Essential Oil Compositions and Antimicrobial Activity of the Leaves of Alphonsea monogyma Merr. & Chun and Goniothalamus banii B. H. Quang, R. K. Choudhary & V.T. Chinh from Vietnam

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Abstract: Essential oils from the leaves of Alphonsea monogyma Merr. & Chun and Goniothalamus banii B. H. Quang, R. K. Choudhary & V.T. Chinh from Vietnam were obtained by hydrodistillation and the chemical components determined by gas chromatography (GC) and gas chromatography coupled with mass spectrometry (GC/MS). The antimicrobial assay was conducted by microdilution broth method. The respective yields of the essential oils were 0.18% (v/w) and 0.355% (v/w), respectively. The major components of A. monogyma were (E)-caryophyllene (13.8%), Δ-cadinene (12.5%), bicyclogermacrene (12.4%), cis-β-elemene (12.1%), and germacrene D (11.4%). However, myrcene (47.1%), α-pinene (9.7%) and (E)-caryophyllene (9.1%) were the dominant constituents of the essential oil of G. banii. The leaf essential oil of A. monogyma displayed potent antimicrobial activity towards the Gram-positive microorganisms of Enterococcus faecalis ATCC29212, Staphylococcus aureus ATCC25923 and Bacillus cereus ATCC14579 with minimum inhibitory concentration (MIC) values of 2.23 µg/mL, 10.45 µg/mL and 10.33 µg/mL, respectively. On the other hand, essential oil from G. banii exhibited the most effective antibacterial against Gram-negative Pseudomonas aeruginosa ATCC27853 (MIC 5.67 µg/mL), and anti-candidal action towards Candida albicans ATCC10231 (MIC 32.67 µg/mL). The chemical constituents and antimicrobial activity of the essential oils of A. monogyma and G. banii were being reported for the first time.

Keywords: Alphonsea monogyma; Goniothalamus banii; essential oil; terpenes; antimicrobial activity; anti-candidal activity. © 2022 ACG Publications. All rights reserved.

1. Plant Source

Recently, the authors have published data on compositions and antimicrobial activity of hydrodistilled essential oils from some unexploited flora of Vietnam [1,2]. Also, previously reported were the essential oil composition of some species of Alphonsea [3,4] and Goniothalamus [6-8] plants harvested in Vietnam. Large quantity of the leaves of A. monogyma Merr. & Chun were collected from Pù Mát National Park (GPS: 19°51′1′N; 104°38′7′E) at height of 210 m, in the month August 2020. Moreso, Goniothalamus banii (Blume) B. H. Quang, R. K. Choudhary & V.T. Chinh were also harvested at an elevation of 762 m in the month of September 2020 from Pù Hoat Nature Reserve (GPS: 19°42′43′N; 104°49′29′E). The botanical authentication of the plants was performed by Dr. Le Thi Huong. Voucher specimens HNU 820 (A. monogyma) and HNU 824 (G. banii), were preserved at the plant specimen room, Vinh University.

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2. Previous Studies

Presently, there is no record on the volatile constituents and pharmacological potentials of A. monogyma and G. banii plants. However, azafluorenone (onchyne) alkaloids, 6,7-dimethoxy-5-hydroxy onychine, as well as cyathocaline, liriodene, isoconodine anddariene were isolated from the stem and branch of A. monogyma [9]. The research was undertaken due to non-availability of reported data on the essential oil composition and antimicrobial studies on A. monogyma and G. banii.

