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Essential Oils of *Phoebe angustifolia* Meisn., *Machilus velutina* Champ. ex Benth. and *Neolitsea polycarpa* Liou (Lauraceae) from Vietnam#

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Abstract: The essential oils of the leaves of *Phoebe angustifolia* Meisn, *Machilus velutina* Champ. ex Benth and *Neolitsea polycarpa* H. Liu., were analyzed by gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC-MS). The major compound found in the oils of *Phoebe angustifolia* were *n*-hexacadecanoic acid (13.0%), spathulenol (17.0%), sabinene (6.0%), artemisia triene (5.1%) and bicyclogermacrene (5.9%). Appreciable quantities of (*E*)-β-ocimene (9.5%), (*Z*)-β-ocimene (8.2%), germacrene D (6.8%), *allo*-ocimene (6.4%), α-phellandrene (5.9%), β-caryophyllene and bicyclogermacrene (ca 5.5%) could be identified from *Machilus velutina*. However, we have identified (*E*)-β-ocimene (85.6%) as the singly abundant constituent of *Neolitsea polycarpa* with significant amounts of limonene (6.5%). Apart from *allo*-ocimene (1.8%) and spathulenol (1.1%), the other nineteen compounds were identified in amount less than 1%. This is the first comprehensive report on the volatile oils of the studied species.

Keywords: *Phoebe angustifolia ; Machilus velutina ; Neolitsea polycarpa ;* Lauraceae ; essential oil composition ; terpenoids.

1. Introduction

Phoebe is a genus of evergreen trees and shrubs belonging to the Laurel family, Lauraceae. There are approximately 100 species, classified into tropical and subtropical with 35 species endemic in China. They have a broad distribution across Northern South America, Venezuela, Colombia, Peru, Central America from Mexico to Panamá across Costa Rica, South East Asia, India, China,

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Philippines, Australia, Borneo, Papua New Guinea and into the western Pacific Ocean. *Phoebe* species are evergreen shrubs or trees with pinnate leaves [1]. The hermaphroditic flowers are grouped in branched inflorescences. The flowers are white, small and fragrant and are arranged in terminal inflorescences in the form of panicles. The fruit, a berry, has only a single seed dispersed frequently by birds. *Machilus* is a genus of flowering plants belonging to the family Lauraceae. It is distributed in temperate, tropical and subtropical Asia. *Machilus* genus includes currently more than 100 species, mostly in laurel forest habitat. They are characterized in the family Lauraceae by its leaves being alternate and entirely pinnately veined. The genus *Neolitsea* is composed of about 80 species in Asia, Malysia and Australia. All species are trees, although often of small stature [2].

In this work, we report on the volatile compounds identified from the essential oils of *Phoebe angustifolia* Meisn, *Machilus velutina* Champ. ex Benth and *Neolitsea polycarpa* H. Liu.growing in Vietnam. Literature information is scanty on the oil contents of these plants and the present report may represent the first of its kind.

2. Materials and Methods

2.1. Plant Materials

Leaves of *Phoebe angustifolia* Meisn were collected from Sao La Nature Reserve Sao La, Quảng Nam Province, Vietnam, in August 2011, while the leaves of *Machinus velutina* Champ. ex Benth and *Neolitsea polycarpa* H. Liu., were obtained from Nghệ An Province, Vietnam, in July 2011. Voucher specimens DND 1086, DND 2007 and DND 2008 respectively, have been deposited at the Botany Museum Vinh University, Vietnam, for future references.

2.2. Extraction of the oils

About 0.5 kg of air-dried leaves of each plant samples was shredded and their oils were obtained by hydrodistillation for 3h at normal pressure, according to the Vietnamese Pharmacopoeia [3].

2.3 Gas chromatography (GC)

About 15 mg of each oil sample, which was dried with anhydrous sodium sulfate, was dissolved in 1mL of hexane (for spectroscopy or chromatography). GC analysis was performed on Agilent Technologies HP 6890 Plus Gas chromatograph equipped with a FID and fitted with HP-Wax and HP-5MS columns (both 30 m x 0.25 mm, film thickness 0.25 μm, Agilent Technology). The analytical conditions were: carrier gas H_2 (10 mL/min), injector temperature (PTV) 250^{o}C, detector temperature 260^{o}C, column temperature programmed 60^{o}C (2 min hold) to 220^{o}C (10 min hold) at 4^{o}C/min. Samples were injected by splitting and the split ratio was 10:1. The volume injected was 1.0 μL. Inlet pressure was 6.1 kPa. The relative amounts of individual components were computed from the GC peak areas without the use of correction factors.

