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Determination of Volatile Organic Compounds in Fourty Five *Salvia* Species by Thermal Desorption-GC-MS Technique

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Abstract: Volatile organic compounds (VOC) from dried aerial parts (flowers, leafs, leafy branches and stems) of fourty five *Salvia* species, harvested from different regions of Turkey, were determined using thermal desorption technique coupled to gas chromatography-mass spectrometer (TD-GC-MS). Total percentages of the detected volatile organic compounds of the *Salvia* species ranged from 70.30 to 99.65%. Total yield of VOC was found to be highly variable among *Salvia* species, and the percentage of each component also exhibited high variation. While sesquiterpene hydrocarbons represented 0.90-45.02% of the volatile organic compounds, the others were found to be monoterpene hydrocarbons 0.00-32.25%, monoterpenoids 0.94-53.60%, sesquiterpenoids 0.00-31.45% and hydrocarbons and derivatives 2.99-46.87%. The rest of the composition consisted of diterpene alcohols, fatty acids, phenolics and triterpenes. In total, 108 volatile compounds were identified from studied 45 Anatolian *Salvia* species.

Keywords: Volatile organic compounds; *Salvia;* chemical composition; thermal desorption; GC-MS; cluster analysis.

1. Introduction

Salvia L. (Lamiaceae) species consists of about 900 species distributed throughout the world. In Turkey, this genus is represented by 100 species, 53 (53%) of which are endemic [1, 2]. The genus is named "*Salvia*", derived from latin "Salveo", means "save, or recover" [3]. Many of *Salvia* species are named "adaçayı" in Anatolia, Turkey, and used as herbal tea due to their antiseptic, stimulant, diuretic and wound healing properties [4]. *Salvia* species are generally known for their several pharmacological effects including antibacterial [5], antituberculous [6], antiviral, cytotoxic [7] and cardiovascular [8] activities. Moreover, the studies indicated the presence of various compounds

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belonging mainly to terpenoids, flavonoids, phenolic acids, phenolic glycosides and other phenolics groups. *Salvia* is one of the most recognized herbs for its aromatic compounds and biologically active compounds [9]. The essential oil composition of *Salvia* species, similar to the most of the medicinal and aromatic plants, is highly influenced by genetic and environmental factors [10]. Assesment of these compounds in different conditions might be informative in their quantities and qualities [11]. Aim of the present study is to examine the VOC compositions of fourty-five species, which are *S. adenocaulon* (**1**), *S. adenophylla* (**2**), *S. aethiopis* (**3**), *S. aramiensis* (**4**), *S. atropatana* (**5**), *S. aucheri* var. *aucheri* (**6**), *S. blepharochlaena* (**7**), *S. bracteata* (**8**), *S. cadmica* (**9**), *S. caespitosa* (**10**), *S. candidissima* (**11**), *S. chionantha* (**12**), *S. cilicica* (**13**), *S. cryptantha* (**14**), *S. divaricata* (**15**), *S. euphratica* var. *leiocalycina* (**16**), *S. frigida* (**17**), *S. glutinosa* (**18**), *S. heldreichiana* (**19**), *S. huberi* (**20**), *S. hydrangea* (**21**), *S. hypargeia* (**22**), *S. kronenburgii* (**23**), *S. limbata* (**24**), *S. macrochlamys* (**25**), *S. microstegia* (**26**), *S. modesta* (**27**), *S. multicaulis* (**28**), *S. nemorosa* (**29**), *S. pachystachys* (**30**), *S. palestina* (**31**), *S. pisidica* (**32**), *S. poculata* (**33**), *S. potentillifolia* (**34**), *S. recognita* (**35**), *S. rosifolia* (**36**), *S. russellii* (**37**), *S. sclarea* (**38**), *S. staminea* (**39**), *S. suffruticosa* (**40**), *S. syriaca* (**41**), *S. tomentosa* (**42**), *S. trichoclada* (**43**), *S. verticillata* subsp. *amasiaca* (**44**) and *S. virgata* (**45**). Among these species **1**, **2**, **17**, **27**, **30** and **33** were investigated for the first time. We report herein the main volatile organic components and chemotaxonomic evaluation of 45 different *Salvia* taxa from Turkey.

2. Materials and Methods

2.1. Plant Materials

Table 1. List of *Salvia* species and their locality

Plant No	Herbarium No[a]	*Salvia* species	Plant Part Used	Locality	Altitude (m)	Collection date
1	103298	*Salvia adenocaulon* P. H. Davis	Aerial parts	Karaman: Kazancı Gökçekent-Sarıvadi	1100	2013
2	103286	*Salvia adenophylla* Hedge & Hub.-Mor	Leafy branches	Burdur: Yeşilova	1200	2003
3	103295	*Salvia aethiopis* L.	Aerial parts	Afyon-Kütahya	1000	2001
4	103299	*Salvia aramiensis* Rech. f.	Leafy branches	Hatay: Samandağ-Gözene Village	310	2013
5	103272	*Salvia atropatana* Bunge	Aerial parts	Van: Gürpınar, 12.km	2014	2013
6	103300	*Salvia aucheri* Bentham var. *aucheri*	Leafy branches	Adana: Pozantı-Gülek Village	1200	2013
7	103289	*Salvia blepharochlaena* Hedge & Hub.-Mor.	Aerial parts	Kayseri: Pınarbaşı-Sarız, 10-12. km	1520	2004
8	103296	*Salvia bracteata* Banks & Sol.	Aerial parts	Afyon-Kütahya	1000	2001
9	103287	*Salvia cadmica* Boiss.	Aerial parts	Denizli: Honaz Mountain-Cankurtaran	1800	2006
10	103274	*Salvia caespitosa* Montbret & Aucher ex Benth.	Aerial parts	Kahramanmaraş: Binboğa Mountain	2400	2004
11	103278	*Salvia candidissima* Vahl subsp. *candidissima*	Aerial parts	Malatya: Hekimhan-Malatya, 50.km	1100	2005
12	103277	*Salvia chionantha* Boiss.	Aerial parts	Burdur: Korkuteli-Çavdır	1400	2005

Table 1 continued

Plant No	Herbarium No[a]	*Salvia* species	Plant Part Used	Locality	Altitude (m)	Collection date
13	103266	*Salvia cilicica* Boiss. & Kotschy	Leafy branches	Kahramanmaraş: Ilıca	1300	2004
14[b]	103302	*Salvia cryptantha* Montbret & Aucher ex Benth. (*Salvia absconditiflora* Greuter & Burdet)	Aerial parts	Malatya-Inonu University Campus	900	2005
15	103304	*Salvia divaricata* Montbret & Aucher ex Benth.	Leafy branches	Erzincan: İliç-Refahiye	1310	2014
16	103284	*Salvia euphratica* Montbret & Aucher ex Benth. var. *leiocalycina* (Rech. f.) Hedge	Aerial parts	Malatya-Elbistan, Kahramanmaraş	1400	2005
17	103271	*Salvia frigida* Boiss.	Aerial parts	Doğubayazıt-Gürbulak, Ağrı	1600	2002
18	103285	*Salvia glutinosa* L.	Leafy branches	Trabzon: Maçka-Sümela	550	2006
19	103279	*Salvia heldreichiana* Boiss. ex Benth.	Aerial parts	Karaman: Ermenek-Kazancı	1700	2013
20	103270	*Salvia huberi* Hedge	Aerial parts	Artvin-Erzurum	676	2008
21	103303	*Salvia hydrangea* DC. ex Benth.	Aerial parts	Iğdır: Tuzluca	1200	2004
22	103282	*Salvia hypargeia* Fisch. & C.A. Mey.	Aerial parts	Adana: Saimbeyli-Obruk plateau	1200	2002
23	103301	*Salvia kronenburgii* Rech. f.	Aerial parts	Erzincan: İliç-Refahiye	1310	2014
24	103264	*Salvia limbata* C.A. Mey.	Aerial parts	Iğdır: Tuzluca-Digor	1300-1400	2004
25	103294	*Salvia macrochlamys* Boiss. & Kotschy	Aerial parts	Hakkari: Başkale-Depin	1200	2004
26	103288	*Salvia microstegia* Boiss. & Balansa	Aerial parts	Kahramanmaraş: Çokak-Andırın, Tiril Mountain	1200	2004
27	103268	*Salvia modesta* Boiss.	Aerial parts	Kahramanmaraş: Kayranlı Mountain	1700-2200	2004
28	103306	*Salvia multicaulis* Vahl	Aerial parts	Malatya: Darende, Doğanlar Village	1000	2005
29	103305	*Salvia nemorosa* L.	Aerial parts	Kars: Halefoğlu Village	1860	2004
30	103265	*Salvia pachystachys* Trautv	Aerial parts	Ağrı: Çaldıran-Doğubayazıt	2100	2002
31	103275	*Salvia palestina* Benth.	Aerial parts	Malatya	900	2005
32	103263	*Salvia pisidica* Boiss. & Heldr.	Aerial parts	Antalya: Kızılkaya-Korkuteli	1500-1600	2002
33	103273	*Salvia poculata* Nábělek	Aerial parts	Van: Liçan Village	2500-2600	2001
34	103262	*Salvia potentillifolia* Boiss. Heldr. ex Benth.	Aerial parts	Denizli: Çavdır-Antalya, 10.km	1200-1300	2003
35	103283	*Salvia recognita* Fisch. & C.A. Mey.	Leafy branches	Kahramanmaraş: Çokak-Andırın, Tiril Mountain	1200	2004
36	103297	*Salvia rosifolia* Sm.	Aerial parts	Artvin: Ardanuç	360	2008

Table 1 continued

Plant No	Herbarium No[a]	*Salvia* species	Plant Part Used	Locality	Altitude (m)	Collection date
37	103276	*Salvia russellii* Benth.	Aerial parts	Van: Gürpınar-Çatak	1880	2001
38	103291	*Salvia sclarea* L.	Aerial parts	Osmaniye: Yarpuz-Yaylapınar plateau 8.km	1100-1200	2004
39	103281	*Salvia staminea* Montbret & Aucher ex Benth.	Leafy branches	Erzincan: Spikör Mountain	2200-2450	2004
40	103269	*Salvia suffruticosa* Montbret & Aucher ex Benth.	Aerial parts	Hakkari: Yüksekova-Esendere	1800	2002
41	103292	*Salvia syriaca* L.	Aerial parts	Kayseri: Pınarbaşı-Sarız	1600	2004
42	103293	*Salvia tomentosa* Mill.	Aerial parts	Antalya: Çavdır, 10.km	1200-1300	2003
43	103267	*Salvia trichoclada* Benth.	Aerial parts	Hakkari: Hakkari-Çukurca, 10 km.	1200	2001
44	103280	*Salvia verticillata* L. subsp. *amasiaca* (Freyn & Bornm.) Bornm.	Aerial parts	Sivas: Sivas-Kangal	1500	2005
45	103290	*Salvia virgata* Jacq.	Aerial parts	Antalya: Çavdır	1166	2003

[a]The voucher specimens were deposited in the Herbarium, Faculty of Pharmaceutical Science (ISTE), Istanbul University, Turkey. The taxonomic identification of plant materials was identified by a senior botanist Dr. Tuncay Dirmenci, in Department of Biology, Balıkesir University, Balikesir, Turkey.

[b]Since 1985, *Salvia cryptantha* Montbret & Aucher ex Benth. is used synonym for *Salvia absconditiflora* Greuter & Burdet in the flora of Turkey [223].

