# LEAF OIL COMPOSITIONS AND BIOACTIVITIES OF ABACO BUSH MEDICINES

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**Summary**

**Introduction:** Four aromatic plants used in traditional "bush" medicine on Abaco Island, Bahamas were studied. *Amyris elemifera* (Rutaceae), "white torch", is taken as a febrifuge and applied to sores and wounds, to treat influenza, and as an external bath and general tonic. *Eugenia axillaris* (Myrtaceae), "white stopper", is used as an aphrodisiac, as well as to treat diarrhea and for bathing women after childbirth. *Lantana involucrata* (Verbenaceae), "wild sage", is used to treat itching of the skin, measles and chicken pox. *Myrica cerifera* (Myricaceae), "bayberry", is taken as a general tonic and diuretic. **Methods:** The leaf essential oils of the four aromatic plants were obtained by hydrodistillation and analyzed by GC-MS. The antimicrobial activity against *Bacillus cereus*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Candida albicans*, and *Aspergillus niger*, and the *in-vitro* cytotoxicity of the oils on MDA-MB-231, MCF7, Hs 578T, Hep G2, and PC-3 human tumor cells have also been examined. **Results:** The most abundant components of *Amyris elemifera* were limonene (45.0%) and linalool (20.8%). *Eugenia axillaris* leaf oil was largely composed of α-pinene (15.5%) and dihydroagarofuran (9.2%). The leaf oil of *Lantana involucrata* was made up largely of germacrene D (21.1%), α-humulene (15.2%), and β-caryophyllene (13.7%). The most abundant essential oil components of *Myrica cerifera* were 1,8-cineole (30.7%) and α-terpineol (14.2%). *L. involucrata* leaf oil showed slight antibacterial activity against *B. cereus* and *Staph. aureus* and was weakly cytotoxic against our panel of cell lines. Neither *A. elemifera*, *E. axillaris*, nor *M. cerifera* leaf oils were appreciably antimicrobial or cytotoxic. **Conclusions:** The reported biological activities of the major constituents of *A. elemifera* leaf oil are consistent with the ethnopharmacological uses of this plant. The major components in the leaf oil and slight antimicrobial activity are consistent with the ethnobotanical use of *L. involucrata* to treat itching skin.

Key Words: *Amyris elemifera*, *Eugenia axillaris*, *Lantana involucrata*, *Myrica cerifera*, Bahamas, leaf essential oil, composition, antimicrobial activity, cytotoxic activity.

## Introduction

For many generations, people living in remote locations of the Bahamas have utilized "bush medicine" to ameliorate their maladies (1). In this paper, we report on the chemical compositions, antimicrobial activities, and cytotoxic activities, of the leaf essential oils of four aromatic herbal medicines used by the people of Abaco Island, Bahamas. A leaf decoction of *Amyris elemifera* L. (Rutaceae), "white torch", is taken as a febrifuge and applied to sores and wounds, to treat influenza, and as an external bath and general tonic (2). A decoction of the leafy branch tips of *Eugenia axillaris* (Myrtaceae), "white stopper", is used for "building up men's energy and body" (*i.e.*, as an aphrodisiac); it is also used to treat diarrhea and for bathing women after childbirth (1,2). *Lantana involucrata* (Verbenaceae), "wild sage", is used in the Bahamas to treat itching of the skin, measles and chicken pox (1). In Bahamian bush medicine, a tea made from the leafy branchlets of *Myrica cerifera* (Myricaceae), "wax myrtle" or "bayberry", is taken as a general tonic and diuretic (2).

## Methods

**Plant Collection.** The plants were collected from Abaco Island, Bahamas, and identified by M. A. Vincent. Essential oils were obtained by hydrodistillation of freshly chopped leaves and dichloromethane extraction of the distillate (Table 1).