2.4. Gas chromatography-Mass Spectrometry (GC-MS)

An Agilent Technologies HP 6890N Plus Chromatograph fitted with a fused silica capillary HP-5 MS column (30 m x 0.25 mm, film thickness 0.25 μm) and interface with a mass spectrometer HP 5973 MSD was used for the GC/MS analyses, under the same conditions used for GC analysis, with He (10 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.

2.5. Identification of constituents

The identification of constituents was performed on the basis of retention indices (RI) determined with reference to a homologous series of *n*-alkanes (C_4-C_{30}), under identical experimental conditions, co-injection with either standards (Sigma-Aldrich, St. Louis, MO, USA) or known essential oil constituents, MS library search (NIST 08 and Wiley 9th Version), and by comparing with MS literature data [4-6].

3. Results and Discussion

The plant samples yielded low content of essential oils: 0.16 (v/ w; *P. angustifolia*; light yellow); 0.15% (v/w; *M. velutina*; light yellow) and 0.12 (v/w; *N. polycarpa;* light yellow), on a dry weight basis. Table 1 showed the identities of compounds identified from the studied volatile oils. About 101 compounds were identified in the oil of *P. angustifolia*. Sesquiterpenes (61.9%) were the most prominent class of compound in both oils. The main compounds identified in the oils were spathulenol (17.0%), *n*-hexadecanoic acid (13.0%), sabinene (6.0%), bicyclogermacrene (5.9%) and artemisia triene (5.1%). There were significant amounts of β-eudesmol (4.3%), *trans*-α-bergamotene (3.3%), undecenal (2.6%), viridiflorol (2.5%), (*E*)-nerolidol (2.4%), aromadendrene (2.2%), γ-gurjunene (2.1%), (*E*, β)-farnesene (2.0%) and γ-curcumene (2.0%).

Table 1. Compounds identified from the studied oil samples

Compounds	**RI$^{\$}$**	**RI^{c}**	**1**	**2**	**3**	**M.I**
(*Z*)-4-Ethylhex-2-ene	758	-	0.2	-	-	a
Artemisia triene	927	923	5.1	-	-	b
α-Thujene	930	924	-	1.0	-	b
α-Pinene	939	932	0.4	5.9	0.3	b
3-Methylcyclohexanone	952	945	-	0.2	-	b
α-Fenchene	953	945	-	0.1	-	b
Camphene	953	946	0.1	0.8	0.1	b
Sabinene	976	969	6.4	2.4	0.1	b
β-Pinene	980	974	0.4	1.2	0.2	b
β-Myrcene	990	988	0.2	1.9	0.6	b
α-Phellandrene	1006	1002	0.2	1.8	0.1	b
δ-3-Carene	1001	1008	-	0.7	-	b
α-Terpinene	1017	1014	0.1	0.2	-	b
o-Cymene	1025	1022	0.7	-	-	b
ρ-Cymene	1026	1020	-	0.2	-	b
Limonene	1032	1024	-	1.9	6.5	b
β-Phellandrene	1028	1025	0.4	-	-	b
(*Z*)-β-Ocimene	1043	1032	0.4	8.2	-	b
(*E*)-β-Ocimene	1052	1044	0.2	9.5	85.6	b
γ-Terpinene	1061	1054	0.1	0.5	-	b
Acetophenone	1063	1059	0.1	-	-	b
α-Terpinolene	1090	1086	t	1.8	-	b
Linalool	1100	1095	-	0.2	0.7	b
n-Undecane	1100	1100	0.1	-	-	b
Perillene	1102	1102	0.1	-	-	b
Nonanal	1106	1100	0.1	0.1	-	b
trans-Thujone	1110	1112	0.1	-	-	b
allo-Ocimene	1128	1128	-	6.4	1.8	b
neo-*allo*-Ocimene	1140	1140	0.2	0.4	-	b
Camphor	1145	1141	-	0.9	-	b
Borneol	1167	1165	-	-	0.4	b
Terpinen-4-ol	1177	1174	1.1	0.2	-	b
Cryptone	1189	1183	0.1	-	-	b
(2*E*)-Decenal	1259	1260	0.1	0.2	-	b
(*E*)-Anethole	1285	1282	-	-	0.3	b
Bornyl acetate	1289	1287	-	0.2	-	b