Figure 1. Geographical distribution of the studied *Salvia* species [12]

2.2. Sample preparation, Thermal desorption and GC-MS Analysis

Perkin Elmer Turbomatrix ATD was used for thermal desorption analysis [13]. 35-70 mg of air-dried samples weighed into empty glass tubes. The program and conditions are as follows: The tube, transfer line and valve temperatures were kept at 150 ^{o}C. Tenax-TA (a porous polymer resin based on 2,6-diphenyleneoxide) was used for trapping at the lowest temperature (-30 ^{o}C) and the highest temperature (280 ^{o}C). Pneumatic program; inlet split 30 mL/min, outlet split 20 mL/min, desorb flow 30 mL/min, tube desorb time 10 min and trap hold time 5 min.

GC-MS analyses were performed on Thermo Electron Trace 2000 GC model gas chromatography and Thermo Electron DSQ quadrupole mass spectrometry [13]. A nonpolar Phenomenex DB5 fused silica column (30 m, 0.32 mm, with 0.25 mm film thickness) was used with Helium at 1 mL/min (20 psi) as a carrier gas. The GC oven temperature was kept at 60 ^oC for 10 min and programmed to reach 220 ^oC at a rate of 4 ^oC/min and then kept constant at 220 ^oC for 15 min. The split ratio was adjusted to 1:20, the injection volume was 0.1 mL and EI/MS was recorded at 70 eV ionization energy. Mass range was m/z 35-500 amu. A homologous series of n-alkanes (C_6-C_{32}) with a direct injection was used as a reference in the calculation of Kovats Indices (KI). Identification of the compounds was based on the comparison of their retention time and mass spectra with those obtained from authentic samples and/or the NIST and Wiley spectra as well as the literature data.

3. Results and Discussion

3.1. Chemical composition of the volatile organic compounds

Majority of the aerial parts of the fourty-five *Salvia* species were assessed for their volatile organic compounds by using TD-GC-MS technique, 108 components of which were identified, accounted for 70.30-99.65% of the total VOC composition. The components were classified as 10 classes of compound on the base of their chemical structures such as hydrocarbons and derivatives, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, fatty acids and derivatives, phenolic compounds and the others. The volatile components obtained from *Salvia* species are listed in Table 3.

The *Salvia* species were determined to compose of mainly monoterpenes (1.23-76.30%) in which while monoterpene haydrocarbons were identified from trace to 32.25%, *α*-pinene, camphene, *β*-pinene and myrcene were the most abundant monoterpene hydrocarbons, and 1,8-cineole, camphor, borneol, verbenone and *trans*-pinocarvyl acetate were accounted for 0.94-53.6% of the total oxygenated monoterpenes. Additionally, sesquiterpenes were identified to be between 1.00-55.61%, 0.90-45.02% of which were found to be sesquiterpene hydrocarbons. *α*-Bourbonene, (*Z*)-caryophyllene, longifolene, (*E*)-*β*-caryophyllene, *allo*-aromadendrene, aromadendrene, *γ*-muurolene, germacrene-D, *β*-bisabolene and bicyclogermacrene were the most abundant sesquiterpene hydrocarbons. Germacrene-D-4-ol, isoaromadendrene epoxide, caryophyllene oxide, humulene epoxide II, spathulenol, isolongifolol, *β*-santalol, longipinocarvone and sclareol oxide were accounted for most of the oxygenated sesquiterpenes, composition of which varied from trace to 31.45% of the total oxygenated sesquiterpenes. We determined the following chemical markers; *α*-pinene, camphene, *β*-pinene, 1,8-cineole, camphor and borneol in monoterpene rich species and *β*-caryophyllene, aromadendrene, germacrene D, *β*-bisabolene, bicyclogermacrene, caryophyllene oxide, humulene epoxide II, spathulenol and sclareol oxide in sesquiterpene rich species.

In many species, *α*-pinene, *β*-pinene and camphene were observed as major monoterpene hydrocarbons. However, *α*-pinene constituted the most abundant compound in the VOCs of *S. rosifolia* (**36**) (19.73%), *S. divaricata* (**15**) (10.20%) and *S. recognita* (**35**) (7.56%). *β*-Pinene constituted the most abundant compound in the VOCs of *S. pachystachys* (**30**) (10.10%) and *S. multicaulis* (**28**) (9.84%). Camphene was found to be the most abundant compound in the VOCs of *S. hydrangea* (**21**) (14.10%) and *S. divaricata* (**15**) (9.31%). The other major compounds in the VOCs of the studied *Salvia* species were 1,8-cineole; *S. divaricata* (**15**) (23.10%), *S. recognita* (**35**) (14.94%), *S. pisidica* (**32**) (13.23%), *S. aucheri* (**6**) (12.18%) and *S. multicaulis* (**28**) (10.70%), camphor; *S. divaricata* (**15**) (13.00%) and *S. multicaulis* (**28**) (9.79%), borneol; *S. cryptantha* (**14**) (37.40%), *S. blepharochlaena* (**7**) (28.33%), *S. virgata* (**45**) (23.41%), *S. caespitosa* (**10**) (16.00%) and *S. bracteata* (**8**) (14.40%). The sesquiterpene hydrocarbons *β*-caryophyllene and *β*-bisabolene are present in almost all of the studied *Salvia* species *β*-caryophyllene; *S. kronenburgii* (**23**) (10.27%) and *S. aramiensis* (**4**) (7.55%), *β*-bisabolene; *S. chionantha* (**12**) (7.96%) and *S. trichoclada* (**43**) (6.82%), bicyclogermacrene; *S. palestina* (**31**) (33.31%) and *S. chionantha* (**12**) (12.66%), germacrene-D; *S. cryptantha* (**14**) (3.20%) and *S. pisidica* (**32**) (1.86%). The other major components of the VOCs of the *Salvia* species were caryophyllene oxide; *S. bracteata* (**8**) (11.25%), *S. potentillifolia* (**34**) (6.93%) and *S. modesta* (**27**) (5.31%), humulene epoxide II; *S. tomentosa* (**42**) (6.53%), *S. pachystachys* (**30**) (3.52%), *S. aucheri* (**6**) and *S. aramiensis* (**4**) (3.32%), spathulenol; *S. atropatana* (**5**) (14.07%), *S.*

syriaca (**41**) (7.99%), *S. pachystachys* (**30**) (6.26%) and *S. huberi* (**20**) (6.10%). Herein, the volatile organic compounds of *S. adenocaulon* (**1**), *S. adenophylla* (**2**), *S. frigida* (**17**), *S. modesta* (**27**), *S. pachystachys* (**30**) and *S. poculata* (**33**) are reported for the first time. In *S. adenocaulon* (**1**), 68 volatile organic components were identified, representing 87.44% of the total oil. The oil mainly consisted of oxygenated sesquiterpenes (9.76%), sesquiterpene hydrocarbons (2.44%) and oxygenated monoterpenes (14.31%). Borneol (9.69%), germacrene D-4-ol (3.24%), cetyl alcohol (18.93%), palmitic acid (8.03%) and stigmasterol (8.98%) were the major components. In *S. adenophylla* (**2**), 77 volatile organic components were identified representing 80.09% of the total oil. It mainly consisted of oxygenated sesquiterpenes (11.29%), sesquiterpene hydrocarbons (16.80%) and oxygenated monoterpenes (33.03%), which were identified to be *α*-pinene (2.60%), 1.8-cineole (2.98%), camphor (7.60%), verbenone (6.39%) and longifolene (7.94%). In *S. frigida* (**17**), 77 components consisting of 82.40% of the total oil were identified. It mainly involved oxygenated sesquiterpenes (10.62%), sesquiterpene hydrocarbons (7.14%) and oxygenated monoterpenes (8.46%). Spathulenol (3.18%), palmitic acid (5.32%), *tert*-hexadecanthiol (4.59%) and tetracosane (24.06%) were the major components. In *S. modesta* (**27**), 76 volatile organic components were determined, representing 86.39% of the total oil, which consisted of oxygenated sesquiterpenes (14.09%), sesquiterpene hydrocarbons (15.35%), oxygenated monoterpenes (19.93%) and monoterpene hydrocarbons (11.27%). *α*-Pinene (6.46%), borneol (4.39%), *Z*-caryophyllene (3.55%), *β*-(*E*)-caryophyllene (3.78%), caryophyllene oxide (5.31%) and sclareol (4.16%) were the major components. In *S. pachystachys* (**30**), 73 volatile organic components were identified to be representing 92.75% of the total oil. The oil contained oxygenated sesquiterpenes (21.24%), sesquiterpene hydrocarbons (12.77%), oxygenated monoterpenes (25.69%) and monoterpene hydrocarbons (23.49%). The components were *α*-pinene (6.27%), *β*-pinene (10.10%), 1,8-cineole (4.71%), borneol (10.71%), *β*-caryophyllene (4.83%) and spathulenol (6.26%). Finally, *S. poculata* (**33**) was determined to contain 68 volatile organic components as 73.48% of the total oil, which were oxygenated sesquiterpenes (8.15%), sesquiterpene hydrocarbons (8.13%), oxygenated monoterpenes (6.91%), diterpene alcohols (5.64%) and fatty acids and derivatives (9.16%). The main constituents were identified to be verbenol acetate (4.74%), cetyl alcohol (3.60%), lauric acid (4.00%), isochiapin B (8.64%), methyl (*Z*)-13-docosenoate (5.95%) and octacosane (6.10%).

It has been shown that the oils of fourty five *Salvia* species from Turkey are rich in monoterpenes, sesquiterpenes and diterpenes. Interestingly, a few triterpenes, betulin, squalene, oleanolic acid having 30 C atoms, and two steroids 24,25-dihydroxycholecalciferol (27 C) and stigmasterol (29 C) were detected.

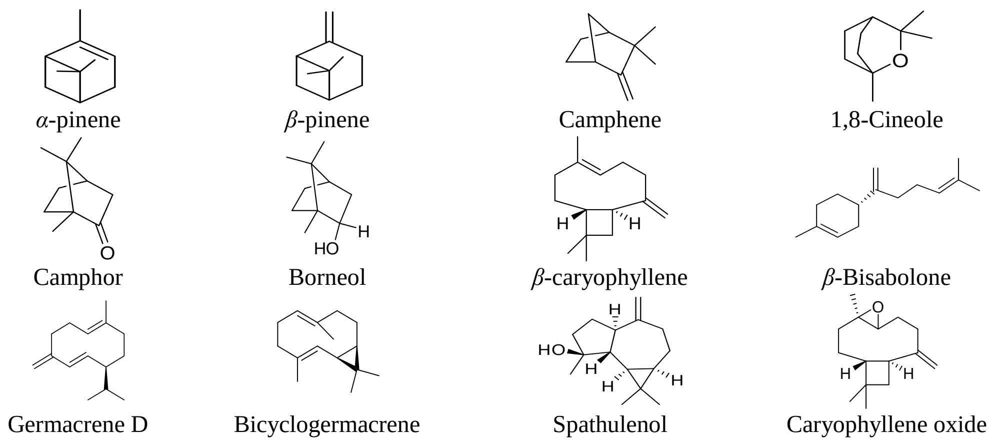

Figure 2. Major monoterpenes and sesquiterpenoids as chemical markers in the volatile organic compounds of *Salvia* species

3.2. Chemotaxonomic Evaluation

Salvia species was succesfully compared with major volatile organic compounds containing especially 1,8-cineole, camphor, borneol, *β*-caryophyllene, *β*-bisabolone, bicyclogermacrene, caryophyllene oxide and spathulenol, applying chemometric methods such as Similarity (Euclidean distance measurement) and Hierarchical Cluster Analysis, which was evaluated using IBM SPSS Statistics 22 to determine the chemical relationship of the species. The results were standardized using Z score and euclidean distance to group the species and perform group linkages to obtain a dendrogram (Figure 3).

