *Alpinia laosensis* Gagnep. from Indochina. **J Essent Oil Res** 12: 213 - 215.

Feng H, Luo JY, Kong WJ, Dou XW, Wang Y, Zhao XS, Zhang WP, Qiong L, Yang M. 2012. Enhancement effect of essential oils from the fruits and leaves of *Alpinia oxyphylla* on skin permeation and deposition of indomethacin. **The Royal Soc Chem** 1: 1 - 15.

Giang MP, Son TP, König WA. 2007. Chemical Composition of the essential oil from the rhizomes of *Alpinia henryi* K. Schum. of Vietnam. **J Essent Oil Res** 19: 507 - 508.

Hương LT, 2016. **Study on biological characteristics, chemical composition of essential oils of the species of genus *Alpinia* Roxb. and *Amomum* Roxb. (Zingiberaceae) in North Center of Vietnam.** PhD. Dissertation, Institute of Ecology and Biological Resources, Vietnam Acadamy of Science and Technology.

Huong LT, Thang TD, Ogunwande IA. 2015a. Chemical constituents of essential oils from the leaves, stems, roots and fruits of Vietnamese species of *Alpinia polyantha*. **Nat Prod Comm** 10: 367 - 368.

Huong LT, Thang TD, Ogunwande IA. 2015b. Volatile constituents of essential oils from the leaves, stems, roots and fruits of Vietnamese species of *Alpinia malaccencis*. **Eur J Med Plant** 7: 118 - 124.

Islam F, Islam S, Shahjahan M, Nandi NC, Satter MA. 2014. Chemical constituents of essential oil from the leaf of *Alpinia nigra* of Bangladesh. **Int Food Res J** 21: 161 - 164.

Joshi S, Prakash O, Anil KP, Mathela CS. 2010. Chemical composition, and antioxidant and antimicrobial activities of *Alpinia nutans* Rosc. **J Essent Oil Res** 22: 85 - 90.

Jusoh S, Sirat HM, Ahmad F. 2013. Essential oils of *Alpinia rafflesiana* and their antimicrobial activities. **Nat Prod Commun** 8: 1317 - 1320.

Kanjilal PB, Rumi K, Couladis M. 2010. Essential oil composition of leaf and rhizome oil of *Alpinia nigra* (Gaertner) B. L. Burtt. from Northeast India. **J Essent Oil Res** 22: 358 - 360.

Kress WJ, Prince LM, Willia KJ. 2005. The molecular phylogeny of *Alpinia* (Zingiberaceae): a complex and polyphyletic genus of gingers. **Amer J Bot** 92: 167 - 178.

Leclercq PA, Dung NX, Trinh DC, Dô DR. 1994. Composition of the root oil of *Alpinia chinensis* Rosc. from Vietnam. **J Essent Oil Res** 6: 401 - 402.

Mendes FRS, Silva FGE, Sousa EO, Rodrigues FFG, Costa JGM, Monte FJQ, Lemos TLG, Assunção JCC. 2015. Essential oil of *Alpinia zerumbet* (Pers.) B.L. Burtt. & R.M. Sm. (Zingiberaceae): chemical composition and modulation of the activity of aminoglycoside antibiotics. **J Essent Oil Res** 27: 259 - 263.

NIST. 2011. **Chemistry Web Book**. Data from NIST Standard Reference Database 69.

Raji G, Pradeep DP, Yusufali C, Sabulal B. 2013. Chemical profiles of volatiles in four *Alpinia* species from Kerala, South India. **J Essent Oil Res** 25: 97 - 102.

Sethi S, Prakash O, Pant AK. 2015. Essential oil

composition, antioxidant assay and antifungal activity of essential oil and various extracts of *Alpinia allughas* (Retz.) Roscoe leaves. **Cogent Chem** 1: 121 - 127

Sirat HM, Nordin BA. 1995. Chemical composition of the rhizome oil of *Alpinia conchigera* Griff from Malaysia. **J Essent Oil Res** 7: 195 - 197.

Suresh VN, Menon AN, Esakkidurai T, Pitchumani K. 2016. Essential oil composition of *Alpinia calcarata* and *Alpinia galanga* rhizomes-a comparative study. **J Essent Oil-Bearing Pl** 19: 82 - 87.

Victório CP, Leitão SG, Lage CLS. 2010. Chemical composition of the leaf oils of *Alpinia zerumbet* (Pers.) Burtt et Smith and *A. purpurata* (Vieill) K. Schum. from Rio de Janeiro, Brazil. **J Essent Oil Res** 22: 52 - 54.

Vietnamese Pharmacopoeia. 1997. Medical Publishing House, Hanoi, Vietnam.

Wang CZ, Yuan HH, Bao X, Minbo L. 2014. Chemical composition, *in vitro* cytotoxic and antioxidant activities of the fruit essential oil of *Alpinia oxyphylla*. **Asian J Chem** 26: 4201 - 4205.

Wu Y, Zhang WJ, Huang DY, Ying W, 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.