Undecenal	1313	1305	2.6	-	-	b
Bicycloelemene	1339	1338+	0.5	7.1	-	b
α-Cubebene	1351	1345	0.1	0.1	-	b
α-Copaene	1377	1374	-	1.0	-	b
Geranyl acetate	1381	1379	0.7	-	-	b
β-Cubebene	1388	1387	-	1.1	-	b
β-Elemene	1391	1389	-	3.8	0.2	b
1-Dodecenal	1411	1408	0.5	-	-	b
α-Cedrene	1412	1410	0.1	-	-	b
α-Gurjunene	1412	1409	1.9	-	-	b
β-Caryophyllene	1419	1417	0.2	5.5	0.3	b
trans- α-Bergamotene	1428	1432	3.3	-	-	b
γ-Elemene	1433	1434	-	-	0.1	b
β-Gurjunene	1434	1431	0.2	-	-	b
Aromadendrene	1441	1439	2.2	t	0.2	b
(*Z*)-β-Farnesene	1443	1440	0.3	-	-	b
α-Humulene	1454	1452	-	2.1	-	b
(*E*)-β-Farnesene	1454	1454	2.0	-	-	b
Dehydroaromadendrene	1463	1460	-	1.5	-	b
γ-Gurjunene	1477	1475	2.1	0.3	-	b
γ-Muurolene	1480	1478	0.5	0.7	-	b
ar-Curcumene	1481	1479	2.0	-	-	b
γ-Curcumene	1483	1481	0.9	-	-	b
γ-Himachalene	1483	1481	0.4	-	-	b
Germacrene D	1485	1484	-	6.8	0.1	b
α-Amorphene	1485	1483	0.4	0.2	-	b
iso-Lepidozene	1485	1483+	-	0.4	-	b
β-Selinene	1486	1489	0.1	0.1	0.2	b
Bicyclosesquiphellandrene	1489	1487+	-	0.3	-	b
α-Zingiberene	1494	1493	1.1	-	-	b
cis-Cadina-1,4-diene	1496	1495	-	0.1	-	b
Ledene (=*Viridiflorene*)	1496	1496	0.8	-	-	b
Bicyclogermacrene	1500	1500	5.9	5.5	-	b
(*E,E*)-α-Farnesene	1506	1505	-	-	0.7	b
endo-1-Bourbonanol	1520	1518	-	0.5	-	b
δ-Cadinene	1525	1522	0.3	2.4	-	b
α-Cadinene	1541	1537	1.4	-	-	b
(*E*)-Nerolidol	1563	1561	2.4	0.2	0.1	b
Spathulenol	1578	1577	17.0	0.7	1.1	b
Caryophyllene oxide	1583	1582	1.0	1.4	-	b
Globulol	1588	1590	0.5	-	-	b
β-Copaene-4α-ol	1591	1590	-	0.4	-	b
Viridiflorol	1593	1592	2.5	0.4	-	b
allo-Aromadendrene	1623	1639	0.8	-	-	b
Isospathulenol [d]	1625	-	1.2	-	-	a
allo-Aromadendrene epoxide	1640	1639	1.7	-	-	b
α-Muurolol	1646	1644	-	0.1	-	b
epi-α-Muurolol	1648	1640	-	1.0	-	a
β-Eudesmol	1651	1649	4.3	-	-	b
α-Cadinol	1654	1652	-	0.9	-	b
Valerianol	1658	1656	0.9	-	-	b
Ledene oxide II [d]	1682	-	0.9	-	-	a
(*Z,E*)-Farnesol	1722	1722	1.1	-	-	b
Mint sulfide	1741	1740	-	0.1	-	b

Benzyl benzoate	1760	1759	-	1.2	-	b
1,2-Benzenediacrboxylic acid [d]	1999	-	0.1	-	-	a
n-Hexadecanoic acid	1962	1959	13.0	-	-	b
n-Eicosane	2000	2000	0.5	-	-	b
Geranyl linalol isomer [d]	2004	-	0.3	-	-	a
Phytol	2125	1942	0.7	-	-	b
Total			**97.0**	**91.6**	**99.2**	
Monoterpene hydrocarbons			14.1	44.5	95.3	
Oxygenated monoterpenes			2.1	1.5	1.0	
Sesquiterpene hydrocarbons			26.7	39.2	1.8	
Oxygenated sesquiterpenes			35.2	5.2	1.1	
Diterpenoids			0.7	-	-	
Carboxylic acids			13.1	1.1	-	
Aliphatic compounds			4.1	0.3	-	
Others			-	0.7	-	