3. Present Study

The leaves of A. monogyma were analysed for essential oil in accordance with procedures used previously [1,2]. After the hydrodistillation, a light-yellow coloured essential oil was produced from the leaves of the plant. Also, a yield of 0.35% (± 0.01, v/w) essential oil was obtained from the process. In Table 1, the compounds identified from GC/MS spectral of the essential oil were documented. The composition of the essential oil consists mainly of sesquiterpene hydrocarbons (73.5%) and monoterpene hydrocarbons (21.9%). The oxygen-containing monoterpenes class of compound was not identified in the essential oil. In addition, the oxygenated sesquiterpenes were identified in the proportion of 4.0%. The main composition of A. monogyma were the sesquiterpenes namely β-caryophyllene (13.8%), δ-cadinene (12.5%), bicyclogermacrene (12.4%), cis-β-elemene (12.1%), germacrene D (11.4%); and monoterpenes represented by limonene (8.6%) and α-pinene (5.0%). In addition, β-pinene (4.8%), α-copaene (3.4%) and (E)-9-epi-caryophyllene (2.8%) were the other compounds present in amount >1%. Since this is the first report on the essential oil from any parts of A. monogyma, the present data could not be compared with other analyzed samples of the same species. In accordance with reports from other previously studied essential oils of the family Alphonsea, terpene compounds were also found to occur in high quantity predominated in this study. The large amount of β-caryophyllene and β-elemene identified in the oil of A. monogyma, was in consistent with data obtained for the leaf oil of A. tonkinensis previously analyzed from Vietnam [3]. In addition, bicyclogermacrene, β-caryophyllene and cis-β-elemene present in A. monogyma were also present in the leaf of A. philastreana and A. gaudichaudiana [4]. In accordance with chemotaxonomic analysis, the essential oils of Alphonsea plants from Vietnam can be classified as belonging to the group which has high content of sesquiterpene hydrocarbons.

A light-yellow coloured essential oil of yield of 0.27% (± 0.01, v/w) was obtained from leaves of G. banii. The identified compositional patterns of the essential oil are seen in Table 1. The classes of compound namely, monoterpenic hydrocarbons (72.9%) and sesquiterpene hydrocarbons (12.5%), predominate in the essential oil. The oxygen-containing terpene compounds were less common in the proportion of 2.7% (oxygenated monoterpenes) and 5.9% (oxygenated sesquiterpenes). The mixture of monoterpenes and sesquiterpenes hydrocarbons represented by myrcene (47.1%), α-pinene (9.7%), β-caryophyllene (9.1%), and α-cymene (8.4%) were the main compounds of the oil. There were significant amount of caryophyllene oxide (3.0%), limonene (2.5%), linalool (2.3%), spathulenol (2.3%), and (E)-β-ocimene (2.1%). A comparison of the composition of G. banii essential oils revealed some variation with data reported for other Goniothalamus plants from Vietnam (Table 2). The comparative results showed sesquiterpene hydrocarbons were the dominant class of compounds in the leaf of G. banii, stem of G. tamirensis [5], leaf of G. tamirensis [6], as well as the leaf and stem of G. multitovulatus [7]. Moreover, monoterpenic hydrocarbons were found mainly in the leaf of G. macrocalyx [5]. The leaf of G. albiflorus [8], as well as leaf and stem of G. takhtajani [7] contained monoterpenic hydrocarbons and oxygenated counterparts. Also oxygen containing monoterpenes and sesquiterpene hydrocarbons were found in the leaf of G. wightii [7]. A mixture of monoterpene and sesquiterpene hydrocarbons was found in the stem of G. albiflorus [5]. The stems of G. albiflorus [8] and G. wightii [7] consist of monoterpenic hydrocarbons, oxygen containing monoterpenes and sesquiterpene hydrocarbons. Also, the mixture of monoterpenic hydrocarbons, sesquiterpene hydrocarbons and oxygenated sesquiterpenes were found in the stem of G. tamirensis [5]. Non-terpene compounds were found additionally in the stem of G. macrocalyx and the leaf of G. albiflorus [5]. Thus, essential oils from the various Goniothalamus plants exhibited chemical variability. However, the identities of these terpenes differed from one species to another. A noteworthy observation was that myrcene has not been described as a major compound of essential oils of Goniothalamus plants analyzed from Vietnam [5,6,8,11], Malaysia [12-14] and Borneo [15].
## Table 1. Constituents of the leaf essential oils of *Alphonsea monogyma* and *Goniothalamus banii*