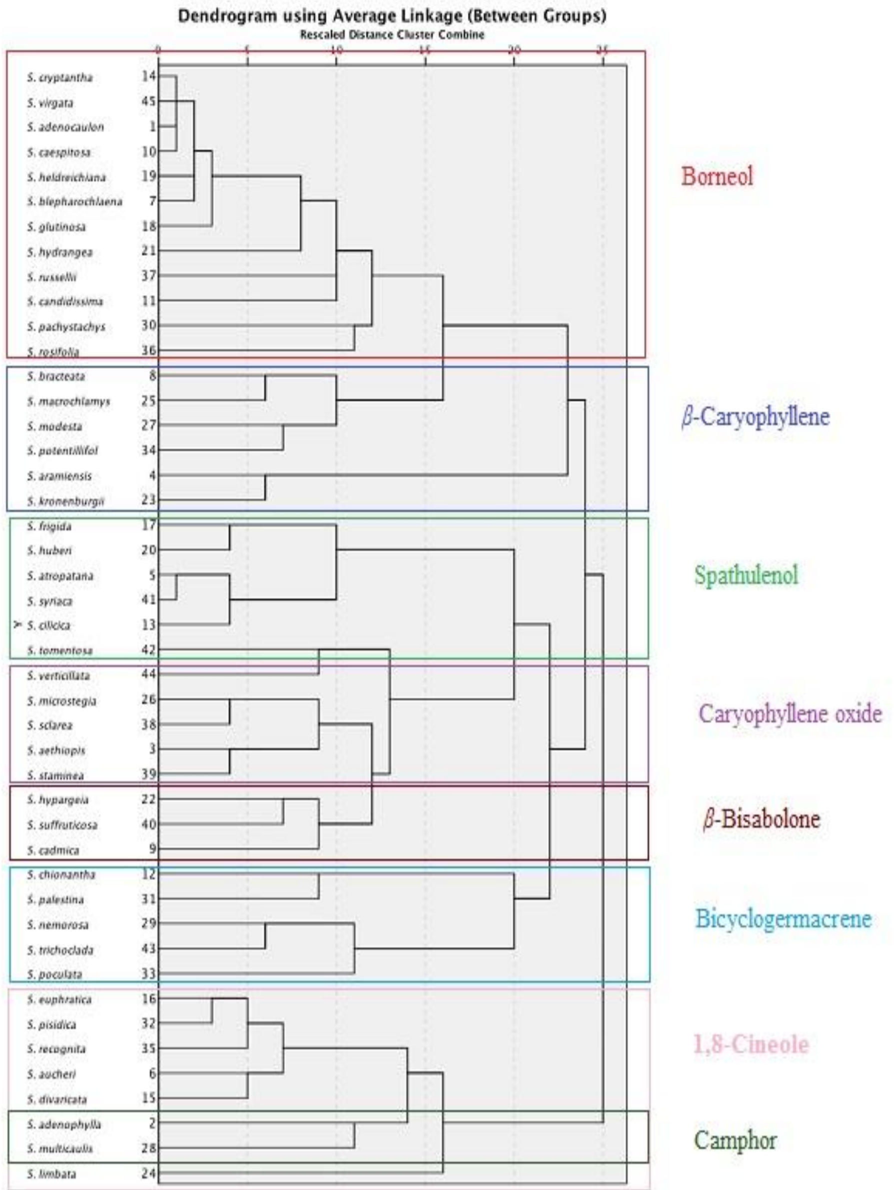

Figure 3. Average linkage dendrogram of the fourty-five *Salvia* species resulting from the cluster analysis (based on Euclidean distances) of the major volatile organic compounds

The VOC yield was found to be variable among *Salvia* species, and the percentage of each component exhibited a high variation such as borneol (0.09-37.4%), *β*-caryophyllene (0.23-10.27%), spathulenol (0.03-14.07%), caryophyllene oxide (0.03-11.25%), *β*-bisabolone (0.21-7.96%), bicyclogermacrene (0.06-33.31%), 1,8-cineole (eucalyptol) (0.04-23.1%) and camphor (0.05-13%).

Table 2. Classification of the species of *Salvia* by monoterpenes/sesquiterpenes ratio of the volatile organic compounds of the studied *Salvia* species[a]

Group A	Group B	Group C	Group D	Group E	Group F	Group G
2 (1.34)	**8** (1.09);(0.04)*	**14** (3.88);(0.02)*	**11** (1.63);(0.99)*	**4** (0.58)	**1** (1.37)	**3** (0.17);(0.04)*
7 (8.50);(0.20)*	**9** (0.41);(0.06)*	**16** (0.68)	**12** (0.24);(1.44)*	**9** (0.41);(0.06)*	**13** (0.19);(0.95)*	**27** (1.06)
10 (1.89);(0.10)*	**6** (1.58)	**9** (0.41)	**5** (0.30)	**15** (7.84)	**17** (0.50)	**33** (0.43);(0.90)*
19 (1.11)	**35** (2.80);(0.05)*	**23** (0.28)	**24** (0.78);(1.45)*	**18** (1.60)	**27** (1.06)	**39** (0.17);(2.64)*
20 (0.26)	**43** (0.04)	**28** (1.41)	**26** (0.12);(1.44)*	**22** (0.27);(0.58)*	**29** (0.41)	**41** (0.24);(0.90)*
21 (76.30);(0.10)*			**38** (0.33);(2.14)*	**25** (0.45);(0.30)*	**33** (0.43);(0.90)*	
30 (1.45);(0.20)*				**31** (0.04)	**37** (0.85)	
32 (1.45)				**42** (1.08);(0.05)*	**44** (0.14);(1.41)*	
34 (0.82);(0.40)*					**45** (5.23);(1.05)*	
36 (3.14)						
40 (0.37)						

[a] Groups A-G of species of *Salvia* were described in references [1], [14].

*The 18:3/18:2 ratios of seed oil of species are given in parenthesis and the values were taken from the literature for the species [15].

In the flora of Turkey, according to Hedge and Davis's classification, the Turkish species of *Salvia* were classified into seven subgroups, depending upon the shapes of their leaves, calyx texture and the length and colour of corolla [1], [14]. The reported species were classified as follows; Group A (**2**, **7**, **10**, **19**, **20**, **21**, **30**, **32**, **34**, **36** and **40**), Group B (**8**, **9**, **6**, **35** and **43**), Group C (**9**, **14**, **16**, **23** and **28**), Group D (**5**, **11**, **12**, **24**, **26** and **38**), Group E (**4**, **9**, **15**, **18**, **22**, **25**, **31** and **42**), Group F (**1**, **13**, **17**, **27**, **29**, **33**, **37**, **44** and **45**), Group G (**3**, **27**, **33**, **39** and **41**) [14]. In this study, volatile organic compounds of 45 *Salvia* species, 24 of which were previousely classified as 18:3/18:2 ratio of seed oil of species, were classified according to the ratio of monoterpenes and sesquiterpenes (Table 2) [15]. The ratio for *Salvia* species were found in the range of 0.36-76.30 for Group A, 0.04-2.79 for Group B, 0.28-3.67 for Group C, 0.24-1.48 for Group D, 0.04-6.49 for Group E, 0.14-5.23 for Group F and 0.15-1.06 for Group G.

The difference of the species **14**, **45**, **1**, **10**, **19**, **7**, **18**, **21**, **37**, **11**, **30** and **36** was clearly observed in the numerical cluster analysis. As they were found to be rich in borneol they were classified as borneol chemotype (Figure 3). Following the same way trend the rest were classified as follows; The species **8**, **25**, **27**, **34**, **4** and **23** high in *β*-caryophyllene content were *β*-caryophyllene chemotype, the species **17**, **20**, **5**, **41**, **13** and **42** high in spathulenol content were spathulenol chemotype, the species **44**, **26**, **38**, **3** and **39** high in caryophyllene oxide content were caryophyllene oxide chemotype, the species **22**, **40** and **9** high in *β*-bisabolone content were *β*-bisabolone chemotype, the species **12**, **31**, **39**, **43** and **33** high in bicyclogermacrene content were bicyclogermacrene chemotype. And, the species **16**, **32**, **35**, **6** and **15** high in 1,8-cineole content were 1,8-cineole chemotype. On the other hand, the species **2** and **28** were differentiated from their 1,8-cineole content, and thus classified as camphor chemotype.

Using quantitative volatile organic compounds and 45 *Salvia* species, similarity analysis of confirmed the cluster analysis results. The grouping in the cluster analysis (Figure 3) was found to be in well agreement with Hedge's classification (Table 2), *i.e.* **7**, **10**, **19** and **21** (Group A), **26** and **38** (Group D), **1**, **37** and **45** (Group F) and **3** and **39** (Group G) [1].

However, as shown in Table 2, it was revealed that the volatile organic compositions of the species are not good choice for chemotaxonomical evaluation as the phenotypic variations observed in the *Salvia* species due to different geographic localities, seasons, harvest periods, properties of soils and climatic conditions, collection years, which strongly affect the compositions of volatile organic compounds of plant species.

