Original Research Article

Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*

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Article history:
Received: Nov 13, 2014
Received in revised form: Feb 7, 2015
Accepted: June 14, 2015
Vol. 5, No. 6, Nov-Dec 2015, 540-552.

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Keywords:
Essential oil
*Eucalyptus microtheca*
*Eucalyptus viminalis*
Myrtaceae
Hydro-distillation, GC/MS

Abstract

Objective: *Eucalyptus* (Fam. Myrtaceae) is a medicinal plant and various *Eucalyptus* species possess potent pharmacological actions against diabetes, hepatotoxicity, and inflammation. This study aims to investigate essential oil composition from leaves and flowers of *E. microtheca* and *E. viminalis* leaves growing in the Southeast of Iran.

Materials and Methods: The aerial parts of these plants were collected from Zahedan, Sistan and Baluchestan province, Iran in 2013. After drying the plant materials in the shade, the chemical composition of the essential oils was obtained by hydro-distillation method using a Clevenger-type apparatus and analyzed by GC/MS.

Results: In the essential oil of *E. microtheca* leaves, 101 compounds representing 100%, were identified. Among them, α-phellandrene (16.487%), aromadendrene (12.773%), α-pinene (6.752%), globulol (5.997%), ledene (5.665%), P-cymen (5.251%), and β-pinene (5.006%) were the major constituents. In the oil of *E. microtheca* flowers, 88 compounds representing 100%, were identified in which α-pinene (16.246%), O-cymen (13.522%), β-pinene (11.082%), aromadendrene (7.444%), α-phellandrene (7.006%), globulol (5.419%), and 9-octadecenamide (5.414%) were the major components. Sixty six compounds representing 100% were identified in the oil of *E. viminalis* leaves. The major compounds were 1, 8-cineole (57.757%), α-pinene (13.379%), limonene (5.443%), and globulol (3.054%).

Conclusion: The results showed the essential oils from the aerial parts of *Eucalyptus* species are a cheap source for the commercial isolation of α-phellandrene, α-pinene, and 1, 8-cineole compounds to be used in medicinal and food products. Furthermore, these plants could be an alternative source of insecticide agents.

Please cite this paper as:
Maghsoodlou MT, Kazemipoor N, Valizadeh J, Falak Nezhad Seifi M, Rahneshan N. Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*. Avicenna J Phytomed, 2015; 5 (6): 540-552.
Introduction
Plants and their derivatives such as essential oils have long been used as food flavoring, beverages, and antimicrobial agents (Ghasemi et al., 2005). Nowadays, developing countries pay more attention to herbal medicines due to the noxious side effects of synthetic medicines on patients. In addition, the application of natural antioxidants in food factories has attracted a growing interest (Asghari and Mazaheritehrani, 2010) to minimize such oxidative damages in human body. Therefore, research works concerning essential oils as potential antioxidants for treatment of human diseases and free radical-related disorders are important. Concomitantly, public attention to natural antioxidants has been increased during the last years, and it is necessary to find natural sources of antioxidants that could replace synthetic antioxidants or at least reduce their use as food additives. For these reasons, numerous researches have been conducted in the extraction field of biologically active compounds from the herbs (Shahidi, 2000). Eucalyptus (Fam. Myrtaceae) is a genus of evergreen aromatic flowering trees, which has over 600 species (Jahan et al., 2011; Nagpal et al., 2010). It is indigenous in Australia and its Northern islands (Mozaffarian, 1996). Because of their economic value, various species of Eucalyptus are cultivated in sub-tropical and warm temperate regions (Sastri, 2002). Some of the Eucalyptus species are used for feverish conditions (malaria, typhoid, and cholera) and skin problems such as burns, ulcers, and wounds (Reynolds and Prasad, 1982). Eucalyptus species contain volatile oils that are most plentiful in the plant leaves (Pearson, 1993). Anticancer, antifungal, anti-inflammatory (Sadlon and Lamson, 2010), and antioxidant properties (Grassmann et al., 2000) have been attributed to the leaf extracts of this plant.

For this reason, the importance of these plants as an herbal medicine, the aim of the present study was to investigate the chemical composition of the essential oil from leaves and flowers of Eucalyptus microtheca and E. viminalis leaves from Zahedan (with latitude of 29° 29’ N and longitude of 60° 51’ E and 1352 m above sea level in summer of 2013) in Sistan and Baluchestan province, Iran as an important geographical zone for medicinal plants.

Material and Methods
Plant materials
Eucalyptus microtheca and E. viminalis were collected in June, 2013 from Zahedan in Sistan and Baluchestan province (GPS coordinates: 60.8628, 29.4964), Iran during the flowering stage. The taxonomic identification of each plant was confirmed by Professor V. Mozaffarian, Research Institute of Forests and Ragelands, Tehran, Iran. The voucher specimens were deposited in the national herbarium of Iran (TARI). Collected plant materials were separated with a meticulous care and dried in the shade to avoid extra damaging and minimizing cross-contamination of the plant leaves.

Isolation of the essential oil
The leaves and flowers of E. microtheca and E. viminalis leaves were dried and milled into a fine powder. The volatile oils were isolated by hydrodistillation method using a Clevenger-type apparatus. For the extraction, 50 g of the cleaned, air-dried and powder of leave samples of E. microtheca and E. viminalis were hydro-distilled with 500 mL water in a Clevenger-type apparatus for 4 h. Moreover, 30 g of the E. microtheca flower samples were hydro-distilled with 300 mL water for 4 h. The oils were dried over anhydrous Na₂SO₄ (Merck), stored in a dark glass bottle and kept at -8 °C until analysis.
Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*

Essential oil analysis

The essential oils were analyzed on an Agilent 6890 gas chromatograph interfaced to an Agilent 5973 N mass selective detector (Agilent Technologies, Palo Alto, USA). A fused silica capillary column (30 m length × 0.025 mm internal diameter × 0.25 μm film thickness; HP-1; silica capillary column, Agilent Technologies) was used. The data were acquired under the following conditions: The oven temperature increased from 40 °C to 250 °C at a rate of 3 °C/min.

The temperatures of injector and detector also were 250 °C and 230 °C, respectively. The carrier gas was helium (99.999%) with a flow rate of 1 ml/min and the split ratio was 50 ml/min. For GC–MS detection, an electron ionization system with ionization energy of 70 eV was used. The retention indices were calculated for all volatile constituents using retention time of *n*-alkanes (C₈–C₂₂) which were injected at the same chromatographic conditions. The components were identified by comparing retention indices with those of standards. The results were also confirmed by comparing their mass spectra with the published mass spectra or Wiley library.