| No. | Compound a | RI (Exp.) | Range of RI b | A. monogyma c | G. banii d |
|-----|------------|-----------|---------------|---------------|------------|
| 1.  | α-Thujene  | 930       | 921-939       | -             | 0.1        |
| 2.  | α-Pinene   | 937       | 924-941       | 5.0           | 9.7        |
| 3.  | Camphene   | 954       | 933-954       | -             | 0.2        |
| 4.  | Sabinene   | 979       | 944-980       | 0.5           | -          |
| 5.  | β-Pinene   | 983       | 964-985       | 4.8           | 0.8        |
| 6.  | Myrcene    | 990       | 981-993       | 0.5           | 47.1       |
| 7.  | α-Phellandrene | 1009     | 995-1011     | 0.3           | -          |
| 8.  | δ-3-Carene | 1016      | 1010-1020     | -             | 0.8        |
| 9.  | α-Cymene   | 1029      | 1024-1031     | -             | 8.4        |
| 10. | β-Phellandrene | 1032    | 1026-1032     | 0.8           | 0.6        |
| 11. | Limonene   | 1033      | 1028-1038     | 8.6           | 2.5        |
| 12. | 1,8-Cineole | 1037      | 1032-1044     | -             | 0.4        |
| 13. | (E)-β-Ocimene | 1049     | 1041-1054     | 1.6           | 2.1        |
| 14. | β-Terpinene | 1062      | 1042-1064     | -             | 0.4        |
| 15. | Linalool   | 1101      | 1098-1101     | -             | 2.3        |
| 16. | Perillene  | 1104      | 1102-1111     | -             | 0.2        |
| 17. | (E)-4,8-Dimethyl-1,3,7-triene | 1118 | 1116-1120 | -              | 0.1        |
| 18. | α-Cubebene | 1347      | 1335-1350     | 1.1           | -          |
| 19. | γ-Ylangene | 1383      | 1379-1389     | 0.3           | -          |
| 20. | α-Copaene  | 1388      | 1367-1394     | 3.4           | 0.3        |
| 21. | cis-β-Elemene | 1403  | 1385-1407     | 12.1          | 0.1        |
| 22. | β-Caryophyllene | 1437    | 1416-1451     | 13.8          | 9.1        |
| 23. | trans-α-Bergamotene | 1445 | 1427-1446 | -          | 0.6        |
| 24. | α-Guaiene  | 1451      | 1430-1459     | 0.1           | -          |
| 25. | Aromadendrene | 1455  | 1437-1460     | -             | 0.3        |
| 26. | α-Humulene | 1471      | 1444-1476     | 1.6           | 1.7        |
| 27. | 9-epi-(E)-Caryophyllene | 1477 | 1457-1480 | 2.8          | 0.1        |
| 28. | trans-Cadin-1(6)-4-diene | 1489 | 1461-1493 | 0.3          | 0.3        |
| 29. | Germacrene D | 1498    | 1471-1500     | 11.4          | -          |
| 30. | trans-Muurola-4(14)-5-diene | 1509 | 1478-1510 | 0.5          | -          |
| 31. | Viridiflorene | 1510    | 1480-1522     | -             | 0.2        |
| 32. | Bicyclogermacrene | 1513  | 1483-1525     | 12.4          | 0.4        |
| 33. | α-Bulnesene | 1520      | 1502-1527     | 0.3           | -          |
| 34. | γ-Cadinene | 1530      | 1515-1541     | 0.6           | -          |
| 35. | δ-Cadinene | 1532      | 1516-1547     | 12.5          | 0.2        |
| 36. | α-Calacorene | 1558     | 1531-1567     | 0.1           | -          |
| 37. | Elemicin   | 1561      | 1538-1560     | -             | 0.2        |
| 38. | Elemol     | 1563      | 1544-1564     | 0.2           | -          |
| 39. | (E)-Nerolidol | 1568    | 1549-1569     | -             | 0.1        |
| 40. | 4,8,12-Trimethyldec-1,3,7,11-tetraene | 1582   | 1550-1572     | -             | 0.3        |
| 41. | Scapanol   | 1592      | 1560-1599     | 0.5           | -          |
| 42. | Spathulenol | 1598      | 1571-1601     | 0.7           | 2.3        |
| 43. | Caryophyllene oxide | 1605 | 1578-1613 | 0.6           | 3.0        |
| 44. | Guaiol (=Champacol) | 1610 | 1595-1616 | 0.7           | -          |
| 45. | Cubeban-11-ol | 1612   | 1601-1618     | -             | 0.1        |
| 46. | Humulene epoxide II | 1629   | 1610-1636     | -             | 0.4        |
| 47. | 1-epi-Cubenol | 1644 | 1622-1648 | 0.3           | -          |
| 48. | epi-α-Cadinol | 1656 | 1641-1663        | 0.2         | -          |
| 49. | α-Murolol  | 1663      | 1649-1671     | 0.2           | -          |
| 50. | α-Cadinol  | 1672      | 1642-1680     | 0.2           | -          |
| 51. | Bulnesol   | 1683      | 1656-1690     | 0.4           | -          |

