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# Chemical Composition of Essential Oils from the Stem Barks of Three *Cinnamomum* Species

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors TDT and DND designed the study and performed both the hydrodistillation of the essential oils and the GC/MS analysis. Author LCS collected the samples assisted by author DDH. Authors TOO and AO managed the literature searches while author IAO wrote the first draft of the manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

The stem barks essential oils of three Vietnamese species of *Cinnamomum* grown in Vietnam were analyzed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC/MS). The main monoterpene compounds of *Cinnamomum kunstleri* Rild., were 1, 8-cineole (25.3%), α-terpineol (10.7%) and terpinen-4-ol (6.7%). However, linalool (27.0%), limonene (23.4%), terpinen-

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4-ol (9.8%) and α-phellandrene (9.5%) were the principal monoterpene components of *Cinnamomum cambodianum* Lecomte. Sesquiterpenes represened mainly by aromadendrene (26.0%), β-caryophyllene (17.2%) and α-copaene (5.7%) were the dominant compounds in the bark oil of *Cinnamomum rigidifolium* Kosterm.

**Aims:** The aim of this study was to isolate essential oils from the stem barks of *Cinnamomum kunstleri*, *Cinnamomum cambodianum* and *Cinnamomum rigidifolium* and investigate the volatile constituents present therein.

**Study Design:** Disitillation of essential oils from the plant materials and analysis of their chemical composition.

**Place and Duration of Study:** The stem barks of *C. kunstleri*, *C. cambodianum* and *C. rigidifolium* were collected from Bạch Mã National Park, Thừa Thiên-Huế Province, Vietnam, in August 2012.

**Methodology:** About 500 g of air-dried plant samples was shredded and their oils were obtained by separate hydrodistillation for 4 h at normal pressure, according to the Vietnamese Pharmacopoeia. The chemical constituents of the distilled oils were analyzed by means of gas chromatography-flame ionization detector (GC-FID) and gas chromatography coupled with mass spectrometry (GC-MS).

**Results:** The major constituents of *C. kunstleri* were identified as 1, 8-cineole (25.3%), α-terpineol (10.7%) and terpinen-4-ol (6.7%) while linalool (27.0%), limonene (23.4%), terpinen-4-ol (9.8%) and α-phellandrene (9.5%) were the principal components of *C. cambodianum*. However, aromadendrene (26.0%), β-caryophyllene (17.2%) and α-copaene (5.7%) were the dominant compounds in *C. rigidifolium*

**Conclusion:** The present oil compositions were found to be different from the results obtained previously from the essential oils of *Cinnamomum* species grown in Vietnam and other parts of the world.

*Keywords: Cinnamomum; essential oil composition; terpenes.*

## 1. INTRODUCTION

Vietnam is blessed with many medicinal plants. Literature information has shown that the volatile oils of these plants have received little chemical analysis. In view of this, we have developed interest in the analysis of essential oil constituents of plant species from Vietnam [1,2]. *Cinnamomum* is a genus of evergreen trees and shrubs belonging to the Laurel family, Lauraceae. *Cinnamomum* species have aromatic oils in their leaves and bark. The genus contains over 300 species, distributed in tropical and subtropical regions of North America, Central America, South America, Asia, Oceania and Australasia. The genus is a source of various biologically active compounds [3,4].

Majority of *Cinnamomum* species are aromatic trees with a characteristic smell and the reports on their volatile components are readily available in the literature. Recent findings revealed that the volatile oils of *Cinnamomum* species possess variety of biological activities such as cytokine modulatory effect [5], antioxidant and antibacterial [6], toxicity and insecticidal activity [7,8], anti-inflammatory [9], xanthine oxidase inhibitor [10] and cytotoxicity [11]. The volatile compounds are usually mono- and sesquiterpene compounds, though (*E*)-cinnamaldehyde featured prominently as the major compound of some species which included *C. paciflorum* [12], *C. pubescens* [6], *C. aromaticum* [8] and *C. zeylanicum* [13]. On the other hand, compounds such as linalool in *C. camphora* var. *linaloolifera* [14] safrole and benzyl benzoate in *C. parthenoxylon* [15] as well as 2-methylene-3-buten-1-yl-benzoate in *Cinnamomum* sp [16]. A high content of eugenol and 1, 8-cineole were reported in *C. albiflorum* [17] while spathulenol, caryophyllene oxide and β-caryophyllene constituted the major compounds in *C. sericans* [1]. However, the significant compounds of *C. durifolium* were ρ-cymene, limonene and α-phellandrene while bicyclogermacrene, β-caryophyllene were present in *C. magnificum* [1]. On the other hand β-caryophyllene, caryophyllene oxide and spathulenol were identified previously in *C. iners* [1].