Table 1. Essential oil yields of Abaco bush medicines.

| Plant | Collection Date and Location | Mass of Leaves | Mass of Oil (% yield) |
|---|---|---|---|
| *Amyris elemifera* | June 10, 2002<br>26° 34.5′ N, 77° 7.4′ W, 1-2 m a.s.l. | 209.9 g | 7.309 g<br>(3.48%) |
| *Eugenia axillaris* | June 10, 2002<br>26° 34′ N, 77° 8′ W, 1-2 m a.s.l. | 228.9 g | 2.642 g<br>(1.15%) |
| *Lantana involucrata* | December 18, 2000<br>26° 31.09′ N, 77° 4.26′ W, 13 m a.s.l. | 190.0 g | 125 mg<br>(0.0658%) |
| *Myrica cerifera* | June 9, 2002<br>26° 34.55′ N, 77° 8.35′W, 1-2 m a.s.l. | 141.8 g | 1.772 g<br>(1.25%) |

**Gas chromatographic-mass spectral analysis.** The leaf essential oils were subjected to GC-MS analysis on an Agilent system consisting of a model 6890 gas chromatograph, an HP-5ms GC column, a model 5973 mass selective detector (MSD), and an Agilent ChemStation data system as described previously (3). Identification of oil components was achieved based on their retention indices (determined with reference to a homologous series of normal alkanes), and by comparison of their mass spectral fragmentation patterns (NIST database/ChemStation data system) (4).

**Antimicrobial assays.** The essential oils and the purified major components were screened for antimicrobial activity against Gram-positive bacteria, *Bacillus cereus* (ATCC No. 14579) and *Staphylococcus aureus* (ATCC No. 29213); Gram-negative bacteria, *Pseudomonas aeruginosa* (ATCC No. 27853) and *Escherichia coli* (ATCC No. 25922); and the fungi *Candida albicans* (ATCC No.10231) and *Aspergillus niger* (ATCC No. 16401). Minimum inhibitory concentrations (MIC) were determined using the microbroth dilution technique (5,6). The antimicrobial activities of the essential oils and components are summarized in Table 2.

**Cytotoxicity assays.** The essential oils and purified major components were screened for cytotoxic activity against PC-3 (human prostatic adenocarcinoma), MDA-MB-231 (human mammary adenocarcinoma), MCF7 (human mammary adenocarcinoma), Hs 578T (human ductal carcinoma), and Hep G2 (human hepatocellular carcinoma), using the MTS assay as described previously (5,6). Cytotoxic activities are summarized in Table 3.

## Results

The essential oil of *A. elemifera* as revealed by GC-MS is made up of 71.3% monoterpenoids, 21.0% sesquiterpenoids, and 7.7% other compounds. The most abundant compounds are limonene (45.0%), linalool (20.8%), β-caryophyllene (5.6%), 3-hexadecanone (5.3%), caryophyllene oxide (3.9%), and β-sesquiphellandrene (3.6%). In this study, we find neither the leaf oil nor its major components to be notably antimicrobial. However, linalool is slightly active against *S. aureus*, while caryophyllene and caryophyllene oxide show slight activity against *B. cereus*. Although *A. elemifera* leaf oil shows no cytotoxic activity against our panel of tumor cell lines, β-caryophyllene and caryophyllene oxide are active. The other major components, limonene and linalool, are not cytotoxic, according to our study. GC-MS analysis of the leaf oil of *E. axillaris* shows the oil to be composed of oxygenated sesquiterpenoids (31.6%), sesquiterpene hydrocarbons (24.4%), monoterpene hydrocarbons (21.6%), and oxygenated monoterpenoids (19.4%). The most abundant constituents of *E. axillaris* leaf oil are α-pinene (15.5%), β-dihydroagarofuran (9.2%), β-caryophyllene (8.8%), α-humulene (6.9%), 1,8-cineole (6.6%), and germacrene D (6.2%). *E. axillaris* leaf oil is neither appreciably antimicrobial nor cytotoxic. In addition, none of the major components from the essential oil shows notable activity in our antimicrobial or cytotoxicity assays. The oil of *L. involucrata* is dominated by sesquiterpenoids with 67.6% sesquiterpene hydrocarbons and 24.0% oxygenated sesquiterpenoids. The most abundant components are germacrene D (21.1%), α-humulene (15.2%), β-caryophyllene (13.7%), and caryophyllene oxide (5.3%). *M. cerifera* leaf oil is made up of 57.4% oxygenated monoterpenoids, dominated by 1,8-cineole (30.7%), α-terpineol (14.2%), and 4-terpineol (9.0%); 24.4% sesquiterpene hydrocarbons, mostly β-caryophyllene (6.4%) and δ-cadinene (5.0%); and 16.8%