| Total |RI (Exp.) | Range of RI | A. monogyma | G. banii |
|-------|----------|-------------|-------------|----------|
|       | 99.4     | 95.4        | 21.9        | 72.9     |
| Monoterpane hydrocarbons (No. 1-11, 13, 14, 16) | - | - | 2.7 |
| Oxygenated monoterpenes (No. 12, 15) | - | - | - |
| Sesquiterpane hydrocarbons (No. 18-38) | 73.5 | 13.5 | - |
| Oxygenatedsesquiterpenes (No. 39, 40, 42-52) | 4.0 | 5.9 | - |
| Non-terpenes (No. 17, 41) | - | 0.4 | - |

a Elution order on HP-5MS column; RI (Exp.) Retention indices on HP-5MS column; b Range of LRI Literature retention indices on HP-5MS column as seen in NIST [10]; c Standard deviation were insignificant and excluded from the Table to avoid congestion; No. Number
Constituent and biological activity of Alphonsea monogyma and Goniothalamus banii

Table 2. Antimicrobial activity of Alphonsea monogyma and Goniothalamus banii leaf oils

| Microorganisms | MIC (µg/mL) *<sup>a,b</sup> | IC<sub>50</sub> (µg/mL) *<sup>c</sup> |
|----------------|-----------------------------|-----------------------------|
|                | A. monogyma | G. banii | A. monogyma | G. banii |
| Enterococcus faecalis ATCC29212 | 2.20 ± 0.01 | 8.89 ± 0.01 | 4.00 ± 0.11 | 16.00 ± 0.00 |
| Staphylococcus aureus ATCC25923 | 10.50 ± 0.31 | 24.56 ± 0.01 | 32.00 ± 0.50 | 128.0 ± 0.91 |
| Bacillus cereus ATCC14579 | 10.33 ± 0.05 | 56.78 ± 1.50 | 32.00 ± 0.15 | 128.00 ± 1.00 |
| Pseudomonas aeruginosa ATCC27853 | 12.45 ± 0.01 | 5.67 ± 0.01 | 32.00 ± 0.05 | 16.00 ± 0.01 |
| Candida albicans ATCC10231 | 63.89 ± 1.02 | 32.67 ± 0.32 | 128.00 ± 0.50 | 64.00 ± 0.10 |
| Escherichia coli ATCC25922 | NA | NA | NT | NT |
| Salmonella enterica ATCC13076 | NA | NA | NT | NT |

Na: No activity; NT: Not tested; * means of three replicate analysis; ± standard deviation; b standard Gram-positive antibacterial; streptomycin gave MIC values between 0.42 µg/mL and 4.10 µg/mL; standard Gram-negative antibacterial, nystatine had MIC value of 1.10 µg/mL; c standard anti-fungal, nystatine showed value of 2.20 µg/mL.

