Identification of Aroma Compounds of Lamiaceae Species in Turkey Using the Purge and Trap Technique

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Abstract: The present research was planned to characterize the aroma composition of important members of the Lamiaceae family such as Salvia officinalis, Lavandula angustifolia and Mentha asiatica. Aroma components of the S. officinalis, L. angustifolia and M. asiatica were extracted with the purge and trap technique with dichloromethane and analyzed with the gas chromatography–mass spectrometry (GC–MS) technique. A total of 23, 33 and 33 aroma compounds were detected in Salvia officinalis, Lavandula angustifolia and Mentha asiatica, respectively including, acids, alcohols, aldehydes, esters, hydrocarbons and terpenes. Terpene compounds were both qualitatively and quantitatively the major chemical group among the identified aroma compounds, followed by esters. The main terpene compounds were 1,8-cineole, sabinene and linalool in Salvia officinalis, Lavandula angustifolia and Mentha asiatica, respectively. Among esters, linalyl acetate was the only and most important ester compound which was detected in all samples.

Keywords: aroma; purge and trap; Salvia officinalis; Lavandula angustifolia; Mentha asiatica

1. Introduction

Throughout human history, medicinal and aromatic plants have been used for flavor enrichment in culinary and medicinal purpose in folk medicine. Today, the usage of these plants in daily diet has increased significantly all over the world. Within this trend, the family of Lamiaceae has been of great importance due to the unique aroma and nutritional value [1]. Lamiaceae is one of the widespread and the most exclusive medicinal and aromatic family of flowering plants, containing about 220 genera and around 4000 species all over the world. Generally, this family is cultivated in the dry, mild, and cold districts of Asia, Europe and North Africa [2]. Archeological excavations showed that the usage of this family member is based on prehistoric times and harvested not only wild but also in local balances [3]. This great diversity includes the following species: lavenders, sage, and mints.

One of the most important members of the Lamiaceae family is Lavenders (Lavandula spp.). This genus is native and widely distributed in the Mediterranean region. Lavandula contains sesional, medicanal shrubs and small herbs, which have aromatic parts [4]. Lavandula angustifolia is an endemic, widely distributed and taxon of the Mediterranean part of Turkey. It has a great market value owing to the strong and characteristic aroma. Thus, dry herb or essential oil of the plant is very demanded in flavorful, pharmaceutical, and food industries [5]. The Salvia L. (sage) is one of the main genera of the Lamiaceae family and contains almost 900 species all over the world, of which 94 taxa, belonging...
to 89 species, are grown in Turkey. *Salvia officinalis* L. is also endemic to the Mediterranean districts as a seasonal medicinal and aromatic herb. The plant has been widely used traditionally in food preparation, flavoring agents in perfumery, and cosmetics. Additionally, it has been used for medicinal purposes for a long list of diseases [6]. The *Mentha spp.* is another famous essential oil herb of medicinal and aromatic plants and is an important commodity owing to the huge requisitions for its volatiles oil in foodstuff, medicinal and hygiene manufactures. Globally, the genus Mints consist of 62 taxa and 18 species. Furthermore, mints have been consumed in folk medicine for the treatment of many complaints owing to its anti-inflammatory, analgesic, and sedative effects [7,8].

The volatile composition of *Lamiaceae* is affected by several different and very heterogeneous chemicals (e.g., alcohols, aldehydes, esters, ketones, acids, terpenes, etc.). Some of the short chain terpenes that constitute the main fraction of the *Lamiaceae* family, especially C10 mono- and C15 sesquiterpenes, overwhelmingly affect the flavor and taste of this family [9]. This group includes some pleasant smelling volatiles and terpenes-rich herbs which are very important in culinary and perfumery industry. In addition, many of its members have anti-bacterial effects and these specialties are mainly owing to the C10 mono- and C15 sesquiterpenes in the herb [10]. To the best of our knowledge, there is some research regarding the essential oil of these three members of *Lamiaceae* but no combined clarification of information from GC and gas chromatography–mass spectrometry (GC–MS) analysis, has been conducted on the aroma composition of Turkish origin.

Therefore, the aim of the present research was to identify and quantify the volatile composition of three members, *Salvia officinalis*, *Lavandula angustifolia* and *Mentha asiatica*, of the *Lamiaceae* family, all of which are cultivated in Turkey. In the present study, the aroma extraction method selected was the purge and trap technique with dichloromethane solvent. This technique is a very sensitive extraction method for many aroma compounds, especially with low boiling points. Additionally, by using this technique, it is possible to extract volatile compounds without artifacts formation with high reliability gas chromatography (GC) together with mass spectrometry (MS) and a flame ionization detector (FID) for quantification and identification of volatile compounds.

