Abstract: In this study, the yields and composition of essential oils obtained from the cones of Pinaceae family species natively grown in Turkey were investigated. Essential oils were obtained by hydrodistillation. Oil yields were 0.13-0.48 mL/100 g in pine cones, 0.42-0.59 mL/100g in fir, 0.36 mL/100g in spruce and 0.37 mL/100g in cedar. While α-pinene (47.1-14.8%) was the main constituent of P. sylvestris, P. nigra and P. halepensis, limonene (62.8%) in P. pinea and β-pinene (39.6%) in P. brutia were found in higher amounts. Like in P. pinea, limonene was the main compound in Cedrus libani (22.7%). In fir species the major compounds were α-pinene (70.6-53.0%) and β-pinene (10.9-8.2%). Contrary to other species β-pinene (32.7%) was found as a major compound in Picea orientalis.

Keywords: essential oil; terpenes; Pinaceae, fir, cones; GC/MS

1. Introduction

Essential oils are used in many industrial fields for the perfuming and flavouring of various products [1,2]. Essential oils are natural, complex, multi-component systems composed mainly of terpenes, in addition to some other non-terpene components. Several techniques can be used to extract
essential oils from different parts of the aromatic plant, including water or steam distillation, solvent extraction, expression under pressure, supercritical fluid and subcritical water extractions [3].

Essential oils from aromatic and medicinal plants have been known since antiquity to possess biological activity, most notably antibacterial, antifungal and antioxidant properties. With growing interest in the use of essential oils in both the food and pharmaceutical industries, the systematic examination of plant extracts for these properties has become increasingly important. The terpene composition of seed cone oleoresin has been reported, and headspace techniques were developed to isolate volatile compounds from plant odour compounds in order to determine the composition of the host odour, which is attractive to insects [4-8].

Turkey, because of its geographical position at the crossing region of temperate continental and Mediterranean climates, is rich in coniferous woods that grow in different regions of the country, occupying about half of the county’s total forest area [9,10].

Five pine species are recorded in Turkey (Pinus brutia, Pinus nigra, Pinus sylvestris, Pinus pinea, Pinus halepensis) and three of them (P. brutia, P. nigra, P. sylvestris) are commercially utilized. Previous studies on Pinus species in Turkey were mainly focused on improving the yield of turpentine production. Pine oils are widely used as fragrances in cosmetics, as flavoring additives for food and beverages, as scenting agents in a variety of household products, and intermediates in the synthesis of other perfume chemicals [11,12].

Fir species exhibit parallel variation in indumentum characteristics and in the presence or absence of resinous buds. These features are well correlated with their geographical distribution [13]. Fir species are represented in Turkey by Abies nordmanniana (Stev.) Spach., Abies bornmulleriana Mattf., Abies equi-trojani (Asch.&Sint. ex Boiss.) Mattf. and Abies cilicica (Ant. et Kotschy) Carr. A. bornmulleriana, A. equi-trojani and A. cilicica subsp. isaurica are also endemic plants in Turkey [14,15]. A. nordmanniana, A. bornmulleriana, A. equi trojani are distributed in northern Turkey and A. cilicica (Ant. et Kotschy) Carr. is distributed in southern Turkey [13,16–18].

Cones of some coniferous species find uses in industry [19]. Essential oil constituents of the cones of the family Pinaceae are poorly known, although there have been some studies on the antioxidant activity, terpenoids, steroids, anti-HIV activity, procyanidins, etc. of all the Pinaceae cones [20-22].

2. Results and Discussion

Oil yields of pine species are given in Figure 1 and those of fir, spruce and cedar species given in Figure 2. Evidently, the highest oil content (0.48%) was found in P. brutia and the lowest (0.13%) in P. sylvestris among the pine species. The essential oil compounds of pine cones are given in Table 1 and those of fir, spruce and cedar in Table 2. As can be seen from these tables, the main compounds were as follows: α-pinene, β-pinene, β-myrcene, Δ3-carene, limonene and β-caryophyllene. α-Pinene was the major compound in the cones of Pinaceae family. This compound was also found to account for more than 50% of the contents in the fir species too. α-Pinene was also identified as a major compound in P. nigra (45.36%) and P. halepensis (47.09%). Except for P. brutia and P. orientalis, β-pinene was found to be the second most important component in all cones. In the P. brutia (39.56%) and P. orientalis (32.67%) samples this compound was the most abundant compound. Limonene was the dominant component in P. pinea (69.54%, combined with β-phellandrene) and in C. libani
(17.71%). This terpene is used as an antimicrobial inhibitor in the food industry. Although β-caryophyllene, an important sesquiterpene, was found to be less than 1% in the Abies species, the amount of this compound was more than 10% in *P. halepensis* (11.22%).