The volatile oil content of several species of *Cinnamomum* growing in Vietnam has been characterized with low content of (*E*)-cinnamaldehyde [1,2,14-19]. Only the oil of *C. tonkinensis* [20] contained an appreciable amount of (*E*)-cinnamaldehyde. In this paper, we report the volatile constituents identified from the

stem barks of *Cinnamomum kunstleri* Rild., *Cinnamomum rigidifolium* Kosterm and *Cinnamomum cambodianum* Lecomte, endemics to Vietnam. *Cinnamomum cambodianum* was known to possessed anti-allergic effect [21]. Although, the chemical composition of essential oils from the leaves of these *Cinnamomum* plants have been characterized and reported [2], information is scanty on the volatile and non-volatile contents of other parts of these plant species. In addition, *C. cambodianum* oil was reported to contain α-terpineol (33.4%), linalool (22.4%) and terpinen-4-ol (13.3%) as the main constituents [18]. The lack of readily available information on the chemical constituents of these plants arouses our interest to investigate the volatile oils of these poorly studied Vietnamese grown floras.

## 2. MATERIALS AND METHODS

### 2.1 Plant Materials

Stem bark samples of *C. kunstleri*, *C. cambodianum* and *C. rigidifolium* were collected from Bạch Mã National Park, Thừa Thiên - Huế Province, Vietnam, in August 2012. Botanical identification was performed by curators at the Herbarium Botany Museum, Vinh University, Vietnam. Voucher specimens LCS 241, LCS 254 and LCS 260 respectively, were deposited at the Botany Museum, Vinh University, Vietnam. Plant samples were air-dried prior to extraction.

### 2.2 Distillation of the Essential Oils

About 0.5 kg of air-dried plant samples was shredded and their oils were obtained by separate hydrodistillation for 4 h at normal pressure, according to the Vietnamese Pharmacopoeia [22].

### 2.3 Analysis of the Oils

Gas chromatography (GC) analysis was performed on an Agilent Technologies HP 6890 Plus Gas chromatograph equipped with a FID and fitted with HP-5MS column (30 m x 0.25 mm, film thickness 0.25 μm, Agilent Technology). The analytical conditions were: carrier gas $H_2$ (1 mL/min), injector temperature (PTV-programmed temperature vaporization injection) 250℃, detector temperature 260℃, column temperature programmed from 60℃ (2 min hold) to 220℃ (10 min hold) at 4℃/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.

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 interfaced with a mass spectrometer HP 5973 MSD was used for the GC/MS 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. The MS fragmentation patterns were checked with those of other essential oils of known composition with Wiley (Wiley 9$^{th}$ Version), NIST 08 Libraries (on ChemStation HP), with those in the literature, and also with standard substances.

### 2.4 Identification Procedure

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 ($C_5$-$C_{30}$), under identical experimental conditions. Further identification was performed by comparison of their mass spectra with those from NIST 08 and Wiley 9$^{th}$ Version 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 values [23,24].

## 3. RESULTS AND DISCUSSION

The plant samples afforded low content of essential oils: 0.2% (v/w, *C. kunstleri*), 0.35% (v/w, *C. cambodianum*) and 0.25% (v/w, *C. rigidifolium*), calculated on a dry weight basis. All the oil samples were light yellow colored. The percentage of each constituent identified in the oil samples as well as the experimental and literature retention indices are summarized in Table 1, according to their elution order on an HP-5MS column. Monoterpenes (74.1%) and sesquiterpenes (23.4%) were the main constituent groupings identified in the bark oil of *C. kunstleri*. The main monoterpene compounds were 1, 8-cineole (25.3%), α-terpineol (10.7%), terpinen-4-ol (6.7%), α-pinene (5.3%), sabinene (4.4%), β-pinene (4.0%) and borneol (3.5%). The sesquiterpenes were represted by α-amorphene (4.3%), δ-cadinene (3.7%) and α-copaene (2.5%). However, methyl eugenol, the main

compound present in the leaf oil [2] was not identified in the stem oil.