oxygenated sesquiterpenoids. Neither the volatile leaf oil of *M. cerifera* nor its major components exhibited either antimicrobial activity or antineoplastic activity in our assays.

Table 2. Antimicrobial activity (MIC, μg/mL) of leaf essential oils and their major components of Abaco bush medicinal plants.

| Material | *Bacillus cereus* | *Staphylococcus aureus* | *Escherichia coli* | *Pseudomonas aeruginosa* | *Candida albicans* | *Aspergillus niger* |
|---|---|---|---|---|---|---|
| *A. elemifera* | 625 | 1250 | 625 | 625 | 1250 | 625 |
| *E. axillaris* | 625 | 625 | 625 | 625 | 625 | 625 |
| *L. involucrata* | 312 | 312 | 625 | 625 | 625 | 625 |
| *M. cerifera* | 625 | 625 | 312 | 625 | 625 | 625 |
| α-Pinene | 625 | 312 | 312 | 625 | 156 | 625 |
| Limonene | 625 | 312 | 625 | 1250 | 1250 | 2500 |
| 1,8-Cineole | 156 | 625 | 625 | 625 | 312 | 312 |
| Linalool | 625 | 156 | 625 | 1250 | 625 | 625 |
| 4-Terpineol | 1250 | 1250 | 1250 | 625 | 312 | 1250 |
| α-Terpineol | 625 | 1250 | 1250 | 625 | 1250 | 625 |
| β-Caryophyllene | 156 | 312 | 312 | 1250 | 1250 | 625 |
| α-Humulene | 312 | 312 | 625 | 1250 | 625 | 78 |
| Germacrene D | 625 | 156 | 625 | 1250 | 625 | 39 |
| Caryophyllene oxide | 156 | 1250 | 1250 | 1250 | 625 | 625 |
| Positive Control | 1.22[1] | 0.61[1] | 2.44[1] | 1.22[1] | 0.61[2] | 0.61[2] |

[1]Gentamicin sulfate. [2]Amphotericin B

## Discussion

***A. elemifera.*** Linalool and β-caryophyllene are also moderately abundant constituents of *A. diatrypa* (7). Both *A. diatrypa* leaf oil (7) and *A. balsamifera* wood essential oil (8) contain moderate amounts of β-sesquiphellandrene. Limonene is an abundant constituent of many essential oils of the Rutaceae, especially *Citrus* (9), and has exhibited cancer chemopreventive activity (10,11), possibly due to induction of glutathione-S-transferase and glutathione peroxidase (12). In addition, limonene has been shown to have muscle relaxant and sedative activities (13). Linalool, abundant in rosewood (*Aniba roseadora*) (14) and sweet basil (*Ocimum basilicum*) (15) essential oils, has been found to exhibit anti-inflammatory (16), antinociceptive (17), and sedative (18) effects. In addition, linalool inhibited the growth of bacteria and fungi (19-21) and showed antileukemic activity (22). β-Caryophyllene has shown anti-inflammatory (23) and anesthetic (24) effects in addition to anticarcinogenic (25) and antineoplastic (26) activities. Caryophyllene oxide exhibited anti-dermatophytic activity (27) and smooth-muscle-relaxant activity (28). β-Sesquiphellandrene has shown antirhinoviral (29) and antiulcer (30) activities.