Results

The oils were isolated by hydrodistillation and analyzed by capillary gas chromatography, using flame ionization and mass spectrometric detection. The obtained results of the identified compounds in the essential oil of leaves and flowers of *E. microtheca* and *E. viminalis* leaves with their percentage, retention index (RI), and retention time (tR) are shown in Tables 1, 2, and 3, respectively. The chromatographic analysis of extracted volatile oil of *E. microtheca* leaves revealed the presence of sesquiterpenes (47.852%), monoterpenes (46.844%), polyketides and fatty acids (3.496%), diterpene (0.140%), alkanes (0.085%), aromatic compounds (0.029%), and other compounds (1.521%).

Table 1. Composition of the volatile oil of *Eucalyptus microtheca* leaves.

| No. | Compound          | %    | RI  | tR (min) |
|-----|------------------|------|-----|----------|
| 1   | α–thujene        | 0.742| 742 | 9.381    |
| 2   | α -pinene        | 6.752| 767 | 9.716    |
| 3   | comphene         | 0.079| 792 | 10.063   |
| 4   | β - pinene       | 5.006| 817 | 11.33    |
| 5   | β -myrcene       | 0.533| 850 | 12.025   |
| 6   | α-phellandrene   | 16.487| 871 | 12.755   |
| 7   | α -terpinene     | 0.832| 892 | 13.103   |
| 8   | p -cymene        | 5.251| 913 | 13.374   |
| 9   | β-phellandrene   | 2.194| 934 | 13.626   |
| 10  | Limonene         | 1.503| 955 | 13.722   |
| 11  | Cis-ocimene      | 1.655| 976 | 14.144   |
| 12  | β–ocimene Y      | 0.101| 997 | 14.546   |
| 13  | γ -terpinene     | 1.235| 1018| 14.976   |
| 14  | Cymene           | 0.024| 1038| 16.021   |
| 15  | α -terpinolene   | 0.425| 1054| 16.267   |
| 16  | Roesfuran        | 0.024| 1073| 16.499   |
| 17  | Cycloheptanmethanol | 0.061| 1092| 16.581   |
| 18  | Linalool L       | 0.093| 1112| 16.806   |

1 Compound percentage  2 Retention index  3 Retention time
Continued table 1.

| No. | Compound                        | % | RI  | RT (min) |
|-----|---------------------------------|---|-----|---------|
| 19  | Isoamyl isovalerate             | 0.529 | 1131 | 17.038 |
| 20  | Isoamyl valerate                | 0.056 | 1151 | 17.152 |
| 21  | Fenchol                         | 0.076 | 1170 | 17.222 |
| 22  | Trans-pinene hydrate            | 0.062 | 1190 | 17.598 |
| 23  | Allocimene                      | 0.049 | 1209 | 18.247 |
| 24  | 1-terpineol                     | 0.045 | 1229 | 18.412 |
| 25  | 1-methylnorcarane               | 0.051 | 1267 | 19.229 |
| 26  | Ethylbenzoate                   | 0.124 | 1287 | 19.367 |
| 27  | 1-(adamantyl) cyclohexene       | 2.028 | 1507 | 23.545 |
| 28  | cis-fenchol                     | 0.224 | 1404 | 21.183 |
| 29  | Thiophene, 2-ethyl-5-methyl     | 0.085 | 1448 | 21.866 |
| 30  | Ascaridole                      | 0.042 | 1429 | 21.729 |
| 31  | Dicyclobutylidene oxide         | 0.084 | 1527 | 24.404 |
| 32  | Divinyldimethylsilane           | 0.114 | 1507 | 23.545 |
| 33  | 1-methoxyhept-1-yne             | 1.809 | 1478 | 22.992 |
| 34  | Citronellyl formate              | 0.287 | 1516 | 24.67  |
| 35  | Carvacrol                       | 0.120 | 1428 | 21.729 |
| 36  | Δ-cubebene                      | 0.160 | 1927 | 28.309 |
| 37  | Isolatedene                     | 0.124 | 1287 | 19.367 |
| 38  | Lapine                           | 0.224 | 1404 | 21.183 |
| 39  | Alloarmadendrene                | 0.224 | 1404 | 21.183 |
| 40  | Acaridol                        | 0.042 | 1429 | 21.866 |
| 41  | Dicyclobutylidene oxide         | 0.084 | 1527 | 24.404 |
| 42  | 1-methoxyhept-1-yne             | 1.809 | 1478 | 22.992 |
| 43  | Citronellyl formate              | 0.287 | 1516 | 24.67  |
| 44  | Carvacrol                       | 0.120 | 1428 | 21.729 |
| 45  | Δ-cubebene                      | 0.160 | 1927 | 28.309 |
| 46  | Isolatedene                     | 0.124 | 1287 | 19.367 |
| 47  | Lapine                           | 0.224 | 1404 | 21.183 |
| 48  | Alloarmadendrene                | 0.224 | 1404 | 21.183 |
| 49  | Acaridol                        | 0.042 | 1429 | 21.866 |
| 50  | Dicyclobutylidene oxide         | 0.084 | 1527 | 24.404 |
| 51  | 1-methoxyhept-1-yne             | 1.809 | 1478 | 22.992 |
| 52  | Citronellyl formate              | 0.287 | 1516 | 24.67  |
| 53  | Carvacrol                       | 0.120 | 1428 | 21.729 |
| 54  | Δ-cubebene                      | 0.160 | 1927 | 28.309 |
| 55  | Isolatedene                     | 0.124 | 1287 | 19.367 |
| 56  | Lapine                           | 0.224 | 1404 | 21.183 |
| 57  | Alloarmadendrene                | 0.224 | 1404 | 21.183 |
| 58  | Acaridol                        | 0.042 | 1429 | 21.866 |
| 59  | Dicyclobutylidene oxide         | 0.084 | 1527 | 24.404 |
| 60  | 1-methoxyhept-1-yne             | 1.809 | 1478 | 22.992 |
| 61  | Citronellyl formate              | 0.287 | 1516 | 24.67  |
| 62  | Carvacrol                       | 0.120 | 1428 | 21.729 |
| 63  | Δ-cubebene                      | 0.160 | 1927 | 28.309 |
| 64  | Isolatedene                     | 0.124 | 1287 | 19.367 |
| 65  | Lapine                           | 0.224 | 1404 | 21.183 |
| 66  | Alloarmadendrene                | 0.224 | 1404 | 21.183 |