[$] Retention indices on HP-5Ms capillary column; [c] Literature retention indices (Adam, 2007); M.I = Mode of identification which are: [a] Co-injection, Mass fragmentation pattern, Retention indices from column; [b] Co-injection, Mass fragmentation pattern, Retention indices from column and Literature Retention indices; [+] Found in Joulain and Koenig (1998); - not identified and not present in Literature; [d] tentative identification; t, trace amount < 0.1%; 1. *P angustifolia*; 2. *M. velutina*; 3. *N. polycarpa*

Table 2 gives the chemical constituents identified from the volatile oils of other *Phoebe* species grown in other region of the world. Although the leaf oil constituents of *P. angustifolia* consisted of sesquiterpene hydrocarbons, like those of *P. kwangciensis* [7], *P. lanceolata* [9] and *P. porphyria* [8]; and oxygenated sesquiterpenoids like those of *P. porosa* [10, 11], their main components differed. Further comparison with the leaf oil of *P. faberi* [12], which was predominantly aliphatic compounds and differed from the leaf oil of *P. angustifolia*. However, n-hexadecanoic acid, one of the major compounds of *P. angustifolia*, was not previously characterized as main compound of previously studied *Phoebe* species [7-12]. Therefore, the volatile constituents of *Phoebe* species could be delineated into three chemical classes. These are (i) oils dominated by sesquiterpene hydrocarbons e.g. *P. nigrifoli* [7], *P. kwangciensis* [7], *P. porphyria* [8] and *P. lanceolata* [9]; (iii) oil with significant proportion of oxygenated sesquiterpenoids as could be seen in *P. porosa* [10, 11] and (iv) oils containing appreciable amounts of aliphatic compounds e.g. *P. faberi* [12]. The present volatile of *P. angustifolia* would be classified into group ii. Noteworthy observation is the fact that *n*-hexadecanoic acid has not been previously described as constituent of *Phoebe* oils. Moreover, prominent compounds in other *Phoebe* oils [7-12] such as 1, 8-cineole, eremoligenol, oreodaphnenol, *trans*-α-bergamot-2-en-10-one, porosadienone and γ-elemene could be not identified in the present study. This is the first comprehensive report on the volatile constituent of *P. angustifolia*.

The main class of compounds identified in *M. velutina,* as seen in Table 1, consisted mainly of monoterpenes hydrocarbons (44.5%) and sesquiterpene hydrocarbons (39.2%). The compounds of significant quantities are by α-phellandrene (5.9%), (*Z*)-β-ocimene (8.2%), (*E*)-β-ocimene (9.5%), *allo*-ocimene (6.4%), β-caryophyllene (5.5%), germacrene D (6.8%), and bicyclogermacrene (ca 5.5%). The oxygenated terpenoids are less common (totaling 6.7%). Previous analysis revealed that the volatiles of *Machilus* species are of diverse chemical compounds of terpenes and non-terpenes. For example, the major compound of *M. japonica* [13] were caryophyllene (18.6%), β-phellandrene (14.7%), geranylacetate (9.4%), bornylacetate (6.5%) and β-pinene (5.5%) while *M. bombycina* [14] consists mainly of decanal (12.5%), 11-dodecenal (8.1%) and dodecanal (26.5%). The leaf oil constituents of *M. velutina* were primarily monoterpenoid hydrocrocarbons, like those of *M. longipedicellata* and *M. yunnanensis* [7]; and sesquiterpenoid hydrocarbons like those of *M. thumbergii* [15], their main components differed. In addition, this oil differed from *M. bombycina* [14] by its low content of aliphatic compounds.

