ORIGINAL ARTICLE

Chemical Composition and Synergistic Repellent Activity of Jasminum officinale and Anthemis nobilis Essential Oils Against Aedes aegypti Mosquitoes

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ABSTRACT

Introduction: Mosquitoes are important vectors responsible for transmission of many pathogens that cause major human morbidity and mortality. Natural repellents such as essential oils may provide a means of protection from mosquito bites that are safe and more pleasant to use. **Methods:** In this study, essential oils from the flowers of *Jasminum officinale* and *Anthemis nobilis* were characterised by gas chromatography-mass spectrometry and were further tested for their repellent efficacy, individually and in combinations, against *Aedes aegypti* using a rat model. **Results:** Forty-two compounds accounting for 77.50% of *J. officinale* essential oil and fifty-one compounds representing 87.96% of *A. nobilis* essential oil, respectively. For *A. nobilis* essential oil, oxygenated monoterpenes accounted for 84.79% of the compounds identified. The essential oils of *J. officinale* and *A. nobilis* at 20% concentration provided repellency of 68.45% and 73.15%, respectively, against *Ae. aegypti* for 120 min. The mixture of essential oils in a 1:1 ratio (JC1) exhibited 88.20% repellency for 120 min, which was significantly higher than the repellency of 20% concentration of the individual oils. **Conclusion:** The synergistic interactions among the varied constituents of *J. officinale* and *A. nobilis* essential oils enhanced the mosquito repellent activity.

Keywords: Essential oil, Jasminum officinale, Anthemis nobilis, Repellent efficacy, Aedes aegypti

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INTRODUCTION

Essential oils are complex mixtures of volatile organic compounds that contribute to the flavour and fragrance of a plant. They also act as a repellent/deterrent against phytophagous insects (1,2). Therefore, plants have been used for protection against insects or other pests. For instance, plant materials are burnt to produce smoke or bruised plants are placed in homes, and also plant oils or oil mixtures are applied onto the skin for protection from biting insects, particularly mosquitoes (3–5).

Dengue fever is an arboviral infection caused by a flavivirus transmitted by *Aedes aegypti* or *Aedes albopictus* mosquitoes (6). The World Health Organisation (WHO) reported the global occurrence of dengue has expanded over the last 50 years and estimated about 50 to 100 million new infections happen every year, with around 20,000 deaths (7). A more recent study has revealed an estimation of 390 million dengue infections to occur each year using cartographic approaches (8). Personal protection plays a crucial role in preventing mosquito bites and thereby reducing the risk of infection. DEET (N,N-diethyl-3methylbenzamide)-based insect repellents have been used globally for more than 60 years. Despite its wide usage for protection against mosquito bites and its proven effectiveness, DEET comes with several drawbacks. For example, it emits an unpleasant odour and it was found to damage synthetic fabrics, plastics and painted surfaces which prevents its use in bed nets and in many urban locations (9,10). Besides that, instances of DEET resistance have been shown in mosquitoes (11,12), as well as in flies (13). DEET also blocks sodium and potassium ion channels of mammals, which may contribute to lip numbness (14).

In recent decades, plant-based insect repellents have gained increasing popularity among consumers. For example, lemon eucalyptus (*Corymbia citriodora*) is an effective natural repellent against several species of mosquitoes and ticks (15). The essential oil from *C. citriodora* contains p-menthane-3,8-diol (PMD), citronella, citronellol, geraniol, isopulegol, and delta pinene (16). Protection against Anopheles by PMD was found to be comparable to that of DEET. Therefore, its use is advocated by the Centers for Disease Control (CDC) for use in malaria endemic areas (17,18). However, blends of pure compounds were shown to be less effective at repelling mosquitoes compared to their corresponding essential oil (19–21).

The flowers and leaves of jasmine are well-known for their multiusage. For instance, the flowers were used conventionally for the treatment of various ailments such as diarrhoea, fever, conjunctivitis, abdominal pain, dermatitis, eye diseases etc. (22,23). Chamomile is commonly used in herbal teas to relieve spasms or inflammatory disorders related to the gastrointestinal tract (24), and it also is used to relieve sleeping disorders, diarrhoea, colic, wounds, mucositis, and eczema (25,26). The mosquito repellent studies of jasmine were reported concerning the essential oil derived from Jasminum grandiflorum L. (27–29). The chemical composition of Roman chamomile essential oil has been determined previously (30-32), and only three studies have evaluated its mosquito repellent activity to date (27-29).

To our knowledge, this study reports for the first time the chemical composition and mosquito repellent activity of Jasminum officinale. Moreover, it is interesting to evaluate the repellent efficacy of J. officinale in combination with chamomile, the plant renowned for its enormous medicinal properties (33). Furthermore, chemical compounds such as champene, α -pinene, β -pinene and 1,8-cineole found in *A. nobilis* have been shown to repel mosquitoes (19,34,35). Thus, A. nobilis can be a good candidate for mosquito repellent study. Therefore, the goal of this study was to determine the chemical composition of jasmine (Jasminum officinale L.) and Roman chamomile (Anthemis nobilis L.) essential oils and to evaluate their repellent efficacy, individually and in combinations, against Ae. aegypti using a rat model.

MATERIALS AND METHODS

Test Materials

Essential oils extracted from the flowers of *J. officinale* and *A. nobilis* were purchased from Renaissance of Switzerland (Singapore). Fractionated coconut oil was purchased from doTerra (Pleasant Grove, Utah, USA), and DEET was obtained from the Vector Control Research Unit at Universiti Sains Malaysia (USM, Penang, Malaysia).

Essential Oil Analysis

The essential oils were analysed by gas chromatographymass spectrometry (GC-MS) on an Agilent 7890 GC instrument coupled with an Agilent 5975c mass specific detector (Santa Clara, CA, USA). Separation was performed on a 5% phenyl methyl silicon capillary column HP-5MS (30 m x 0.25 mm ID and 0.25 µm

film thickness). The initial oven temperature was set at 40 °C for 10 min and it was raised to 230 °C at 5 °C/ min and to 300 °C at 20 °C/min. This temperature was held for 10 min. Helium was used as the carrier gas at a constant flow rate of 1 mL/min. Electron impact mass spectra were recorded in the 30-800 amu range at 71 eV ionisation energy, and ion source temperature was 230 °C. Essential oils were diluted (1:10, v/v) with methanol and filtered through a 0.22 µm membrane. The injector was set at 230 °C, and the samples were run in split mode (50:1) with an injection volume of 2 µL. Retention indices of the components were determined by a series of n-alkanes C_7 - C_{30} on the HP-5MS column. The compounds were identified by comparison of their mass spectra with those from the NIST 2005 Mass Spectral Library and their retention indices with those available in the literature (36,37).