This paper reports for the first time the antimicrobial activity of essential oils from the leaves of A. monogyma and G. banii. Both essential oils displayed antimicrobial activity against the tested gram-positive and gram-negative bacteria with the minimum inhibitory concentrations (MIC) less than 100.0 µg/mL (Table 2). Essential oil from the leaf of A. monogyma displayed antimicrobial activity towards four of the tested microorganisms, and anti-candidal activity, with the minimum inhibitory concentration (MIC) values in the range of about 2 µg/mL - 60 µg/mL. The order of antibacterial activity was E. faecalis ATCC29212 (MIC, 2.20 µg/mL) > B. cereus ATCC14579 (MIC, 10.33 µg/mL) ≥ S. aureus ATCC25923 (MIC, 10.45 µg/mL) > P. aeruginosa ATCC27853 (MIC, 12.45 µg/mL). The IC<sub>50</sub> values were obtained in the range of 4.00 µg/mL - 128.00 µg/mL. The essential oil of A. monogyma exhibited anti-candidal action towards C. albicans ATCC10231 with MIC value of 63.89 µg/mL, with IC<sub>50</sub> value of 128.00 µg/mL.

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There is no report on the antimicrobial activity of essential oils from any Alphonsea plants. However, the antimicrobial properties of essential oils from some Goniothalamus plants have been evaluated and reported [17-19]. Comparing the antimicrobial activities of essential oils of Goniothalamus plants, the leaf essential oil of G. banii was superior to the essential oils from the roots and twigs of G. macrophyllus against S. aureus (MIC, 0.3 mg/mL and 2.5 mg/mL, respectively), P. aeruginosa (MIC > 5.0 mg/mL) and C. albicans (MIC 0.3 mg/mL) [17]. Also, G. banii leaf oil with MIC value of 24.56 µg/mL was
more potent against S. aureus than the flower essential oil of G. macranii with MIC value of 31.25 μg/mL [18] and the stem oil of G. cardiopetalus having MIC value of 1.5 mg/mL [19]. In addition, the leaf oil of
G. banii G. banii (MIC, 56.78 μg/mL) exhibited greater inhibitory action against B. cereus than the stem of
G. cardiopetalus with MIC value of 1.5 mg/mL. Interestingly, while G. banii leaf oil could not inhibit the
growth of E. coli, essential oils from the twigs of G. macrophyllus [17], the flower of G. macranii [18] and
the stem of G. cardiopetalus [19] displayed antimicrobial action with MIC values of 2.5 mg/mL, 15.62
μg/mL, and 1.5 mg/mL, respectively. Overall, G. banii essential oil possessed antimicrobial activity
comparable with other studied Goniothalamus oil.

It is believed that the constituents present in the studied essential oils might have influenced the
observed antimicrobial activity of A. monogyma and G. banii against microorganisms. Previous studies
have shown that the biological activities of essential oils from different species of plants are dependent of
the major compounds of abundance. In some other cases, synergies between the major and some minor
constituents have also enhanced the activity of natural products including essential oils [20]. The
antimicrobial potential of G. macrophyllus was attributed to α-pinene because its activity was reported to
surceeds those of other tested compounds [17]. In addition, G. macranii essential oil contained large
amount of caryophyllene oxide and (E)-caryophyllene, and the antimicrobial action was due to these
compounds among others [18]. Moreover, linalool and α-pinene were thought to be responsible for the
observed activity of G. cardiopetalus [19]. All these compounds were present in one form or the other in
the essential oil of A. monogyma and G. banii. For example, β-caryophyllene demonstrated selective
antibacterial activity against S. aureus [21] and antifungal effect [22]. In addition, some other compounds
identified in the essential oils, including δ-cadinene [23] and germacrene D [24] were previously reported to
display broad spectrum of antimicrobial actions. Myrcene was reported to acts as an antibacterial agent
against S. aureus [25], E. coli [24] and Salmonella enterica [24]. Moreover, α- and β-pinene, linalool, 1,8-
cineol are ubiquitous monoterpenoids in conifer and the other aromatic plants, and each compound were
widely tested against many organisms [1, 2, 24].

In conclusion, in this study, the main constituents of the leaf oil of A. monogyma were identified as (E)-
caryophyllene, δ-cadinene, bicyclogermacrene, cis-β-elemene and germacre D, while myrcene, α-pinene and
(Е)-caryophyllene were present in G. banii. Also, the essential oils effectively inhibited the growth of
standard strains of E. faecalis, S. aureus, B. cereus, P. aeruginosa and C. albicans with reasonable
MIC and IC50 thus depicting the antimicrobial activity.

