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**Research Article**

# Essential oils of Lauraceae: antimicrobial activity and constituents of *Cinnamomum auricolor* Kosterm. and *Cinnamomum petelotii* Kosterm leaves essential oils from Vietnam

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**Abstract**
In this study, the antimicrobial activity and constituents of essential oils from the leaves of *Cinnamomum auricolor* Kosterm. and *C. petelotii* Kosterm collected from Pù Hoạt Natural Reserve (Hạnh Dịch Commune, Quế Phong District), Vietnam were reported. The essential oils obtained by separate hydrodistillation were analyzed by means of gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC-MS). The antimicrobial activities were evaluated by microbroth dilution susceptibility assay. The main constituents of *C. auricolor* comprised of oxygenated sesquiterpenes mainly caryophyllene oxide (26.0%), spathulenol (11.1%), and (*E*)-nerolidol (10.7%). However, oxygen-containing monoterpenes were the main compounds identified in *S. petelotii* and they are linalool (34.3%), 1,8-cineole (20.8%) and terpinene-4-ol (9.9%). The essential oil of *C. auricolor* displayed prominent antimicrobial activity towards *Bacillus cereus* ATCC14579 and *Staphylococcus aureus* ATCC25923 with minimum inhibitory concentration (MIC) value of 16.0 µg/mL. In addition, the essential oil of *C. auricolor* also exhibited antimicrobial activity against *Enterococcus faecalis* ATCC29212, and anti-candidal activity towards *Candida albicans* ATCC10231 with MIC value of 32.0 µg/mL. The leaf essential oil of *C. petelotii* only exhibited activity towards *S. aureus* and *C. albicans* with MIC value of 64.0 µg/mL. The chemical constituents and antimicrobial activity of both essential oils are being reported for the first time.

**Keywords**
*Cinamomum,* Gram-positive bacteria, anti-candidal activity

## Introduction

*Cinnamomum auricolor* Kosterm (Vietnamese name: Re tía) is a tree that grows up to 20 m tall and 45 cm in diameter. The branch is black grey. The leaf blade is oval, ca. 4-5 x 1.5 cm, with long-acuminate ápex. The upper surface is leathery and light brown, while the low surface is red brown. The petiole is 1-1.2 cm long and black. The inflorescences panicles bears few flowers[1]. *Cinnamomum petelotii* Kosterm (Vietnamese name: Re petelot) is a small tree up to 6-10 m tall. The leaves are opposite or subopposite while the leaf blade is ovate, apex retuse or short acuminate, base subrounded, ca. 2-4 x 1,5-2,5 cm, sparsely hairy. The petiole is 4-6 mm in diameter. Inflorescences panicle, axillary or subterminal, 2-4 cm long, peduncles 3 mm. The ovary is ovoid, small style[1].

In continuation of an extensive research aimed at the characterization of the chemical constituents and biological of essential oils from Lauraceae plants in particular[2-4] and poorly studied species of the genus *Cinnamomum* grown in Vietnam[5-11], we have investigated upon the volatile constituents and antimicrobial activity of the leaves of *C.*

*auricolor* and *C. petelotii* collected from Pù Hoạt Natural Reserve (Hạnh Dịch Commune, Quế Phong District). Information revealed that the chemical constituents and biological activities of essential oils and non-volatile extracts from *C. auricolor* and *C. petelotii* were not reported previously. Literature information indicated that the chemical compositions of essential oils from some *Cinnamomum* plants grown in Vietnam[5-11] and other parts of the world[12-15] have been described previously. The results indicated that essential oils from *Cinnamomum* plants exhibited chemical variability. The dominant compounds in the essential oils consist of variety of classes of compounds including terpenes, phenypopanoid and non-terpenes etc[5-15]. Moreover, it was noted previously that the volatile constituents of several species of *Cinnamomum* plants already reported from Vietnam contained low amounts of (*E*)-cinnamaldehyde[5-9], or none[10].

## Materials and methods

All experimental methods and analytical procedures employed in this study follows the patterns used in our previous reports[5-11]. They are hydodistillation process, gas chromatography (GC), gas chromatography-mass spectrometry (GC/MS), identification of the constituents of the essential oils, determination of antimicrobial activity and statistical analysis.