Repellent Test

Experimental animals

Twenty-four female Sprague Dawley rats (8 weeks old) were obtained in batches from the Animal Research Section, Advanced Medical and Dental Institute of USM. The animals were acclimatised for 1 week to the new environment, and they were kept three per ventilated cage with a 12:12 (light: dark) cycle and a continuous supply of food and water. The rats were shaved on the ventral surface prior to the experiment. All procedures involving the use of animals were in compliance with the global and national rules and guidelines, and they were approved by the Institutional Animal Care and Use Committee at our institution (Approval/2013/(90)(508)).

Mosquitoes

Adult female *Ae. aegypti* mosquitoes (5–7 days old) were acquired from the Vector Control Research Unit at USM. Mosquitoes were reared in the laboratory at 27 \pm 2°C and 75–80% relative humidity in a 12:12 (light: dark) photoperiod. Adult mosquitoes were maintained in cages measuring 30 cm x 30 cm x 30 cm and fed with 10% sucrose solution in water. The sucrose solution was removed from the cage at least 12 h before testing.

Preparation of the oils

Fractionated coconut oil served as the negative control, and 10% DEET prepared in absolute ethanol was used as the positive control. The essential oils were diluted to the concentrations of 5%, 10%, and 20% (v/v) in fractionated coconut oil to assess their repellent properties. The concentration that showed good repellent activity was used in the preparation of oil mixtures. The oil mixtures JC1, JC2, and JC3 were prepared with 20% *J. officinale* and *A. nobilis* at the ratio of 1:1, 2:1, and 1:2, respectively.

Mosquito repellent efficacy of essential oils using a rat model

The evaluation method used was adapted from previous study with some modifications (38). Briefly, the rat was

confined in a customised wire mesh cage. Subsequently, 0.5 mL of test substance was applied onto a 2 x 6 cm hairless area of the rat abdomen using a camel hairbrush. The application was left to dry for 30 min. Thereafter, the rat was placed on top of the mosquito cage (30 cm x 30 cm x 30 cm) containing 50 nulliparous female Ae. aegypti mosquitoes for the first 5 min of every half-hour interval. Before the test was conducted, the mosquitoes were tested for their readiness to feed. An untreated rat was placed on top of the mosquito cage, and the test was conducted if at least two mosquitoes bit the untreated rat. The number of mosquitoes biting at the marked area was recorded at each interval for a duration of 2 h. The experiment was performed in triplicate with a new batch of mosquitoes on alternate days. The percentage of repellency was determined using the number of mosquitoes biting at the control and treated areas using the following formula:

Percentage of repellency (%) = $[C - T] \times 100$

where C is the total number of mosquitoes biting at the control area and T is the total number of mosquitoes biting at the treated area.

Statistical Analysis

All experiments were repeated three times, and the data were expressed as mean \pm standard error of the mean (SEM). Differences between the treatment means were analysed using analysis of variance (ANOVA) with Tukey's multiple comparison test. Differences were considered significant at p < 0.05. All statistical analyses were performed using IBM SPSS Statistics, Version 24.0 (Armonk, NY, USA).

RESULTS

Chemical composition of J. officinale and A. nobilis essential oils

The chemical compositions of *J. officinale* and *A. nobilis* essential oils were characterised by GC-MS. Forty-two compounds representing 77.50% of jasmine oil and fifty-one compounds representing 87.96% of chamomile oil were identified (Table I and Table II). The chemical constituents of *J. officinale* varied entirely from those present in *A. nobilis*. Oxygenated monoterpenes were the major constituents (84.79%) of *A. nobilis*, whereas they accounted for only 31.14% of the total found in *J. officinale*. Fig. 1 and Fig. 2 show the total ion chromatogram of *J. officinale* and A. nobilis, respectively.

Synergistic mosquito repellent activity of combined essential oils

Table III shows the repellency of the essential oils, individually and in combinations, at every half-hour interval. The *J. officinale* essential oil provided repellency of 13.69%, 27.38%, and 68.45% against *Ae. aegypti* at concentrations of 5%, 10%, and 20%, respectively, at