The reported biological activities of the major constituents of *A. elemifera* leaf oil are consistent with the ethnopharmacological uses of the plant to reduce fever, treat symptoms of flu, treat sores and wounds, and its use as a general tonic and bath.

Table 3. Cytotoxic activity of leaf oils and their major components of Abaco medicinal plants.

| Material | Cytotoxicity | | | | |
|---|---|---|---|---|---|
| | MDA-MB-231 | MCF7 | Hs 578T | PC-3 | Hep-G2 |
| *A. elemifera* [1] | 0 | 23.37(3.34) | 16.95(11.49) | 6.91(28.68) | 19.41(6.22) |
| *E. axillaris* | 0 | 11.99(3.30) | 8.77(3.00) | 0 | 16.45(5.63) |
| *L. involucrata* | 42.66(19.80) | 30.21(1.76) | 95.79(1.43) | 67.47(6.38) | 92.21(2.42) |
| *M. cerifera* | 0 | 0 | 2.74(9.31) | 3.23(4.89) | 14.76(18.01) |
| α-Pinene[2] | > 735 | > 735 | > 1840 | > 735 | 970(260) |
| Limonene | > 735 | > 735 | > 1840 | > 735 | 1150(110) |
| 1,8-Cineole | > 650 | > 650 | > 1625 | > 650 | > 1625 |
| Linalool | > 650 | > 650 | > 1625 | > 650 | > 1625 |
| 4-Terpineol | > 650 | > 650 | > 1625 | > 650 | > 1625 |
| α-Terpineol | > 650 | > 650 | > 1625 | > 650 | > 1625 |
| β-Caryophyllene | 155(1) | 190(26) | 383(41) | 153(6) | 347(74) |
| α-Humulene | 108(1) | 131(18) | 251(26) | > 490 | 260(23) |
| Germacrene D | 331(12) | 341(12) | 270(26) | 127(10) | 272(19) |
| Caryophyllene oxide | 324(33) | 178(33) | 350(1) | 150(3) | 116(8) |
| Doxorubicin hydrochloride[3] | 44.6(4.1) | 49.4(3.3) | 17.9(2.1) | 63.7(8.8) | 2.28(0.40) |

[1]Cytotoxicity for essential oils is expressed as % kill at 250 μg/mL for Hs 578T and Hep-G2 cells; % kill at 100 μg/mL for MDA-MB-231, MCF7, and PC-3 cells; standard deviations are shown in parentheses. [2]Cytotoxicity for pure compounds is expressed as $LC_{50}$ values in μM; standard deviations are shown in parentheses. [3]Positive control.

***E. axillaris.*** α-Pinene, β-caryophyllene, α-humulene, 1,8-cineole, and germacrene D are relatively common in *Eugenia* spp. Thus, α-pinene is abundant in the leaf oil of *E. jambolana* (31), 1,8-cineole is the major component of *E. haitiensis* essential oil (32), β-caryophyllene and α-humulene are abundant constituents of *E. dysenterica* leaf essential oil (33), and germacrene D is abundant in *E. stipitata* fruits (34). β-Dihydroagarofuran has been found in the many essential oils, but has apparently not been previously detected in *Eugenia* essential oils.

***L. involucrata.*** The presence of germacrene D, α-humulene, and β-caryophyllene as major components is consistent with the ethnopharmacological use of *L. involucrata* to treat skin problems. Thus, commercially marketed herbal treatments for skin problems include goldenrod (*Solidago canadensis*) oil, rich in germacrene D (35); salves from purple coneflower (*Echinacea purpurea*) root extract, rich in germacrene D and β-caryophyllene (36); and lotions from extracts of hops (*Humulus lupulus*) "flowers", rich in α-humulene and β-caryophyllene (37).