Monoterpene hydrocarbons (53.0%) and oxygenated monoterpenes (39.9%) were the main classs of compounds identified in the bark oil of *C. cambodianum.* The main constituents featured significant amounts of linalool (27.0%), limonene (23.4%), terpinen-4-ol (9.8%) and α-phellandrene (9.5%). Other significant compound includes (*E*)-β-ocimene (5.9%), *o*-cymene (5.8%) and eugenol (5.6%). Although, linalool and terpinen-4-ol constitutes larger portion of the leaf oil [2], the content of limonene in the stem is higher than that of the leaf. The chemical pattern of this oil resemble those of *C. camphora* var. *linaloolifera* [14] and previous analysis on *C. cambodianum* [18], only in the general prevalence of linalool and terpinen-4-ol, but the identity of most other prominent compounds differed from each other.

**Table 1. Chemical composition of the stem barks essential oils of *Cinnamomum* species**

| Compounds[b] | RI[c] | RI[d] | Percentage composition (± SD)[a] | | |
|---|---|---|---|---|---|
| | | | ***C. kunstleri*** | ***C. cambodianum*** | ***C. rigidifolium*** |
| α-Thujene | 930 | 924 | 1.7 | - | - |
| α-Pinene | 939 | 932 | 5.3 | 1.7 | - |
| Sabinene | 976 | 969 | 4.4 | 2.1 | - |
| β-Pinene | 980 | 974 | 4.0 | - | - |
| β-Myrcene | 990 | 988 | 1.5 | 1.8 | - |
| α-Phellandrene | 1006 | 1002 | 2.7 | 9.5 | - |
| α-Terpinene | 1017 | 1014 | - | 1.4 | - |
| *o*-Cymene | 1026 | 1022 | 1.9 | 5.8 | - |
| Limonene | 1032 | 1024 | - | 23.4 | 0.8 |
| 1,8-Cineole | 1034 | 1026 | 25.3 | - | 0.5 |
| (*E*)-β-Ocimene | 1052 | 1044 | - | 5.9 | 0.5 |
| γ-Terpinene | 1061 | 1054 | 1.8 | 0.8 | - |
| *cis*-Sabinene hydrate | 1075 | 1065 | 0.1 | - | - |
| α-Terpinolene | 1090 | 1086 | 0.7 | 0.6 | - |
| Linalool | 1100 | 1095 | 0.2 | 27.0 | 1.4 |
| *trans*-*p*-Menth-2-en-1-ol | 1136 | 1136 | 0.2 | - | - |
| *trans*-Sabinol | 1137 | 1137 | 0.2 | - | - |
| *trans*-Pinocarveol | 1138 | 1135 | 0.1 | - | - |
| Borneol | 1167 | 1165 | 3.5 | - | - |
| Linalool oxide (pyranoid) | 1173 | 1170 | 0.2 | - | - |
| Terpinen-4-ol | 1177 | 1174 | 6.7 | 9.8 | 1.3 |
| α-Terpineol | 1189 | 1186 | 10.7 | - | - |
| Nerol | 1227 | 1227 | 0.2 | - | - |
| (*E*)-Cinnamaldehyde | 1270 | 1270 | 0.1 | 1.0 | 0.8 |
| Bornyl acetate | 1289 | 1287 | 0.1 | - | - |
| Carvacrol | 1300 | 1298 | 0.1 | - | - |
| (*Z*)-Dimethoxy citral | 1318 | 1316 | 0.1 | 2.1 | - |
| Bicycloelemene | 1337 | 1338 | - | - | 2.1 |
| δ-Elemene | 1340 | 1335 | 0.4 | - | - |
| α-Cubebene | 1351 | 1345 | 0.6 | - | 0.8 |
| Eugenol | 1356 | 1356 | - | 5.6 | 4.1 |
| Cyclosativene | 1371 | 1369 | 0.6 | - | - |
| α-Ylangene | 1375 | 1373 | 0.2 | - | - |
| α-Copaene | 1377 | 1374 | 2.5 | - | 5.7 |
| β-Cubebene | 1388 | 1387 | - | - | 1.7 |
| β-Elemene | 1397 | 1398 | 1.0 | - | 1.1 |
| Dodecanal | 1408 | 1408 | 0.4 | - | - |
| β-Caryophyllene | 1419 | 1417 | 2.1 | - | 17.2 |
| γ-Elemene | 1437 | 1434 | 0.4 | - | - |