Table I: Chemical composition of the essential oil of J. officinale

| 1 17.44 4-Hexenyl acetate 1017 0.03 2 18.53 Benzyl alcohol 1044 2.38 3 20.12 Benzyl (mmate 1084 0.05 4 20.30 p-Cresol 1089 0.25 5 20.73 Methyl benzoate 1099 0.27 6 21.05 Linalool 1109 2.76 7 23.31 Benzyl acetate 1177 11.50 8 24.10 Methyl salicylate 1201 0.04 9 27.05 Indole 1302 0.07 11 28.44 Kegonol 1369 1.46 13 31.27 Ceranyl acetone 1471 1.80 13 31.27 Ceranyl acetone 1462 0.05 14 31.49 2.6.10.14-Tertamethyleptadecane 1472 0.03 15 32.67 eTarax-Nerolidol 1576 0.11 17 34.17 ciarax-Hexenyl acetone 1662 | No. | RT (min) | Compound ^a | RI ^b | Com- position (%) |
|---|----------|-------------|--|-----------------|-------------------------|
| 110.1010.000.00420.30Persol10.900.02520.73Methyl benzoate10.900.07621.04Linalool11.000.07723.31Benzyl acetate11.000.06927.05Indole13.020.001024.40Methyl anhranilate13.020.001128.48Eugenol13.010.011229.05 <i>cleanyl acetone</i> 14.110.011331.07 <i>cleanyl acetone</i> 15.020.011431.492.61.01.41 Tetramethylheptadecane15.020.011532.67 <i>cleanyl acetone</i> 15.020.011634.00(21.7ars.Nerolidol15.020.011734.17 <i>cleanyl acetone</i> 16.020.031834.032.01acetylaminobenzoia caid, methylester16.120.041935.04Methyl asmonate16.020.032036.05Benzyl benzoate16.020.032140.13Methyl asmonate16.020.012240.05Benzyl benzoate16.020.022341.73Methyl asmonate16.020.022442.22kophylorfarnesyl acetone16.020.022542.55Genzyl benzoate17.020.022643.03Hyl honolate21.010.022743.05Methyl asiloylate21.040.02 </td <td>1</td> <td>17.44</td> <td>4-Hexenyl acetate</td> <td>1017</td> <td>0.03</td> | 1 | 17.44 | 4-Hexenyl acetate | 1017 | 0.03 |
| A20.30P.C.520.73Methyl benzoate1090.07621.05Linalool11092.76723.31Benzyl acetate117711.50824.10Methyl anicylate12010.04927.05Indole13600.001028.40Methyl anicylate13520.001128.84Eugenol13691.051229.95cif-Jasmone1411.801331.27Ceranyl acetone1430.051431.492.610.14-Tetramethylheptadecane1420.051532.07acFarasene1560.651634.000.12ransene1560.651734.17cis-3-Hexenyl benzoate16120.46189.411.801.560.451935.40Benzyl benzoate1680.45103.61Benzyl benzoate1680.451240.63Benzyl acitone18590.451241.13Hexadecanoate19411.201442.20Sophytol2063.612.721532.55Geranyl linalool20482.721643.03Ethyl linoleate21190.011743.52Hernyl linoleate21300.451844.54Methyl citadecanoate21490.151445.29Hyl linoleate21300.15 <td< td=""><td>2</td><td>18.53</td><td>Benzyl alcohol</td><td>1044</td><td>2.38</td></td<> | 2 | 18.53 | Benzyl alcohol | 1044 | 2.38 |
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| 621.05Indool11092.76723.31Benzyl acetate117711.50824.10Methyl salicylate12010.04927.05Indole13020.0601028.40Methyl anthranilate13520.071128.43Eugenol13611.501229.55ciclasmone1430.051331.27Ceranyl acetone1430.051431.402.61.0.14-Tetramethylheptadecane1420.031532.67af-arasene15200.561634.00el-trans-Nerolidol15760.111734.17cis-3-Hexenyl benzoate16620.631834.832-Diacetylaminobenzoic acid, methylester16620.641034.61Benzyl barzoate17666.1411Hexahydrofamesyl acetone18590.041240.53Benzyl salicylate1860.031341.73Methyl Inoleate21100.271442.22kophylol cadecanoate21690.031545.55Methyl Inoleate21110.271645.43Hylol cadecanoate21340.031745.44Methyl Inoleate2140.131845.27Phylol2140.141945.14Hyll noleate2140.141945.14Hyll noleate21620.161945 | 4 | 20.30 | p-Cresol | 1089 | 0.25 |
| 11.1.11.1.111.1.101.1.50824.10Methyl salicylate12010.04927.05Indole13020.0601028.40Methyl anthranilate13520.07112.8.41Eugenol13691.1661229.95 <i>cis</i> Jasone14111.8001331.27Geranyl acetone14200.0551634.09e-Farasene15200.551634.00(e-Farasene15200.561634.00(e-Farasene15200.561734.17 <i>cis</i> -3-Hexenyl benzoate16120.461935.94Methyl jasnonate16620.632038.61Benzyl benzoate18590.452140.11Hexabycrolaresyl acetone18590.452240.63Benzyl alicylate18690.002341.73Methyl Inseadecanoate19410.272442.22kophytol inolenate21110.272542.50Methyl Inolenate21190.3012643.03Ithyl syl octadecanoate21340.032743.75Geranyl linolenate21390.012845.29Hyl ol ciadecanoate21390.013945.20Hyl linolenate21400.233145.23Hyl linolenate21360.103245.31Alt,15.1etersmethyl-2.6.01,41.8-eicos- <td>5</td> <td>20.73</td> <td>Methyl benzoate</td> <td>1099</td> <td>0.07</td> | 5 | 20.73 | Methyl benzoate | 1099 | 0.07 |
| AParticleParticleParticle927.05Indole13020.0011028.40Methyl anthranilate13520.071128.44Iugenol13691.4601229.95 <i>cis</i> Jasmone14111.8001331.27Ceranyl acetone14200.0311431.492,6,10,14-Tetramethyleptadecane15200.0561532.47 <i>ei</i> Farasene15200.0511634.00 <i>ei</i> - <i>trans</i> -Nerolidol15760.11117 <i>di</i> .47 <i>cis</i> -3-Hexenyl benzoate16120.0631834.832-Diacetylaminobenzoic acid, methylester16120.0641935.94Methyl jasmonate16620.632038.61Benzyl benzoate18890.0102140.03Benzyl benzoate18890.0162240.03Benzyl bacadecanoate19410.0312442.22kophylo19665.392542.56Aspringene19440.0312643.03Ethyl Inolenate21190.0173045.27Phylol10141.2403145.49Methyl inolenate21360.0163244.50Methyl <i>cis</i> -11-eicosenoate23260.0163345.23Ethyl Inolenate21360.0213445.34Methyl <i>cis</i> -11-eicosenoate23360.0213548.48Methyl <i>cis</i> -11-eico | 6 | 21.05 | Linalool | 1109 | 2.76 |
| 927.05India13020.0011028.40Methyl anthranilate13520.071128.84Eugenol136913691229.95cis-Jasmone14111.801331.27Ceranyl acetone14030.051431.492,6,10,14-Tetramethylheptadecane14720.031532.67a-Farnasene15200.561634.00(a)-trans-Nerolidol15760.111734.17cic-3-Hexenyl benzoate16120.461935.94Methyl jasmonate16620.632038.61Benzyl salicylate18850.102140.11Hexahydrofarnesyl acetone18950.452240.53Benzyl salicylate18640.032341.73Methyl hexadecanoate19840.032442.22kophylo19640.332542.56acspringene12140.272844.92Methyl linolenate21190.312945.55Methyl linolenate21390.313045.27Hyrlo21312.463145.49Methyl ci-1-eicosenoate21490.133145.20Kethyl linolenate21390.153245.15Kethyl ci-1-eicosenoate21390.153346.23Kethyl ci-1-eicosenoate21390.163449.20Cisiooctyl phthalate2150< | 7 | 23.31 | Benzyl acetate | 1177 | 11.50 |