2. Materials and Methods

2.1. Samples and Chemicals

Commercial samples (1 kg) of dried young leaves of *Salvia officinalis*, *Lavandula angustifolia* and *Mentha asiatica* (origin: Turkey) were obtained from a local herbalist supplier, in Gaziantep, Turkey in July 2016. The herbs were identified by the Faculty of Agriculture, University of Cukurova. The moisture content of the herbs was 3.7%–4.5% (dry basis). Water used in this study was purified by a Millipore-Q system (Millipore Corp., Saint-Quentin, France). The standard volatile compounds were purchased from Sigma-Aldrich (Steinheim, Germany). Dichloromethane, sodium sulfate and 4-nonanol were obtained from Merck (Darmstadt, Germany). Dichloromethane was freshly distilled prior to use.

2.2. Extraction of Volatile Compounds

Volatile of herbs were extracted by the purge and trap system which comprises a flow-meter which controls a nitrogen source and is connected to a splitter system to divide the flow into several channels in order to purge three samples at the same time. Lichrolut EN tubes obtained from Merck were used as an adsorbent which is one of most appropriate sorbents for volatile compounds extraction with respect to the previous research [11]. The herb samples were previously mortared and placed into a 20 mL vial; then, the sample was pre-incubated at optimized purging temperature (60 °C) for 10 min. The process was applied for 90 min with a nitrogen flow of 500 mL/min. After purging, the volatiles held in the cartridge were eluted with dichloromethane. The elute was dried by anhydrous sodium sulphate; the pooled organic extract was concentrated to 5 mL in a Kuderna Danish concentrator fitted with a Snyder column at 40 °C (Supelco, St. Quentin, France) and then to 0.5 mL under a gentle flow
of nitrogen. Extracts were then stored at −20 °C in a glass vial equipped with a Teflon-lined cap until analysis. Extractions were carried out in triplicate [12].

2.3. GC-FID, GC–MS Analysis of Volatile Compounds

Agilent 6890 chromatograph interfaced with a flame ionization detector (FID) and Agilent 5973-Network-mass selective detector (MSD) (Wilmington, Delaware, DE, USA) constituted the gas chromatography (GC) system. DB-Wax column (30 m length × 0.25 mm i.d. × 0.5 µm thickness, J&W Scientific, Folsom, CA, USA) were used to separate volatile compounds. An amount of 3 µL of extract was injected in pulsed splitless (40 psi; 0.5 min) mode. Injector and FID detectors were set at 270 °C and 280 °C, respectively. The flow rate of carrier gas (helium) was 1.5 mL·min⁻¹. The conditions of the oven program of the DB-Wax column was 50 °C to 250 °C at 4 °C/min, 10 min hold. As for the mass-selective detector, the identical oven program was used. The MS (electronic impact ionization) conditions were as follows: ionization energy of 70 eV, mass range m/z of 30–300 a.m.u., scan rate of 2.0 scan·s⁻¹, interface temperature of 250 °C, and source temperature of 180 °C. The volatile compounds were analyzed in full scan mode and assigned by comparison of their retention index and their mass spectra on the DB-Wax column with those of a commercial spectra database (Wiley 6, NBS 75k) and the instrument’s internal library made through the aforementioned laboratory researches. After identification, the internal standard method with 4-nonanol was used to determine the mean value of volatile compounds and mean values (µg 100 g⁻¹ dry weight; dw) of the triplicate of GC analyses were calculated for each sample. By using n-alkane (C₈–C₃₂) series, retention indices of the compounds were calculated [12,13].

3. Results and Discussion

GC–MS investigation of the volatiles extracted from three members of the Lamiaceae family by employing the purge and trap extraction method allowed the identification of a total of 66 compounds (Figure 1). As shown in Table 1, a total of 23 volatiles were detected in Salvia officinalis extract, while in Lavandula angustifolia and Mentha asiatica 33 volatiles were extracted. These compounds were classified based on their chemical characteristics: acids, alcohols, aldehydes, esters, hydrocarbons and terpenes. Mean values (µg 100 g⁻¹ dw) of the triplicate of GC analyses were calculated. The highest concentration was found in L. angustifolia (70,695.1 µg 100 g⁻¹ dw) followed by M. asiatica (470,653 µg 100 g⁻¹ dw) and S. officinalis (45691.0 µg 100 g⁻¹ dw) showing the difference of genera on the concentration of compounds detected. When the genera were compared, the major variance was detected at the mean values of volatiles in the L. angustifolia, which was greater than in M. asiatica and S. officinalis.