Table 3. Volatile organic compounds of *Salvia* species

Compounds*	KI	1	2	3	4	5	6	7	8	9
Hydrocarbons and derivatives										
Methyl propanoate	646	0.44	-	-	-	-	0.05	0.57	0.23	0.05
2-Furanmethanol	885	0.90	0.17	0.41	0.56	0.19	0.72	1.57	1.18	0.07
Heptanoic acid	1071	-	0.07	0.28	-	0.41	-	0.10	-	0.05
3-Isopropyl-6,7-dimethyltricyclo [4,4,0,0(2,8)]decane-9,10-diol	1710	1.55	0.32	1.09	0.70	0.77	0.08	0.18	0.39	10.42
2(1*H*)Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)	1790	-	2.60	0.87	0.27	0.39	0.10	0.16	0.25	2.31
Arabinitol, pentaacetate	1823	2.54	0.68	0.87	0.10	1.28	0.31	0.13	1.51	1.14
7-Methyl-*Z*-tetradecen-1-ol-acetate	1822	3.32	0.80	1.94	-	-	0.03	3.34	-	6.20
tert-Hexadecanethiol	1831	-	0.72	2.09	-	-	0.03	-	-	-
1,3,12-Nonadecatriene	1916	1.51	0.26	3.88	0.30	2.07	0.52	0.22	0.46	0.47
Eicosane	2000	-	-	-	-	0.99	-	0.19	0.14	1.12
Docosane	2200	1.36	0.13	1.49	0.10	0.13	0.13	0.41	0.87	0.15
9-Hexylheptadecane	2243	-	0.88	-	2.84	0.54	-	-	0.33	5.49
5-(1-Isopropenyl-4,5-dimethylbicyclo [4,3,0]nonan-5yl)-3-methyl-2-pentanolacetate	2265	-	-	0.94	0.04	0.15	0.20	0.19	-	0.28
Tricosane	2300	-	0.14	-	-	-	-	-	0.90	1.29
2-Pentadecyl-1,3-dioxocane	2390	-	-	0.81	0.13	7.90	0.04	0.17	-	0.69
Tetracosane	2400	0.48	-	0.19	-	-	-	0.29	-	-
Methyl (*Z*)-13-docosenoate	2440	-	-	0.14	0.02	-	0.12	0.09	0.39	0.61
Acetamide,*N*(2-acetyloxy)-2-[3,4-bis(acetyloxy)phenyl]ethyl]-*N*-methyl	2454	0.50	-	0.06	0.22	0.35	0.03	-	0.18	-
Pentacosane	2500	0.17	-	0.39	0.14	-	0.08	0.37	0.31	0.24
Heptacosane	2700	2.35	0.82	4.99	-	0.23	0.21	3.88	1.37	2.34
Octacosane	2800	-	-	0.73	0.42	2.18	0.15	0.42	4.14	0.44
Nonacosane	2900	-	0.06	-	-	-	0.05	-	-	0.41
Dotriacontane	3200	-	0.08	0.59	0.02	0.55	-	-	-	0.06
Pentatriacontane	3500	0.12	0.08	0.31	0.04	-	0.02	0.26	0.35	0.20
Hexatriacontane	3600	0.17	-	4.34	-	-	0.12	0.28	0.38	0.47
		15.41	**7.81**	**26.41**	**5.90**	**18.13**	**2.99**	**12.82**	**13.38**	**34.50**
Monoterpene hydrocarbons										
cis-Salvene	856	0.65	0.06	-	-	-	0.03	0.54	0.20	-
α-Pinene	939	0.37	2.60	0.10	1.76	-	7.62	1.12	0.96	0.37
Camphene	954	0.05	0.95	-	0.40	-	3.41	0.98	0.68	0.07
Sabinene	975	0.16	-	-	-	0.27	0.85	-	0.31	-
β-Pinene	979	-	0.36	-	-	-	2.76	1.02	2.23	-
β-Myrcene	991	0.20	0.11	0.73	11.23	-	3.18	-	-	0.05
p-Cymene	1026	0.20	0.47	-	-	-	-	0.24	1.00	0.41
β-Phellandrene	1030	-	-	-	0.70	0.85	0.39	-	-	-
Limonene	1036	0.20	0.09	-	1.04	-	5.01	0.20	0.16	0.14
Terpinolene	1085	0.61	0.10	-	-	-	0.57	-	1.63	0.20
		2.44	**4.74**	**0.83**	**15.13**	**1.12**	**23.82**	**4.10**	**7.17**	**1.24**

Table 3 continued

Compounds*	**KI**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Oxygenated monoterpenes										
1,8-Cineole	1031	0.09	2.98	1.06	0.19	0.27	12.18	1.66	6.03	0.22
trans-Linalool oxide	1073	-	-	-	0.23	0.15	0.21	0.21	0.85	-
cis-Linalool oxide	1087	0.07	1.72	-	0.34	0.11	0.10	-	0.14	0.12
Linalool	1097	0.32	0.72	0.22	1.43	0.11	0.08	10.84	0.22	0.14
Sabinene hydrate	1098	0.08	0.84	-	0.22	-	0.30	0.53	1.33	0.35
cis-Thujone	1110	0.15	2.02	0.09	0.15	0.12	0.05	0.13	-	0.15
trans-Pinocarveol	1139	-	0.10	0.14	0.19	0.12	0.20	0.41	0.23	0.39
Verbenol	1141	-	2.29	-	0.08	-	0.25	0.14	-	0.72
Camphor	1146	0.08	7.60	0.09	0.92	-	7.79	3.71	1.56	0.46
Pinocarvone	1165	0.18	0.42	0.10	0.14	0.13	0.28	0.28	0.55	0.15
Borneol	1169	9.69	1.34	0.09	0.97	2.99	2.48	28.33	14.40	0.49
p-Cymen-8-ol	1183	0.12	1.70	0.16	0.08	0.97	2.68	0.24	0.30	0.28
cis-Piperitol	1193	-	0.50	0.08	0.14	-	0.16	0.13	0.21	0.11
Myrtenol	1196	-	1.09	-	0.02	-	0.05	0.21	0.18	0.41
Verbenone	1205	0.63	6.39	0.56	-	-	0.25	0.34	0.48	3.17
cis-*p*-Mentha-1(7),8-diene-2-ol	1231	-	-	1.02	0.05	1.86	0.09	-	0.69	-
Carvone	1244	-	-	-	0.03	-	0.07	-	-	-
Perillol	1261	-	0.20	0.13	0.70	-	0.38	-	-	0.14
Verbenol acetate	1283	0.09	-	-	-	1.37	0.05	-	-	-
Bornyl acetate	1285	1.32	-	0.07	4.22	2.87	0.07	-	0.19	-
trans-Pinocarvyl acetate	1298	1.43	0.81	0.06	-	-	0.07	2.63	0.33	0.30
Durenol	1361	-	-	0.40	0.02	-	-	-	-	-
8-Hydroxylinalool	1366	-	0.13	-	0.56	0.15	0.12	0.26	-	0.20
β-Ionone	1489	0.06	1.88	-	6.17	-	1.99	-	0.18	-
trans-2-Menthenol	1571	-	0.30	0.69	-	0.23	0.05	-	0.54	0.61
		14.31	**33.03**	**4.96**	**16.85**	**11.45**	**29.95**	**50.05**	**28.41**	**8.41**
Sesquiterpene hydrocarbons										
α-Bourbonene	1344	0.79	0.44	0.54	1.47	0.72	0.62	0.47	0.16	0.12
β-Cubebene	1390	0.11	1.05	0.35	0.94	0.52	0.30	0.60	0.65	0.18
(Z)-Caryophyllene	1409	-	0.18	0.27	7.32	1.16	3.29	-	1.13	0.09
α-Gurjunene	1412	0.08	1.19	0.18	0.88	-	0.04	0.23	-	0.48
Longifolene	1416	0.07	7.94	0.33	0.17	0.70	0.37	0.31	0.23	1.76
(E)-*β*-Caryophyllene	1418	0.23	0.41	0.50	7.55	1.39	3.52	0.23	1.36	0.32
Allo-Aromadendrene	1461	-	-	0.09	6.80	0.87	0.61	0.09	0.30	0.14
Aromadendrene	1475	0.35	1.42	0.25	6.86	0.66	0.99	0.11	0.20	0.66
γ-Muurolene	1477	-	0.41	0.16	5.49	0.66	5.70	0.11	0.16	0.53
Valencene	1483	0.05	1.00	-	3.54	0.34	0.32	0.21	-	0.24
Germacrene-D	1485	0.07	0.64	0.33	0.42	0.74	0.15	0.10	0.76	0.56
β-Selinene	1490	-	0.91	0.13	0.79	0.10	0.04	0.15	-	0.96
β-Bisabolene	1498	0.69	1.21	3.91	1.60	2.75	1.17	0.21	2.96	2.10
δ-Cadinene	1524	-	-	0.14	0.11	0.18	-	-	-	-
Bicyclogermacrene	1755	-	-	0.08	0.16	0.32	-	0.09	0.31	0.99
		2.44	**16.80**	**7.26**	**44.10**	**11.11**	**17.12**	**2.91**	**8.22**	**9.13**

Table 3 continued

Compounds*	**KI**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Oxygenated sesquiterpenes										
cis-Nerolidol	1527	0.05	1.10	0.07	0.33	0.14	0.15	0.13	0.32	0.84
Germacrene D-4-ol	1574	3.24	1.08	0.17	0.91	0.33	0.05	-	0.36	0.81
Isoaromadendrene epoxide	1579	-	1.33	0.76	0.28	0.87	7.26	-	0.41	0.53
Caryophyllene oxide	1581	0.84	0.39	4.25	1.55	2.58	0.03	-	11.25	1.88
Cubenol	1592	-	-	0.13	-	0.31	-	-	0.37	0.13
Humulene epoxide II	1607	0.59	0.59	1.94	3.32	1.07	3.32	0.59	1.58	0.73
Spathulenol	1619	-	2.05	3.25	0.19	14.07	1.30	0.49	4.14	0.73
Cedr-8-en-15-ol	1644	0.49	0.15	2.92	1.78	1.23	0.61	0.14	1.52	0.26
β-Eudesmol	1654	0.15	1.33	0.75	-	0.11	1.97	0.61	0.47	0.70
Cedr-8-en-13-ol	1689	0.27	0.59	2.88	0.81	1.29	-	-	0.57	0.53
Isolongifolol	1715	0.76	0.54	1.16	0.33	1.92	0.18	0.13	0.91	1.32
β-Santalol	1716	0.74	0.19	1.10	1.85	0.61	1.39	0.94	0.43	0.81
Cedryl propyl ether	1741	1.38	1.72	1.63	0.04	0.62	0.34	0.32	1.33	2.65
Longipinocarvone	1747	1.25	-	1.02	-	-	-	0.11	0.72	2.03
Cedrane-8,13-diol	1876	-	0.23	1.92	-	6.30	0.16	-	-	-
Sclareol oxide	1906	-	-	2.71	0.03	-	0.16	-	-	0.66
		9.76	**11.29**	**26.66**	**11.42**	**31.45**	**16.92**	**3.46**	**24.38**	**14.61**
Diterpene alcohols										
Cetyl alcohol	1876	18.93	0.67	-	0.26	1.92	0.13	1.41	1.60	3.23
Phytol	1943	-	-	2.45	0.07	0.13	0.21	-	0.34	0.30
Sclareol	2223	0.73	-	3.64	-	1.31	0.47	-	-	0.14
		19.66	**0.67**	**6.09**	**0.33**	**3.36**	**0.81**	**1.41**	**1.94**	**3.67**
Fatty acids and derivatives										
Lauric acid	1567	0.78	0.87	1.20	0.81	0.80	0.47	0.47	0.36	0.39
Myristic acid	1724	1.77	0.15	0.89	-	-	0.56	1.48	0.74	0.59
Palmitic acid	1922	8.03	0.46	8.53	0.17	0.88	0.42	5.92	2.01	2.57
Stearic acid, allyl ether	2251	2.32	-	0.86	-	-	-	0.51	0.16	0.17
		12.90	**1.48**	**11.48**	**0.98**	**1.68**	**1.45**	**8.38**	**3.27**	**3.72**
Phenolic compounds										
Thymol	1290	-	-	-	1.40	0.20	0.21	0.30	-	0.16
Carvacrol	1299	0.63	0.63	0.51	2.67	1.96	0.25	0.29	0.18	0.48
		0.63	***0.63***	***0.51***	***4.07***	***2.16***	***0.46***	***0.59***	***0.18***	***0.64***
Oxygenated Triterpenes										
Betulin	1752	-	2.17	1.32	0.62	0.85	0.41	-	-	2.22
Oleanolic acid	3242	-	0.10	0.34	0.02	0.25	0.04	-	0.15	0.95
Myristyl oleate	3377	0.44	-	0.81	0.06	-	0.02	0.13	0.14	-
		0.44	**2.27**	**2.47**	**0.70**	**1.10**	**0.47**	**0.13**	**0.29**	**3.17**
Others compounds										
Tetraneurin D	2494	-	-	0.67	-	0.15	-	-	-	0.14
Isochiapin B	2577	0.47	0.17	2.48	0.08	2.61	0.29	0.69	0.92	0.98
Squalene	2914	-	-	-	0.03	0.83	-	-	-	-
24,25-Dihydroxycholecalciferol	3124	-	1.20	0.58	0.02	-	-	-	-	0.13
Stigmasterol	3170	8.98	-	0.62	0.04	0.15	0.46	-	-	-
		9.45	**1.37**	**4.35**	**0.17**	**3.74**	**0.75**	**0.69**	**0.92**	**1.25**
TOTAL		**87.44**	**80.09**	**91.02**	**99.65**	**85.30**	**94.74**	**84.54**	**88.16**	**80.34**