![Figure 1. Essential Oil Yields of Pine Species from Turkey (%).](image1)

As it can be seen in Figure 2, the highest essential oil yield of cones was found in *A. equi trojani* with 0.59% and the lowest was in *P. orientalis* at 0.36%. Among the *Pinaceae* family the highest essential oil yield was observed in *A. equi trojani* and the lowest was determined in *P. sylvestris*.

![Figure 2. Essential Oil Yields of Fir Spruce and Cedar species from Turkey (%).](image2)

Terpene groups in the essential oils of *Pinaceae* cones were investigated. The terpenes were grouped into monoterpene hydrocarbons, monoterpane alcohols, sesquiterpene hydrocarbons, sesquiterpene alcohols and diterpenes. Those terpene groups and their amounts in different cones are given in Table 3 and Figure 3. Monoterpene hydrocarbons was found to be at the highest level in *A.*
cilicica (93.14%), the highest level of monoterpane alcohols was found in A. equi-trojani (10.70%), sesquiterpene hydrocarbons were highest in P. halepensis (20.82%), diterpenes were the highest in P. sylvestris at 28.94%.

Table 1. Percent (w/w %) composition\(^1\) of components in Pines.

| Nr | RI  | Compounds\(^2\) | P. pinea | P. brutia | P. sylvestris | P. nigra | P. halepensis |
|----|-----|-----------------|---------|----------|---------------|---------|---------------|
| 1  | 925 | tricyclene      | 0.02    | 0.04     | 0.05          | 0.08    | 0.16          |
| 2  | 936 | α-Pinene        | 17.90   | 30.91    | 14.76         | 45.36   | 47.09         |
| 3  | 949 | camphene        | 0.32    | 0.64     | 0.60          | 1.04    | 0.88          |
| 4  | 955 | 2,4 (10)-Thujadiene | 0.19 | 0.15     | 0.62          | 0.39    | 0.60          |
| 5  | 978 | β-Pinene        | 1.70    | 39.56    | 1.78          | 1.50    | 2.75          |
| 6  | 989 | β-Myrcene       | 0.79    | 1.13     | 0.17          | 0.16    | 6.25          |
| 7  | 1010| Δ\(^3\)-carene   | -       | 7.80     | -             | -       | 1.72          |
| 8  | 1021| p-cymene        | 0.29    | 0.37     | 0.47          | 0.30    | 0.42          |
| 9  | 1026| limonene + beta-phellandrene | 69.54 | 2.05     | 0.48          | 1.88    | 0.79          |
| 10 | 1087| α-terpinolene   | 0.04    | 0.48     | 0.04          | 0.03    | 0.09          |
| 11 | 1088| p-cymenene      | 0.13    | 0.14     | 0.23          | 0.16    | 0.21          |
| 12 | 1123| α-campholen aldehyde | 0.27 | 0.13     | 0.87          | 0.47    | 0.45          |
| 13 | 1135| trans-pinocarveol| 0.47    | 1.38     | 0.91          | 0.49    | 0.88          |
| 14 | 1138| cis-verbenol    | 0.06    | 0.03     | 0.02          | 0.02    | 0.24          |
| 15 | 1141| trans-verbenol  | 0.25    | 0.07     | 0.05          | 0.07    | 0.71          |
| 16 | 1145| p-menth-1,5-dien-8-ol\(^3\) | 0.08 | 0.11     | 0.49          | 0.26    | 0.38          |
| 17 | 1156| pinocarvone     | 0.10    | 0.42     | 0.22          | 0.15    | 0.27          |
| 18 | 1162| borneol         | -       | 0.10     | 0.03          | 0.07    | 0.11          |
| 19 | 1165| p-menth-1,5-dien-8-ol | 0.18 | 0.24     | 1.07          | 0.42    | 1.03          |
| 20 | 1177| 4-terpineol     | 0.08    | 0.26     | 0.01          | 0.03    | 0.08          |