Among the aroma compounds, terpenes were quantitatively and qualitatively the most abundant volatiles detected in the three members of the Lamiaceae family. Many plants and parts of them are well known with their pleasant odors, spicy tastes or to show pharmacological activities due to the terpene compounds. These specialties are formed predominantly by terpenes. However, producing purposes known with their pleasant odors, spicy tastes or to show pharmacological activities due to the terpene compounds so as to charm insects for pollination or to protect herbs from being eaten by animals [10]. A total of 43 terpenes were detected and quantified in the herb extracts: 17 detected in S. officinalis, 18 in L. angustifolia and 25 in M. asiatica.

Our results are in accordance with MÉNDEZ-TOVAR, et al. [14] who observed the main aroma compound of wild populations of Labiatae species as oxygenated monoterpenes. Within these, terpene β-myrcene and caryophyllene compounds were the only terpene compounds identified in all studied herbs. The mean value of the terpene compounds in L. angustifolia (47,635 µg 100 g⁻¹ dw) was higher than in S. officinalis (44,055 µg 100 g⁻¹ dw) and M. asiatica (37,501 µg 100 g⁻¹ dw). The main terpene compounds in S. officinalis were 1,8-cineole, α-pinene and β-pinene. The total concentration of these compounds was 21,341 µg 100 g⁻¹ dw, 4233 µg 100 g⁻¹ dw and 3044 µg 100 g⁻¹ dw, respectively, and accounted for 64% of the total terpene compounds identified in S. officinalis.
| No | LRI * | Chemical Class | Sum Formula | Compounds | Concentration (µg 100 g⁻¹ dw) * | Identification $ |
|----|--------|----------------|-------------|-----------|--------------------------------|-----------------|
| 1  | 1008   | Alcohol        | C₅H₁₀O     | 2-Methyl-3-buten-2-ol | nd            | 309 ± 9.27     | nd LRI, MS, tent |
| 2  | 1027   | Terpene        | C₁₀H₁₆      | α-Pinene  | 4233 ± 97.3  | 240 ± 5.52    | nd LRI, MS, std |
| 3  | 1038   | Terpene        | C₁₀H₁₆      | α-Thujene | nd            | 2290 ± 38.9  | nd LRI, MS, tent |
| 4  | 1075   | Ester          | C₄H₁₀O₂     | n-Butyl acetate | 178 ± 6.05  | 169 ± 5.74    | nd LRI, MS, tent |
| 5  | 1082   | Aldehyde       | C₆H₁₀O      | Hexanal   | nd            | 304 ± 12.7   | LRI, MS, std |
| 6  | 1087   | Terpene        | C₁₀H₁₆      | α-Pinene  | 389 ± 1.32   | nd LRI, MS, tent |
| 7  | 1108   | Alcohol        | C₄H₁₀O₂     | 1-Methoxy-2-propanol | nd          | 173 ± 2.87   | nd LRI, MS, std |
| 8  | 1124   | Terpene        | C₁₀H₁₆      | β-Pinene  | 208 ± 8.52   | LRI, MS, std |