### *Collection and identification of the leaves of C. auricolor and C. petelotii*

The leaves of *C. auricolor and C. petelotii* plants were collected during flowering stage (April-May 2020) from Pù Hoạt Natural Reserve (Hạnh Dịch Commune, Quế Phong District, GPS: 19°41′135″N, 104°49′33″E). The raw materials were immediately separated from unwanted materials by hand-picking, and transported to the laboratory where they are allowed to dry at ambient temperature (20-25°C) under shade for about a week. Plant materials were identified by Assoc. Dr. Le Thi Huong, and voucher specimens LTH898 and LTH 899, respectively, were deposited in the plant specimen room, Vinh University, Vietnam.

### *Hydrodistillation of essential oils*

The essential oils as usual were obtained from the leaves of *C. auricolor and C. petelotii* by the conventional hydrodistillation method. The hydrodistillation process was performed in a Clevenger-type distillation unit according to the specification of the Vietnamese *Pharmacopeia* as described in previous studies[5-12]. The individual leaves of *C. auricolor and C. petelotii* after pulverization was divided into three portions which make it easier to perform the hydrodistillation three times each. For hydrodistillation to proceed, each portion of the plant sample was at different times introduced into the 5 L distillation flask where distilled water was added to submerge the sample completely. The distillation apparatus was connected to a source of heat and the experiment proceeded for 3 h under the normal atmospheric pressure. The hydrodistillation process was repeated three times each for the studied plant samples. Each of the distilled volatile oils was collected into prepared previously weighed sample bottles. The essential produced by hydrodistillation of the leaves of *C. auricolor and C. petelotii* were kept under refrigeration (4°C) until the moment of analysis. The essential oil yield (%) was calculated by mass (g) of the essential oil divided by the mass (g) of the dried leaves of the plant as reported previously[5-11,16-19].

### *Gas chromatograph (GC/FID) analysis*

Quantitative analyses of the essential oils were carried out by GC on a HP-5MS column (30 m x 0.25 mm with a film thickness of 0.25 µm), using an Agilent Technologies HP 7890A Plus Gas chromatograph equipped with FID. The GC oven temperature was programmed from 60°C (isothermal for 2 min) to 220°C (isothermal for 10 min) at a rate of 4°C/min. The injector temperature (PTV: programmable temperature vaporization) and detector temperature were maintained at 250°C and 260°C, respectively. The flow rate of the carrier gas (helium) was 1.0 mL/min, split ratio 10:1, at inlet pressure was 6.1 kPa. The essential oil (1.0 mL; 10% *n*-hexane solution) was injected into GC column. At least three repetitions ($n \geq 3$) per analysis were

performed and the results are presented as an average composition. Quantification was done using the calibration curves generated from the analyses of representative standard compounds from each class as done previously[5-11,16-19].

***Gas chromatography coupled with mass spectrometry (GC-MS) analysis***

Qualitative analyses were performed by GC-mass spectrometry, using a chromatograph HP 7890A Plus (HP-5MS column; dimension 30 m x 0.25 mm; film thickness 0.25 µm) and interfaced with a mass spectrometer HP 5973 MSD. The GC conditions were reported as above. The mass spectra in electron mode were generated at 70 eV, acquisitions mass range of 45-450 amu and emission current of 40 mA, at a sampling rate of 1.0 scan/s as described previously[5-11,16-19].

***Identification of individual components***

Quantitative analysis was based on the comparison of retention indexes on column (RI Exp.) with reference to a homologous series of n-alkanes ($C_8$-$C_{40}$), under identical experimental conditions. Furthermore, co-injection of some reference compounds under the same GC conditions was employed, while the mass spectral (MS) fragmentation patterns were compared with corresponding data in the lietarture[20] as described recently[5-11,16-19].