| 21 | 1190| α-terpineol     | 0.14    | 0.93     | 0.41          | 0.77    | 0.30          |
| 22 | 1194| myrtenal + myrenol | 0.47 | 1.30     | 1.22          | 0.58    | 0.91          |
| 23 | 1206| verbenone       | 0.08    | 0.08     | 0.59          | 0.12    | 0.22          |
| 24 | 1218| trans-carveol   | 0.64    | 0.04     | 0.04          | 0.09    | 0.12          |
| 25 | 1286| bornyl acetate  | 0.26    | 0.22     | 0.02          | 0.69    | 0.64          |
| 26 | 1348| α-longipinene   | 0.18    | -        | -             | -       | -             |
| 27 | 1374| α-copaene       | -       | 0.06     | 0.06          | 0.24    | 0.34          |
| 28 | 1403| longifolene     | 0.52    | 0.06     | 1.16          | 0.34    | -             |
| 29 | 1420| β-caryophyllene | 0.73    | 5.01     | 2.87          | 6.73    | 11.22         |
| 30 | 1453| α-humulene      | 0.10    | 1.25     | 0.61          | 1.48    | 2.65          |
| 31 | 1484| germacrene-D    | -       | 0.38     | 0.01          | 0.06    | 0.02          |
| 32 | 1502| α-murolene      | -       | 0.06     | 0.02          | 0.11    | 0.31          |
| 33 | 1514| gamma-cadinene  | -       | 0.04     | 0.01          | 0.09    | 0.25          |
| 34 | 1525| trans-calamenene + Δ-cadinene | - | 0.13     | 0.01          | 0.28    | 0.32          |
| 35 | 1578| caryophyllene oxide | 0.33 | 1.61     | 12.58         | 8.05    | 7.47          |
| 36 | 1607| humulene epoxide | -        | 0.23     | 1.48          | 1.07    | 1.11          |
| 37 | 1960| 19-norabieta-8,11,13-triene\(^3\) | 0.02 | 0.03     | 4.75          | 0.70    | 0.37          |
| 38 | 1974| isopimaradiene\(^5\) | -        | -        | -             | 0.26    | 0.81          |
| 39 | 1974| manoyl oxide    | -       | 0.33     | -             | -       | -             |
| 40 | 1987| norabieta-4(18),8,11,13-tetraene\(^3\) | 0.02 | 0.03     | 4.59          | 0.50    | 0.17          |
| 41 | 2002| manoyl oxide    | 0.25    | -        | -             | -       | -             |
| 42 | 2005| palustradiene\(^3\) | -        | 0.08     | 0.39          | 0.87    | 0.39          |
| 43 | 2007| 18-norabieta-8,11,13-triene\(^3\) | 0.11 | 0.14     | 15.78         | 3.42    | 1.17          |
| 44 | 2055| abiet-8,11,13-triene | 0.06 | 0.14     | 5.20          | 1.48    | 0.78          |
| 45 | 2083| abiet-7,13-diene\(^3\) | -        | 0.09     | 0.96          | 0.33    | 0.83          |
| 46 | 2158| neobietadiene\(^3\) + cis-abienol\(^3\) | 0.44 | 0.05     | 0.10          | 0.03    | 0.68          |
Table 1. Cont.

| Nr | RI  | Compounds | 47 | 2174 | pimaral<sup>1</sup> | 5801 | 0.05 | - | 0.60 | 0.91 | 0.01 |
|----|-----|-----------|----|------|-------------------|------|------|---|------|---|------|---|
| 48 | 2230 | isopimaral<sup>1</sup> | -  | 0.05 | 0.31 | 0.62 | 0.41 |
| 49 | 2247 | palustral<sup>3</sup> | 0.17 | 1.54 | 2.59 | 0.83 |
| 50 | 2278 | dehydroabietal | 0.07 | 0.12 | 7.12 | 3.33 | 0.78 |
| 51 | 2313 | abietal | 0.06 | 0.06 | 0.83 | 0.61 | 0.60 |
| 52 | 2372 | neoabietal<sup>3</sup> | 0.04 | 0.03 | 0.24 | 0.45 | 0.39 |

Sum of minor and unidentified components 2.97 1.27 13.63 10.32 0.79
Total 100 100 100 100 100