| 1028.40Methyl anthranilate13520.071128.44Eugenol1369136913691229.95Cix-Jasmone14111.801331.27Geranyl acetone1420.031431.492,6,10,14-Tetramethylheptadecane14720.031532.67a-Farnasene15200.561634.00(±)-trans-Nerolidol15760.111734.17cix-3-Hexenyl benzoate16120.631834.59eDitacetylamiobenzoi acid, methylester16120.631935.94Methyl jasmonate16620.632036.61Benzyl benzoate18890.012140.11Hexahydrofarnesyl acetone18890.012240.63Benzyl salicylate18690.032341.73Kethyl hexadecanoate19840.032442.22Isophytol19665.392542.56aSpringene19840.032643.03Ethyl hexadecanoate21190.013045.27Phytol21310.243145.49Methyl Inolenate21190.013346.23Athyl inolenate21360.233445.24Kethyl cix-11-eicosenoate23260.153545.27Phytol23760.243645.27Jachottjelate2481.553745.23Athyl inolenate< | 8 | 24.10 | Methyl salicylate | 1201 | 0.04 |
| 1128.84Eugenol13691.4101229.95cic/asmone14111.001331.27Geranyl acetone14230.031431.492,61,0,1.4-Tetramethylheptadecane14200.0561532.67a-farnasene15200.561634.00(e)-trans-Nerolidol15760.111734.17cis-3-t-texenyl benzoate15840.051834.832-Diccetylaminobenzoic acid, methylester16120.611935.94Methyl jasmonate16620.632038.61Benzyl benzoate17868.142140.11Hexadycforaneyl acetone18850.102341.33Methyl hexadecanoate19411.202442.22Isophylo19665.392542.56a-Springene19840.032643.03Ehyl Inoleate21140.222743.55Geranyl linalool21312.462844.92Methyl Inoleate21190.3013045.27Phylol21312.463145.33Atelyl pi-2-cadecadienoate21790.503346.33Sthyl linolenate21320.163447.233,71,15-Tetramethyl-2,6,10,14,18-eices-23220.163548.48Methyl <i>cis</i> -11-eicosenoate23390.513652.07Disocycl phthalate25040.36371 | 9 | 27.05 | Indole | 1302 | 0.60 |
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| 1331.27Geranyl acetone14630.0511431.492,6,10,14-Tetramethylheptadecane14720.031532.67a-Farnasene15200.5611634.00(±)-trans-Nerolidol15760.111734.17c/s-3-Hexenyl benzoate15840.8531834.832-Diacetylaminobenzoic acid, methylester16120.4611935.94Methyl jasmonate16620.632038.61Benzyl benzoate17868.142140.11Hexahydrofarnesyl acetone18850.012341.73Methyl hexadecanoate19411.202442.22Isophytol19665.392542.56a-Springene19840.022643.03Ethyl hexadecanoate20180.052743.75Geranyl Inalool20182.722844.92Methyl linolenate21110.272945.05Methyl linolenate21190.013045.27Phytol21312.463145.49Methyl dis-11-eicosenate21490.013246.31Ehyl hexadecanoate21320.163345.49Methyl dis-11-eicosenate21490.023445.29Disoctyl phthalate2.370.373546.40Methyl dis-11-eicosenate2.840.16369.12Ajcl_16-Tetramethyl-2,6,10,14,18-eicos- apentaeric2.86 | 11 | 28.84 | Eugenol | 1369 | 1.96 |
| 14.1.4.21.4.21.4.215.3.4.67a-f-anasene15.200.5.616.3.4.00(±)-trans-Nerolidol15.760.1117.3.4.17c/s-3-Hexenyl benzoate15.840.8.618.3.4.332-Diacetylaminobenzoic acid, methylester16.120.6.619.3.5.94Methyl jasmonate16.620.6.320.3.6.61Benzyl benzoate17868.1421.40.11Hexahydrofarnesyl acetone18590.4.522.40.63Benzyl salicylate18690.0.323.41.73Methyl hexadecanoate19411.2.024.42.22Isophytol19665.3.925.42.50Acfrigene20080.0.326.43.03Ethyl inoleate20180.0.327.43.75Geranyl linalool20482.7.228.44.92Methyl inolenate21100.2.729.45.05Methyl inolenate21400.3.130.45.27Phylo21312.4.631.45.49Methyl ci-11-cicosenoate21800.3.133.46.11Ethyl Jinolenate21800.3.134.45.22Bihyl linolenate21800.3.135.Ashtapentamethyl-2,6,10,14,18-2;0.1.60.3.136.45.70Bisopentamethyl-2,6,10,14,18-2;0.3.137.45.27Joicotyl phthalate25760.4.638.50. | 12 | 29.95 | <i>cis</i> -Jasmone | 1411 | 1.80 |
| 15232.67a-Farmasene15200.561634.00(a)-trans-Nerolidol15760.111734.17cis-3-Hexenyl benzoate15840.851834.832-Diacetylaminobenzoic acid, methylester16120.631935.94Methyl jasmonate16620.632038.61Benzyl benzoate17868.142140.11Hexahydrofarnesyl acetone18590.452240.63Benzyl salicylate18650.102341.73Methyl hexadecanoate19411.202442.22kophytol20680.032542.56a-Springene9840.032643.03Ethyl hexadecanoate20180.052743.75Geranyl linalool20482.722844.92Methyl chadecanoate21110.272945.05Methyl p.12-octadecadienoate21193.013045.27Phytol21312.463145.49Methyl octadecanoate21790.073346.23Ethyl linolenate21600.103447.233,71,115-Tetramethyl-2-hexadecen-1-ol224412.313548.49Methyl dixi 1-teicosenoate23290.153649.124,81,216-Tetramethyl-2,6,10,14,18-eicos- apentaene23600.563649.124,81,216-Tetramethyl-1,61,01,14,18-eicos- apentaene23685,7636 | 13 | 31.27 | Geranyl acetone | 1463 | 0.05 |
| 1494.00(a)-trans-Nerolidol15760.111734.17cis-3-Hexenyl benzoate15840.685182-Diacetylaminobenzoic acid, methylester16120.4611935.49Methyl jasmonate17868.1412038.61Benzyl benzoate17868.1412140.11Hexahydrofarnesyl acetone18850.0102341.73Methyl hexadecanoate19411.2022442.22Isophytol19665.3312542.56a-Springene20080.0312643.03Ethyl hexadecanoate20080.0312743.75Geranyl linalool20482.722844.92Methyl linoleate21110.272945.05Methyl linolenate21132.463145.49Methyl octadecanoate21790.073346.23J.7,11,15-Tetramethyl-2-hexadecen-1-ol224412.313548.49Methyl <i>cis</i> -11-eicosenoate23780.233749.29Aj.01,14,18-Pentamethyl-2,6,10,14,18-eicos- apentame23790.363850.77Diisocyt J phthalate25760.483952.07Diisocyt J phthalate25690.464053.40Aj.14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2,6,10,14,18-Pentamethyl-2 | 14 | 31.49 | 2,6,10,14-Tetramethylheptadecane | 1472 | 0.03 |