1 Compound percentage  2 Retention index  3 Retention time
Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*

Continued table 1.

| No. | Compound | % | RI | RT (min) |
|-----|----------|---|----|---------|
| 67  | Globulol | 5.997 | 2786 | 37.554 |
| 68  | Veridiflorol | 1.243 | 2816 | 37.74 |
| 69  | 1, 3-dimethyl-5-ethyladamantane | 0.285 | 2845 | 37.80 |
| 70  | Ledol | 0.753 | 2875 | 38.036 |
| 71  | γ-curcumene | 0.391 | 2963 | 38.965 |
| 72  | Isospathulenol | 0.300 | 2992 | 39.259 |
| 73  | Tau-murolol | 1.580 | 2509 | 39.495 |
| 74  | δ-cadinol | 0.231 | 2529 | 39.562 |
| 75  | Guaia-3, 9-diene | 0.292 | 2548 | 39.767 |
| 76  | α-cadinol | 0.806 | 2568 | 39.908 |
| 77  | Vulgarol A | 0.129 | 2587 | 40.375 |
| 78  | Hexadecanoic acid | 0.093 | 2886 | 51.074 |
| 79  | 2-tridecanol | 0.028 | 2909 | 51.382 |
| 80  | Hexadecanoic acid ethyl ester | 0.025 | 2932 | 51.755 |
| 81  | Decyltetraglycol | 0.025 | 2955 | 59.356 |
| 82  | Tricosane | 0.012 | 2979 | 61.218 |
| 83  | Benzoinitrile, m-phenethyl | 0.032 | - | - |
| 84  | Pentacosane | 0.073 | - | 0.046 |
| 85  | Pentaoxyethylated pentadecyl alcohol | 0.036 | - | - |
| 86  | 1-cyclohexene-1-carboxaldehyde, 4-(1-methylethyl) | 0.170 | - | - |
| 87  | Cyclohexene, 3-methyl-6-(1-methylethyl) | 0.108 | - | - |
| 88  | 2- cyclohexene-1-ol, 2-methyl-5-(1-methylethyl)-, trans- | 0.059 | - | - |
| 89  | 2, 3-dimethyl-cyclohexa-1, 3-diene | 0.390 | - | - |
| 90  | α-campholic acid | 0.049 | - | - |
| 91  | Furan, 2, 3-dihydro-4-(1-methylpropyl) | 0.458 | - | - |
| 92  | (E)-3-isopropyl-6-oxo-2-heptenal | 0.058 | - | - |
| 93  | 1, 5, 5-trimethyl-6-methylene-cyclohexene | 0.056 | - | - |
| 94  | 2, 6, 10-trimethyl-2, 5, 7, 10-dioxido-dodeca-3, 11-diene-5-ol | 0.268 | - | - |
| 95  | Tricyclo [6.3.0.1(2, 3)]undec-7-ene, 6, 10, 11, 11-tetramethyl | 0.138 | - | - |
| 96  | 1-methyl-4-isopropyl-cis-3-hydroxyxyclohex-1-ene-6-one | 0.230 | - | - |
| 97  | 1H-cycloprop[a]napthalene, decahydro-1,1,3-a-trimethyl-7-methylene-\[1a[1.alphal,5a.alphal,7a.beta,7b.alphal.]] | 0.235 | - | - |
| 98  | Naphthalene, 1, 2, 3, 4, 4alpha, 7hexahydro-1, 6-dimethyl-4-(1-methylethyl) | 0.139 | - | - |
| 99  | Bicyclo[3.1.0]hex-2-ene,2-methyl-5-(1-methylethyl) | 0.026 | - | - |
| 100 | (++)-1R, 2S, 4R, 7R-7-isopropyl-5-methyl-5-bicycle [2.2.2]octen-2-ol | 0.140 | - | - |
| 101 | 1, 6-dimethyl-2-cyano-3-ethyl-3-piperidine | 0.612 | - | - |

1 Compound percentage  
2 Retention index  
3 Retention time

Table 2. Composition of the volatile oil of *Eucalyptus microtheca* flowers.

| No. | Compound | % | RI | RT (min) |
|-----|----------|---|----|---------|
| 1   | α-pinene | 0.504 | 817 | 9.331 |
| 2   | α-pinene | 0.246 | 841 | 9.652 |
| 3   | α-terpinene | 0.078 | 866 | 9.976 |
| 4   | Comphene | 0.271 | 891 | 10.028 |
| 5   | Verbenene | 0.051 | 916 | 10.198 |
| 6   | β-pinene | 11.082 | 940 | 11.256 |
| 7   | β-myrcene | 0.263 | 955 | 11.957 |
| 8   | α-Phoenixene | 0.086 | 976 | 12.477 |
| 9   | α-terpinene | 0.367 | 997 | 12.983 |
| 10  | α-cymene | 13.522 | 1018 | 13.246 |