| Compounds[b] | RI[c] | RI[d] | Percentage composition (± SD)[a] | | |
|---|---|---|---|---|---|
| | | | *C. kunstleri* | *C. cambodianum* | *C. rigidifolium* |
| Aromadendrene | 1441 | 1439 | 0.1 | - | 26.0 |
| α-Humulene | 1454 | 1452 | 0.5 | - | 3.0 |
| α-Amorphene | 1485 | 1483 | 4.3 | - | - |
| β-Selinene | 1489 | 1489 | 0.4 | - | - |
| δ-Selinene | 1493 | 1492 | 0.1 | - | - |
| *cis*-Cadina-1,4-diene | 1496 | 1495 | 1.4 | - | 1.1 |
| α-Muurolene | 1500 | 1500 | 0.6 | - | - |
| Bicyclogermacrene | 1501 | 1500 | - | - | 2.9 |
| γ-Cadinene | 1513 | 1513 | 0.8 | - | - |
| *cis*-Z-α-Bisabolene epoxide | 1515 | 1515 | 0.5 | - | 1.7 |
| δ-Cadinene | 1526 | 1522 | 3.7 | - | - |
| α-Calacorene | 1546 | 1544 | 0.3 | - | - |
| Spathulenol | 1578 | 1577 | 0.4 | - | 3.6 |
| Caryophyllene oxide | 1583 | 1582 | 0.6 | - | 5.6 |
| Viridiflorol | 1593 | 1592 | - | - | 0.7 |
| *trans*-β-Elemenone | 1601 | 1601 | 0.7 | - | - |
| Methoxy eugenol | 1610 | 1609 | - | - | 4.2 |
| Tetradecanal | 1611 | 1611 | 0.5 | - | - |
| Fonenol | 1621 | 1621 | 0.1 | - | - |
| 5-*epi*-Neointermedeol | 1639 | 1639 | - | 1.1 | - |
| τ-Muurolol (*epi*-α-Muurolol) | 1646 | 1640 | - | - | 3.2 |
| α-Cadinol | 1654 | 1653 | 1.0 | - | 1.2 |
| Valerianol | 1655 | 1656 | 0.1 | - | - |
| Phenylethyl benzoate | 1842 | 1841 | - | - | 2.3 |
| 1,2-Benzenedicarboxylic acid | 1917 | 1917 | 1.0 | - | 3.1 |
| Hexadecanoic acid methyl ester | 1928 | 1926 | - | - | 3.8 |
| Hexadecanoic acid | 1960 | 1959 | 0.1 | - | - |
| (*Z*)-13-Docosenamide | 2499 | 2499 | 0.1 | 0.1 | 0.3 |
| TOTAL | | | 99.6 | 99.7 | 98.7 |
| Monoterpene hydrocarbons | | | 26.3 | 53.0 | 1.3 |
| Oxygenated monoterpenes | | | 47.8 | 39.9 | 6.2 |
| Sesquiterpene hydrocarbon | | | 21.2 | - | 61.6 |
| Oxygenated sesquiterpenes | | | 2.2 | 1.1 | 16.0 |
| Phenylpropanoids | | | - | 5.6 | 4.1 |
| Aromatic esters | | | - | - | 2.3 |
| Fatty acids | | | 0.6 | - | 3.8 |
| Non-terpenes | | | 1.5 | 0.1 | 3.4 |

*[a]SD Standard deviation, values were insignificant and excluded from the table to avoid congestion; [b] Elution order on HP-5MS capillary column; [c] Retention indices on HP-5MS capillary column; [d] Literature Retention indices; - Not identified*

Sesquiterpene hydrocarbons (61.6%) and oxygenated sesquiterpenes (16.0%) represent the major fractions of the bark oil of *C. rigidifolium*. The main constituents of the oil were aromadendrene (26.0%), β-caryophyllene (17.2%) and α-copaene (5.7%). Monoterpenes (7.5%) were less common and are represented mainly by linalool (1.4%) and terpinen-4-ol (1.3%). It should be noted that α-selinene and germacrene D the main constituents of the leaf oil [2] were conspicuously absent in the stem oil.

It is well known that the biological activities of an essential oil may depend on the major constituents or a synergy between the major and some minor compounds. Referring to literature, essential oils containing large amounts of the major compounds found in the studied *Cinnamomum* species such as 1, 8-cineole, α-terpineol, terpinen-4-ol, linalool, limonene and β-caryophyllene have shown antimicrobial, antioxidant, anti-inflammatory, cytotoxicity, larvicidal and insecticidal potentials [25-27]. This

may as well contribute to the biological potentials of the plant samples.