1) peak area percents from total eluted components on GC-MS; 2) identified by MS and retention index (RI) data from literature (R.P. Adams, 2007); 3) identification was based on MS-data only

Table 2. Percent (w/w %) composition<sup>1</sup> of components in fir, spruce and cedar.

| Nr | RI  | Compounds<sup>3</sup> | A. nordmanniana | A. ciliicica | A. equi-trojani | A. bornmuelleriana | P. orientalis | C. libani |
|----|-----|----------------------|-----------------|-------------|---------------|-------------------|--------------|----------|
| 1  | 925 | tricyclene           | 0.08 | 0.04 | 0.11 | 0.17 | 0.47 | 0.03 |
| 2  | 936 | α-pinene            | 65.74 | 53.03 | 64.21 | 70.58 | 23.41 | 12.30 |
| 3  | 949 | camphene            | 0.89 | 0.60 | 0.78 | 0.93 | 1.13 | 0.24 |
| 4  | 955 | 2,4 (10)-thujadiene | 0.79 | 0.07 | 0.97 | 0.44 | 0.41 | 0.04 |
| 5  | 978 | β-pinene            | 9.62 | 10.88 | 8.17 | 8.60 | 32.67 | 8.25 |
| 6  | 989 | β-myrcene           | 0.49 | 21.33 | 0.26 | 2.54 | 2.50 | 4.94 |
| 7  | 1003 | 1,5,8-p-menthatriene<sup>3</sup> | 0.23 | 0.03 | 0.23 | 0.06 | 0.20 | 0.05 |
| 8  | 1010 | 3-carene           | 0.88 | 1.12 | -   | 0.03 | 0.13 | 0.11 |
| 9  | 1021 | p-cymene          | 0.36 | 0.15 | 0.54 | 0.34 | 0.45 | 0.46 |
| 10 | 1026 | limonene          | 7.24 | 5.43 | 1.79 | 1.16 | 14.99 | 17.71 |
| 11 | 1087 | α-terpinolene      | 0.10 | 0.24 | 0.13 | 0.10 | 0.19 | 0.29 |
| 12 | 1088 | p-cymenene        | 0.21 | 0.07 | 0.50 | 0.22 | 0.16 | 0.10 |
| 13 | 1101 | perillene          | -   | 0.17 | -   | 0.05 | 0.15 | 0.08 |
| 14 | 1123 | α-campholenaldehyde | 0.51 | 0.04 | 0.76 | 0.20 | 0.43 | 0.01 |
| 15 | 1130 | 4-acetyl-1-methycyclohexene<sup>3</sup> | 0.05 | 0.01 | -   | -   | 0.04 | 0.18 |
| 16 | 1135 | trans-pinocarveol  | 1.18 | 0.16 | 2.17 | 0.57 | 2.62 | 0.18 |
| 17 | 1138 | cis-verbenol       | 0.20 | 0.01 | 0.13 | -   | 0.07 | 0.01 |
| 18 | 1141 | trans-verbenol     | 0.79 | 0.04 | 0.58 | 0.24 | 0.16 | 0.02 |
| 19 | 1145 | p-mentha-1,5-dien-8-ol<sup>3</sup> | 0.45 | 0.04 | 0.75 | 0.18 | 0.28 | 0.01 |
| 20 | 1156 | pinocarvone        | 0.21 | 0.06 | 0.35 | 0.07 | 0.75 | 0.04 |
| 21 | 1162 | borneol            | 0.11 | 0.05 | 0.17 | 0.30 | 0.40 | 0.02 |
| 22 | 1165 | p-mentha-1,5-dien-8-ol | 0.99 | 0.03 | 1.23 | 0.25 | 0.72 | 0.03 |
| 23 | 1177 | 4-terpineol        | 0.07 | 0.08 | 0.14 | 0.11 | 0.29 | 0.14 |
| 24 | 1190 | α-terpineol        | 0.47 | 1.17 | 1.52 | 0.75 | 0.77 | 0.33 |
| 25 | 1194 | myrtalen + myrtenol | 1.19 | 0.21 | 2.42 | 0.64 | 3.02 | 0.18 |
| 26 | 1206 | verbenone          | 0.84 | 0.06 | 4.12 | -   | 0.27 | 0.01 |
| 27 | 1218 | trans-carveol      | 0.20 | 0.02 | 0.31 | 0.05 | 0.30 | 0.08 |
| 28 | 1235 | thymol methyl ether | -   | -   | -   | -   | 0.04 | 0.17 |
| 29 | 1242 | carvone            | 0.08 | 0.02 | 0.11 | 0.02 | 0.24 | 0.08 |
| 30 | 1286 | bornyl acetate     | -   | -   | 0.32 | -   | 1.94 | 0.18 |
| 31 | 1374 | α-copaene          | -   | 0.02 | 0.10 | 0.13 | 0.91 | 1.17 |
| 32 | 1420 | β-caryophyllene    | 0.95 | 0.04 | 0.25 | 0.42 | 1.35 | 0.44 |
| 33 | 1453 | α-humulene         | 0.70 | 0.02 | 0.13 | 0.25 | 0.42 | 0.10 |
| 34 | 1464 | β-farnesene<sup>3</sup> | 0.01 | 0.02 | - | - | - | 0.30 |
| 35 | 1478 | gamma-muurolene    | 0.01 | 0.09 | 0.08 | 0.24 | 0.03 | 0.08 |
| 36 | 1484 | germacrene-D       | 0.02 | 0.88 | 1.01 | 1.85 | 0.12 | 0.01 |
Table 2. Cont.