1 Compound percentage  
2 Retention index  
3 Retention time
| No. | Compound                        | %    | RI² | RT³ (min) |
|-----|---------------------------------|------|-----|-----------|
| 11  | Sabinene                        | 2.131| 1038| 13.465    |
| 12  | Limonene                        | 2.713| 1059| 13.586    |
| 13  | cis-cimene                      | 0.149| 1080| 13.993    |
| 14  | γ -terpinene                    | 0.868| 1101| 14.857    |
| 15  | Isoeicosapentadecane-cymene      | 0.093| 1122| 15.942    |
| 16  | α -terpinolene                  | 0.189| 1143| 16.195    |
| 17  | Linalool L                      | 0.058| 1151| 16.669    |
| 18  | Appel oil                       | 0.113| 1170| 16.956    |
| 19  | D-fenchyl alcohol               | 0.085| 1190| 17.108    |
| 20  | Hexadecane                      | 0.147| 2639| 38.511    |
| 21  | Trans-pinocarveol               | 0.365| 1229| 18.155    |
| 22  | Pinocarveone                    | 0.303| 1248| 18.779    |
| 23  | 4-methyl-1,3-heptadiene (c,t)   | 0.088| 1267| 19.161    |
| 24  | 2, 4-hexadiene, 2, 5-dimethyl-   | 0.070| 1287| 19.351    |
| 25  | 4-terpineol                     | 1.052| 1306| 20.011    |
| 26  | Myrcenol                        | 0.202| 1326| 20.218    |
| 27  | α -terpineol                    | 0.425| 1345| 20.561    |
| 28  | Myrtenol                        | 0.160| 1365| 20.916    |
| 29  | Dodecane                        | 0.392| 1408| 21.584    |
| 30  | β -citronellol                  | 0.365| 1428| 22.624    |
| 31  | Piperitone                       | 0.167| 1448| 22.879    |
| 32  | Citronol                        | 0.063| 1487| 23.727    |
| 33  | Citronellol formate             | 0.115| 1507| 24.60     |
| 34  | Dicyclo dimethacrylate          | 0.787| 1527| 25.673    |
| 35  | Carvacrol                       | 0.494| 1546| 25.898    |
| 36  | 2-butylpyridine                 | 0.129| 1750| 29.074    |
| 37  | Isolatedene                     | 0.170| 1779| 29.249    |
| 38  | Copene                          | 0.150| 1809| 29.322    |
| 39  | Tetradecane                     | 0.063| 1839| 29.463    |
| 40  | β -elemene                      | 0.063| 1815| 29.933    |
| 41  | α -gurjunene                    | 0.542| 1631| 30.707    |
| 42  | Seychelene                      | 0.040| 1647| 30.833    |
| 43  | Trans-Caryophyllene             | 0.227| 1664| 30.967    |
| 44  | γ - selinene                    | 0.122| 1680| 31.272    |
| 45  | Calarene                        | 0.112| 1697| 31.524    |
| 46  | β - gurjunene                   | 0.073| 1713| 31.621    |
| 47  | Aromadendrene                   | 7.444| 1729| 31.901    |
| 48  | α -humulene                     | 0.080| 1746| 32.31     |
| 49  | Alloaromadendrene               | 1.632| 1762| 32.619    |
| 50  | α -amorphene                    | 0.400| 1779| 33.272    |
| 51  | β -selinene                     | 0.311| 1795| 33.58     |
| 52  | α -guaiene                      | 0.320| 1811| 33.744    |
| 53  | Ledene                          | 2.135| 1828| 34.051    |
| 54  | α -murolene                     | 0.318| 1844| 34.225    |
| 55  | γ -cadinene                     | 0.667| 1861| 34.686    |
| 56  | Calamene                        | 0.248| 1877| 34.81     |
| 57  | δ -cadinene                     | 1.040| 1893| 36.28     |
| 58  | Cadina-1, 4-diene               | 0.045| 1910| 35.395    |
| 59  | α -calacore                     | 0.070| 1926| 35.507    |
| 60  | Epiglobulol                     | 0.975| 2374| 36.334    |
| 61  | β -maaliene                     | 0.253| 2403| 36.482    |
| 62  | Plustrol                        | 0.221| 2433| 36.637    |
| 63  | Spathulenol                     | 1.848| 2462| 36.864    |
| 64  | Globulol                        | 5.419| 2492| 37.288    |
| 65  | Veridiflorol                    | 1.044| 2521| 37.497    |
| 66  | Ledol                           | 0.631| 2580| 37.867    |
| 67  | Hexadecane                      | 0.212| 2698| 38.735    |
| 68  | α -ylangene                     | 0.196| 2727| 38.826    |
| 69  | Isopatuleneol                   | 0.217| 2757| 39.071    |
| 70  | Tau-cadinol                     | 0.791| 2786| 39.268    |
| 71  | α -cadinol                      | 0.444| 2372| 39.708    |
| 72  | Cadalene                        | 0.120| 2392| 40.257    |
| 73  | N-octadecane                    | 0.246| 3211| 45.874    |
| 74  | Tetradecanamide                 | 0.321| 2653| 50.157    |
| 75  | n-hexadecanoic acid             | 0.375| 2676| 50.804    |
| 76  | Ecosane                         | 0.167| 2700| 52.389    |
| 77  | Hexadecanamide                  | 0.918| 2723| 56.50     |
| 78  | Octadecanoic acid               | 0.425| 2746| 56.848    |
| 79  | Docosan                         | 0.145| 2769| 58.363    |
| 80  | 9-octadecanamide                | 5.414| 2793| 61.623    |

¹ Compound percentage  
² Retention index  
³ Retention time
The presence of monoterpenes (60.899%), sesquiterpenes (28.328%), polyketides and fatty acids (1.714%), alkanes (1.372%), amides (6.653%), aromatic (0.115%), and other compounds (0.871%) was revealed for *E. microtheca* flower oils. In *E. viminalis* leaf oils, monoterpenes (83.037%) were the major components followed by sesquiterpenes (14.97%) and other minor components such as polyketides and fatty acids (0.496%), alkanes (0.046%), aromatic compounds (0.013%), and other compounds (1.404%).

The results showed in the essential oil of *E. microtheca* leaves, 101 compounds representing 100%, were identified. Among them, α-phellandrene (16.487%), aromadendrene (12.773%), α-pinene (6.752%), globulol (5.997%), ledene (5.665%), P-cymen (5.251%), and β-pinene (5.006%) were the major constituents (Table 1).

In the oil of *E. microtheca* flowers, 88 compounds representing 100%, were identified in which α-pinene (16.246%), O-cymen (13.522%), β-pinene (11.082%), aromadendrene (7.444%), α-phellandrene (7.006%), globulol (5.419%), and 9-octadecenamide (5.414%) were the major components (Table 2). Sixty six compounds representing 100% were identified in the essential oil of *E. viminalis* leaves. The major compounds were 1, 8-cineole (57.757%), α-pinene (13.379%), limonene (5.443%), and globulol (3.054%) (Table 3).
Continued table 3.