| 34.17 is -3-Hexenyl benzoate 1584 0.46 18 34.83 2-Diacetylaminobenzoic acid, methylester 1612 0.46 19 35.94 Methyl jasmonate 1662 0.63 20 8.61 Benzyl benzoate 1786 8.14 21 40.11 Hexahydrofarnesyl acetone 1859 0.45 22 40.63 Benzyl salicylate 1885 0.10 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 Isophytol 208 0.03 25 42.56 a-Springene 208 0.03 26 43.03 Ethyl hexadecanoate 2018 0.27 27 43.75 Geranyl linoleate 2111 0.27 28 44.92 Methyl octadecanoate 2113 2.46 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2179 0.07 33 46.23 3.7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 34 47.23 | 15 | 32.67 | α-Farnasene | 1520 | 0.56 |
| 18 34.83 2-Diacetylaminobenzoic acid, methylester 1612 0.46 19 35.94 Methyl jasmonate 1662 0.63 20 38.61 Benzyl benzoate 1786 8.14 21 40.11 Hexahydrofarnesyl acetone 1859 0.45 22 40.63 Benzyl salicylate 1865 0.10 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 kophytol 1966 5.39 25 42.56 a-Springene 1944 0.03 26 43.03 Ethyl hexadecanoate 2048 2.72 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linolenate 2111 0.27 30 45.27 Phytol 2131 2.46 31 45.49 Methyl circatecanoate 2179 0.07 32 46.11 Ethyl p.12-octadecanoate 2180 0.10 34 47.23 3.7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 | 16 | 34.00 | (±)- <i>trans</i> -Nerolidol | 1576 | 0.11 |
| 15.94 Methyl jamonate 1662 0.63 20 38.61 Benzyl benzoate 1786 8.14 21 40.11 Hexahydrofarnesyl acetone 1859 0.45 22 40.63 Benzyl salicylate 1885 0.10 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 Isophytol 1968 0.33 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.03 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.07 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2179 0.07 33 46.23 Ethyl inolenate 2186 0.10 34 47.23 3.71,11,5-Tetramethyl-2,6,10,14,18-eicos-apentaene 2382 0.16 34 9.12 2,6,10,14,1 | 17 | 34.17 | <i>cis</i> -3-Hexenyl benzoate | 1584 | 0.85 |
| 1111 1111 1111 1111 20 38.61 Benzyl benzoate 1786 8.14 21 40.01 Hexahydrofarnesyl acetone 1859 0.45 22 40.63 Benzyl salicylate 1865 0.10 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 Isophytol 1966 5.39 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linolenate 2111 0.27 29 45.05 Methyl otadecanoate 2149 0.18 31 45.49 Methyl otadecanoate 2149 0.10 34 47.23 3,71,1,5-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 50.77 Diisooctyl phthalate 2360 0.15 38 50.77 Diisoocty | 18 | 34.83 | 2-Diacetylaminobenzoic acid, methylester | 1612 | 0.46 |
| 140.11Hexahydrofarnesyl acetone18590.452240.63Benzyl salicylate18850.102341.73Methyl hexadecanoate19411.202442.22Isophylol19665.392542.56a-Springene19840.032643.03Ethyl hexadecanoate20080.052743.75Geranyl linalool20482.722844.92Methyl linoleate21110.272945.05Methyl otadecanoate21493.013045.27Phytol21312.463145.49Methyl octadecanoate21490.033246.31Ethyl 9.12-octadecadienoate21600.073346.233.711.15-Tetramethyl-2-hexadecen-1-ol224412.313548.48Methyl ci-11-eicosenoate23250.163649.124,8,12,16-Tetramethyl-2,6,10,14,18-eicos-apentaene23260.153749.292,610,14,18-Pentamethyl-2,6,10,14,18-eicos-apentaene23680.363850.77Disooctyl phthalate25760.483952.07Benzyl linolenate28031.694052.44 <i>trans</i> -Squalene28685.764153.122,3-Oxidosqualene28685.764253.67Iotal identified (%)7.507.504453.67Total identified (%)7.505.61045And identified (%) | 19 | 35.94 | Methyl jasmonate | 1662 | 0.63 |
| 22 40.63 Benzyl salicylate 1885 0.10 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 Isophytol 1966 5.39 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9.12-octadecadienoate 2130 0.07 33 46.23 Ethyl Inolenate 2160 0.10 34 47.23 3,711.15-Tetramethyl-2,6,10,14,18-ecios- 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-ecios- 2376 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 | 20 | 38.61 | Benzyl benzoate | 1786 | 8.14 |
| 23 41.73 Methyl hexadecanoate 1941 1.20 24 42.22 Isophytol 1966 5.39 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2149 0.07 33 46.23 Ethyl Inolenate 2160 0.07 34 47.23 3,71,115-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>is</i> :11-eicosenoate 2378 0.23 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- 2392 0.15 38 50.77 Diisoctyl phthalate 256 0.48 39 52.07 Benzyl linolenate 2160 1.55 41 <t< td=""><td>21</td><td>40.11</td><td>Hexahydrofarnesyl acetone</td><td>1859</td><td>0.45</td></t<> | 21 | 40.11 | Hexahydrofarnesyl acetone | 1859 | 0.45 |
| 24 42.22 Isophytol 1966 5.39 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl Inolenate 2169 0.07 33 46.23 Ethyl linolenate 2160 0.10 34 47.23 3,7,11,15-Tetramethyl-2,hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-Eicos- apertaene 2326 0.48 39 52.07 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 280 1.59 41< | 22 | 40.63 | Benzyl salicylate | 1885 | 0.10 |
| 25 42.56 a-Springene 1984 0.03 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linoleate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2166 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 16,610,14,18,22-Tetracosahexaen-3-ol, 2,6,610,15,19,23-hexamethyl-, | 23 | 41.73 | Methyl hexadecanoate | 1941 | 1.20 |
| 26 43.03 Ethyl hexadecanoate 2008 0.05 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2166 0.10 33 46.23 Ethyl linolenate 2325 0.16 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- 2325 0.15 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- 2325 0.16 38 50.77 Diisooctyl phthalate 260 0.48 39 52.07 Benzyl linolenate 2803 1.55 41 53.12 2,3-Oxidosqualene 2979 6.8 | 24 | 42.22 | Isophytol | 1966 | 5.39 |
| 27 43.75 Geranyl linalool 2048 2.72 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2507 8enzyl linolenate 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 7.50 70tal identified (%) 77.50 7.90 31.14 54.5 Konot | 25 | 42.56 | α-Springene | 1984 | 0.03 |