*Identification via MS data and KI (on DB-5 column)

Table 3 continued

Compounds*	**KI**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Hydrocarbons and derivatives										
Methyl propanoate	646	0.33	-	0.11	0.08	1.10	-	-	-	0.18
2-Furanmethanol	885	0.95	0.49	0.47	0.06	1.50	-	0.05	0.08	0.35
Heptanoic acid	1071	0.09	0.37	0.10	0.61	-	-	-	0.09	0.10
3-Isopropyl-6,7-dimethyltricyclo [4,4,0,0(2,8)]decane-9,10-diol	1710	0.08	1.30	0.47	1.34	-	-	0.17	0.64	0.81
2(1*H*)Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)	1790	0.37	-	0.54	0.54	-	-	0.31	0.53	0.82
Arabinitol, pentaacetate	1823	0.47	0.76	1.58	1.05	-	-	1.20	2.13	0.75
7-Methyl-*Z*-tetradecen-1-ol-acetate	1822	-	-	-	0.98	-	-	9.52	1.58	5.40
tert-Hexadecanethiol	1831	0.69	0.37	4.76	1.64	-	-	-	4.59	-
1,3,12-Nonadecatriene	1916	1.34	2.22	-	2.77	0.70	1.70	0.10	2.98	0.93
Eicosane	2000	-	-	-	0.65	-	0.90	-	1.67	-
Docosane	2200	0.47	1.23	0.96	2.26	-	-	0.33	1.65	0.70
9-Hexylheptadecane	2243	-	-	-	3.58	-	-	-	1.65	-
5-(1-Isopropenyl-4,5-dimethylbicyclo [4,3,0]nonan-5yl)-3-methyl-2-pentanolacetate	2265	0.77	0.75	0.80	0.53	-	-	0.44	0.45	1.59
Tricosane	2300	0.13	0.42	-	1.30	-	-	-	-	-
2-Pentadecyl-1,3-dioxocane	2390	-	-	0.13	-	-	-	0.25	-	0.30
Tetracosane	2400	0.59	0.27	-	0.87	-	-	1.76	24.06	0.38
Methyl (*Z*)-13-docosenoate	2440	0.24	-	0.48	0.59	-	-	-	-	0.41
Acetamide,*N*(2-acetyloxy)-2-[3,4-bis(acetyloxy)phenyl]ethyl]-*N*-methyl	2454	-	0.23	0.36	0.22	-	-	-	-	0.18
Pentacosane	2500	0.93	0.34	0.86	0.29	-	0.60	0.11	-	0.30
Heptacosane	2700	1.81	1.71	0.09	5.37	4.60	0.60	0.06	0.30	0.07
Octacosane	2800	0.93	-	3.71	1.10	-	-	9.44	3.43	5.44
Nonacosane	2900	0.07	0.49	0.49	-	-	8.60	0.18	0.54	1.11
Dotriacontane	3200	0.77	-	0.54	2.42	-	1.40	0.35	0.39	0.95
Pentatriacontane	3500	0.52	0.22	-	0.49	-	-	0.08	0.06	0.80
Hexatriacontane	3600	0.39	0.18	-	0.63	-	-	0.14	0.05	0.85
		11.94	**11.35**	**16.45**	**29.37**	**7.90**	**13.80**	**24.49**	**46.87**	**22.42**
Monoterpene hydrocarbons										
cis-Salvene	856	0.17	0.25	0.17	-	-	-	0.07	0.12	0.17
α-Pinene	939	1.28	1.81	0.08	0.36	-	10.20	0.86	0.06	0.08
Camphene	954	0.08	3.15	-	0.11	-	9.30	0.38	-	-
Sabinene	975	0.09	0.27	-	0.20	-	-	-	-	-
β-Pinene	979	1.36	0.34	-	0.10	-	1.70	-	-	-
β-Myrcene	991	0.29	-	-	0.05	-	-	0.06	-	0.04
p-Cymene	1026	0.18	1.15	0.62	0.10	-	-	0.18	-	0.06
β-Phellandrene	1030	-	-	-	-	-	-	-	-	-
Limonene	1036	0.17	-	-	-	-	-	0.36	-	0.05
Terpinolene	1085	0.46	0.30	0.10	0.10	-	-	0.14	0.18	0.21
		4.08	**7.27**	**0.97**	**1.02**	**0.00**	**21.20**	**2.05**	**0.36**	**0.61**

Table 3 continued

Compounds*	**KI**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Oxygenated monoterpenes										
1,8-Cineole	1031	1.32	0.36	0.17	0.41	-	23.10	2.94	0.29	0.12
trans-Linalool oxide	1073	0.05	-	-	-	-	-	0.08	-	-
cis-Linalool oxide	1087	-	0.14	0.27	0.10	7.10	-	0.14	-	0.05
Linalool	1097	0.41	0.42	0.18	0.21	1.30	-	0.06	0.06	0.24
Sabinene hydrate	1098	0.13	0.14	0.07	0.18	-	-	0.06	0.07	0.04
cis-Thujone	1110	-	0.12	0.08	-	-	-	0.11	-	-
trans-Pinocarveol	1139	0.12	2.06	0.07	0.15	-	-	0.15	0.15	0.29
Verbenol	1141	0.05	0.36	-	0.05	-	-	-	-	-
Camphor	1146	0.15	1.28	-	0.06	-	13.00	0.81	0.05	0.13
Pinocarvone	1165	0.07	1.78	-	0.07	-	-	0.08	-	0.07
Borneol	1169	16.00	6.22	2.83	0.16	37.40	6.20	0.81	2.56	4.51
p-Cymen-8-ol	1183	0.26	1.86	0.32	0.68	-	-	0.17	0.35	0.31
cis-Piperitol	1193	0.08	1.25	0.10	0.06	1.20	-	0.09	0.13	-
Myrtenol	1196	0.07	1.65	-	0.11	-	-	-	-	-
Verbenone	1205	0.69	5.28	0.36	0.29	-	-	0.20	0.29	0.31
cis-*p*-Mentha-1(7),8-diene-2-ol	1231	0.24	0.51	-	-	-	0.80	1.33	3.56	-
Carvone	1244	0.10	0.16	-	0.05	-	-	-	-	0.08
Perillol	1261	0.05	0.09	-	-	-	-	-	-	-
Verbenol acetate	1283	1.09	3.52	0.36	-	-	-	-	0.45	0.88
Bornyl acetate	1285	-	-	0.98	-	-	-	-	0.08	3.60
trans-Pinocarvyl acetate	1298	0.75	-	-	-	-	-	-	0.07	7.89
Durenol	1361	-	-	-	-	-	-	-	-	0.38
8-Hydroxylinalool	1366	-	0.09	0.26	-	-	-	0.31	-	-
β-Ionone	1489	0.06	0.25	-	0.14	-	-	0.05	-	0.34
trans-2-Menthenol	1571	0.15	1.19	0.69	1.66	-	-	3.51	0.35	-
		21.84	**28.73**	**6.74**	**4.38**	**47.00**	**43.10**	**10.90**	**8.46**	**19.24**
Sesquiterpene hydrocarbons										
α-Bourbonene	1344	0.78	0.88	0.36	0.51	-	-	0.10	0.31	0.28
β-Cubebene	1390	0.27	0.94	0.17	0.66	-	-	0.06	0.05	0.39
(Z)-Caryophyllene	1409	1.21	0.15	0.09	0.07	-	-	-	0.08	0.08
α-Gurjunene	1412	-	0.31	0.09	0.09	-	-	1.65	0.04	0.43
Longifolene	1416	0.14	0.40	-	0.60	-	-	-	0.13	0.04
(E)-*β*-Caryophyllene	1418	1.44	0.38	0.32	0.30	-	-	0.23	0.31	0.31
Allo-Aromadendrene	1461	0.18	0.34	0.82	0.21	-	-	1.46	1.33	0.66
Aromadendrene	1475	-	0.70	0.90	0.11	-	0.90	0.19	0.19	-
γ-Muurolene	1477	0.12	0.33	0.12	0.07	-	-	-	0.16	-
Valencene	1483	0.11	0.34	0.11	0.21	-	-	0.09	0.15	0.09
Germacrene-D	1485	0.10	0.22	-	0.54	3.20	-	0.34	0.67	0.24
β-Selinene	1490	-	0.30	-	0.17	-	-	0.25	0.58	0.09
β-Bisabolene	1498	0.88	2.53	7.96	1.23	-	-	0.45	1.99	0.84
δ-Cadinene	1524	-	0.22	-	0.16	-	-	0.06	0.13	0.06
Bicyclogermacrene	1755	0.43	0.17	12.66	0.33	-	-	0.16	1.02	0.48
		5.66	**8.21**	**23.60**	**5.26**	**3.20**	**0.90**	**5.04**	**7.14**	**3.99**

Table 3 continued

Compounds*	KI	10	11	12	13	14	15	16	17	18
Oxygenated sesquiterpenes										
cis-Nerolidol	1527	0.09	0.32	0.27	0.14	-	-	0.05	0.12	0.08
Germacrene D-4-ol	1574	-	0.17	0.22	0.15	-	-	-	-	0.24
Isoaromadendrene epoxide	1579	-	0.60	0.45	0.74	-	-	-	0.56	0.18
Caryophyllene oxide	1581	1.66	0.55	0.29	0.26	-	-	-	1.39	0.66
Cubenol	1592	-	-	-	0.84	-	-	1.09	0.10	1.42
Humulene epoxide II	1607	1.44	0.92	1.25	1.76	-	-	1.48	1.39	0.59
Spathulenol	1619	0.10	2.73	0.16	5.12	-	-	-	3.18	0.47
Cedr-8-en-15-ol	1644	1.41	0.66	2.09	0.44	1.60	-	0.93	1.86	1.08
β-Eudesmol	1654	0.22	0.43	-	1.21	-	-	-	0.45	-
Cedr-8-en-13-ol	1689	0.18	0.55	0.41	0.17	6.40	-	0.81	0.07	0.18
Isolongifolol	1715	0.60	0.72	0.43	0.53	-	-	0.45	0.54	-
β-Santalol	1716	0.64	0.71	-	1.11	-	-	0.25	0.78	0.31
Cedryl propyl ether	1741	0.67	1.30	-	1.58	-	-	1.09	0.18	1.95
Longipinocarvone	1747	0.47	0.34	0.95	0.72	-	-	0.15	t	1.25
Cedrane-8,13-diol	1876	0.18	-	-	-	-	6.60	7.76	-	-
Sclareol oxide	1906	0.39	3.85	1.99	7.98	0.90	0.70	-	-	-
		8.05	**13.85**	**8.51**	**22.75**	**8.90**	**7.30**	**14.06**	**10.62**	**8.41**
Diterpene alcohols										
Cetyl alcohol	1876	0.76	0.85	5.32	0.09	-	-	-	-	5.64
Phytol	1943	-	0.79	1.21	-	-	-	3.54	-	-
Sclareol	2223	1.17	1.76	1.68	1.85	-	-	0.09	-	3.89
		1.93	**3.40**	**8.21**	**1.94**	**0.00**	**0.00**	**3.63**	**0.00**	**9.53**
Fatty acids and derivatives										
Lauric acid	1567	2.20	1.17	0.26	1.41	-	-	1.52	0.75	0.93
Myristic acid	1724	9.00	0.54	2.57	1.31	-	-	4.32	0.27	1.55
Palmitic acid	1922	16.10	0.89	8.67	1.69	0.80	-	12.99	5.32	10.09
Stearic acid, allyl ether	2251	-	-	0.40	-	-	-	1.42	0.24	0.46
		27.30	**2.60**	**11.90**	**4.41**	**0.80**	**0.00**	**20.25**	**6.58**	**13.03**
Phenolic compounds										
Thymol	1290	0.20	0.38	-	-	-	-	0.09	0.43	-
Carvacrol	1299	0.24	0.28	0.29	0.68	-	-	0.60	0.24	0.32
		0.44	**0.66**	**0.29**	**0.68**	**0.00**	**0.00**	**0.69**	**0.67**	**0.32**
Oxygenated triterpenes										
Betulin	1752	1.89	0.66	-	1.17	-	-	-	0.53	-
Oleanolic acid	3242	-	0.65	0.11	0.36	-	-	0.16	0.07	0.33
Myristyl oleate	3377	0.53	1.82	-	2.63	1.60	1.70	0.17	0.05	0.50
		2.42	**3.13**	**0.11**	**4.16**	**1.60**	**1.70**	**0.33**	**0.65**	**0.83**
Others compounds										
Tetraneurin D	2494	-	-	0.12	2.25	-	0.60	-	-	0.09
Isochiapin B	2577	1.91	1.90	2.14	-	-	0.60	-	0.94	4.81
Squalene	2914	1.02	-	-	0.15	0.90	-	-	0.05	0.23
24,25-Dihydroxycholecalciferol	3124	-	0.24	-	-	-	-	-	-	-
Stigmasterol	3170	-	1.09	-	-	-	-	0.11	0.06	-
		2.93	**3.23**	**2.26**	**2.40**	**0.90**	**1.20**	**0.11**	**1.05**	**5.13**
TOTAL		**86.59**	**82.43**	**79.04**	**76.37**	**70.30**	**89.20**	**81.55**	**82.40**	**83.51**