The authors have no literature citation on the volatile contents of the bark oils of these plant species and such the present results may represent the first of its kind. Nevertheless ubiquitous terpenes were the main compounds present in the oil samples. These findings provided additional information on the chemical constituents of essential oils from different parts of the studied plant samples and may be of chemotaxonomic importance.

The low content of (*E*)-cinnamaldehyde (0.1-1.0%) in the studied oil samples is in agreement with previous results for majority of *Cinnamomum* species already reported from Vietnam. It could be seen that each species has its own compositional pattern quite different from the leaves oils. It is well known that different parts of plant accumulate different phytochemicals [1,2]. These differences in accumulated phytochemicals may be attributed to differences in ethnomedical uses and biological potentials of the different parts of the same plant. Other factors such as the nature of the plant, geographical areas, time of collection, method of extraction, plant parts and maturation of the harvested plant may be responsible for the varying compositional pattern between the studied samples and other *Cinnamomum* plants grown in Vietnam.

## 4. CONCLUSION

For the first time, the chemical constituents of essential oils from the stem barks *C. kunstleri, C. rigidifolium* and *C. cambodianum* endemics to Vietnam are being reported. The compositional patterns were found to be different from those reported previously for other *Cinnamomm* plants grow in Vietnam and other parts of the world. In addition, the compounds present in the oil maybe responsible for the observed biological potentials of the plant samples.

## COMPETING INTERESTS

Authors have declared that no competing interests exist

## REFERENCES

1. Son LC, Dai DN, Thai TH, Huyen DD, Thang TD, Ogunwande IA. The leaf essential oils of four Vietnamese species of *Cinnamomum* (Lauraceae). J Essent Oil Res. 2013;25(4):267-71.
2. Son LC, Dai DN, Thai TH, Huyen DD, Thang TD, Ogunwande IA. Study on *Cinnamomum* oils: Compositional pattern of seven species grown in Vietnam. J Oleo Sci. 2014;63(10):1035-43.
3. Liu CH, Chen CY, Huang AM, Li LH. Subamolide A, a component isolated from *Cinnamomum subavenium*, induces apoptosis mediated by mitochondria-dependent, p53 and ERK1/2 pathways in human urothelial carcinoma cell line NTUB1. J Ethnopharm. 2011;137(1):503-11.
4. Zhong RJ, Wu LY, Xiong W, Xie EL, Zhou GP, Zhang DM. A new 3-(3,4-methylenedioxyphenyl)-propane-1,2-diol glycoside from the roots of *Cinnamomum camphora*. Chinese Chem Lett. 2011; 22(8):954-6.
5. Shih-Shen CL, Lu TM, Chao PC, Lai YY, Tsai HT, Chen CS, Lee YP, Chen SC, Chou MC, Yang CC. *In vivo* cytokine modulatory effects of cinnamaldehyde, the major constituent of leaf essential oil from *Cinnamomum osmophloeum Kaneh*. Phytother Res. 2011;25(10):1511-8.
6. Siddiq IA, Zaman FQ, Mariod AA, Yaacob M, Abdelmageed AHA, Khamis S. Chemical composition, antioxidant and antibacterial properties of the essential oils of *Etlingera elatior* and *Cinnamomum pubescens* Kochummen. J Sci Food Agric. 2010;90(15):2682-8.
7. Fichi G, Flamini J, Zaralli LJ, Perrucci S. Efficacy of an essential oil of *Cinnamomum zeylanicum* against *Psoroptes cuniculi*. Phytomed. 2007;14(2-3):227-31.
8. Rezuanul I, Khan RI, Al-Reza SM, Jeong YT, Song CH, Khalequzzaman M. Chemical composition and insecticidal properties of *Cinnamomum aromaticum* (Nees) essential oil against the stored product beetle *Callosobruchus maculatus* (F.). J Sci Food Agric. 2009;89(7):1241-6.
9. Chien-Tsong L, Chen CJ, Lin TY, Tung JC, Wang SY. Anti-inflammation activity of fruit essential oil from *Cinnamomum insularimontanum* Hayata. Biores Tech. 2008;99(18):8783-7.
10. Wang SY, Yang CW, Liao JW, Zhen WW, Chu FH, Chang ST. Essential oil from leaves of *Cinnamomum osmophloeum* acts as a xanthine oxidase inhibitor and reduces the serum uric acid levels in