| No | Compound                     | %<sup>3</sup> | RF<sup>2</sup> | RT<sup>3</sup> (min) |
|----|------------------------------|---------------|---------------|---------------------|
| 15 | Calenate                     | 0.407         | 1631          | 31.367              |
| 16 | Selma-3, 7 (11)-diene        | 0.057         | 1647          | 31.657              |
| 17 | Arocamadrene                 | 3.925         | 1664          | 31.949              |
| 18 | Alloaromadrene               | 2.023         | 1680          | 32.707              |
| 19 | Isoamyl phenyl acetate       | 0.202         | 1697          | 33.12               |
| 20 | β -selinene                  | 0.156         | 1713          | 33.617              |
| 21 | Leucene                      | 0.639         | 1729          | 34.089              |
| 22 | α - murolene                 | 0.089         | 1746          | 34.258              |
| 23 | γ -cadinene                  | 0.201         | 1762          | 34.723              |
| 24 | calamenene                   | 0.279         | 1774          | 34.848              |
| 25 | δ -cadinene                  | 0.233         | 1795          | 35.119              |
| 26 | Epiglobulol                  | 0.555         | 2138          | 36.403              |
| 27 | γ –gurjene                   | 0.169         | 2168          | 36.538              |
| 28 | Palustrol                    | 0.142         | 2197          | 36.688              |
| 29 | Globulol                     | 3.054         | 2227          | 37.369              |
| 30 | Veridiflorol                 | 0.881         | 2256          | 37.586              |
| 31 | 1, 3-dimethyl-5-ethyladamantane | 0.250   | 2286          | 37.674              |
| 32 | Trans-β -farnesene           | 0.070         | 2374          | 38.289              |
| 33 | α –cadinol                   | 0.106         | 2138          | 39.765              |
| 34 | Citronellyl acetate          | 0.063         | 2158          | 42.108              |
| 35 | N-hexadecanoic acid          | 0.030         | 2327          | 50.917              |
| 36 | Pentacosane                  | 0.046         | 2351          | 66.562              |
| 37 | Octanal                      | 0.019         | 866           | 7.611               |
| 38 | 2-methyl-1, 3-cycloheptadiene| 0.041         | 891           | 8.907               |
| 39 | α -thujene                   | 0.035         | 916           | 9.373               |
| 40 | α -pinene                    | 13.379        | 940           | 9.732               |
| 41 | α -fenchene                  | 0.018         | 965           | 10.009              |
| 42 | compheene                    | 0.063         | 990           | 10.055              |
| 43 | β -pinene                    | 0.555         | 1014          | 11.191              |
| 44 | β -myrcene                   | 0.857         | 1018          | 12.001              |
| 45 | α -phellandrene              | 0.169         | 1038          | 12.443              |
| 46 | α -cymene                    | 0.118         | 1059          | 13.283              |
| 47 | 1, 8-cineole                 | 5.757         | 1080          | 13.919              |
| 48 | Limonene                     | 5.443         | 1101          | 13.98               |
| 49 | Cis-ocimene                  | 0.013         | 1122          | 14.113              |
| 50 | β -cimene Y                  | 0.011         | 1143          | 14.56               |
| 51 | isoamyl butyrate             | 0.013         | 1164          | 14.686              |
| 52 | γ –terpinene                 | 0.514         | 1185          | 14.941              |
| 53 | Dehydro-p-cymen              | 0.094         | 1206          | 16.012              |
| 54 | α -terpinol                  | 0.771         | 1209          | 16.276              |
| 55 | Linalool L                   | 0.099         | 1229          | 16.784              |
| 56 | Appel oil                    | 0.668         | 1248          | 17.031              |
| 57 | Isoamyl valerate             | 0.028         | 1267          | 17.14               |
| 58 | Freesol                      | 0.035         | 1287          | 17.275              |
| 59 | Valeric acid 4-pentenyl ester| 0.119         | 1306          | 17.407              |
| 60 | Trans-punocarveol            | 0.212         | 1326          | 18.248              |
| 61 | (+)-2S, 4R)-p-mentha-1(7), 8-|              |               |                     |
|    | dien-2-ol                    | 0.067         | 1507          | 22.283              |
| 62 | 1H-indene, 1-ethylideneoctahydro-7a-methyl-, | 0.466      | 2315          | 37.931              |
|    | (IE, 3a, alpha. 7a, beta)    |              |               |                     |
| 63 | Bicyclo [4.4.0] dec-1-ene, 2-|              |               |                     |
|    | isopropyl-5-methyl-9-methylene| 0.191         | 2433          | 39.327              |
| 64 | Caryophylla-2(12), 6(13)-dien-5-| 0.230        | 2344          | 38.107              |
|    | one                          |              |               |                     |
| 65 | 1-2′-hydroxy-3′, 4′-dime thylphenyl)ethane| 0.598        | 2403          | 38.692              |
| 66 | 2-propenoic acid, 2-methyl-1,2-| 0.068         | 1527          | 25.832              |
|    | ethanediyl ester             |              |               |                     |

1 Compound percentage  
2 Retention index  
3 Retention time

Table 4. Comparison of the composition of the volatile oil of *E. microtheca* leaves and flowers with *E. viminalis* leaves from Zahedan.

| No | Compound                     | %<sup>3</sup> | %<sup>3</sup> | %<sup>3</sup> |
|----|------------------------------|---------------|---------------|---------------|
| 1  | α –thujene                   | 0.742         | 0.504         | 0.035         |
| 2  | α –pinene                    | 6.752         | 16.246        | 13.379        |
| 3  | Comphene                     | 0.079         | 0.271         | 0.63          |
| 4  | β - pinene                   | 5.006         | 11.082        | 0.555         |
| 5  | β -myrcene                   | 0.533         | 0.263         | 0.857         |
| 6  | α –phellandrene              | 16.487        | 7.006         | 0.169         |
| 7  | α -terpinene                 | 0.832         | 0.367         | -             |
| 8  | P - cymene                   | 5.251         | -             | -             |
| 9  | β –phellandrene              | 2.194         | -             | -             |
| 10 | Limonene                     | 1.503         | 2.713         | 5.443         |
| 11 | Cis-ocimene                  | 1.655         | 0.149         | 0.013         |

1 *E. microtheca* leaves  
2 *E. microtheca* flower  
3 *E. viminalis* leave

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## Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*

Continued table 4.