Both *Lantana camara* (38) and *L. aculeata* (39) are used in traditional medicine to treat itching and other skin problems. *L. camara* essential oil has abundant quantities of α-humulene and β-caryophyllene (40), and *L. aculeata* essential oil is high in β-caryophyllene (39). *L. xenica* is also rich in β-caryophyllene and germacrene D (41). The essential oils of *L. camara* (38,40), *L. aculeata* (39), *L. xenica* (41), and *L. achyranthifolia* (42) have exhibited weak antimicrobial activity, consistent with the results of *L. involucrata* leaf oil.

***M. cerifera.*** The large percentage of 1,8-cineole may account for its use in traditional herbal medicine. *Eucalyptus* oil and tea tree (*Melaleuca alternifolia*) oil are commercially important medicines, and these essential oils are also rich in 1,8-cineole (43). 1,8-Cineole has been reported to exhibit insecticidal (32), antimicrobial (19), and antioxidant (44) activity, and may synergistically enhance the biological activities of other essential oil components (45).

## Acknowledgments

Support for this work was provided by a generous grant from an anonymous private donor. We are grateful to the bush herbalist, Ms. Dolly Davis, for the plants and their uses. We thank Forest Heights Academy, Marsh Harbour, for allowing us the use of their laboratory facilities on Abaco. We thank Dr. Michael A. Vincent (W.S. Turrell Herbarium, Miami University, Oxford, Ohio) for plant identification, Rebecca Bifulco, Mary Setzer, Robert Werka, and Julie Collier for help with plant collection on Abaco, Amelia Boehme, Angela Rea-Ramsey, Benjamin Plummer, and Anita Bansal for assistance with the biological assays, and Lauren Eiter for collecting GC-MS data.

## References

1. Higgs L. Bush Medicine in the Bahamas. Nassau, Bahamas: Bahamas Nassau Guardian, 1969.
2. Morton JF. Atlas of Medicinal Plants of Middle America. Springfield, IL: Thomas, 1981.
3. Bansal A, Boehme AK, Eiter LC, Schmidt JM, Setzer WN, Vincent MA. Chemical composition and bioactivity of the leaf oil of Calyptranthes pallens (Poir.) Griseb. From Abaco Island, Bahamas. Nat Prod Commun 2006;1:303-306
4. Adams RP. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry. Carol Stream, IL: Allured, 1995.
5. Setzer MC, Setzer WN, Jackes BR, Gentry GA, Moriarity DM. The medicinal value of tropical rainforest plants from Paluma, north Queensland, Australia. Pharmaceut Biol 2001;39:67-78.