***Antimicrobial activity assays***

The analytical procedures previously developed were used to measure and evaluate the antimicrobial activities of the essential oils. These methods were described earlier[2-4,16-19]. The evaluation of the minimum inhibitory concentration (MIC) and the half maximal inhibitory concentration ($IC_{50}$) was done in accordance with the method of microdilution broth susceptibility. The Gram-positive, Gram-negative and yeast used for the study are as available in our laboratory. In addition, the concentration of essential oils used for the study were within the known range of concentration where essential oils are thought to be active and used in previous studies[2-4,16-19]. Both bacteria and fungi were grown in appropriate media of Mueller-Hinton broth and Sabouraud dextrose broth, respectively.

T he colony of bacteria used for the antimicrobial analysis was $5 \times 10^5$ CFU/mL while the fungi was standardized to $1 \times 10^3$ CFU/mL. The essential oils were dissolved separately in 1% dimethylsulfoxide and used to prepare the stock solutions. The concentration of the essential oils were prepared by two-fold dilution from 1.6384 x $10^4$ µg/mL to $2^1$ µg/mL, as described previously[2-4,16-19]. Then both the solutions of essential oils and microorganisms were transferred to 96-well microtiter plates and incubated for 24 h, at 37 °C. At the end of the experiment, the MIC values were assessed from the microplate wells in which the lowest concentration of essential oils totally inhibited the growth of bacteria and fungi. Likewise, $IC_{50}$ values were recorded and determined by the turbidity measurement data of EPOCH2C as the percentage of the growth of microorganisms inhibited by the tested media. Similar antimicrobial sensitivity measurements were determined against the positive control, Streptomycin (antibacterial), nystatin and cycloheximide (anticandidal), as well as the negative (microtiter plates having only the serial dilutions of the essential oils without microorganisms) control.

***Statistical analysis***

All results of chemical composition and antimicrobial experiments were repeated three times and are expressed as mean ± standard deviation (SD).

## Results and discussion

***Chemical compositions of the essential oils***

The full chemical compositions of *C. auricolor* (yield, 0.35% w/w, 0.39 g) and *C. petelotii* (yield, 0.15% w/w, 0.19 g) essential oils obtained from the leaves during the flowering stage are presented in table 1. In general, 65 components were identified in the essential oils. The 45 and 41 constituents of the essential oils of *C. auricolor* and *C. petelotii* accounted for 90.0 and 99.1% of the total essential oil contents, respectively. The individual essential oils differ in fractions of the components identified.