| No | Compound | %[^1] | %[^2] | %[^3] |
|----|----------|-------|-------|-------|
| 12 | β-ocimene Y | 0.101 | - | 0.011 |
| 13 | γ-terpinene | 1.235 | 0.868 | 0.514 |
| 14 | Cymene | 0.024 | - | - |
| 15 | α-terpinolene | 0.425 | 0.189 | 0.771 |
| 16 | Roseluran | 0.024 | - | - |
| 17 | Cycloheptanemethanol | 0.061 | - | - |
| 18 | Linalool L | 0.093 | 0.058 | 0.099 |
| 19 | Isoamyl isovalerate | 0.529 | - | - |
| 20 | Isoamyl valerate | 0.056 | - | 0.028 |
| 21 | Fenchol | 0.076 | - | - |
| 22 | Trans-pinene hydrate | 0.062 | - | - |
| 23 | Allocimene | 0.049 | - | - |
| 24 | 1-terpineol | 0.045 | - | - |
| 25 | 1-methylnorcarane | 0.051 | - | - |
| 26 | Ethylbenzoate | 0.124 | - | - |
| 27 | 4-terpineol | 1.256 | 1.052 | 0.722 |
| 28 | 1-(adamantly) cyclohexene | 0.042 | - | - |
| 29 | β-fenchol | 0.203 | - | - |
| 30 | cis-sabinol | 0.224 | - | - |
| 31 | Thiophene, 2-ethyl-5-methyl | 0.120 | - | - |
| 32 | Ascaridole | 0.085 | - | - |
| 33 | Dicyclobutylidene oxide | 0.084 | - | - |
| 34 | Divinylidimethylsilane | 0.114 | - | - |
| 35 | Piperitone | 0.196 | - | - |
| 36 | 1-methoxyhept-1-yn | 1.809 | - | - |
| 37 | Citronellol formate | 0.029 | 0.115 | - |
| 38 | Carvacrol | 0.420 | 0.494 | - |
| 39 | α-cubebene | 0.160 | - | - |
| 40 | Isolatedene | 0.278 | 0.170 | - |
| 41 | Copaene | 0.308 | 0.150 | 0.059 |
| 42 | 2-pentene-1-ol, 2-methyl | 0.215 | - | - |
| 43 | α-gurjunene | 1.897 | 0.542 | 1.372 |
| 44 | Trans-caryophyllene | 0.539 | 0.227 | - |
| 45 | Aromadendrene | 12.773 | 7.444 | 3.925 |
| 46 | Epizonaren | 0.067 | - | - |
| 47 | α-humulene | 0.142 | 0.080 | - |
| 48 | alloaromadendrene | 2.520 | 1.632 | 2.023 |
| 49 | γ-gurjunene | 0.327 | - | 0.169 |
| 50 | α-copaene | 0.755 | - | - |
| 51 | β-selinene | 0.525 | - | 0.156 |
| 52 | β-panasinsene | 0.702 | - | - |
| 53 | ledene | 5.665 | - | 0.639 |
| 54 | α-murolene | 0.398 | - | 0.089 |
| 55 | Gerermacrene B | 0.099 | - | - |
| 56 | α-amorphene | 1.666 | 0.4 | - |
| 57 | cis-calamenene | 0.207 | - | - |
| 58 | δ-cadinene | 2.663 | - | 0.233 |
| 59 | Cadina-1, 4-diene | 0.103 | 0.045 | - |
| 60 | α-calacorene | 0.087 | 0.070 | - |
| 61 | α-cadinene | 0.163 | - | - |
| 62 | Ledane | 0.092 | - | - |
| 63 | Epiglobulol | 1.167 | 0.975 | 0.555 |
| 64 | β-maaliene | 0.306 | 0.253 | - |
| 65 | Palustrol | 0.190 | 0.221 | 0.142 |
| 66 | Spathulenol | 1.915 | 1.848 | - |
| 67 | Globulol | 5.997 | 5.419 | 3.054 |
| 68 | Veridiflorol | 1.243 | 1.044 | 0.881 |
| 69 | 1, 3-dimethyl-5-ethyladamantane | 0.285 | - | 0.250 |
| 70 | Ledol | 0.753 | 0.631 | - |
| 71 | γ-curcumene | 0.391 | - | - |
| 72 | Isoisopathulene | 0.300 | 0.217 | - |
| 73 | Taumuurolol | 1.580 | - | - |
| 74 | δ-cadinol | 0.231 | - | - |
| 75 | Guai-3, 9-diene | 0.292 | - | - |
| 76 | α-cadin | 0.806 | 0.444 | 0.106 |
| 77 | Vulgarol A | 0.129 | - | - |
| 78 | Hexadecanoic acid | 0.093 | 0.375 | 0.030 |
| 79 | 2-tridecanol | 0.028 | - | - |
| 80 | Hexadecanoic acid ethyl ester | 0.025 | - | - |
| 81 | Dectytretraglycol | 0.025 | - | - |
| 82 | Tricosane | 0.012 | - | - |

[^1]: *E. microtheca* leaves  
[^2]: *E. microtheca* flower  
[^3]: *E. viminalis* leaf
Continued table 4.

| No | Compound                                                                 | %   | %   | %   |
|----|--------------------------------------------------------------------------|-----|-----|-----|
| 83 | Benzothinitrate, m-phenethyl                                            | 0.032 | - | - |
| 84 | Pentacosane                                                              | 0.073 | - | - |
| 85 | Pentaethoxylated pentadecyl alcohol                                      | 0.036 | - | - |
| 86 | 1-cyclohexene-1-carboxaldehyde, 4-(1-methylthyl)                         | 0.170 | - | - |
| 87 | Cyclohexene, 3-methyl-6-(1-methylthyl)                                   | 0.108 | - | - |
| 88 | 2-cyclohexene-1-ol, 2-methyl-5-(1-methylthyl)-, trans-                  | 0.059 | - | - |
| 89 | 2, 3-dimethyl-cyclohexa-1, 3-diene                                       | 0.390 | - | - |
| 90 | α–cantholnic acid                                                        | 0.049 | - | - |
| 91 | Furan, 2, 3-dihydro-4-(1-methylpropyl)                                  | 0.458 | - | - |
| 92 | (E)-3-isopropyl-6-oxo-2-heptenal                                        | 0.058 | - | - |
| 93 | 1, 5, 5-trimethyl-6-methylene- cyclohexene                               | 0.056 | - | - |
| 94 | 2, 6, 10-trimethyl-2, 5, 7, 10-dioxido-dodeca-3, 11-diene-5-ol           | 0.268 | - | - |
| 95 | Tricyclo[6.3.0.1(2, 3)] undec-7-ene, 6, 10, 11-tetramethyle             | 0.138 | - | - |
| 96 | 1-methyl-4-isopropyl-cis-3-hydroxycyclohex-1-ene-6-one                  | 0.230 | - | - |
| 97 | 1H-cyclopropa[1]naphthalene, decahydro-1,1,3a-trimethyl-7-methylene-   | 0.235 | - | - |
|     | [1a.1a.alpha.,3a.alpha.,7a.beta.,7b.alpha.]                             |     |     |     |
| 98 | Naphthalene, 1, 2, 3, 4, 4a, 7-hexahydro-1, 6-dimethyl-4-(1-methylthyl) | 0.139 | - | - |
| 99 | Bicyclo[3.1.0]hex-2-ene,2-methyl-5-(1-methylthyl)                       | 0.026 | - | - |
| 100| (+)-(1R, 2S, 4R, 7R)-7-isopropyl-5-methyl-5-bicycle [2.2.2] octen-2-ol  | 0.140 | - | - |
| 101| 1, 6-dimethyl-2-cyano-3-ethyl-3-piperidine                               | 0.612 | - | - |