|   |   |   |   |   |   |   |
|---|---|---|---|---|---|---|
| 37| 1502| α-muurolene | 0.02 | 0.04 | 0.19 | 0.46 | 0.29 | 0.13 |
| 38| 1514| gamma-cadinene | 0.01 | 0.06 | 0.09 | 0.25 | -   | 0.02 |
| 39| 1525| trans-calamenene + Δ-cadinene | 0.04 | 0.12 | 0.40 | 0.65 | 0.12 | 0.20 |
| 40| 1546| cis-α-bisabolene | 0.64 | 0.62 | 0.03 | 0.06 | 0.07 | 4.66 |
| 41| 1578| caryophyllene oxide | 0.67 | -   | 0.21 | 0.26 | 2.16 | 0.18 |
| 42| 1607| humulene epoxide | 0.28 | -   | -   | 0.14 | 0.36 | 0.03 |
| 43| 1642| α-muurolol | 0.03 | 0.06 | 0.34 | 0.63 | 0.02 | 0.01 |
| 44| 1974| manoyl oxide | 0.07 | 0.13 | 0.08 | 0.06 | 0.12 | 0.26 |
| 45| 2005| palustradiene | -   | -   | -   | -   | 0.10 | 7.05 |
| 46| 2007| 18-norabieta-8,11,13-triene | 0.09 | 0.05 | 0.17 | 0.03 | 0.28 | -   |
| 47| 2055| abiet-a-8,11,13-triene | 0.02 | 0.16 | 0.07 | 0.02 | 0.27 | 17.00 |
| 48| 2083| abiet-7,13-diene | 0.07 | 0.09 | 0.12 | 0.02 | 1.11 | 8.32 |
| 49| 2158| neoabietadiene | 0.03 | 0.03 | 0.04 | -   | 0.10 | 0.87 |
| 50| 2247| palustral | 0.01 | 0.13 | 0.04 | -   | 0.05 | 0.33 |
| 51| 2278| dehydroabietal | 0.03 | 0.16 | 0.10 | 0.01 | 0.06 | 0.36 |
| 52| 2304| 7-oxo-abiet-a-8,11,13-triene | -   | -   | -   | -   | -   | 1.07 |
| 53| 2313| abietal | 0.15 | 0.20 | 0.35 | 0.05 | 0.55 | 0.34 |
| 54| 2372| neoabietal | 0.03 | 0.05 | 0.07 | 0.01 | 0.55 | 0.08 |

Sum of minor and unidentified components 2.15 1.87 3.36 5.86 2.26 10.75

1) peak area percents from total eluted components on GC-MS; 2) identified by MS and retention index (RI) data from literature (R.P. Adams, 2007); 3) identification was based on MS-data only.