6. Setzer MC, Moriarity DM, Lawton RO, Setzer WN, Gentry GA, Haber WA. Phytomedicinal potential of tropical cloudforest plants from Monteverde, Costa Rica. Rev Biol Trop 2003;51:647-674.
7. Adams RP, Zanoni TA, van Beek TA, Posthumus MA, van de Haar C. Essential leaf oil of Amyris diatrypa Sprengel from the Dominican Republic. J Essent Oil Res 1998;10:175-178.
8. van Beek TA, Kleis R, Posthumus MA, van Veldhuizen A. Essential oil of Amyris balsamifera. Phytochemistry 1989;28:1909-1911.
9. Attaway JA, Pieringer AP, Barabas LJ. A study of the percentage variations in peel and leaf oil terpenes during one season. Phytochemistry 1967;6:25-32.
10. Elson CE, Maltzman TH, Boston JL, Tanner MA, Gould MN. Anti-carcinogenic activity of d-limonene during the initiation and promotion/progression stages of DMBA-induced rat mammary carcinogenesis. Carcinogenesis 1988;9:331-332.
11. Crowell PL. Prevention and therapy of cancer by dietary monoterpenes. J Nutrition 1999;129:775S-778S.
12. van Lieshout EM, Posner GH, Woodard BT, Peters WH. Effects of the sulforaphane analog compound 30, indole-3-carbinol, D-limonene or relafen on glutathione S-transferases and glutathione peroxidase of the rat digestive tract. Biochim Biophys Acta 1998;1379:325-336.
13. do Vale TG, Furtado EC, Santos JG, Viana GS. Central effects of citral, myrcene and limonene, constituents of essential oil chemotypes from Lippia alba (Mill.) n.e. Brown. Phytomedicine 2002;9:709-714.
14. Gaydou EM, Randriamiharisoa RP. Gas chromatographic diastereomer separation of linalool derivatives. Application to the determination of the enantiomeric purity of linalool in essential oils. J Chromatogr A 1987;396:378-381.
15. Grayer RJ, Kite GC, Goldstone FJ, Bryan SE, Paton A, Putievsky E. Infraspecific taxonomy and essential oil chemotypes in sweet basil, Ocimum basilicum. Phytochemistry 1996;43:1033-1039.
16. Peana AT, D'Aquila PS, Panin F, Serra G, Pippia P, Moretti MD. Anti-inflammatory activity of linalool and linalyl acetate constituents of essential oils Phytomedicine 2002;9:721-726.
17. Peana AT, D'Aquila PS, Chessa ML, Moretti MD, Serra G, Pippia P. (-)-Linalool produces antinociception in two experimental models of pain. Eur J Pharmacol 2003;460:37-41.
18. Buchbauer G, Jirovetz L, Jager W, Dietrich H, Plank C. Aromatherapy: evidence for sedative effects of the essential oil of lavender after inhalation. Z Naturforschung C 1991;46:1067-1072.
19. Carson CF, Riley TV. Antimicrobial activity of the major components of the essential oil of Melaleuca alternifolia. J Appl Bacteriol 1995;78:264-269.
20. Pattnaik S, Subramanyam VR, Bapaji M, Kole CR. Antibacterial and antifungal activity of aromatic constituents of essential oils. Microbios 1997;89:39-46.

21. Pitarokili D, Couladis M, Petsikos-Panayotarou N, Tzakou O. Composition and antifungal activity on soil-borne pathogens of the essential oil of Salvia sclarea from Greece. J Agric Food Chem 2002;50:6688-6691.
22. Chiang LC, Chiang W, Chang MY, Ng LT, Lin CC. Antileukemic activity of selected natural products in Taiwan. Amer J Chinese Med 2003;31:37-46.
23. Martin S, Padilla E, Ocete MA, Galvez J, Jimenez J, Zarzuelo A. Anti-inflammatory activity of the essential oil of Bupleurum fruticescens. Planta Med 1993;59:533-536.
24. Ghelardini C, Galeotti N, Di Cesare Mannelli L, Mazzanti G, Bartolini A. Local anaesthetic activity of □-caryophyllene. Farmaco 2001;56:387-389.
25. Zheng GQ, Kenney PM, Lam LK. Sesquiterpenes from clove (Eugenia caryophyllata) as potential anticarcinogenic agents. J Nat Prod 1992;55:999-1003.
26. Kubo I, Chaudhuri SK, Kubo Y, Sanchez Y, Ogura T, Saito T, Ishikawa H, Haraguchi H. Cytotoxic and antioxidative sesquiterpenoids from Heterotheca inuloides. Planta Med 1996;62:427-430.
27. Yang D, Michel L, Chaumont JP, Millet-Clerc J. Use of caryophyllene oxide as an antifungal agent in an in vitro experimental model of onychomycosis. Mycopathologia 1999;148:79-82.
28. Mata R, Rojas A, Acevedo L, Estrada S, Calzada F, Rojas I, Bye R, Linares E. Smooth muscle relaxing flavonoids and terpenoids from Conyza filaginoides. Planta Med 1997;63:31-35.
29. Denyer CV, Jackson P, Loakes DM, Ellis MR, Young DA. Isolation of antirhinoviral sesquiterpenes from ginger (Zingiber officinale). J Nat Prod 1994;57:658-662.
30. Yamahara J, Hatakeyama S, Taniguchi K, Kawamura M, Yoshikawa M. Pungent and anti-ulcer effects of low polar constituents isolated from ginger, the dried rhizome of Zingiber officinale Roscoe cultivated in Taiwan. The absolute stereostructure of a new diarylheptanoid. Yakugaku Zasshi 1992;112:645-655.
31. Craveiro AA, Andrade CHS, Matos FJA, Alencar JW, Machado MIL. Essential oil of Eugenia jambolana. J Nat Prod 1983;46:591-592.
32. Jacobson M, Haller HL. The insecticidal component of Eugenia haitiensis identified as 1,8-cineol. J Am Chem Soc 1947;69:709-710.
33. Costa TR, Fernandes OFL, Santos SC, Oliveira CMA, Liao LM, Ferri PH, Paula JR, Ferreira HD, Sales BHN, Silva MdRR. Antifungal activity of volatile constituents of Eugenia dysenterica leaf oil. J Ethnopharmacol 2000;72:111–117.
34. Franco MRB, Shibamoto T. Volatile composition of some Brazilian fruits: Umbu-caja (Spondias citherea), Camu-camu (Myrciaria dubia), Araça-boi (Eugenia stipitata), and Cupuaçu (Theobroma grandiflorum). J Agric Food Chem 2000;48:1263-1265.
35. Steliopoulos P, Wüst M, Adam KP, Mosandl A. Biosynthesis of the sesquiterpene germacrene D in Solidago canadensis: $^{13}C$ and $^{2}H$ labeling studies. Phytochemistry 2002;60:13-20.