Supporting Information

Supporting Information accompanies this paper on http://www.acgpubs.org/journal/records-of-
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References

[1] L.T. Huong, L.T., N.T. Chung, D.T.M. Chau, D.N. Dai and I.A. Ogunwande (2022). Annonaceae essential oils:
antimicrobial against S. aureus, P. aeruginosa, E. coli, and antifungal activity of Uvaria hamiltonii. Hook. f. & Thoms. and
Fissistigma kwangsiensis Tsiang & P. T. Li, Rec. Nat. Prod. 16, 387-392.
[2] L.T. Huong, D.T.M. Chau, D.N. Dai, D.N. and Ogunwande, I.A. (2022). Essential oils of Lauraceae:
constituents and antimicrobial activity of Dehaasia cuneata (Blume) Blume and Caryodaphnopsis tonkinensis
(Lecomte) Airy- Shaw (Lauraceae) from Vietnam, Rec. Nat. Prod. 16, 477-482.
[3] N.H. Hung, D.N. Dai, T. H. Thai, T.D. Thang and I.A. Ogunwande (2018). Essential oil of Alphonsea
tonkinensis A.DC (Annonaceae), Chem. Nat. Comppsds. 54, 1170-1171.
[4] T.D. Thang, L.T. Huong, D.N. Dai and I.A. Ogunwande (2013a). Essential oil compositions of Alphonsea
philastreana (Pierre) Pierre ex Finet & Gagnep. and Alphonsea gaudichaudiana (Baill.) Finet & Gagnep. from Vietnam,
Nat. Prod. Res. 27, 2022-2026.
[5] T.D. Thang, L.T. Huong, D.N. Dai and I.A. Ogunwande (2013b). A comparative analysis of essential oils of
Goniothalamus macrocalyx Ban., Goniothalamus albiflorus Ban. and Goniothalamus tamirensis Pierre ex Fin.
& Gagnep. from Vietnam, Nat. Prod. Res. 27, 1999-2005.
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[6] T.D. Thang, D.N. Dai, T.M. Hoj and I.A. Ogunwande (2013c). Chemical compositions of the leaf essential oils of some Annonaceae from Vietnam, *J. Essent. Oil Res.* 25, 85-91.

[7] T.D. Thang, D.N. Dai and I.A. Ogunwande (2016). Identification of the main volatile compounds in the leaf and stem bark of three *Goniothalamus* species from Vietnam, *J. Essent. Oil Bearing. Plant.* 19, 743-749.

[8] L.T.M. Chau, T.D. Thang, L.V. Diep, N.T.M. and I.A. Ogunwande (2014). Constituents of some essential oil bearing plants from Vietnam, *Am. J. Plant Sci.* 5, 760-765.

[9] N. Xie, and N.Y. Yang (1999). A new azafuorenone alkaloid from *Alphonsea monogyma*, *Chinese Chem. Lett.* 10, 671-672.

[10] National Institute of Science and Technology (2018). Chemistry Web Book. Data from NIST Standard Reference Database 69.

[11] J.K.R. Wanner, D.N. Dai, L.T. Huong, N.V. Hung, E. Schmidt and L. Jirovetz (2016). Chemical compositions of Vietnamese essential oils of *Cinnamomum rigidifolium, Dasmachalon longisculum, Fissistigma maclurei* and *Goniothalamus albiflorus*, *Nat. Prod. Commun.* 11, 1701-1703.

[12] B.A. Moharam, I. Jantan, F. bin Ahmad and J. Jalil (2010). Antiplatelet aggregation and platelet activating factor (PAF) receptor antagonistic activities of the essential oils of five *Goniothalamus* species, *Molecules* 15, 5124-5138.