Table 3. Terpene groups in Pinaceae family cones (%).

| Species          | MTHK | MT-OL | STHK | ST-OL | Diterpene | Others |
|------------------|------|-------|------|-------|-----------|--------|
| A.cilicica       | 93.14| 1.20  | 1.31 | -     | 0.66      | 3.69   |
| A.nordmanniana   | 85.72| 4.10  | 2.80 | -     | 0.39      | 6.99   |
| A.equi-trojani   | 77.22| 10.70 | 2.85 | 0.10  | 0.65      | 8.48   |
| A.bornmülleriana| 84.00| 1.80  | 4.17 | 0.41  | 0.18      | 9.44   |
| P. orientalis    | 78.40| 7.55  | 6.16 | -     | 1.83      | 6.06   |
| C. libani        | 57.30| 0.90  | 6.78 | -     | 27.01     | 8.01   |
| P.sylvestris     | 19.31| 2.28  | 13.14| -     | 28.94     | 36.33  |
| P.nigra          | 51.08| 1.44  | 15.70| -     | 16.08     | 15.70  |
| P.halepensis     | 54.50| 1.70  | 20.82| -     | 4.10      | 18.88  |
| P.pinea          | 82.62| 0.64  | 1.34 | -     | 0.67      | 14.73  |
| P.brutia         | 83.94| 3.53  | 8.11 | -     | 0.62      | 3.80   |

MTHK: Monoterpene Hydrocarbons; MT-OL: Monoterpene alcohol; STHK: Sesquiterpene Hydrocarbons; ST-OL: Sesquiterpene alcohols.
3. Experimental

3.1. Plant Material

Eleven different coniferous cones were used in this study. Four different fir species (A. equi-trojani, A. ciliicica, A. nordmanniana, A. bornmülleriana) and five different pine species (P. sylvestris, P. nigra, P. halepensis, P. pinea, P. brutia) and also C. libani and P. orientalis were collected directly from different parts of the trees. Approximately 5 kg of cones were collected for each species from their growth sites just at the time of maturity and stored in -24 °C until the laboratory studies. Species names, sampling site, collection date, climate zone, and altitude of all specimens are listed in Table 4.

Table 4. Names, collection place, climate zone, date and altitude of the analysed tree species.

| Species             | Sampling Site            | Climate Zone | Collection Date | Altitude |
|---------------------|--------------------------|--------------|-----------------|----------|
| A. equi-trojani     | Edremit-West Turkey      | Mediterranean| October, 2007   | 800 m    |
| A. ciliicica        | Adana-South Turkey       | Mediterranean| May, 2007       | 700 m    |
| A. nordmanniana     | Trabzon-Northeast Turkey | Temperate    | October, 2007   | 1,000 m  |
| A. bornmülleriana   | Bartin-Northwest Turkey  | Temperate    | October, 2007   | 1,100 m  |
| P. orientalis       | Trabzon-Northeast Turkey | Temperate    | October, 2007   | 1,200 m  |
| C. libani           | Adana-South Turkey       | Mediterranean| May, 2007       | 1,300 m  |
| P. halepensis       | Gokova, Mugla-West Turkey| Mediterranean| November, 2007  | 900 m    |
| P. pinea            | Bartin-Northwest Turkey  | Temperate    | March, 2007     | 600 m    |
| P. sylvestris       | Bartin-Northwest Turkey  | Temperate    | September, 2007 | 700 m    |
| P. nigra            | Bartin-Northwest Turkey  | Temperate    | September, 2007 | 750 m    |
| P. brutia           | Izmir-West Turkey        | Mediterranean| May, 2007       | 850 m    |

3.2. Isolation of the Essential Oil

The essential oils of each sample were obtained by hydrodistillation with a Clevenger apparatus (ILDAM CAM Ltd. Ankara-Turkey) using 100 g of fresh cones. The oils were collected for 3 h. and dried over anhydrous sodium sulphate in a sealed vial until used [23]. The results calculated as freeze dried samples were given in mL/100 g per dry raw material and given in Figures 1 and 2 [24,25].

3.3. Essential Oil Analysis

The GC-MS analyses for the hydrodistilled samples were performed using an HP 6890-5973 GC-MSD instrument (Agilent Technologies Canada Inc., Mississauga, ON, Canada) equipped with an HP-5 capillary column (25 m/0.25 mm i.d., 0.11 μm film thickness). Helium was used as the carrier gas at
1.0 mL/min flow rate. The column oven was temperature programmed starting from 50 °C (0.5 min) to 250 °C, at 4 °C/min heating rate. After 10 min of hold time at 250 °C the temperature program was continued at 10 °C/min to 290 °C for 15 min. The split-injector and MS-transfer line were held at 260 °C and 280 °C, respectively. The MSD was operated in electron impact ionisation mode at 70 eV electron energy [26]. Compound identifications was based on mass spectra, referring to NIST98 and WILEY275 mass spectral libraries, and also comparing measured retention index (RI) values of components with literature data [27]. The quantitative area-percent measurements were based on peak-areas from the GC-MS data. Although, some researchers [28,29] have used cluster analysis to evaluate statistical data, the preliminary studies showed that there was no statistically significant differences between extraction and injections since the material was collected at one time [30-33]. Therefore, no statistical analysis was applied in this study.