* E. microtheca leaves  
* E. microtheca flower  
* E. viminalis leave

**Discussion**

The comparison of results showed that there are some differences and similarities between the oil compositions of these Eucalyptus species. These results are shown in Table 4. The percentages of sesquiterpene and monoterpen compounds were similar in E. microtheca leaf oils, but the percentages of these components were less than those of E. viminalis leaf and E. microtheca flower oil. Studies have revealed that monoterpenes have insecticidal activities against the stored-product insects (Rajendran and Sriranjini, 2008; Papachristos et al., 2004). Our study showed that the major monoterpen compounds were in E. microtheca leaf and E. microtheca flower oil. These compounds consist of 1, 8-cineole, α-pinene, and β-pinene which have been shown to have insecticidal effects against some major insects that infect the stored crops (Rajendran and Sriranjini, 2008). Therefore, the essential oil of E. viminalis leaves and E. microtheca flowers from Zahedan, Iran could be a valuable alternative to chemical control strategies which have undesirable effects such as environmental pollution and direct toxicity to people. As it is evident from Table 3, the main component of the essential oils of E. viminalis leaves was 1, 8-cineole (57.757%), but it was not identified in E. microtheca leaf and flower oils. 1, 8-cineole, which is a terpenoid oxide present in many plant essential oils, displays antimicrobial, anti-inflammatory, and antinociceptive effects (Juergens et al., 2003; Santos and Rao, 2000).

The percentage of α-pinene in the oil of E. microtheca flowers and E. viminalis leaves was 16.246% and 13.379%, respectively, while in E. microtheca leaf oil it was less than 10%. Results indicated that some of E. microtheca leaf oil compounds such as α-phellandrene (16.487%) and aromadendrene (12.773%) were higher compared with E. microtheca flower and E. viminalis leaf oils. The oil
Essential oil composition of Eucalyptus microtheca and Eucalyptus viminalis

of E. microtheca flower contained β-pinene (11.082%), while it was less than 10% in other oils (E. microtheca and E. viminalis leave oil). The compounds such as α-pinene and β-pinene were the main components in the essential oil of E. microtheca flowers (16.246% and 11.082%) and E. viminalis leaves (13.379% and 0.555%), respectively. These compounds have been proven to be strong antioxidant and antimicrobial agents as emphasized elsewhere (Ho, 2010).

Chemical composition of the essential oil of Eucalyptus microtheca leaves growing in different geographical locations has been widely studied. Ogunwande et al., (2003) reported that in the volatile oil of Eucalyptus microtheca leaves from Nigeria, 1, 8-cineole (53.80%) was the main constituent in leaves (Ogunwande et al., 2003). Sefidkon et al., (2007) identified 22 components in the oil of E. microtheca from Kashan in the central region of Iran. The major components were 1, 8-cineole (34.0%), P-cymene (12.40%), α-pinene (10.70%), β-pinene (10.50%), and viridiﬁlore (5.20%) (Sefidkon et al., 2007). In another study, the major constituent of E. microtheca leaf oils from Semnan province was 1, 8-cineole (48.51%), followed by aromadendrene (18.31%), α-pinene (9.47%), and alloaromadendrene (4.67%) as the other dominant constituent (Hashemi-Moghaddam et al., 2013). There are many references about the composition of other Eucalyptus species in the literature. For example, the main constituents of the oil of E. sargentii from Isfahan province were 1, 8-cineole (55.48%), α-pinene (20.95 %), aromadendrene (6.45 %), and trans-pinocarveol (5.92%) (Safaei and Batooli, 2010). Assareh et al., (2007) also reported chemical composition of the essential oils of six Eucalyptus species from South West of Iran. The main components identified in E. intertexta oil were 1, 8-cineole (64.80%), terpinen-1-ol (7.20%), and α-pinene (5.70%); in E. largiflorens were 1, 8-cineole (47.0%), P-cymene (10.60%), and α-terpineol (8.50%); in E. kingsmillii were 1, 8-cineole (77.0%), α-pinene (8.70%), and camphene (3.80%); in E. dealbata were 1, 8-cineole (70.60%), α-pinene (13.0%), and terpinen-1-ol (3.70%). The major components of the oil of E. largiflorens were 1, 8-cineole (41.90%), α-pinene (13.70%), and aromadendrene (3.70%), while the major components of E. kruseana were bicyclogermacrene (28.80%), α-pinene (17.70%), and 1, 8-cineole (12.10%) (Assareh et al., 2007). Abd El-Mageed et al., (2011) identified chemical composition of the essential oils of some Eucalyptus species from Egypt. The major components identified in E. citridora oil were 3-hexen-1-ol (31.26%), cis-geraniol (19.66%), citronellol acetate (13.68%), 5-hepten-1-ol, 2, 6-dimethyl (13.14%), and citronellal (9.36%); in E. gomphocephala were dihydrocarveol acetate (50.82%) and P-cymene (10.62%); and the major components of E. resinifera were eucalyptol (51.97%), spathulenol (9.22%), α-terpineol acetate (8.78%), and trans-nerolidol (8.75%) (Abd El-Mageed et al., 2011). Mubarak et al., (2014) reported γ-terpinene (71.36%) and O-cymene (17.63%) as the major components of E. camaldulensis from Malaysia (Mubarak et al., 2014). Comparing the results of different studies showed that although 1, 8-cineole has not been identified in E. microtheca leaf and flower oil from Zahedan, it was as the major constituent of E. microtheca leaf oil from Nigeria (53.80%), Semnan (48.51%), Kashan (34.0%), and other Eucalyptus species (E. kingsmillii 77.0%, E. dealbata 70.60%, E. intertexta 64.80%, E. viminalis 57.75%, E. sargentii 55.48%, E. largiflorens 47.0%, and E. loxophleba 41.90%). The essential oil of some Eucalyptus species rich in 1, 8-cineole are widely used as a flavoring agent in production of softeners, soap, toothpaste, and other medicines (Sefidkon et al., 2007), but the percentage of this compound is different in species. This can
be related to the type of the plant, the plant parts (aerial or flower and leaf parts), the geographical regions of the plant growing places, and also the ecological conditions of the plant. In addition, α-pinene compound, which appeared as the major constituent in the oil of *E. sargentii* (20.95%), *E. kruseana* (17.70%), *E. viminalis* (13.379%), *E. loxophleba* (13.70%), *E. dealbata* (13.0%), and *E. microtheca* from Kashan (10.70%) and Semnan (9.47%), were present in low concentration in *E. microtheca* leaf oils (6.752%) from Zahedan. The amount of P-cymene compound in the oil of *E. microtheca* leave from Kashan (12.40%) also was much higher than that of *E. gomphocephala* (10.62%), *E. largiflorens* (10.60%), and *E. microtheca* (5.21%) from Zahedan.