| 9  | 1130   | Hydrocarbon    | C₆H₁₀       | m-Xylene  | 137 ± 2.87   | LRI, MS, std |
| 10 | 1134   | Terpene        | C₁₀H₁₆      | Sabinene  | nd            | 7091 ± 219   | LRI, MS, std |
| 11 | 1133   | Alcohol        | C₅H₁₀O     | 3-Penten-2-ol | 75.3 ± 2.25  | 91.5 ± 2.74   | LRI, MS, tent |
| 12 | 1167   | Terpene        | C₁₀H₁₆      | β-Myrcene | 2573 ± 59.1  | 519 ± 11.9    | 1688 ± 38.8  | LRI, MS, std |
| 13 | 1072   | Terpene        | C₁₀H₁₆      | Camphene  | 2881 ± 48.9  | 275 ± 4.67    | LRI, MS, std |
| 14 | 1178   | Terpene        | C₁₀H₁₆      | α-Terpine  | nd           | 3788 ± 128   | LRI, MS, std |
| 15 | 1190   | Terpene        | C₁₀H₁₆      | dl Limonene | nd          | 1537 ± 64.5  | LRI, MS, std |
| 16 | 1199   | Terpene        | C₁₀H₁₈O     | 1,8-Cineole | 21341 ± 533  | 6160 ± 154   | LRI, MS, tent |
| 17 | 1225   | Terpene        | C₁₀H₁₈O     | β-Thujene  | nd           | 1485 ± 50.4  | LRI, MS, tent |
| 18 | 1260   | Terpene        | C₁₀H₁₈O     | β-Ocimene | 217 ± 8.89   | 453 ± 18.5   | LRI, MS, std |
| 19 | 1265   | Terpene        | C₁₀H₁₈O     | γ-Terpine  | 919 ± 19.2   | 6588 ± 138   | LRI, MS, std |
| 20 | 1272   | Terpene        | C₁₀H₁₄      | α-Cymene  | nd           | 701 ± 21.7   | LRI, MS, std |
| 21 | 1280   | Terpene        | C₁₀H₁₄      | β-Cymene  | nd           | 683 ± 20.4   | LRI, MS, std |
| 22 | 1285   | Aldehyde       | C₂H₆O       | 2-Hexanal | nd           | 27.3 ± 0.62  | LRI, MS, std |
| 23 | 1290   | Terpene        | C₁₀H₁₆      | α-Terpinolene | 54.4 ± 0.92  | nd         | 1250 ± 21.2  | LRI, MS, std |
| 24 | 1321   | Alcohol        | C₂H₄O       | Hexanol   | 179 ± 6.08   | nd LRI, MS, std |
| 25 | 1360   | Ester          | C₁₀H₂₀O₃    | 1-Octenol acetate | nd          | 2627 ± 110   | LRI, MS, tent |
| 26 | 1372   | Aldehyde       | C₂H₄O       | Nonanal   | 128 ± 3.2   | nd           | 79.4 ± 1.98  | LRI, MS, std |
| 27 | 1402   | Acid           | C₂H₆O₂      | Acetic acid | nd          | 665 ± 22.6   | 406 ± 13.8  | LRI, MS, std |
| 28 | 1415   | Terpene        | C₁₀H₁₈O     | β-Thujone  | 1008 ± 41.3  | nd LRI, MS, tent |
| 29 | 1422   | Terpene        | C₁₀H₁₈O     | α-Thujone  | 113 ± 2.37   | nd LRI, MS, tent |
| 30 | 1436   | Terpene        | C₁₀H₁₈O     | (E)-linalool oxide | nd          | 5448 ± 168   | 60.6 ± 1.87  | LRI, MS, tent |
| 31 | 1445   | Alcohol        | C₂H₄O       | 1-Octen-3-ol | 178 ± 5.34  | nd LRI, MS, std |
| 32 | 1456   | Terpene        | C₁₀H₁₈O     | Epoxylinalool | nd          | 469 ± 10.7   | LRI, MS, std |
| 33 | 1466   | Ester          | C₁₀H₁₈O     | Sabinene hydrate | nd          | 5224 ± 88.8  | LRI, MS, tent |
Table 1. Cont.