| 28 44.92 Methyl linoleate 2111 0.27 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 36 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 41 53.12 2,3-Oxidosqualene 2808 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracoshexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 7.50 7.50 7.50 50.41 53.67 | 26 | 43.03 | Ethyl hexadecanoate | 2008 | 0.05 |
| 29 45.05 Methyl linolenate 2119 3.01 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2303 1.69 40 52.47 Benzyl linolenate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2868 1.55 7.50 Grouped components (%) 77.50 77.50 8 Grouped components (%) 0.56 0.56 9 0,31 Sesquiterpene hydrocarbons (15, 21, 23, 26, 28-29, 31) | 27 | 43.75 | Geranyl linalool | 2048 | 2.72 |
| 30 45.27 Phytol 2131 2.46 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2303 1.69 40 52.44 <i>trans</i> -Squalene 2803 1.69 40 52.44 <i>trans</i> -Squalene 2803 1.69 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 16,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 77.50 42 53.67 Monoterpene hydrocarbons (9) 0.60 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 59 51,1 Sesquiterpene hydrocarbons (15) | 28 | 44.92 | Methyl linoleate | 2111 | 0.27 |
| 31 45.49 Methyl octadecanoate 2144 0.18 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethylheptadecan-4-olide 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2803 1.69 38 50.77 Diisooctyl phthalate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2803 1.69 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 77.50 45 Konoterpene hydrocarbons (9) 0.60 0.56 67 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 58 Sequiterpene hydrocarbons (15) 0.56 60xygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31 7.99 </td <td></td> <td></td> <td>,</td> <td></td> <td></td> | | | , | | |
| 32 46.11 Ethyl 9,12-octadecadienoate 2179 0.07 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethyl-2,6,10,14,18-eicos- apentaene 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 77.50 7 Total identified (%) 77.50 77.50 7 Grouped components (%) Monoterpene hydrocarbons (9) 0.60 0xygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 58 5esquiterpene hydrocarbons (15) 0 | 30 | | Phytol | 2131 | 2.46 |
| 33 46.23 Ethyl linolenate 2186 0.10 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethylheptadecan-4-olide 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 77.50 77.50 Grouped components (%) Monoterpene hydrocarbons (9) 0.60 0xygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 0xygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 0xygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other | | | , | | |
| 34 47.23 3,7,11,15-Tetramethyl-2-hexadecen-1-ol 2244 12.31 35 48.48 Methyl <i>cis</i> -11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethylheptadecan-4-olide 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 77.50 Grouped components (%) Monoterpene hydrocarbons (9) 0.60 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 Oxygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 Oxygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other constituents (37, 39, 40-42) 15.95 | | | | | |
| 35 48.48 Methyl cis-11-eicosenoate 2325 0.16 36 49.12 4,8,12,16-Tetramethylheptadecan-4-olide 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 52.44 trans-Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 3068 1.55 Total identified (%) 77.50 77.50 77.50 Grouped components (%) Monoterpene hydrocarbons (9) 0.60 0.56 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 53.17 5.56 31 Sesquiterpene hydrocarbons (15) 0.56 0.56 Oxygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 7.91 31.14 Sesquiterpene hydrocarbons (14, 25) 0.06 0.02 Oxygenated diterpenes (24, 27, 30, 32-36, 38) | | | | | |
| 36 49.12 4,8,12,16-Tetramethylheptadecan-4-olide 2378 0.23 37 49.29 2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicos- apentaene 2392 0.15 38 50.77 Diisooctyl phthalate 2576 0.48 39 52.07 Benzyl linolenate 2803 1.69 40 52.44 <i>trans</i> -Squalene 2868 5.76 41 53.12 2,3-Oxidosqualene 2979 6.80 42 53.67 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 3068 1.55 70tal identified (%) 77.50 Grouped components (%) 77.50 Monoterpene hydrocarbons (9) 0.60 0xygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 0xygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 0xygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other constituents (37, 39, 40-42) 15.95 15.95 15.95 | | | · · · · · · · · · · · · · · · · · · · | | |
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| 42 53.67 1,61,01,41,41,822-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)- 3068 1.55 7 total identified (%) 77.50 77.50 Grouped components (%) Monoterpene hydrocarbons (9) 0.60 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 Oxygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 Oxygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other constituents (37, 39, 40-42) 15.95 | | | | | |
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| Monoterpene hydrocarbons (9) 0.60 Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 Oxygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 Oxygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other constituents (37, 39, 40-42) 15.95 | | | | | 77.50 |
| Oxygenated monoterpenes (1-8, 10-13, 17-20, 22) 31.14 Sesquiterpene hydrocarbons (15) 0.56 Oxygenated sesquiterpenes (16, 21, 23, 26, 28-29, 31) 7.99 Diterpene hydrocarbons (14, 25) 0.06 Oxygenated diterpenes (24, 27, 30, 32-36, 38) 21.20 Other constituents (37, 39, 40-42) 15.95 | | | Grouped components (%) | | |
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| Other constituents (37, 39, 40-42) 15.95 | | | Diterpene hydrocarbons (14, 25) | | 0.06 |
| | | | | | |
| | Notos: P | T retentio | | rom a HD | |