**Table 1.** Chemical constituents of *C. auricolor* and *C. petelotii* leaf essential oils

| Sr. No. | Compounds [a] | RI (Exp.) | RI (Lit.) | *C. auricolor* [b] | *C. petelotti* [b] |
|---|---|---|---|---|---|
| 1 | α-thujene | 930 | 921 | - | 0.9±0.00 |
| 2 | α-pinene | 939 | 932 | 2.6 ±0.00 | 5.3 ±0.01 |
| 3 | Camphene | 956 | 941 | 0.3 ±0.00 | 1.3 ±0.00 |
| 4 | Sabinene | 979 | 961 | 2.2 ±0.01 | 0.5 ±0.00 |
| 5 | β-pinene | 986 | 978 | 3.5 ±0.01 | 3.1±0.00 |
| 6 | Myrcene | 992 | 988 | 0.1 ±0.00 | 0.8 ±0.00 |
| 7 | α-phellandrene | 1011 | 1008 | - | 0.7 ±0.01 |
| 8 | α-terpinene | 1022 | 1018 | - | 0.3±0.00 |
| 9 | o-cymene | 1030 | 1022 | 1.2 ±0.00 | 1.6 ±0.00 |
| 10 | Limonene | 1032 | 1030 | 0.7 ±0.00 | 2.4 ±0.00 |
| 11 | 1,8-Cineole | 1034 | 1034 | 1.3 ±0.00 | 20.8± 0.01 |
| 12 | (*Z*)-β-ocimene | 1036 | 1035 | - | 1.0 ±0.00 |
| 13 | β-phellandrene | 1037 | 1036 | - | 0.2 ±0.00 |
| 14 | γ-terpinene | 1064 | 1056 | - | 0.7±0.00 |
| 15 | Linalool oxide (furanoid) | 1077 | 1077 | - | 0.1 ±0.00 |
| 16 | Terpinolene | 1094 | 1093 | - | 0.4 ±0.00 |
| 17 | Linalool | 1102 | 1100 | - | 34.3 ±0.00 |
| 18 | Hotrienol | 1106 | 1106 | - | 0.4 ±0.00 |
| 19 | α-camphonelal | 1133 | 1135 | 0.1 ±0.00 | - |
| 20 | *trans*-sabinol | 1148 | 1150 | 1.6±0.00 | 0.2 ±0.00 |
| 21 | *trans*-verbenol | 1152 | 1152 | 0.8 ±0.00 | - |
| 22 | Camphor | 1155 | 1154 | - | 0.2 ±0.00 |
| 23 | Pinocarvone | 1172 | 1175 | 0.2 ±0.00 | 0.3 ±0.00 |
| 24 | Borneol | 1175 | 1178 | - | 1.1 ±0.00 |
| 25 | Terpinene-4-ol | 1188 | 1189 | 0.2 ±0.00 | 9.9 ±0.00 |
| 26 | p-cymene-8-ol | 1190 | 1190 | 0.6 ±0.00 | - |
| 27 | α-terpineol | 1197 | 1196 | 1.3 ±0.00 | 3.1 ±0.00 |
| 28 | Estragole | 1204 | 1204 | 1.2 ±0.00 | - |
| 29 | Myrtenal | 1207 | 1206 | 0.6 ±0.00 | 0.2 ±0.00 |
| 30 | Verbenone | 1219 | 1220 | 0.4 ±0.00 | - |
| 31 | Bornyl acetate | 1294 | 1292 | 0.5 ±0.00 | 0.4 ±0.00 |
| 32 | Sabinyl acetate | 1306 | 1306 | 0.8 ±0.00 | - |
| 33 | d-elemene | 1348 | 1345 | - | 0.2 ±0.00 |
| 34 | Geranyl acetate | 1384 | 1382 | 0.4 ±0.00 | - |
| 35 | α-copaene | 1390 | 1392 | 4.9 ±0.00 | - |
| 36 | *cis*-β-elemene | 1403 | 1401 | 0.4 ±0.00 | 0.2±0.00 |
| 37 | β-caryophyllene | 1437 | 1440 | 0.4 ±0.01 | 0.6 ±0.00 |
| 38 | *trans*-α-bergamotene | 1448 | 1446 | 3.6 ±0.00 | - |
| 39 | Aromadendrene | 1457 | 1455 | 1.0 ±0.00 | - |
| 40 | α-humulene | 1472 | 1474 | 0.3 ±0.00 | 0.3 ±0.00 |
| 41 | 9-*epi*-(*E*)-caryophyllene | 1479 | 1481 | 1.2 ±0.00 | - |
| 42 | γ-muurolene | 1490 | 1490 | 0.3 ±0.00 | - |
| 43 | Germacrene D | 1498 | 1500 | - | 1.1 ±0.00 |
| 44 | β-selinene | 1504 | 1504 | 0.1 ±0.00 | - |