| No  | LRI * | Chemical Class | Sum Formula | Compounds          | Concentration (µg 100 g\(^{-1}\) dw) * | Identification § |
|-----|-------|----------------|-------------|--------------------|----------------------------------------|------------------|
|     |       |                |             | Salvia officinalis | Lavandula angustifolia | Mentha asiatica |
| 34  | 1495  | Terpene        | C\(_{10}\)H\(_{18}\)O\(_{2}\) | (Z)-Linalool oxide | nd 3809 ± 129 | nd | LRI, MS, tent |
| 35  | 1515  | Terpene        | C\(_{10}\)H\(_{18}\)O | Camphor | nd 2769 ± 116 | nd | LRI, MS, std |
| 36  | 1548  | Terpene        | C\(_{10}\)H\(_{18}\)O | Linalool | 755 ± 18.8 19773 ± 494 | nd | LRI, MS, std |
| 37  | 1564  | Ester          | C\(_{12}\)H\(_{20}\)O\(_{2}\) | Linalyl acetate | 700 ± 23.8 13075 ± 384 3443 ± 117 | nd | LRI, MS, tent |
| 38  | 1596  | Ester          | C\(_{12}\)H\(_{20}\)O | α-Fenchyl acetate | nd nd 45.7 ± 1.87 | 19773 ± 494 | LRI, MS, tent |
| 39  | 1603  | Terpene        | C\(_{10}\)H\(_{18}\)O | 4-Terpineol | 755 ± 18.8 19773 ± 494 | nd | LRI, MS, std |
| 40  | 1515  | Terpene        | C\(_{10}\)H\(_{18}\)O | Camphor | nd nd 45.7 ± 1.87 | 19773 ± 494 | LRI, MS, std |
| 41  | 1548  | Terpene        | C\(_{10}\)H\(_{18}\)O | Linalool | 755 ± 18.8 19773 ± 494 | nd | LRI, MS, std |
| 42  | 1564  | Ester          | C\(_{12}\)H\(_{20}\)O\(_{2}\) | Linalyl acetate | 700 ± 23.8 13075 ± 384 3443 ± 117 | nd | LRI, MS, tent |
| 43  | 1596  | Ester          | C\(_{12}\)H\(_{20}\)O | α-Fenchyl acetate | nd nd 45.7 ± 1.87 | 19773 ± 494 | LRI, MS, tent |
| 44  | 1603  | Terpene        | C\(_{10}\)H\(_{18}\)O | 4-Terpineol | 755 ± 18.8 19773 ± 494 | nd | LRI, MS, std |
| 45  | 1638  | Acid           | C\(_{12}\)H\(_{20}\)O | α-Terpineol | 755 ± 18.8 19773 ± 494 | nd | LRI, MS, tent |
| 46  | 1655  | Terpene        | C\(_{10}\)H\(_{18}\)O | Butyric acid | nd 3809 ± 129 | nd | LRI, MS, tent |
| 47  | 1685  | Terpene        | C\(_{15}\)H\(_{24}\)O | α-Terpineol | 428 ± 9.84 4241 ± 144 | nd | LRI, MS, tent |
| 48  | 1700  | Terpene        | C\(_{10}\)H\(_{18}\)O | (Z)-Piperitol | 428 ± 9.84 4241 ± 144 | nd | LRI, MS, tent |
| 49  | 1714  | Terpene        | C\(_{15}\)H\(_{24}\)O | Caryophyllene | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 50  | 1720  | Terpene        | C\(_{15}\)H\(_{24}\)O | Caryophyllene | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 51  | 1723  | Terpene        | C\(_{15}\)H\(_{24}\)O | Neryl acetate | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 52  | 1727  | Terpene        | C\(_{15}\)H\(_{24}\)O | Neryl acetate | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 53  | 1735  | Terpene        | C\(_{15}\)H\(_{24}\)O | Neryl acetate | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 54  | 1742  | Terpene        | C\(_{15}\)H\(_{24}\)O | Neryl acetate | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 55  | 1808  | Terpene        | C\(_{15}\)H\(_{24}\)O | Neryl acetate | 2385 ± 73.9 1605 ± 49.7 1949 ± 60.4 | nd | LRI, MS, std |
| 56  | 2028  | Acid           | C\(_{10}\)H\(_{18}\)O | Octanoic acid | nd 844 ± 25.32 | nd | LRI, MS, std |
| 57  | 2102  | Terpene        | C\(_{10}\)H\(_{18}\)O | Octanoic acid | nd 844 ± 25.32 | nd | LRI, MS, std |
| 58  | 2162  | Terpene        | C\(_{10}\)H\(_{18}\)O | Octanoic acid | nd 844 ± 25.32 | nd | LRI, MS, std |
| 59  | 2219  | Terpene        | C\(_{10}\)H\(_{18}\)O | Octanoic acid | nd 844 ± 25.32 | nd | LRI, MS, std |
| 60  | 2450  | Hydrocarbon    | C\(_{15}\)H\(_{24}\)O | Coumarin | nd 229 ± 7.78 | nd | LRI, MS, tent |
| 61  | 2930  | Acid           | C\(_{16}\)H\(_{32}\)O | Palmitic acid | nd 183 ± 7.78 | nd | LRI, MS, std |
| 62  | 3184  | Acid           | C\(_{16}\)H\(_{32}\)O | Oleic acid | nd 229 ± 7.78 | nd | LRI, MS, tent |