4. Conclusions

Comparing the essential oil yields of Pinacea family tree cones, pine species yielded less than fir species. However, on a volatile compound basis, pine species yielded more than fir species except for α-pinene and β-pinene. On the other hand, monoterpen e hydrocarbon compounds, an important group of terpenes, were more abundant in fir species rather than in pine species.

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References and Notes

1. Kivanc, A.; Akgul, A. Antibacterial activities of essential oils from Turkish spices and citrus. *Flavour Fragr. J.* 1986, 1, 75-179.
2. Bagci, E.; Digrak, M. Antibacterial activities of essential oils from Turkish spices and citrus. *Flavour Fragr. J.* 1996, 11, 251-256.
3. Edris, E. Pharmaceutical and Therapeutic Potentials of Essential Oils and Their Individual Volatile Constituents: A Review. *Phytother. Res.* 2007, 21, 308-323.
4. Baratta, M.T.; Damien Dorman, H.J.; Deans, S.G.; Cristina Figueiredo, A.; Barroso, J.G.; Ruberto G. Antimicrobial and antioxidant properties of some commercial essential oils. *Flavour Fragr. J.* 1998, 13, 235–244.
5. Gabriela, M.; Lucia, B.; Giuseppe, S. Antimicrobial properties of the linalol-rich essential oil of Hyssopus officinalis L. var decumbens (Lamiaceae). *Flavour Fragr. J.* 1998, 13, 289–294.
6. Vila, R.; Valenzuela, L.; Bello, H.; Canigueral, S.; Montes, M.; Adzet, T. Composition and antimicrobial activity of the essential oil of Peumus boldus leaves. *Planta Med.* 1999, 65, 178-179.
7. Teissedre, P.L.; Waterhouse, A.L. Inhibition of oxidation of human low-density lipoproteins by phenolic substances in different essential oils varieties. *J. Agric. Food Chem.* 2000, 48, 3801-3805.

8. Kurose, K.; Okamura, D.; Yataga, M. Inhibition of oxidation of human low-density lipoproteins by phenolic substances in different essential oils varieties. *Flavour Fragr. J.* 2007, 22, 10-20.

9. Muthoo, M.K. *Forests and Forestry in Turkey*; Food and Agriculture Organization of the United Nations (FAO): Ankara, Turkey, 1997.

10. Hafizoglu, H.; Usta, M. Chemical composition of coniferous wood species occurring in Turkey. *Holz Roh-Werkstoff* 2005, 63, 83-85.

11. Ustun, O.; Sezik, E., Kurkcuoglu, M.; Baser, K.H.C. Study Of The Essential Oil Composition Of *Pinus sylvestris* From Turkey. *Chem. Nat. Compd.* 2006, 42, 26-31.

12. Sezik, E.; Osman, U.; Demirci, B.; Baser, K.H.C. Composition of the essential oils of *Pinus nigra* Arnold from Turkey. *Turk. J. Chem.* 2010, 34, 313-325.

13. Bagci, E.; Baser, K.H.C.; Kurkcuoglu, M.; Baabac, T.; Celik, S. Study of the essential oil composition of two subspecies of *Abies cilicica* (Ant. et Kotschy) Carr. from Turkey. *Flavour Fragr. J.* 1999, 14, 47-49.

14. Yaltirik, F. *Dendrology, Gymnospermae*, 2nd ed.; University Press: Istanbul, Turkey, 1993; pp. 386-3443.

15. Saribas, M. *Dendrology, Gymnospermae*, I; Donmez Press: Bartin, Turkey, 2008; pp. 192-198.

16. Aytug, B. The Morphological and Anatomical Researches on Abies Species (Abies Tourn.) of Turkey. *J. For. Fac. Istanbul* 1959, 49, 165-217.