36. Hudaib M, Fiori J, Bellardi MG, Rubies-Autonell C, Cavrini V. GC-MS analysis of the lipophilic principles of Echinacea purpurea and evaluation of cucumber mosaic cucumovirus (CMV) infection. J Pharmaceut Biomed Anal 2002;29:1053-1060.
37. Eri S, Khoo BK, Lech J, Hartman TG. Direct thermal desorption-gas chromatography and gas chromatography-mass spectrometry profiling of hop (Humulus lupulus L.) essential oils in support of varietal characterization. J Agric Food Chem 2000;48:1140-1149.
38. Deena MJ, Thoppil JE. Antimicrobial activity of the essential oil of Lantana camara. Fitoterapia 2000;71:453-455.
39. Saxena VK, Sharma RN. Antimicrobial activity of the essential oil of Lantana aculeata. Fitoterapia 1999;70:67-70.
40. Alitonou G, Avlessi F, Bokossa I, Ahoussi E, Dangou J, Sohounhloué DCK. Composition chimique et activités biologiques de l'huile essentielle de Lantana camara Linn. C R Chimie 2004;7:1101-1105.
41. Juliani HR, Biurrun F, Koroch AR, Oliva MM, Demo MS, Trippi VS, Zygadlo JA. Chemical constituents and antimicrobial activity of the essential oil of Lantana xenica. Planta Med 2002;68:762-764.
42. Hernandez T, Canales M, Avila JG, Garcia AM, Martinez A, Caballero J, Romo de Vivar A, Lira R. Composition and antibacterial activity of essential oil of Lantana achyranthifolia Desf. (Verbenaceae). J Ethnopharmacol 2005;96:551-554.
43. Balacs T. Cineole-rich Eucalyptus. Int J Aromather 1997;8:15-21.
44. Carson CF, Mee BJ, Riley TV. Mechanism of action of Melaleuca alternifolia (tea tree) oil on Staphylococcus aureus determined by time-kill, lysis, leakage, and salt tolerance assays and electron microscopy. Antimicrob Agents Chemother 2002;46:1914-1920.
45. Ruberto G, Baratta MT. Antioxidant activity of selected essential oil components in two lipid model systems. Food Chem 2000; 69:167-174.