oxonate-induced mice. Phytomed. 2008; 15(11):940-5.
11. Mehmet U, Ergene E, Gulhan UV, Zeytinoglu HS, Nilufer V. Composition, antimicrobial activity and in vitro cytotoxicity of essential oil from *Cinnamomum zeylanicum* Blume (Lauraceae). Food Chem Toxicol. 2010; 48(11):3274-80.
12. Subhan CN, Baruah A, Kanjilal PB. Chemical composition of the leaf essential oil of *Cinnamomum pauciflorum* Nees. Flav Fragr J. 2006;21(3):531-3.
13. Jayaprakasha GK, Rao LJM, Sakariah KK. Chemical composition of the flower oil of *Cinnamomum zeylanicum* Blume. J Agric Food Chem. 2000;48(9):4294–5.
14. Nguyêñ XD, Khiên PV, Chiên HT, Leclercq PA. The essential oil of *Cinnamomum camphora* (L.) Sieb. var. *linaloolifera* from Vietnam. J Essent Oil Res. 1993;5(4):451-3.
15. Nguyêñ XD, Mõi LD, Nguyêñ DH, Leclercq PA. Constituents of the essential oils of *Cinnamomum parthenoxylon* (Jack) Nees from Vietnam. J Essent Oil Res. 1995;7(1):53-5.
16. Nguyêñ XD, Khiên PV, Nguyên TQV, Hoàng TL, van de Ven JLM, Leclercq PA. 2-Methylene-3-buten-1-yl benzoate: The major constituent of the leaf, stem and wood oils from "Re Gúng," a Vietnamese *Cinnamomum* sp. tree. J Essent Oil Res. 1997;9(1):57-65.
17. Nguyen XD, Sothy N, Ngoc VL, Leclerq PA. Chemical composition of the wood oil of *Cinnamomum albiflorum* Nees from Kampuchea. J Essent Oil Res. 1994;6(2): 201-2.
18. Nguyen XD, Sothy N, Ngoc VL, Leclerq PA. Chemical composition of the essential oil of *Cinnamomum cambodianum* H. Lee. J Essent Oil Res. 1993;6(6):667-8.
19. Thang TD, Dai DN, Huy DQ, Nguyen XD. Chemical composition of the leaf essential oil of *Cinnamomum ovatum* Allen from Vietnam. J Mater Med Hanoi Vietnam. 2008;13(1):94-6.
20. Nguyen TH, Son LC, Dai DN, Thang TD, Thai TH. Chemical composition of the leaf oil of *Cinnamomum tonkinensis* (Lecomte) A. Chev. from Ha Tinh. J Pharm Vietnam. 2010;413(1):28-30.
21. Chae HS, Khiev P, Lee HK, Oh SR, Chin YW. Anti-allergic effect of a chloroform-soluble extract of *Cinnamomum cambodianum* in bone marrow-derived mast cells. Immunopharmacol Immuno-toxicol. 2012;34(4):639-44.
22. Vietnamese Pharmacopoeia. Medical Publishing House, Hanoi, Vietnam; 1997.
23. Adams RP. Identification of essential oil components by Gas Chromatography/ Quadrupole Mass Spectrometry. 4th Edition, Carol Stream. IL: Allured Publishing; 2007.
24. Joulain D, Koenig WA. The Atlas of Spectral Data of Sesquiterpene Hydrocarbons. E. B. Verlag, Hamburg, Germany; 1998.
25. Lawal OA, Ogunwande IA, Salvador AF, Sanni AA, Opoku AR. *Pachira glabra* Pasq. Essential oil: Chemical constituents, antimicrobial and insecticidal activities. J Oleo Science. 2014;63(6):629-35.
26. Dai DN, Huong LT, Hung NH, Thang TD, Ogunwande IA. Chemical compositions of essential oils of selected medicinal plants from Thùa Thiên-Huê Province, Vietnam. J Herbs Spic Med Pl. 2014;26(3):269-81.
27. Lawal OA, Ogunwande IA, Opoku AR, Kasali AA, Oyedeji AO. Chemical composition and antibacterial activities of essential oil of *Warbugia salutaris* (Bertol f.). Chiov from South Africa. J Biol Active Prod Nature. 2014;4(4):272-7.



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