In general, great quantitative and qualitative variations in volatile composition of *E. viminalis* and *E. microtheca* were seen between this and other studies. These variations may be due to the influence of geographical differences, environmental and growing conditions, physiological and biochemical states of plants, genetic factors, and different extraction and analytical procedures (Kokkini et al., 2004; Hassanpouraghdam et al., 2011).

It can be concluded that the oils of these two *Eucalyptus* species are good sources of natural antioxidants to be used in medicinal and food products to promote human health and prevent diseases, which should be investigated in further studies. In addition, regarding environmental problem and human health, these plants could be an alternative source of insecticide agents because many of their components have little or no harmful effects on humans and environment.

**Acknowledgments**

We are thankful to the University of Sistan and Baluchestan Research Council for the partial support of this research.

**Conflict of interest**

There is not any conflict of interest in this study.

**References**

Abd El-Mageed AA, Osman AK, Tawfik AQ, Mohammed HA. 2011. Chemical composition of the essential oils of four *Eucalyptus* species (Myrtaceae) from Egypt. Res J Phytochem, 5: 115-122.

Asghari J, Mazaheritehrani K. 2010. Pinacol coupling of carbonyl compounds by using microwave irradiation. Iran J Med Aromatic, 26: 184-195.

Assareh MH, Jaimand K, Rezaee MB. 2007. Chemical compositions of the essential oils of six *Eucalyptus* species (Myrtaceae) from South West of Iran. J Essent oil Res, 19: 8.

Ghasemi Y, Faridi P, Mehregan I, Mohaghehzadeh A. 2005. Ferula gummosa fruits: an aromatic antimicrobial agent. Chem Nat Comp, 41: 311-314.

Grassmann J, Hippeli S, Dornisch K, Rohnert U, Beuscher N, Elstner EF. 2000. Antioxidant properties of essential oils. Possible explanations for their anti-inflammatory effects. Arzneimittelforschung, 50: 135-139.

Hashemi-Moghaddam H, Kalatejari A, Afshari H, Ebadi AH. 2013. Microwave accelerated distillation of essential oils from the leaves of *Eucalyptus microtheca*: Optimization and comparison with conventional hydrodistillation. Asian J Chem, 25: 5423-5427.

Hassanpouraghdam MB, Akhgari AB, Aazami MA, Emarat-Pardaz J. 2010. New menthone type of *Mentha pulegium* L. volatile oil from Northwest Iran. Czech J Food Sci, 29: 285-290.

Ho JC. 2010. Chemical composition and bioactivity of essential oil of seed and leaf from *Alpinia speciosa* grown in Taiwan. J Chinese Chem Soc, 57:758-757.

Jahan M, Warsi MK, Khatoon F. 2011. Studies on Antibacterial Property of *Eucalyptus-The Aromatic Plant*. Int J Pharm Sci Rev Res, 7:86-88.

Juergens UR, Dethlefsen U, Steinkamp G, Gillissen A, Repges R, Vetter H. 2003. Anti-inflammatory activity of 1, 8-cineole (eucalyptol) in bronchial asthma: a double
Essential oil composition of *Eucalyptus microtheca* and *Eucalyptus viminalis*

blind placebo-controlled trial. Respiratory Med, 97: 250-6.

Kokkini S, Hanlidou E, Karousou R, Lanaras T. 2004. Clinical variation of Mentha pulegium essential oils along the climatic gradient of Greece. J Essent Oil Res, 16: 588-593.

Mozaffarian V. 1996. A dictionary of Iranian plant names, pp. 56. Tehran: Farhang Moaser publisher.

Mubarak EE, Mohajer S, Ahmed I, Mat Taha R. 2014. Essential oil compositions from leaves of Eucalyptus camaldulensis and Callistemon viminalis originated from Malaysia. Int Proc Chem Biol Environ Eng, 70: 137-141.

Nagpal N, Shah G, Arora NM, Shri R, Arya Y. 2010. Phytochemical and Pharmacological aspects of Eucalyptus genus. Int J Pharm Sci Rev Res, 1: 28–36.

Ogunwande IA, Olawore NO, Adeline KA, Konig WA. 2003. Chemical composition of the essential oils from the leaves of three Eucalyptus species growing in Nigeria. J Essent Oil, 15: 297-301.

Papachristos DP, Karamanoli KL, Stamopoulos DC, Menkissoglu-Spiroudi U. 2004. The relationship between the chemical composition of three essential oils and their insecticidal activity against Acanthoscelides obtectus (Say). Pest Manag Sci, 60: 514-20.

Pearson M. 1993. Eucalyptus oil distilleries in Australia. J Australas Historical Archaeol, 11: 99-107.

Rajendran S, Sriranjini V. 2008. Plant products as fumigant for stored-product insect control. J Store Pro Res, 44: 126-35.

Reynolds JEF, Prasad AB. 1982. Martindale-the extra pharmacopoeia, pp. 1017-1018. London, Pharmaceutical Press.

Sadlon AE, Lamson DW. 2010. Immune-modifying and antimicrobial effects of Eucalyptus oil and simple inhalation devices. Altern Med Rev, 15: 33–47.

Safaei J, Batooli H. 2010. Chemical composition and antimicrobial activity of the volatile oil of Eucalyptus sargentii cultivated in central Iran. Int J Green Pharm, 4: 174-177.

Santos FA, Rao VS. 2000. Anti-inflammatory and antinociceptive effects of 1, 8-cineole, a terpenoid oxide present in many plant essential oils. Phytother Res, 14: 240-244.

Sastri BN. 2002. The Wealth of India. A Dictionary of India Raw Materials and Industrial Products. Raw Materials. New Delhi: Council of Scientific and Industrial Research, pp. 203-204.

Sefidkon F, Assareh MH, Abravesh Z, Barazandeh MM. 2007. Chemical composition of the essential oils of four cultivated Eucalyptus species in Iran as medicinal plants (E. microtheca, E. spathulata, E. largiflorens and E. torquata). Iran J Pharm Res, 6: 135-140.

Shahidi F. 2000. Antioxidants in food and food antioxidants. Nahrung, 44: 158-163.