Notes: RT, retention time. Compounds are listed in order of their elution time from a HP-5MS co ${}^{\rm b}$ RI, retention indices are determined on HP-5MS column using a series of *n*-alkanes (C₇-C₃₀).

| | Table II: Chemica | al composition of the essential oil of A. nobilis | |
|--|-------------------|---|--|
|--|-------------------|---|--|

| Table | | | | |
|----------|------------------|--|--------------------------|-----------------|
| No. 1 | RT (min) 7.96 | Compound ^a 3-Methyl-1-pentanol | RI ^b C 843 | Composition (%) |
| 2 | 10.18 | 3-methyl-1-pentanol Isopentyl acetate | 843 | 0.41 |
| 3 | 12.71 | Isobutyl isobutyrate | 926 | 0.40 |
| 4 | 13.44 | 1R-α-pinene | 939 | 1.44 |
| 5 | 13.71 | 2-Bromo-2-methylbutane | 944 | 0.31 |
| 6 | 14.18 | , Camphene | 953 | 0.51 |
| 7 | 14.70 | Butyl propyl oxalate | 962 | 0.04 |
| 8 | 15.50 | Allyl acetone | 977 | 0.12 |
| 9 | 15.65 | β-pinene | 979 | 0.17 |
| 10 | 16.83 | Isopropyl 3-methyl-2-butenoate | 1001 | 0.47 |
| 11 | 17.20 | Isobutyl 2-methylbutanoate | 1011 | 0.06 |
| 12 | 17.66 | Isopentyl isobutyrate | 1022 | 1.09 |
| 13 | 17.81 | 2-Methylbutyl isobutyrate | 1026 | 1.45 |
| 14 | 18.20 | 1,8-Cineole | 1036 | 0.30 |
| 15 | 18.80 | 3-Methylbutyl cyclopropanecarboxylate | 1051 | 0.99 |
| 16 | 19.26 | Ethyl 2-methyl cyclopropanecarboxylate | 1062 | 3.10 |
| 17 | 19.49 | cis-2-pentenyl butyrate | 1068 | 0.23 |
| 18 | 19.92 | Cyclohexyl propyl oxalate | 1079 | 11.22 |
| 19 20 | 20.12 21.03 | Hexyl propionate Isopentyl 2-methylbutanoate | 1084 1108 | 0.38 |
| 20 | 21.03 | 2-Methylbutyl 2-methylbutanoate | 1112 | 0.27 |
| 22 | 21.15 | Hexyl isobutyrate | 1128 | 9.43 |
| 23 | 21.87 | α-Campholenal | 1134 | 0.15 |
| 24 | 22.31 | trans-Pinocarveol | 1147 | 3.93 |
| 25 | 22.43 | (-)-Camphor | 1151 | 0.04 |
| 26 | 22.60 | Hexyl methacrylate | 1156 | 2.39 |
| 27 | 22.78 | Isopentyl 3-methyl-2-butenoate | 1161 | 7.76 |
| 28 | 22.92 | Pentyl 3-methyl-2-butenoate | 1165 | 5.96 |
| 29 | 23.09 | Pinocarvone | 1170 | 3.25 |
| 30 | 23.24 | (-)-Borneol | 1175 | 0.33 |
| 31 | 23.46 | <i>cis</i> -Pinocamphone | 1182 | 0.19 |
| 32 | 23.85 | p-Cymen-8-ol | 1193 | 0.15 |
| 33 | 24.15 | Myrtenol | 1203 | 0.55 |
| 34 | 24.45 | Hexyl 3-methylbutanoate | 1213 | 1.68 |
| 35 | 24.54 | Verbenone | 1216 | 0.23 |
| 36 | 24.91 | <i>cis</i> -Carveol | 1229 | 0.21 |
| 37 | 25.50 | (-)- <i>trans</i> -Pinocarvyl acetate | 1249 | 0.47 |
| 38 | 25.74 | 2-Hydroxy-2-methyl-but-3-enyl 2-methyl-2(Z)-butenoate | 1257 | 0.17 |
| 39 40 | 26.07 26.75 | Hexyl 3-methyl-2-butenoate Isopentyl 3-hydroxy-2-methylenebutanoate | 1268 1291 | 26.02 |
| 40 | 29.09 | (+)-Cycloisosativene | 1378 | 0.40 |
| 41 | 29.09 | Copaene | 1376 | 0.13 |
| 43 | 31.13 | cis-Pinonic acid | 1458 | 0.06 |
| 44 | 31.39 | β-Farnesene | 1468 | 0.09 |
| 45 | 31.61 | (-)-Myrtenyl acetate | 1477 | 0.12 |
| 46 | 32.05 | α-Curcumene | 1494 | 0.09 |
| 47 | 32.16 | β-Selinene | 1499 | 0.27 |
| 48 | 34.51 | Caryophyllene oxide | 1598 | 0.17 |
| 49 | 35.13 | Humulene epoxide II | 1626 | 0.25 |
| 50 | 36.87 | 4-(1,5-Dimethyl-4-hexenyl)-2-cyclohexen-1-one | 1704 | 0.06 |
| 51 | 40.11 | Hexahydrofarnesyl acetone | 1859 | 0.14 |
| | | Total identified (%) | | 87.96 |
| | | Grouped components (%) | | |
| | | Monoterpene hydrocarbons (4-6) | | 1.95 |
| | | Oxygenated monoterpenes (1-3, 7-40, 45, 50) | | 84.79 |
| | | Sesquiterpene hydrocarbons (41-42, 44, 46-47) | | 0.51 |
| | | Oxygenated sesquiterpenes (48-49, 51) | | 0.65 |
| | | Other constituents (43) time "Compounds are listed in order of their elution time | | 0.06 |

Abundance

Figure 1: Total ion chromatogram of Jasminum officinale

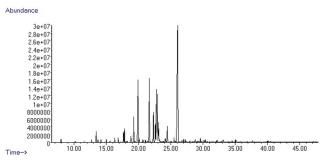




Table III: Repellent efficacy of *J. officinale* and *A. nobilis* essential oils tested individually and in combinations against *Ae. aegypti* mosquitoes.

| T. 1. 1 | Repellency (%) ± SEM at half-hour interval (min) | | | | | |
|-----------------------------|--|---------------------------|------------------------------|---------------------------|--|--|
| Treatment - | 30 | 60 | 90 | 120 | | |
| J. officinale essential oil | | | | | | |
| 5% | 51.52 ± 1.52ª | 41.48 ± 1.48ª | 35.56 ± 2.22ª | 13.69 ± 0.60^{a} | | |
| 10% | 71.46 ± 2.49 ^b | 55.19 ± 2.89 ^b | 39.26 ± 3.23ª | 27.38 ± 1.19 ^b | | |
| 20% | 100 ^c | 86.30 ± 3.16 ^c | 80.37 ± 1.61 ^b | 68.45 ± 2.98° | | |
| A. nobilis essent | tial oil | | | | | |
| 5% | 65.48 ± 2.98^{a} | 52.80 ± 5.14 ^a | 46.33 ± 4.30 ^a | 34.26 ± 5.63 ^a | | |
| 10% | $86.90 \pm 0.60^{\rm b}$ | 81.16 ± 2.36 ^b | 69.80 ± 1.75 ^b | 53.70 ± 1.85 ^b | | |
| 20% | 100 ^c | 88.20 ± 1.28 ^b | 83.57 ± 2.71° | 73.15 ± 3.34° | | |
| Essential oil mixtures | | | | | | |
| JC1 | 100ª | 100ª | 90.19 ± 0.81ª | 88.20 ± 1.28^{a} | | |
| JC2 | 100ª | 87.41 ± 2.06 ^b | 80.37 ± 1.61 ^b | 73.07 ± 2.39 ^b | | |
| JC3 | 100ª | 100ª | 84.07 ± 2.59ª | 76.40 ± 2.57 ^b | | |
| Negative control | | | | | | |
| Fractionated coconut oil | 17.17 ± 0.51 | 16.56 ± 1.75 | 17.42 ± 4.61 | 18.24 ± 2.94 | | |
| Positive Control | | | | | | |
| 10% DEET | 100 | 100 | 100 | 100 | | |

Notes: Data shown are the mean values \pm SEM of three independent experiments. Statistical analysis was performed using ANOVA with Tukey multiple comparisons test. Mean values in each treatment group within a column followed by a different letter are significantly different at p < 0.05. JC1, JC2 and JC3 are composed of 20% of *J. officinale* and *A. nobilis* at the ratio of 1:1, 2:1 and 1:2 respectively.