17. Davis, P.H. *Flora of Turkey and the East Aegean Islands*; University Press: Edinburgh, UK, 1965; Volume 1, pp. 67-69.

18. Dayisoylu, K.S.; Alma, M.H. Chemical analysis of essential oils from cone’s rosin of Cilician fir (*Abies cilicica* subsp. cilicica). *Afr. J. Biotechnol.* 2009, 8, 3502-3505.

19. Villagomez, H.Z., Peterson, D.M., Herrin, L., Young, R.A. Antioxidant activity of different components of pine species. *Holzforschung* 2005, 59,156-162.

20. Sakagami, H.; Kawazoe, N.; Komatsu, N.; Simpson, A.; Nonoyama, M.; Konno, K.; Yoshida, T.; Kuroiwa, Y.; Tanuma, S. Antitumor, antiviral and immunopotentiating activities of pine cone extracts:potential medicinal efficacy of natural and synthetic lignin-related materials. *Anti-Cancer Res.* 1991, 11, 881-888.

21. Tanaka, R.; Matsunaga, S.; Zasashi, Y. Terpenoids and steroids from several euphorbiaceae and pinaceae plants. *J. Pharm. Soc. Jpn.* 1999, 119, 319-39.

22. Sakar, M.K.; Ercil, D.; Engelshtowe, R. Procyanidins in cones of *Pinus halepensis*. *Int. J. Pharmacog.* 1991, 29, 221-224.

23. Shahmir, F.; Ahmadi, L.; Mirza, M.; Korori, S.A.A. Secretory elements of needles and berries of *Juniperus communis* L. ssp. *communis* and its volatile constituents. *Flavour Fragr. J.* 2003, 18, 425-428.

24. Kurose, K.; Okamura, D.; Yatagai, M. Composition of the essential oils from the leaves of nine *Pinus* species and the cones of three of *Pinus* species. *Flavour Fragr. J.* 2007, 22, 10-20.
25. Tumen, I.; Hafizoglu, H.; Kollmannsberger, H.; Zimmermann, B.; Keskiner, A.; Gultekin, H.C. Essential Oil Of Leaves Juniperus Ssp. Natively Grown in Turkey. Pharmacog. Mag. 2010, 6, 137.

26. Wajs, A.; Pranovich, A.; Reunanen, M.; Willför, S.; Holmbom, B. Headspace-SPME Analysis of the Sapwood and Heartwood of Picea Abies, Pinus Sylvestris and Larix Dedicua. J. Essent. Oil Res. 2007, 19, 125-133.

27. Adams, R.P. Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry, 4th ed.; Allured Publishing: Carol Stream, IL, USA, 2007.

28. Jin, M.Z.; He, J.J.; Bi, H.Q; Cui, Y.X.; Duan, C.Q. Phenolic Compound Profiles in Berry Skins from Nine Red Wine Grape Cultivars in Northwest China. Molecules 2009, 14, 4922-4935.

29. Gu, Q.; Xu, J.; Gu, L. Selecting Diversified Compounds to Build a Tangible Library for Biological and Biochemical Assays. Molecules 2010, 15, 5031-5044.

30. Anačkov, G.; Božin, B.; Zorić, L.; Vukov, D.; Dukić, N.M.; Merkulov, L.; Igić, R.; Jovanović, M.; Boža, P. Chemical Composition of Essential Oil and Leaf Anatomy of Salvia bertolonii Vis. and Salvia pratensis L. (Sect. Plethiosphace, Lamiaceae). Molecules 2009, 14, 1-9.

31. Martino, L.; Bruno, M.; Formisano, C.; Feo, V.; Napolitano, F.; Rosselli, S., Senatore, F. Chemical Composition and Antimicrobial Activity of the Essential Oils from Two Species of Thymus Growing Wild in Southern Italy. Molecules 2009, 14, 4614-4624.

32. Dayısoylu, K.S.; Alma, M.H. Chemical analysis of essential oils from cone’s rosin of Cilician fir (Abies cilicica subsp. ciciica). Afr. J. Biotechnol. 2009, 8, 3502-3505.

33. Sezik, E.; Ustun, O.; Demirci, B.; Baser, K.H.C. Composition of the essential oils of Pinus nigra Arnold. From Turkey. Turk. J. Chem. 2010, 34, 313-325.

Sample Availability: Samples of the compounds are available from the authors.

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