*Identification via MS data and KI (on DB-5 column)

Table 3 continued

Compounds*	**KI**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Hydrocarbons and derivatives										
Methyl propanoate	646	0.27	-	-	-	0.16	-	-	0.07	-
2-Furanmethanol	885	0.82	0.41	-	-	0.07	-	1.21	0.07	0.23
Heptanoic acid	1071	-	0.96	-	0.14	-	0.24	-	0.19	0.41
3-Isopropyl-6,7-dimethyltricyclo [4,4,0,0(2,8)]decane-9,10-diol	1710	0.80	0.85	-	0.73	0.57	1.02	0.67	0.84	-
2(1*H*)Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)	1790	0.26	0.46	-	0.21	0.11	0.71	0.46	0.59	0.37
Arabinitol, pentaacetate	1823	0.29	0.71	-	0.67	0.36	1.62	1.29	0.75	0.80
7-Methyl-*Z*-tetradecen-1-ol-acetate	1822	-	1.83	-	9.73	0.26	-	4.48	-	-
tert-Hexadecanethiol	1831	-	1.12	1.00	-	0.25	1.58	-	3.13	0.53
1,3,12-Nonadecatriene	1916	1.53	3.56	-	1.52	0.87	0.86	4.87	1.01	-
Eicosane	2000	-	1.11	-	0.16	0.21	0.41	0.62	0.76	0.80
Docosane	2200	0.80	1.65	2.80	1.91	0.58	1.99	2.24	2.03	1.90
9-Hexylheptadecane	2243	0.22	-	-	0.37	1.31	-	-	0.20	-
5-(1-Isopropenyl-4,5-dimethylbicyclo [4,3,0]nonan-5yl)-3-methyl-2-pentanolacetate	2265	0.22	7.23	-	1.45	0.33	0.84	0.61	0.81	-
Tricosane	2300	-	-	-	-	-	0.47	0.29	-	3.04
2-Pentadecyl-1,3-dioxocane	2390	0.48	5.63	-	0.34	0.23	-	0.19	0.91	-
Tetracosane	2400	0.51	-	-	-	-	0.40	-	0.84	0.32
Methyl (*Z*)-13-docosenoate	2440	-	-	-	0.74	0.23	0.48	-	-	0.31
Acetamide,*N*(2-acetyloxy)-2-[3,4-bis(acetyloxy)phenyl]ethyl]-*N*-methyl	2454	-	0.10	1.10	0.48	0.44	0.24	1.56	0.62	-
Pentacosane	2500	-	0.31	1.00	0.29	-	0.42	1.10	1.12	0.21
Heptacosane	2700	5.25	2.34	-	15.61	0.83	1.83	2.73	8.28	2.02
Octacosane	2800	0.20	-	1.30	-	-	0.36	-	-	-
Nonacosane	2900	0.29	0.29	0.60	1.45	-	0.51	0.59	0.74	0.99
Dotriacontane	3200	0.81	0.99	-	-	-	2.13	-	2.16	1.63
Pentatriacontane	3500	-	0.10	-	0.49	0.28	2.68	1.08	0.17	0.25
Hexatriacontane	3600	-	-	-	0.63	0.05	1.05	0.26	1.40	0.61
		12.75	**29.65**	**7.80**	**36.92**	**7.14**	**19.85**	**24.25**	**26.69**	**14.42**
Monoterpene hydrocarbons										
cis-Salvene	856	0.31	0.06	-	-	0.06	-	0.07	0.13	-
α-Pinene	939	0.53	0.05	6.80	0.16	4.27	0.75	0.40	0.25	6.46
Camphene	954	1.17	-	14.10	-	0.48	0.24	0.07	0.24	0.39
Sabinene	975	-	0.10	-	-	0.69	-	1.55	-	-
β-Pinene	979	0.13	-	-	0.20	3.29	-	1.61	-	2.65
β-Myrcene	991	-	-	1.10	-	-	-	-	0.06	0.55
p-Cymene	1026	0.30	-	0.70	0.10	0.18	3.35	0.15	-	0.32
β-Phellandrene	1030	-	-	-	-	0.12	-	-	-	-
Limonene	1036	-	-	-	-	0.05	-	0.46	-	0.90
Terpinolene	1085	-	0.32	-	-	-	0.72	0.09	0.07	-
		2.44	**0.53**	**22.70**	**0.46**	**9.14**	**5.07**	**4.40**	**0.75**	**11.27**

Table 3 continued

Compounds*	**KI**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Oxygenated monoterpenes										
1,8-Cineole	1031	0.83	0.06	13.90	0.41	0.04	4.80	0.06	0.12	0.83
trans-Linalool oxide	1073	-	-	-	-	-	-	0.11	0.17	0.47
cis-Linalool oxide	1087	-	-	-	-	-	-	-	0.06	0.53
Linalool	1097	0.38	0.07	-	-	-	-	0.13	0.13	0.89
Sabinene hydrate	1098	-	0.11	-	-	-	-	-	0.06	0.64
cis-Thujone	1110	-	-	-	-	-	-	-	-	-
trans-Pinocarveol	1139	1.07	0.07	-	0.22	0.44	0.37	0.30	0.19	1.19
Verbenol	1141	-	0.05	-	0.10	0.36	-	-	0.13	1.43
Camphor	1146	0.53	0.13	0.90	0.19	0.12	0.21	0.09	0.12	0.53
Pinocarvone	1165	0.74	-	-	0.10	0.18	0.18	-	-	0.72
Borneol	1169	9.19	3.24	37.00	-	3.69	1.56	2.26	0.28	4.39
p-Cymen-8-ol	1183	0.34	0.57	-	0.30	0.06	2.50	0.15	0.23	0.61
cis-Piperitol	1193	0.35	-	-	0.13	0.25	0.37	0.68	0.16	0.45
Myrtenol	1196	0.64	-	-	0.10	0.22	0.30	0.06	0.07	0.90
Verbenone	1205	2.86	0.04	0.60	0.15	0.46	0.93	0.09	0.27	1.69
cis-*p*-Mentha-1(7),8-diene-2-ol	1231	0.28	0.82	-	0.64	0.36	-	-	-	0.61
Carvone	1244	-	-	-	-	-	0.40	-	0.20	0.27
Perillol	1261	-	0.13	-	-	-	0.58	-	0.07	0.31
Verbenol acetate	1283	-	1.83	-	-	-	-	-	-	1.85
Bornyl acetate	1285	-	0.20	-	-	-	-	-	-	0.15
trans-Pinocarvyl acetate	1298	-	0.10	-	-	0.14	-	-	-	0.22
Durenol	1361	-	-	-	-	0.09	-	0.11	0.20	-
8-Hydroxylinalool	1366	0.09	-	-	0.27	0.11	-	0.73	0.14	0.91
β-Ionone	1489	9.42	0.06	1.20	-	-	-	-	0.10	-
trans-2-Menthenol	1571	0.60	0.58	-	2.53	0.15	1.28	0.64	0.23	0.34
		27.32	**8.06**	**53.60**	**5.14**	**6.67**	**13.49**	**5.41**	**2.93**	**19.93**
Sesquiterpene hydrocarbons										
α-Bourbonene	1344	0.64	0.65	-	0.23	0.94	0.16	0.68	0.16	2.72
β-Cubebene	1390	0.67	0.34	-	0.69	0.18	-	-	1.53	0.41
(Z)-Caryophyllene	1409	0.19	0.18	-	0.20	10.04	-	-	0.16	3.55
α-Gurjunene	1412	0.99	0.06	-	-	0.16	0.38	-	0.16	0.40
Longifolene	1416	0.84	0.21	-	2.24	0.07	0.28	-	0.20	0.25
(E)-*β*-Caryophyllene	1418	0.42	0.41	-	0.43	10.27	0.24	0.23	0.39	3.78
Allo-Aromadendrene	1461	0.16	1.70	-	-	-	0.29	0.43	-	-
Aromadendrene	1475	0.71	0.25	-	-	0.23	0.21	0.37	0.34	0.32
γ-Muurolene	1477	0.14	0.20	1.00	-	20.94	0.60	-	0.10	1.58
Valencene	1483	0.48	-	-	-	0.93	-	0.30	0.07	-
Germacrene-D	1485	-	1.18	-	0.10	0.36	-	0.36	0.13	0.56
β-Selinene	1490	-	0.31	-	-	-	-	2.06	0.17	-
β-Bisabolene	1498	0.96	3.52	-	1.25	0.84	1.02	0.27	1.46	1.52
δ-Cadinene	1524	-	0.17	-	0.09	0.06	0.21	-	0.16	-
Bicyclogermacrene	1755	-	1.33	-	0.39	-	0.48	-	1.03	0.26
		6.20	**10.51**	**1.00**	**5.62**	**45.02**	**3.87**	**4.70**	**6.06**	**15.35**