Notes: RT, retention time. "Compounds are listed in order of their elution time from a HP-5MS column. ^bRI, retention indices are determined on HP-5MS column using a series of *n*-alkanes $(C_{7}-C_{10})$

120 min. Values for A. nobilis were 34.26%, 53.70%, and 73.15% at 5%, 10%, and 20%, respectively. The percentage of repellency was significantly (p < 0.05) higher at 20% essential oil compared to 5% and 10% at all exposure times. Therefore, the essential oil mixtures JC1, JC2, and JC3 were prepared with 20% of J. officinale and A. nobilis at the ratio of 1:1, 2:1, and 1:2 respectively. JC1, JC2, and JC3 provided 88.20%, 73.07%, and 76.40% repellency, respectively, at 120 min (Table III). The repellency provided by JC1 was significantly (p < 0.05) higher compared to JC2 and JC3. JC1 also exhibited significantly (p < 0.05) greater repellency than 20% jasmine and 20% chamomile individually at 120 min post-treatment (Fig. 3). The positive control (10% DEET) provided 100% repellency against Ae. aegypti for the duration of 120 min.

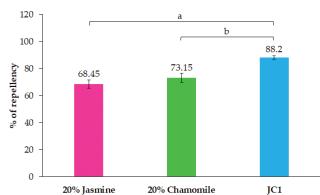


Figure 3: Comparison of repellent efficacy of individual essential oils and oil mixture, JC1 at 120 min post-treatment. Data shown are the mean values \pm SEM for three independent experiments. Statistical analysis was performed using ANOVA with Tukey multiple comparisons test. Values marked with the same alphabet are significantly different at p < 0.05. Error bars represent SEM. JC1 is composed of 20% of *J. officinale* and *A. nobilis* at the ratio of 1:1.

DISCUSSION

The essential oils of *J. officinale* and *A. nobilis* were screened to identify their chemical constituents using GC-MS and their repellent activities against *Ae. aegypti* were studied using a rat model. GC-MS is a commonly used method for the analysis and profiling of volatile compounds. It provides reproducible and accurate measurements of the retention time, m/z and abundance of volatile compounds together with their fragmentation patterns (39). For safety concern, we have used the rat model to assess the mosquito repellent potential of the test substance before it is being applied on human skin. Mosquito repellent studies have been conducted previously using different animal models such as mouse, rabbit and bird (38,40–42).

Eugenol (1.96%), linalool (2.76%), and phytol (2.46%) were present in *J. officinale*, and champene (0.51%) was found in *A. nobilis*. These compounds have been previously reported to show repellent activity against

A. gambiae (19,20). Methyl jasmonate (0.63%), the oxygenated monoterpene found in J. officinale was shown to act as a repellent against *C. quinquefasciatus* (43). Sesquiterpenes and their oxygenated derivatives constituted 8.55% and 1.16% of jasmine and chamomile essential oils, respectively. The oxygenated sesquiterpene, trans-Nerolidol present in J. officinale exhibited 67% spatial repellency for 180 min against Ae. aegypti (44). The A. nobilis essential oil contained the monoterpenes α -pinene (1.44%) and β -pinene (0.17%), and it was reported that 3% α -pinene and β -pinene diluted in olive oil provided 56 and 39 min of protection against *Culex pipiens molestus*, respectively (34). The oxygenated monoterpene 1,8-cineole (0.30%) present in A. nobilis was previously reported to provide 80% repellency (1.4 mg/cm²) against *Ae. aegypti* (35). The essential oils analysed in this study had some similarities in composition with previous studies (39,45). For instance, several compounds which were identified in this study such as isobutyl isobutyrate, 3-methyl-2-butenoate, 1R-α-pinene, isopropyl isobutyl 2-methylbutanoate, trans-Pinocarveol and pinocarvone have been reported previously as major marker compounds of Roman chamomile essential oil (39). As for jasmine, compounds such as nerolidol, geranyl linalool, phytol and squalene were identified in Jasminum grandiflorum L. essential oil (45).

A. nobilis essential oil at 20% was shown to provide complete protection up to 30 min against Ae. aegypti (28). Besides that, the essential oil from the leaves of A. nobilis at 1000 ppm exhibited repellency of 40.73% against Ae. aegypti (27). We have demonstrated that 20% A. nobilis gave 100% repellency for 30 min and decreased to 73.15% at 120 min post-treatment. In addition, the combination of J. officinale and A. nobilis showed enhanced repellency against Ae. aegypti with 100% repellency for 60 min. The greater repellent activity of the essential oil mixture compared to the individual oils can be attributed to the synergistic action between diverse components present as either minor or major constituents of the essential oils. This indicates that the chemical complexity of the two different essential oils provided additional strength to the repellent activity. A mixture of *Litsea cubeba* (LC) and *Litsea salicifolia* (LS) essential oils at 0.075% showed higher non-contact repellency (62.7%) against Ae. aegypti than LC (20%) or LS (20.3%) tested alone (46). In another study, blend of ylang-ylang and citronella essential oils on corn starchbased thixogel significantly enhanced repellent activity against Ae. aegypti compared to the oil independently (47). Moreover, synergist actions were claimed to be functioning in 8% of essential oil containing patents (48). For instance, essential oil of lippia in combination with geranium, lemon eucalyptus or basil essential oils formulated into a gradually vaporising hydrocarbon soluble composition was thought to alter neuronal action in adult mosquitoes and exhibit repellent activity comparable to commercial pyrethroids (49).

CONCLUSION

The essential oils of *J. officinale* and *A. nobilis* studied here are primarily comprised of monoterpenes, the compounds frequently associated with repellent activity (50). This indicates the potential of the essential oils to be a good source of repellent. The combination of *J. officinale* and *A. nobilis* essential oils was shown to repel the *Ae. aegypti* mosquitoes effectively for 1 h. Nevertheless, a decrease in repellency was noted over time due to high volatility of the essential oils. This property of essential oil could be improved through the formulation of nanoemulsion which will be addressed in our future studies.

ACKNOWLEDGEMENTS

This project was funded by the Research University (RU) Grant (1001/CIPPT/812121) of Universiti Sains Malaysia. The authors thank the MyPhD scholarship from the Ministry of Higher Education Malaysia for financially supporting Nithya Niranjini Muttiah.

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