* LRI, linear retention index calculated on a DB-WAX capillary column; * Concentration: Results are the means of three repetitions as µg 100 g\(^{-1}\) dw; § Identification: Methods of identification; LRI (linear retention index), MS tent. (tentatively identified by MS), Std (chemical standard); When only MS or LRI is available for the identification of a compound, it must be considered as an attempt of identification. nd (not detected).
Figure 1. The gas chromatography–mass spectrometry (GC–MS) chromatograms of *Salvia officinalis*, *Lavandula angustifolia* and *Mentha asiatica* (Peak numbers refer to Table 1).

Among the aroma compounds, terpenes were quantitatively and qualitatively the most abundant volatiles detected in the three members of the *Lamiaceae* family. Many plants and parts of them are well known with their pleasant odors, spicy tastes or to show pharmacological activities.
As previously designated, monoterpenes overwhelmingly affected the overall aroma characteristic of the *S. officinalis* by different researchers. Hayouni et al. [15] investigated the oil characterization of Tunisian *S. officinalis*. They found that major constituents were mainly oxygenated monoterpenes. In addition, the researchers pointed out that the major aroma compound of *S. officinalis* is 1,8-cineole with 33.27% of the total compounds being identified. Likewise, research from different locations previously identified these compounds as the major aroma compounds of *S. officinalis* [16–18].

Another studied member of *Lamiaceae* was *M. asiatica*. Sabinene together with γ-terpinene and 4-terpineol were detected as the major terpene compounds in this herb. These terpenes were identified in *M. asiatica* and different species of *Mentha* spp. from a different location in previous studies [7,19]. Verma et al. [7] reported that the aroma compounds identified in the studied *Mentha* spp. are oxygenated monoterpenes (74.0%) and sesquiterpene hydrocarbons (18.0%) with lower amounts of monoterpenes hydrocarbons (2.6%). Terpene synthases are directly responsible for the production of these volatile terpenes.

On the other hand, some of them are formed via modification of the main skeletons of terpene made by terpene synthases by hydroxylation, dehydrogenation, acylation, and other reactions [20]. The last member of *Lamiaceae* studied was *L. angustifolia*. The main terpene compounds of the sample were linalool, 1,8-cineole and (Z)-linalool oxide. Similar to our study, previously published studies highlighted that linalool is the most abundant compound in the *L. angustifolia* [21–23]. This compound is an oxygenated monoterpene and one of the main compound of essential oils in various aromatic species. These linalool rich species have been used in traditional medical systems since prehistoric times [1]. Furthermore, previous articles pointed out that this compound acts as a reversible competitive inhibitor of acetylcholinesterase, has been an alternative to conventional insecticides and has dose-dependent marked sedative effects on the central nervous system [24–26].

Esters were the second most important class of the aroma compounds in the *Lamiaceae* family. Esters compounds have a very wide range of odor and flavoring effects and there are over 200 of these compounds permitted for use in foods. Moreover, these compounds are widely distributed in essential oils and in some instances represent the major constituent. Generally, ester compounds are responsible for the mature and fruity notes [27]. A total of seven esters were identified and quantified in herbs: two in *S. officinalis*, five in *L. angustifolia* and three in *M. asiatica*. Linalyl acetate was the only compounds which was detected in all samples. This compound is one of the major compounds that characterized the overall aroma of the *L. angustifolia* [22]. Linalyl acetate is a significant compound in the perfume industry and is found in large amounts in various plants [28].

Regarding the other compounds, in trace amounts, acids, alcohols, aldehydes and hydrocarbons were also identified and quantified in the three samples. These compounds account for 0.01%, 0.03% and 0.01% of total aroma compounds, which were identified in *S. officinalis*, *L. angustifolia* and *M. asiatica*, respectively. Most of these volatiles were previously identified in these three members of the *Lamiaceae* family [7,16,17,23,24,29].

### 4. Conclusions

In the present paper, the aim was to determine the aroma compounds of three members of the *Lamiaceae*, *Salvia officinalis*, *Lavandula angustifolia* and *Mentha asiatica*, cultivated in the Turkey. A total of 23, 33, and 33 aroma compounds were identified in *Salvia officinalis* *Lavandula angustifolia* and *Mentha asiatica*, respectively including, acids, alcohols, aldehydes, esters, hydrocarbons, and terpenes. Terpene compounds were determined as the main chemical group among the identified aroma compounds, followed by esters. A total of 17 terpene compounds were identified in *S. officinalis*, 18 in *L. angustifolia* and 25 in *M. asiatica*. Linalyl acetate was the only and most important ester compound which was detected in all samples.

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