Table 2. Constituents of some *Phoebe* species

Species	Origin	Main constituents	Reference
P. kwangciensis Liou	China	α-phellandrene (9.13%), γ- elemene (10.74%) sabinene hydrate (13.27%), γ-muurolene (17.38%), β-caryophyllene (11.38%),	[7]
P. nigrifolia S. Lee et F.N. Wei	China	β-phellandrene (24.38%), γ-muurolene (13.60%), (*E*)-β-ocimene (8.79%), β-caryophyllene (6.63%), γ-elemene (7.13%)	[7]
P. porphyria (Griseb.) Mez	Argentina	1, 8-cineole (10.5%), β-caryophyllene (19.3%), spathulenol (17.1%)	[8]
P. porosa Mez [a]	Brazil	α-copaene (6.25%), β-eudesmol (6.56%), valerianol (7.55%)	[10]
P. porosa Mez	Brazil	α-copaene (5.6%), eremoligenol (8.4%), β-eudesmol (8.4%), valerianol (5.0%)	[11]
P. faberi Hemsl	China	(Z)-S-(+)-3, 7, 11- trimethyl-1, 6, 10, dodecantrien-3-ol (39.43%), β-caryopyllene (29.18%)	[12]
P. lanceolata (wall ex. Ness) Ness	Vietnam	bicyclogermacrene (10.96%), β-caryopyllene (12.17%), germacrene D (28.39%)	[9]

[a] This is from the wood oils while others are from the leaf oils

Table 3. Constituents of some *Machilus* species

Species	Origin	Main constituents	Reference
M. japonica Sieb. et Zucc.	Japan	caryophyllene (18.6%), β-phellandrene (14.7%), geranyl acetate (9.4%), bornyl acetate (6.5%), β-pinene (5.5%)	[13]
M. bombycina King	India	decanal (12.5%), 11-dodecanal (8.1%), dodecanal (26.5%)	[14]
M. thumbergii Sieb. et Zucc. [a]	Japan	caryophyllene (21.3%), β-elemene (10.8%), *cis*-ocimene (11.3%), α-pinene (11.3%), α/β-selinene (7.8%)	[15]
M. longipedicellata Lecomte	China	α-pinene (45.32%), β-pinene (24.73%), nerolidol (8.23%)	[7]
M. yunnanensis Lecomte	China	sabinene (30.99%), α-pinene (37.63%), myrcene (15.95%)	[7]
M. obovatifolia Kanehira et Sasaki	Taiwan	β-caryophyllene (10.5%), β-phellandrene (7.8%), τ-muurolol (5.3%), α-phellabdrene (5.1%), δ-cadinene (5.0%)	[16]

[a] Plant part unknown while other are from the leaf oils.

From Table 3, it could be concluded that four chemical classes of M*achilus* oils are discernible. These are: oils with large amounts of monoterpene hydrocarbon as seen in *M. longipedicellata* [7] and *M. yunnanensis* [7]; oil containing only aliphatic compounds represented by *M. bombycina*; sesquiterpene hydrocarbon rich oil as could be seen in *M. thumbergii* [15]; and oils with relative amounts of mono- and sesquiterpenes as could be found in *M. japonica* [13] and *M.*

obovatifolia [16] and the oil under investigation i.e. *M. velutina*. The aliphatic compounds identified in the present study were qualitatively different from those found in other species (especially *M. bombycina*). Also, some other compounds such as β-phellandrene, geranyl acetate, bornyl acetate and α-selinene, which are characteristic of other species were not present in *M. velutina*. Literature information is scanty on the oil constituents of *M. velutina* and as such this report may represent the first of its kind.