*Table 1 cont.*

| Sr. No. | Compounds [a] | RI (Exp.) | RI (Lit.) | *C. auricolor* [b] | *C. petelotti* [b] |
|---|---|---|---|---|---|
| 45 | 10,11-Epoxycalamenene | 1505 | 1508 | 0.1 ±0.00 | - |
| 46 | (*E, E*)-α-farnesene | 1512 | 1514 | - | 0.4 ±0.01 |
| 47 | Bicyclogermacrene | 1515 | 1513 | - | 2.1 ±0.00 |
| 48 | β-bisabolene | 1517 | 1519 | 0.2 ±0.00 | - |
| 49 | *trans*-calamenene | 1538 | 1541 | 0.3 ±0.00 | - |
| 50 | *cis*-calamenene | 1559 | 1560 | 0.5 ±0.00 | 0.8 ±0.00 |
| 51 | Elemol | 1563 | 1561 | - | 0.4 ±0.00 |
| 52 | (*E*)-nerolidol | 1569 | 1571 | 10.7 ±0.00 | 0.5 ±0.00 |
| 53 | Dendrolasin | 1583 | 1587 | - | 0.3 ±0.00 |
| 54 | Spathulenol | 1597 | 1596 | 11.1 ±0.00 | 0.8 ±0.00 |
| 55 | Caryophyllene oxide | 1604 | 1607 | 26.0 ±0.00 | 0.5 ±0.00 |
| 56 | Cubeban-11-ol | 1613 | 1615 | 0.9 ±0.00 | - |
| 57 | Guaiol | 1617 | 1618 | - | 0.7 ±0.00 |
| 58 | Humulene epoxide I | 1620 | 1622 | 0.3 ±0.00 | - |
| 59 | Humulene epoxide II | 1632 | 1637 | 3.9 ±0.00 | - |
| 60 | Caryophylla-3(15),7(14)-dien-6-ol | 1657 | 1663 | 0.5 ±0.00 | - |
| 61 | *cis*-calamenen-10-ol | 1676 | 1678 | 0.8 ±0.00 | - |
| 62 | *trans*-calamenen-10-ol | 1674 | 1674 | 0.2 ±0.00 | - |
| 63 | Bulnesol | 1685 | 1686 | - | 0.1 ±0.00 |
| 64 | 9-*epi*-14-hydroxycaryophyllene | 1689 | 1691 | 1.2 ±0.00 | - |
| 65 | 10-*nor*-calamenen-10-one | 1724 | 1722 | 0.2 ±0.00 | - |
| **Total** | | | | **90.0** | **99.1** |
| Monoterpene hydrocarbons (Sr. No. 1-10, 12-14, 16) | | | | 10.6 | 19.2 |
| Oxygenated monoterpene (Sr. No. 11, 15, 17-32, 34) | | | | 10.3 | 70.9 |
| Sesquiterpene hydrocarbons (Sr. No. 33, 35-44, 46-50) | | | | 13.2 | 5.6 |
| Oxygenated sesquiterpenes (Sr. No. 45, 51-65) | | | | 55.9 | 3.3 |

[a]Elution order on HP-5MS column; RI (Exp.) Retention indices on HP-5MS column; RI (Lit.) Literature retention indices [20]; [b]Standard deviation, means of triplicate analysis; Sr. No. Serial Number; - Not present

In *C. auricolor,* the content of monoterpene hydrocarbons was 10.6% compared to 19.2% in *C. petelotii.* The oxygenated monoterpenes were presented in 10.3% and 70.9%, respectively. The sesquiterpene hydrocarbon contents were averaged 13.2% and 5.6%, respectively. However, *C. auricolor* also contained larger amount of exygenated sesquiterpenes (55.9%) as against 3.3% found in *C. petelotti*.

The main constituents of *C. auricolor* essential oil comprised of oxygenated sesquiterpenes mainly caryophyllene oxide (26.0%), spathulenol (11.1%), and (*E*)-nerolidol (10.7%). Some compounds such as α-copaene (4.9%), humulene epoxide II (3.9%), *trans*-α-bergamotene (3.6%), β-pinene (3.5%), α-pinene (2.6%), and sabinene (2.2%) were also identified in sizeable proportion. However, oxygen-containing monoterpenes were the main compounds identified in *S. petelotii* and they are linalool (34.3%), 1,8-cineole (20.8%) and terpinene-4-ol (9.9%). The essential oil also features significant amount of α-pinene (5.1%), β-pinene (3.1%), α-terpineol (3.1%), limonene (2.4%), and bicyclogermacrene (2.1%).

It is therefore of interest to note that the chemical constituents of *C. auricolor* and *C.*