Table 3 continued

Compounds*	**KI**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Oxygenated sesquiterpenes										
cis-Nerolidol	1527	0.56	0.19	-	0.12	0.06	0.22	0.41	0.14	-
Germacrene D-4-ol	1574	-	0.11	-	-	0.25	0.17	2.10	0.92	0.35
Isoaromadendrene epoxide	1579	0.49	0.93	-	1.87	0.29	0.23	0.29	4.29	0.46
Caryophyllene oxide	1581	0.71	3.10	-	2.32	4.79	0.17	1.79	4.89	5.31
Cubenol	1592	0.26	-	-	0.60	0.45	1.54	0.64	1.20	-
Humulene epoxide II	1607	0.59	2.11	-	2.06	0.81	0.85	2.40	2.67	1.19
Spathulenol	1619	1.00	6.10	-	0.13	0.42	3.68	0.39	2.66	0.58
Cedr-8-en-15-ol	1644	0.56	2.20	-	0.75	0.42	0.57	0.78	0.51	1.30
β-Eudesmol	1654	0.21	0.47	-	0.09	0.31	0.17	0.18	0.99	0.39
Cedr-8-en-13-ol	1689	0.28	2.86	-	0.87	0.44	0.18	0.55	0.59	0.99
Isolongifolol	1715	0.45	0.92	-	2.51	0.33	0.65	-	1.58	1.70
β-Santalol	1716	0.21	1.34	-	0.33	0.67	0.77	1.37	0.68	0.80
Cedryl propyl ether	1741	11.06	0.22	-	1.04	0.37	1.40	2.94	1.68	0.68
Longipinocarvone	1747	-	-	-	2.25	0.75	1.08	1.12	1.87	0.34
Cedrane-8,13-diol	1876	-	1.75	-	-	0.23	-	2.28	-	-
Sclareol oxide	1906	4.35	-	-	-	-	8.26	-	-	-
		20.73	**22.30**	**0.00**	**14.94**	**10.59**	**19.94**	**17.24**	**24.67**	**14.09**
Diterpene alcohols										
Cetyl alcohol	1876	0.15	0.90	-	1.25	0.45	1.52	4.89	3.92	0.83
Phytol	1943	0.94	-	-	0.54	-	0.34	0.92	0.33	1.31
Sclareol	2223	0.80	1.24	-	3.05	-	2.26	0.83	1.65	4.16
		1.89	**2.14**	**0.00**	**4.84**	**0.45**	**4.11**	**6.64**	**5.90**	**6.30**
Fatty acids and derivatives										
Lauric acid	1567	1.21	1.34	-	0.25	0.23	0.49	0.57	0.54	0.49
Myristic acid	1724	1.22	0.20	-	1.18	0.09	0.72	0.87	0.85	-
Palmitic acid	1922	5.40	2.33	-	2.15	0.47	2.45	4.58	1.48	0.78
Stearic acid, allyl ether	2251	-	0.33	-	-	0.08	-	0.11	-	-
		7.83	**4.20**	**0.00**	**3.58**	**0.87**	**3.66**	**6.13**	**2.87**	**1.27**
Phenolic compounds										
Thymol	1290	-	0.65	-	-	0.09	0.26	1.63	-	-
Carvacrol	1299	0.11	0.93	-	-	0.75	0.19	1.47	0.20	-
		0.11	**1.58**	**0.00**	**0.00**	**0.84**	**0.46**	**3.10**	**0.20**	**0.00**
Oxygenated triterpenes										
Betulin	1752	0.60	2.53	-	-	-	-	0.98	-	1.12
Oleanolic acid	3242	2.00	-	-	-	-	2.47	-	0.90	0.42
Myristyl oleate	3377	-	0.43	-	0.85	7.51	6.72	0.17	1.16	-
		2.60	**2.96**	**0.00**	**0.85**	**7.51**	**9.19**	**1.15**	**2.06**	**1.54**
Others compounds										
Tetraneurin D	2494	1.01	1.46	-	-	-	6.09	-	-	-
Isochiapin B	2577	-	-	0.80	5.24	0.09	-	1.06	4.49	2.22
Squalene	2914	-	0.04	-	-	3.93	-	-	-	-
24,25-Dihydroxycholecalciferol	3124	-	-	-	-	-	-	-	0.13	-
Stigmasterol	3170	-	0.28	-	3.31	0.04	-	10.00	-	-
		1.01	**1.78**	**0.80**	**8.55**	**4.06**	**6.09**	**11.06**	**4.62**	**2.22**
TOTAL		**82.88**	**83.71**	**85.90**	**80.90**	**92.29**	**85.73**	**84.08**	**76.75**	**86.39**

*Identification via MS data and KI (on DB-5 column)

Table 3 continued

Compounds*	**KI**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Hydrocarbons and derivatives										
Methyl propanoate	646	-	-	0.08	-	-	0.13	0.28	-	0.30
2-Furanmethanol	885	-	0.06	0.23	0.04	0.14	-	-	0.20	1.27
Heptanoic acid	1071	0.08	0.48	-	0.05	-	0.36	0.05	0.17	0.67
3-Isopropyl-6,7-dimethyltricyclo [4,4,0,0(2,8)]decane-9,10-diol	1710	0.05	0.36	0.84	0.05	0.95	1.19	0.78	0.08	0.21
2(1*H*)Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)	1790	0.16	0.35	0.10	0.05	0.43	-	2.70	0.29	0.07
Arabinitol, pentaacetate	1823	0.20	1.22	0.09	0.25	0.25	0.65	1.03	1.38	0.36
7-Methyl-*Z*-tetradecen-1-ol-acetate	1822	-	-	-	-	0.74	0.31	-	-	-
tert-Hexadecanethiol	1831	-	1.42	-	-	0.59	1.00	-	-	0.86
1,3,12-Nonadecatriene	1916	0.86	1.25	0.33	-	1.01	0.52	0.48	0.06	0.90
Eicosane	2000	0.14	1.51	0.07	1.31	0.65	0.37	0.22	-	0.46
Docosane	2200	0.72	3.88	0.26	-	1.04	0.19	0.78	0.60	0.74
9-Hexylheptadecane	2243	-	-	-	-	-	0.49	-	-	-
5-(1-Isopropenyl-4,5-dimethylbicyclo [4,3,0]nonan-5yl)-3-methyl-2-pentanolacetate	2265	1.15	2.22	-	4.41	0.27	-	0.28	0.49	0.39
Tricosane	2300	-	-	0.11	-	0.37	0.47	0.32	0.19	0.20
2-Pentadecyl-1,3-dioxocane	2390	0.15	1.78	-	-	-	0.93	-	-	0.21
Tetracosane	2400	0.18	2.18	0.18	-	0.23	-	-	0.32	0.37
Methyl (*Z*)-13-docosenoate	2440	0.07	1.33	-	3.77	0.17	5.95	0.94	0.07	0.10
Acetamide,*N*(2-acetyloxy)-2-[3,4-bis(acetyloxy)phenyl]ethyl]-*N*-methyl	2454	0.19	0.79	-	-	-	-	0.56	0.04	0.09
Pentacosane	2500	0.17	0.90	1.07	0.13	0.17	0.29	0.82	0.11	0.30
Heptacosane	2700	1.38	5.36	0.54	-	0.59	0.93	0.52	5.10	1.54
Octacosane	2800	-	1.01	0.42	0.55	-	6.10	-	-	-
Nonacosane	2900	2.14	0.73	-	-	0.52	0.27	0.27	0.14	0.36
Dotriacontane	3200	0.74	3.03	-	-	0.59	3.78	0.43	0.80	-
Pentatriacontane	3500	0.11	0.58	-	-	1.06	0.32	0.69	0.08	0.13
Hexatriacontane	3600	0.21	1.60	0.13	0.04	0.29	-	-	0.15	0.21
		8.71	**32.04**	**4.45**	**10.65**	**10.06**	**24.26**	**11.15**	**10.27**	**9.74**
Monoterpene hydrocarbons										
cis-Salvene	856	-	-	0.11	0.09	-	0.13	0.07	0.09	0.17
α-Pinene	939	2.24	0.15	6.27	-	1.31	-	0.09	7.56	19.73
Camphene	954	0.97	-	2.28	-	0.85	-	-	3.10	2.10
Sabinene	975	0.40	-	1.05	-	-	-	0.08	-	0.42
β-Pinene	979	9.84	0.07	10.10	-	0.14	-	1.90	0.12	3.48
β-Myrcene	991	0.08	-	0.22	0.04	-	-	-	0.70	0.27
p-Cymene	1026	0.18	1.28	-	-	0.23	-	0.19	3.16	3.21
β-Phellandrene	1030	-	-	1.25	-	-	-	-	-	-
Limonene	1036	0.27	-	2.06	0.05	-	-	-	4.37	2.29
Terpinolene	1085	-	0.34	0.15	-	-	-	-	0.60	0.58
		13.99	**1.84**	**23.49**	**0.18**	**2.53**	**0.13**	**2.33**	**19.70**	**32.25**

Table 3 continued

Compounds*	**KI**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Oxygenated monoterpenes										
1,8-Cineole	1031	10.70	0.19	4.71	0.05	13.23	-	-	14.94	5.00
trans-Linalool oxide	1073	0.13	-	0.60	-	-	-	-	-	0.13
cis-Linalool oxide	1087	-	-	-	-	-	-	0.05	0.89	0.15
Linalool	1097	-	0.11	0.18	0.08	-	0.09	0.07	0.54	0.34
Sabinene hydrate	1098	0.11	0.16	0.23	0.04	-	0.17	0.04	0.34	0.16
cis-Thujone	1110	0.05	0.07	-	-	1.19	-	0.03	0.37	0.06
trans-Pinocarveol	1139	0.39	0.20	0.15	-	1.39	-	0.09	0.55	0.53
Verbenol	1141	-	0.12	-	-	0.84	-	0.47	0.16	0.21
Camphor	1146	9.79	-	3.92	-	4.61	-	0.16	4.28	5.89
Pinocarvone	1165	0.21	-	0.10	0.08	0.51	-	0.97	0.68	0.09
Borneol	1169	4.43	0.66	10.71	0.10	3.83	0.32	4.05	1.34	9.46
p-Cymen-8-ol	1183	0.12	0.74	0.70	0.16	0.48	0.95	0.29	1.37	0.38
cis-Piperitol	1193	0.36	0.07	2.19	0.04	0.19	0.11	2.07	0.15	0.14
Myrtenol	1196	0.10	-	-	-	0.21	-	1.84	0.25	0.05
Verbenone	1205	0.05	0.09	0.17	0.09	3.35	-	1.01	0.65	0.44
cis-*p*-Mentha-1(7),8-diene-2-ol	1231	0.13	1.00	1.10	0.22	0.77	0.23	0.44	0.75	0.24
Carvone	1244	0.13	0.15	-	-	0.58	-	0.69	0.38	-
Perillol	1261	1.08	-	-	-	7.54	-	0.82	0.04	0.07
Verbenol acetate	1283	-	-	-	-	-	4.74	0.78	-	-
Bornyl acetate	1285	-	1.35	-	-	-	0.13	-	-	0.62
trans-Pinocarvyl acetate	1298	-	0.11	0.60	-	-	-	4.61	0.09	0.23
Durenol	1361	-	-	-	0.20	-	-	1.24	-	-
8-Hydroxylinalool	1366	-	0.16	0.09	-	0.55	-	0.27	1.03	0.14
β-Ionone	1489	0.93	-	0.24	0.08	-	0.17	0.34	0.10	0.12
trans-2-Menthenol	1571	0.04	0.27	-	0.12	0.33	-	4.11	0.44	0.07
		28.74	**5.45**	**25.69**	**1.26**	**39.60**	**6.91**	**24.44**	**29.34**	**24.52**
Sesquiterpene hydrocarbons										
α-Bourbonene	1344	0.87	-	0.35	0.11	0.39	0.09	0.63	0.09	1.31
β-Cubebene	1390	0.36	0.56	0.13	0.08	0.20	1.36	0.11	0.30	0.53
(Z)-Caryophyllene	1409	1.85	0.35	4.60	0.08	1.30	-	0.86	0.07	1.22
α-Gurjunene	1412	-	0.06	-	-	1.16	0.10	0.62	0.23	0.10
Longifolene	1416	0.15	0.23	0.14	0.19	0.39	0.17	0.60	0.57	1.46
(E)-*β*-Caryophyllene	1418	2.09	0.58	4.83	0.31	1.53	0.25	1.09	0.30	1.45
Allo-Aromadendrene	1461	0.25	-	0.24	0.15	0.63	1.43	0.33	-	-
Aromadendrene	1475	0.10	0.13	0.07	0.11	0.55	1.03	1.19	2.58	0.50
γ-Muurolene	1477	0.06	-	0.83	0.03	-	-	0.44	1.08	0.41
Valencene	1483	0.76	0.94	0.19	0.05	0.71	0.39	0.49	0.11	0.13
Germacrene-D	1485	0.55	1.26	0.87	-	1.86	0.10	0.64	1.03	0.71
β-Selinene	1490	-	-	-	-	2.24	0.14	1.24	1.04	-
β-Bisabolene	1498	3.41	4.12	0.44	0.89	4.47	1.79	1.24	0.35	0.69
δ-Cadinene	1524	0.06	0.08	0.08	0.17	1.11	0.21	0.72	0.18	-
Bicyclogermacrene	1755	-	0.22	-	33.31	-	1.07	0.18	0.18	0.06
		10.51	**8.53**	**12.77**	**35.48**	**16.54**	**8.13**	**10.38**	**8.11**	**8.57**