Table 4. Constituents of some *Neolitsea* species

Species	Origin	Main constituents	Reference
N. fischeri Gamble	India	caryophyllene oxide (33.0%), selin-11-en-4α-ol (14.8%)	[17]
		cadinene (10.2%), α-cadinol (24.5%), α-muurolene (22.2%)[a]	[17]
		α-cadinol (19.9%), caryophyllene oxide (13.2%)[b]	[17]
N. foliosa (Nees) Gamble var. *caesia* (Meisner) Gamble	India	β-caryophyllene (35.3%), caryophyllene oxide (9.6%), elemol (8.2%), β-elemene (6.1%)	[18]
N. australiensis Kosterm	Australia	bicyclogermacrene (12-16%), guaiol (15-17%)	[19]
N. brasii Allen	Australia	bicyclogermacrene (11-15%), cubenol (6-10%), guaiol (7-10%)	[19]
N. dealbata (R. Br.) Merr	Australia	germacrone (10-50%), bicyclogermacrene (12-35%), spathulenol (4-38%), furanogermenone (45%)	[19]
N. dealbata (R. Br.) Merr	Australia	β-eudesmol (3-30%), bicyclogermacrene (0.5-31%), spathulenol (5-31), cubenol (2-8%)	[19]
N. aciculata (Blume) Koidz	Japan	*trans*-ocimene (9.5%), β-elemene (5.3%), caryophyllene (13.4%), β-selinene (22.9%)	[15]
N. oblongifolia Merr. et Chun	China	sabinene (21.86%), 1, 8-cineole (4.58%), ρ-cymene (3.62%), β-pinene (2.88%)	[20]
N. umbrosa (Nass) Gamble	China	1, 8-cineole (15.05%), verbenone (14.12%), pinocarveol (9.04%), β-eudesmol (5.19%)	[20]
N. parvigemma (Hay.) Kanehira & Sasaki	Taiwan	β-caryophyllene (14.2%), β-eudesmol (12.9%), α-cadinol (10.2%), τ-cadinol (8.8%)	[21]
N. aciculata	Korea	dodecen-5-yne (12.5%), calarene (11.8%), elemol (9.5%)	[22]
N. pallens D (Dons)	India	furnaogermenone (30.6%), β-caryophyllene (19.3%), germacrene D (12.7%)	[23]
		furanogermenone (19.1%), germacrone (9.3%), 10-*epi*-γ-eudesmol (7.8%)[a]	[23]
		furanogermenone (54.8%), trans- β-ocimene (8.8%), sabinene (6.4%)[b]	[23]

[a] bark oil; [b] fruit oil; Others are from the leaf oils

We have identified (*E*)-β-ocimene (85.6%), as the most singly abundant constituents of *N. polycarpa*. Apart from limonene (6.5%), *allo*-ocimene (1.8%) and spathulenol (1.1%), the other nineteen compounds were identified in amount less than 1% (Table 1). Although the leaf oil constituents of *N. polycarpa* was primarily monoterpenoids, like those of *N. oblongifolia* and *N. umbrosa* [20], their main components differed. Further comparison with the leaf oil of *N. aciculata* [15, 22], *N. fischeri* [17], *N. foliosa* var. *caesia* [18], *N. australiensis*, *N. brassii*, *N. dealbata* [19], *N. parvigemma* [21] and *N. pallens* [23], were predominantly sesquiterpenoids and differed from the leaf oil of *N. polycarpa*. For example, the major components of *N. foliosa* var. *caesia* of India origin [18] were β-caryophyllene (35.3%), caryophyllene oxide (9.6%), elemol (8.2%) and β-elemene (6.1%). The significant compounds of *N. aciculata* from Japan [15] were caryophyllene (13.4%), β-selinene

(22.9%), *trans*-ocimene (9.5%) and β-elemene (5.3%). As seen in Table 4, literature information revealed that sesquiterpene compounds were the main class of compounds of majority of previously studied *Neolitsea* oils, except those of *N. oblongifolia* and *N. umbrosa* [20]. Several compounds such as α-selinene, bicyclogermacrene, caryophyllene oxide, cadinol, selinen-11-en-4α-ol, α-muurolol, guaiol, cubenol, β-eudesmol, germacrone and furanogermenone [15, 17-19] that were identified in other species could not be detected in *N. polycarpa*. This is the first comprehensive report on the volatile constituents of *N. polycarpa*.

In conclusion, the results have provided information about the oil compositions of *P. angustifolia*, *M. velutina* and *N. polycarpa* grown in Vietnamese and the variability of their composition from species of different origin. In addition, this result differs considerably in composition to those already described in literature from most species in the same genus.

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References

[1] L.M. Perry (1989). Medicinal Plants of East and Southeast Asia: Attributed Properties and Uses. MIT Press, Cambridge (Massachusetts)/ London.

[2] V. V. Dung (1996). Vietnam Forest Trees. Agriculture Publishing House, Hanoi, Vietnam.

[3] Vietnamese Pharmacopoeia (1997). Medical Publishing House, Hanoi.

[4] R.P. Adams (2007). Identification of Essential Oil Components by Gas Chromatography/Quadrupole Mass Spectrometry, 4th Edition. Allured Publishing Corp. Carol Stream, IL.

[5] D. Joulain and Koenig (1998). The Atlas of Spectral Data of Sesquiterpene Hydrocarbons. E. B.- Verlag: Hamburg, Germany.