*petelotii* essential oils have not been previously investigated upon, to the best of our knowledge. Therefore, the data here are being presented for the first time. In consistent with previously reported *Cinnamomum* essential oils analyzed from Vietnam[5-11] and other parts of the world[12-15], terpenes represent the main class of compounds in *C. auricolor* and *C. petelotii*. Expectedly, the compositional patterns of these terpenes differ from each other and one species to another. The absence of (*E*)-cinnamaldehyde in the studied *Cinnamomum* species analyzed from Vietnam is noteworthy. It was noted previously that the volatile constituents of several species of *Cinnamomum* plants already reported from Vietnam contained low amounts of (*E*)-cinnamaldehyde[4-9], or none[10]. Essential oils from the leaves of *C. doederlinii* var. *roaonensis* and *C. scalarinerbium* from Vietnam had no (*E*)-cinnamaldehyde[10]. The leaves and barks essential oils of *C. altissimum, C. scortechinii,* and *C. microphyllum* from Malaysia[21] were devoid of (*E*)-cinnamaldehyde, while the essential oils from all parts of *C. bejolghota* from India had less than 1% (*E*)-cinnamaldehyde[22]. However, the essential oil of *C. cassia* from Vietnam had its main component to be *trans*-cinnamaldehyde[23]. Information from literature showed that *Cinnamomum* essential oils exhibited chemical variability. Essential oil from *C. zeylanicum* had cinnamaldehyde in abundance (80.42%)[12]. The essential oil of *C. verum* from China contained high content of eugenol[13]. The major components in the essential oils of *C. loureirii* from China were cinnamaldehyde (62.6%, 69.6%), α-copaene (16.0%, 5.4%) and β-cadinene (7.7%, 4.7%)[14]. The main components of the essential oil from the leaves of *C. camphora* were identified to be linalool (26.6%), eucalyptol (16.8%), α-terpineol (8.7%), isoborneol (8.1%), β-phellandrene (5.1%), and camphor (5.0%). The essential oil had good activity against Methicillin-resistant *Staphylococcus aureus, Enterococcus faecalis, Bacillus subtilis, Salmonella gallinarum* and *Escherichia coli*[15].

The chemical compositional patterns of essential oils from *Cinnamomum* plants grown in Vietnam have been classified into seven different groups[5]. The essential oil of *C. auricolor* belongs to group with high contents of oxygenated sesquiterpenes, while *C. petelotii* could be classified into group containing higher amount of oxygen-containing monoterpenes. The high amount of linalool and terpinen-4-ol in *C. petelotii* confers similarity with *C. cambodianum* previously analyzed in Vietnam[5] and *C. camphora* from China[15].

As expected, the studied essential oils of *C. auricolor* and *C. petelotii* do not possess the same chemical compositions. In addition, the compositional patterns of the essential oils differ from the data reported for other *Cinnamomm* essential oils. This variation in the chemical constituents of essential oils of *C. auricolor* and *C. petelotii* with several other *Cinnamomum* plants may be possibly due to nature of each plant as well as differences in the ecological and climatic conditions at place of origin of the plants[24]. These factors would contribute greatly to the observed variations and differences in chemical contents and antimicrobial activity when compared with samples analyzed from other parts of the world.

***Results of the antimicrobial activities of the essential oils***

From table 2, the essential oils of *C. auricolor* and *C. petelotii* were active only against Gram-positive microorganisms and fungi. The essential oils did not displayed any activity againt the studied Gram-negative microorganisms comprising of *Pseudomonas aeruginosa* ATCC27853, *E. coli* ATCC25922 and *S. enterica* ATCC13076. The leaf essential oil of *C. auricolor* displayed prominent antimicrobial activity towards *B. cereus* ATCC14579 and *S. aureus* ATCC25923 each with MIC value of 16.0 µg/mL. Also, the essential oil exhibited antimicrobial activity against *E. faecalis* ATCC29212, with MIC value of 32.0 µg/mL. Moreso, the essential oil showed anti-candidal activity towards *Candida albican*s ATCC10231 with MIC value of 32.0 µg/mL. The leaf essential oil of *C. petelotii* exhibited antimicrobial activity towards *S. aureus* and anti-candidal activity to *C. albicans* each with MIC value of 64.0 µg/mL. Overall, the leaf