[13] N.M. Shakri, W.N.M.H. Wan Salleh, K. Shamsul and M.A. Nor Azah (2020). Chemical characterization of *Goniothalamus macrophyllus* and *Goniothalamus malayanus* leaves essential oils, *Zeits. für Naturfors C.* 75, 485-488.

[14] N.M. Shakri, W.N.M.H. Wan Salleh and S.M. Shaharuddin (2021). Review on Malaysian *Goniothalamus* essential oils and their comparative study using multivariate statistical analysis, *Nat. Vol. Essent. Oils*. 8, 1-12.

[15] F. bin Ahmad, B.A. Moharram and I. Jantan (2010). A comparative study of the constituents of the essential oils of *Goniothalamus tapis* Miq. and *G. tapisoides* Mat Salleh from Borneo, *J. Essent. Oil Res.* 22, 499-502.

[16] F.B. Hoeltz, G.L. Pessini, N.R. Sanches, D.A.G. Cortez, C.V. Nakamura and B.P. Dias-Filho (2002). Screening of some plants used in the Brazilian folk medicine for the treatment of infectious diseases, *Mem. Inst. Oswaldo Cruz*, 97, 1027-1031.

[17] A.G.S. Humeirah, M.A. Nor Azah, M. Mastura, J. Mailina, J.A. Saiful, H. Muhajir and A.M. Puad (2010). Chemical constituents and antimicrobial activity of *Goniothalamus macrophyllus* (Annonaceae) from Pasoh Forest Reserve, Malaysia, *Afr. J. Biotech.* 9, 5511-5515.

[18] S. Monggoot and P. Pripdeevech (2017). Chemical composition and antibacterial activities of *Goniothalamus macranii* flower oil, *J. App. Pharm. Sci.* 7, 144-148.

[19] A. Hisham, P. Nirmal, S. Al-Saidi, G. Jayakumar, M.D. Ajitha and B. Harikumar (2006). The composition and antimicrobial activity of stem bark essential oil of *Goniothalamus cardopetalus* (Bl.) Hook.f. et Thoms, *J. Essent. Oil Res.* 18, 451-454.

[20] G. Lang and G. Buchbaeur (2012). A review on recent research results (2008-2010) on essential oils as antimicrobials and antifungals, *Flavour Frag. J.* 27, 13-39.

[21] S.S. Dhham, Y.M. Tabana, M.A. Iqbal, M.B. Ahamed, M.O. Ezzat, A.S. Maid and A.M.S. Majid (2015). The anticancer, antioxidant and antimicrobial properties of the sesquiterpene β-caryophyllene from the essential oil of *Aquilaria crassna*, *Molecules* 20, 11808-11829.

[22] A.C.N. Sobrinho, S.M. de Morais, E.B. de Souza, M.R.S. Albuquerque, H.S. dos Santos, C.S. de Paula Cavalcante, H.A. de souza and R.O dos Santos Fontelle (2020). Antifungal and antioxidant activities of *Veronica chalybaea* Mart. ex. DC. essential oil and their major constituents β-caryophyllene, *Braz. Arch. Biol. Technol.* 63, 177-188.

[23] A. Pérez-López, A.T. Cirio, V.M. Rivas-Galindo, R.S. Aranda and N.W. de Torres (2011). Activity against *Streptococcus pneumoniae* of the essential oil and δ-cadinene isolated from *Schinus molle* fruit, *J. Essent. Oil Res.* 23, 25-28.

[24] J. Benites, D. Ríos, A. Guerrero-Castilla, C. Enríquez, E. Zavala, R. O. Ybañez-Julc, I. Q.-Díaz, R. Jara-Aguilar and P. B. Calderon (2021). Chemical composition and assessment of antimicrobial, antioxidant and antiproliferative activities of essential oil from *Clinopodium sericeum*, a Peruvian medicinal plant, *Rec. Nat. Prod.* 15, 175-186.

[25] Y. Inoue, A. Shiraishi, T. Hada, H. Hamashima and J. Shimada (2004). The antibacterial effects of myrcene on *Staphylococcus aureus* and its role in the essential oil of the tea tree (*Melaleuca alternifolia*), *Nat. Med.* 58, 10-14.