[6] S. R. Heller and G. W. A. Milne (1978,1980,1983). EPA/NIH Mass Spectral Data Base. U.S. Government Printing Office, Washington D.C.

[7] J. Ding, X. Yu, Z. Ding, B. Cheng, Y. Yi, W. Yu, N. Hayashi and H. Komae (1994). Essential oils of some Lauraceae species from the Southwestern Parts of China, *J. Essent. Oil Res.* **6**, 577-585.

[8] M. L. Lopez, M. P. Zunino, J. A. Zygadlo, A. G. Lopez, E. I. Lucini and S. M. Faillaci 92004). Aromatic plants of Yungas. Part II. Chemical composition of the essential oil of *Phoebe porphyria* (Griseb.) Mez. (Lauraceae), *J. Essent. Oil Res.* **16**, 129-130.

[9] T. D. Thang and N. X. Dung (2009). In *Aromatic Plants from Asia, Their Chemistry and Application in Food and Therapy,* vol. 1; Jirovetz, L.; Dung, N. X.; Varshney, V. K., eds.; Har Krishna Bhalla & Son: India.

[10] T. Reynolds and G. Kite (1995). Volatile constituents of *Phoebe porosa* Mez, *J. Essent. Oil Res.* **7**, 415-418.

[11] P. Weyerstahl, W. Hans-Christian, U. Splittgerber and H. Marschal (1994). Volatile constituents of Brazilian Phoebe oil, *Flav. Fragr.* **9**, 179-186.

[12] D.P. Yang, F.S. Wang, and H.D. Zang (2000). Chemical constituents and antifungal activities of essential oil from the leaves of *Phoebe faberi, Guihaia*. **20**, 181-184.

[13] H. Komae and N. Hayashi (1971). Terpenic constituents from *Machilus japonica*, *Phytochemistry.* **10**, 3311.

[14] S. N. Choudhury and P. E. Leclercq (1995). Essential oil of *Machilus bombycina* King from Northeast India, *J. Essent. Oil Res.* **7**, 199-201.

[15] H. Komae and N. Hayashi 91972). Terpenes from *Actinodaphne*, *Machilus* and *Neolitsea* species, *Phytochemistry*. **11**, 1181-1182

[16] H. Chen-Lung, H. Kuang-Ping, W.E. Eugene I-Chen and S. Yu-Chang (2009).Composition and antimicrobial activity of the leaf essential oil of *Machilus obovatifolia* from Taiwan, *J. Essent. Oil Res.* **21**, 471-475.

[17] A.J. John, V.P. Karunakaran, V. George, N.S. Pradeep and M.G. Sethuraman (2008). Chemical composition and antibacterial activity of the leaf, bark and fruit oils of *Neolitsea fischeri* Gamble, *J. Essent. Oil Res.* **20**, 279-282.

[18] A.J. John, V.P. Karunakaran, V. George, N.S. Pradeep and M.G. Sethuraman (2007). Chemical composition and antibacterial activity of leaf oil of *Neolitsea foliosa* (Nees) Gamble var. *caesia* (Meisner) Gamble, *J. Essent. Oil Res.* **19**, 495-500.

[19] J.J. Brophy, R.J. Goldsack, C.J.R. Fookes and P.I. Forster (2002). The leaf oils of the Australian species of *Neolitsea* (Lauraceae), *J. Essent. Oil Res.* **14**, 191-195.

[20] L. Zhu, Y. Li, B. Li, B. Li and N. Xia (1993) Aromatic Plants and Essential Constituents. Hai Feng Publishing Company, Hong Kong.

[21] C.L. Ho, P.C. Liao, E.I.C. Wang and Y.C. Su (2011). Composition and antifungal activities of the leaf essential oil of *Neolitsea parvigemma* from Taiwan, *Nat. Prod. Commun.* **6**, 1357-1360.

[22] S.S. Kim, J.E. Kim, C.G. Hyun and N.H. Lee (2011) *Neolitsea aciculata* essential oil inhibits drug-resistant skin pathogen growth and propionibacterium acnes-induced inflammatory effects of human monocyte leukemia, *Nat. Prod. Commun.* **6**, 1193-1198.

[23] R.C. Padalia, C.S. Chanotiya, B.C. Thakuri and C.S. Mathela (2007) Germacranolide rich essential oil from *Neolitsea pallens*, *Nat. Prod. Commun.* **2**, 591-593.