**Table 2.** Antimicrobial activity of the essential oils from the leaves of *C. auricolor* and *C. petelotii*

| Microorganisms | MIC µg/mL[a] | | $IC_{50}$ µg/mL[a] | |
|---|---|---|---|---|
| | ***C. auricolor*** | ***C. petelotii*** | ***C. auricolor*** | ***C. petelotii*** |
| Gram-positive | | | | |
| *Enterococcus faecalis* ATCC29212 | 32.0 ± 0.00 | 128.0 ± 0.15 | 10.56 ± 0.00 | 45.67 ± 0.10 |
| *Staphylococcus aureus* ATCC25923 | 16.0 ± 0.10 | 64.0 ± 0.10 | 5.67 ± 0.50 | 21.45 ± 0.00 |
| *Bacillus cereus* ATCC14579 | 16.0 ± 0.05 | 128.0 ± 0.02 | 4.67 ± 0.10 | 43.56 ± 0.10 |
| Gram-negative | | | | |
| *Pseudomonas aeruginosa* ATCC27853 | - | - | - | - |
| *Escherichia coli* ATCC25922 | - | - | - | - |
| *Salmonella enterica* ATCC13076 | - | - | - | - |
| Yeast | | | | |
| *Candida albican*s ATCC10231 | 32.0 ± 0.00 | 64.0 ± 0.01 | 10.02 ± 0.01 | 20.45 ± 0.00 |

- No activity; [a] Mean value of three replicate assays

essential oil of *C. auricolor* displayed prominent antimicrobial activity and anti-candidal activity more prominently than the leaf essential oil of *C. petelotii*. The positive antibacterial control, Streptomycin, showed MIC values between 0.18 µg/mL and 1.01 µg/mL while cycloheximide, an anticandidal compound displayed activity with MIC value of 0.73 µg/mL. The antimicrobial activities of both essential oils are being reported for the first time.

Several reports have described the antimicrobial activities of *Cinnamomum* plants from Vietnam and other parts of the world. They described essential oils selectively inhibited the growth of different microorganisms. The essential oil of *C. cassia* from Vietnam and its main component (*trans*-cinnamaldehyde) exhibited antibacterial action against *Listeria innocua* strain[23]. The leaves essential oil of *C. camphora* displayed good antibacterial activity against resistant Gram-positive and Gram-negative strains of *S. aureus, E. faecalis, B. subtilis, S. gallinarum* and *E. coli*[15,25], contrary to the studied *Cinnamomum* essential oils which showed activity only to Gram-positive bacteria. Likewise, essential oil of *C. camphora* also exhibited activity towards *P. aeruginosa* (MIC, 25 mg/mL)[26], whereas the essential oils of *C. auricolor* and *C. petelotii* showed no activity to the organism.

It should be postulated that the compounds present in the essential oils of *C. auricolor* and *C. petelotii* could be responsible or contribute to the antimicrobial activity of the essential oils. For example, caryophyllene oxide and spathulenol have been reported as antimicrobial agent[27]. Essential oil with high contents of linalool and 1,8-cineole was reported displayed good antibacterial activity against *E. faecalis*[28]. In addition, α-and β-pinene, and linalool are widely tested against many microorganisms[29]. (*E*)-Nerolidol exhibited antimicrobial and anti-fungal properties[30], while terpinene-4-ol was noted for its potent activity against *S. aureus*[31]. The observed antimicrobial may be largely due to the effects of the major constituents however, the synergistic actions of several minor compounds cannot be ruled out. For example, an assay demonstrated that combinations of 1,8-cineole and aromadendrene reduce the MIC in most cases [32]. Further studies will aim at determination of the actual compounds responsible for the antimicrobial action of the studied essential oils as well as the mechanism of activity.

## Conclusion

The result indicates that essential oils from the leaves of *C. auricolor* grown in Vietnam possessed potential antimicrobial and anti-candidal activities more than and *C. petelotii*. The leaf oil of *C. auricolor* displayed promising

antibacterial activity against *B. cereus, S. aureus, E. faecalis*and *C. albican*s while the leaf essential oil of *C. petelotii* exhibited antimicrobial activity towards *S. aureus* and anti-candidal activity to *C. albicans*. The main constituents in the leaf essential oil of *C. auricolor* were mainly oxygenated sesquiterpenes namely caryophyllene oxide (26.0%), spathulenol (11.1%), and (*E*)-nerolidol (10.7%), while oxygen-containing monoterpenes were the main compounds identified in *S. petelotii* and they are linalool (34.3%), 1,8-cineole (20.8%) and terpinene-4-ol (9.9%).

## Competing interests

The authors declare that no competing interest exists.

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