Table 3 continued

Compounds*	**KI**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Oxygenated sesquiterpenes										
cis-Nerolidol	1527	0.12	0.17	-	0.07	1.26	0.13	2.03	0.07	0.22
Germacrene D-4-ol	1574	0.18	0.25	0.13	-	1.43	-	7.80	-	0.08
Isoaromadendrene epoxide	1579	0.38	0.42	0.43	0.80	0.15	0.21	0.48	0.67	0.22
Caryophyllene oxide	1581	5.11	0.44	0.43	-	1.14	0.49	6.93	0.13	1.67
Cubenol	1592	-	0.62	-	1.55	-	-	-	-	0.21
Humulene epoxide II	1607	2.36	0.76	3.52	0.59	0.81	0.64	1.13	1.13	0.59
Spathulenol	1619	4.79	1.57	6.26	0.13	0.53	0.16	-	0.03	0.97
Cedr-8-en-15-ol	1644	1.35	0.76	0.23	1.54	0.83	1.78	0.73	0.82	0.53
β-Eudesmol	1654	0.06	0.27	1.24	-	1.23	0.72	0.19	-	0.18
Cedr-8-en-13-ol	1689	1.74	0.27	-	0.23	1.63	0.39	0.47	3.39	1.24
Isolongifolol	1715	0.55	0.63	0.33	-	2.47	0.76	0.17	1.16	0.29
β-Santalol	1716	0.77	0.43	0.95	0.06	0.23	0.75	0.04	0.42	2.30
Cedryl propyl ether	1741	1.38	-	7.14	-	0.65	0.16	1.85	1.30	0.40
Longipinocarvone	1747	-	1.18	-	-	0.24	1.94	0.03	0.31	0.15
Cedrane-8,13-diol	1876	0.78	-	0.25	-	-	-	0.23	-	0.30
Sclareol oxide	1906	0.12	1.43	0.33	0.61	-	-	0.06	-	0.17
		19.69	**9.20**	**21.24**	**5.58**	**12.60**	**8.15**	**22.14**	**9.43**	**9.52**
Diterpene alcohols										
Cetyl alcohol	1876	0.56	1.25	0.39	-	0.30	3.60	0.41	0.45	0.88
Phytol	1943	0.35	1.44	-	-	0.76	-	0.09	1.37	-
Sclareol	2223	2.42	3.45	0.20	8.63	-	2.04	0.47	0.19	0.81
		3.33	**6.14**	**0.59**	**8.63**	**1.06**	**5.64**	**0.97**	**2.01**	**1.69**
Fatty acids and derivatives										
Lauric acid	1567	0.42	0.14	0.21	0.52	0.76	4.00	1.67	1.13	1.11
Myristic acid	1724	0.43	2.26	0.14	-	0.37	1.05	0.15	0.36	0.16
Palmitic acid	1922	2.09	3.94	-	2.57	0.75	3.74	0.75	0.49	2.15
Stearic acid, allyl ether	2251	-	-	-	-	0.40	0.37	0.22	0.12	-
		2.95	**6.34**	**0.35**	**3.09**	**2.28**	**9.16**	**2.79**	**2.10**	**3.42**
Phenolic compounds										
Thymol	1290	0.10	-	0.10	-	1.02	-	3.18	0.11	-
Carvacrol	1299	0.05	-	0.11	0.11	-	-	4.09	0.45	1.42
		0.15	**0.00**	**0.21**	**0.11**	**1.02**	**0.00**	**7.27**	**0.56**	**1.42**
Oxygenated triterpenes										
Betulin	1752	1.04	-	1.28	-	1.27	1.00	0.26	-	0.35
Oleanolic acid	3242	0.40	0.22	-	1.70	0.60	0.49	0.61	-	0.04
Myristyl oleate	3377	0.52	0.68	0.08	-	0.19	-	-	0.21	-
		1.95	**0.90**	**1.36**	**1.70**	**2.06**	**1.50**	**0.87**	**0.21**	**0.39**
Others compounds										
Tetraneurin D	2494	-	4.25	-	-	1.20	0.29	0.28	-	-
Isochiapin B	2577	6.08	0.71	2.60	13.10	0.24	8.64	0.48	0.77	0.60
Squalene	2914	-	0.24	-	4.73	-	0.37	0.14	-	-
24,25-Dihydroxycholecalciferol	3124	0.06	-	-	-	-	0.29	-	-	-
Stigmasterol	3170	-	-	-	-	-	-	0.41	-	0.72
		6.14	**5.20**	**2.60**	**17.83**	**1.44**	**9.60**	**1.31**	**0.77**	**1.32**
TOTAL		**96.16**	**75.64**	**92.75**	**84.51**	**89.19**	**73.48**	**83.65**	**82.50**	**92.84**

*Identification via MS data and KI (on DB-5 column)

Table 3 continued

Compounds*	KI	37	38	39	40	41	42	43	44	45
Hydrocarbons and derivatives										
Methyl propanoate	646	0.08	0.10	0.06	-	0.40	-	-	-	0.71
2-Furanmethanol	885	0.04	0.35	0.31	-	0.38	1.23	-	-	2.98
Heptanoic acid	1071	0.16	0.19	0.24	0.24	0.31	0.06	-	-	0.43
3-Isopropyl-6,7-dimethyltricyclo [4,4,0,0(2,8)]decane-9,10-diol	1710	0.27	1.48	1.26	0.83	1.23	0.69	0.37	0.14	0.97
2(1*H*)Naphthalenone,3,5,6,7,8,8a-hexahydro-4,8a-dimethyl-6-(1-methylethenyl)	1790	0.19	-	-	0.16	0.50	0.22	2.28	1.56	-
Arabinitol, pentaacetate	1823	0.08	1.50	0.57	2.02	1.27	0.20	1.22	0.63	-
7-Methyl-*Z*-tetradecen-1-ol-acetate	1822	-	-	0.60	10.62	-	0.21	-	10.01	-
tert-Hexadecanethiol	1831	0.68	7.55	2.71	-	-	0.15	2.52	-	-
1,3,12-Nonadecatriene	1916	0.29	0.82	2.43	0.80	1.43	1.74	-	0.22	-
Eicosane	2000	-	-	3.43	0.22	0.47	0.23	-	-	-
Docosane	2200	0.65	1.81	2.18	1.30	1.37	0.96	-	0.65	0.35
9-Hexylheptadecane	2243	-	-	-	0.73	-	-	-	-	-
5-(1-Isopropenyl-4,5-dimethylbicyclo [4,3,0]nonan-5yl)-3-methyl-2-pentanolacetate	2265	-	1.40	0.26	1.37	2.80	0.28	-	0.15	1.76
Tricosane	2300	0.52	-	0.92	-	-	-	0.41	-	-
2-Pentadecyl-1,3-dioxocane	2390	0.11	1.27	-	-	0.55	0.11	0.57	0.25	-
Tetracosane	2400		0.82	0.66	-	0.75	0.09	0.53	0.86	0.75
Methyl (*Z*)-13-docosenoate	2440	0.22	-	0.96	4.09	0.38	-	-	-	-
Acetamide,*N*(2-acetyloxy)-2-[3,4-bis(acetyloxy)phenyl]ethyl]-*N*-methyl	2454	0.08	0.66	0.37	-	0.21	0.09	4.22	-	0.12
Pentacosane	2500	0.05	0.86	0.41	0.36	1.06	0.29	1.57	0.44	0.14
Heptacosane	2700	1.20	9.46	8.59	10.43	3.88	1.27	-	8.42	3.09
Octacosane	2800	-	-	-	-	-	-	3.52	-	-
Nonacosane	2900	0.19	-	0.39	1.18	1.07	0.14	0.20	0.80	-
Dotriacontane	3200	0.71	2.11	-	0.88	1.94	0.44	0.51	-	-
Pentatriacontane	3500	-	0.14	0.14	0.62	0.72	0.63	0.35	0.39	0.52
Hexatriacontane	3600	0.07	0.76	0.39	1.22	0.59	0.06	1.00	0.51	-
		5.60	**31.27**	**26.88**	**37.07**	**21.32**	**9.09**	**19.27**	**25.03**	**11.82**
Monoterpene hydrocarbons										
cis-Salvene	856	-	-	0.04	-	0.13	-	-	-	1.16
α-Pinene	939	-	0.18	0.11	0.25	0.78	5.47	-	0.11	0.27
Camphene	954	-	0.39	-	0.16	0.23	0.28	0.29	-	0.37
Sabinene	975	0.04	1.33	0.12	-	-	-	-	0.45	-
β-Pinene	979	-	0.12	-	0.11	-	-	-	0.43	-
β-Myrcene	991	-	-	-	-	-	22.11	-	-	0.17
p-Cymene	1026	1.40	2.40	-	-	0.31	0.22	-	0.07	-
β-Phellandrene	1030	-	-	-	-	-	0.32	-	-	-
Limonene	1036	-	-	-	-	-	0.79	-	-	0.52
Terpinolene	1085	0.22	0.18	-	0.19	0.25	-	-	0.06	-
		1.66	**4.58**	**0.27**	**0.71**	**1.70**	**29.19**	**0.29**	**1.12**	**2.49**

Table 3 continued

Compounds*	**KI**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Oxygenated monoterpenes										
1,8-Cineole	1031	0.15	-	0.10	0.24	-	0.78	-	0.32	-
trans-Linalool oxide	1073	-	0.29	-	-	0.14	0.28	-	-	-
cis-Linalool oxide	1087	-	0.10	-	0.11	-	0.19	-	-	4.16
Linalool	1097	0.11	0.12	0.15	-	0.18	0.14	-	-	0.50
Sabinene hydrate	1098	0.09	0.27	0.10	0.15	0.18	0.21	-	-	0.98
cis-Thujone	1110	0.06	0.16	-	-	-	0.09	-	-	0.26
trans-Pinocarveol	1139	0.04	-	-	0.17	0.39	2.37	-	0.07	0.16
Verbenol	1141	-	-	-	0.17	-	0.12	-	-	-
Camphor	1146	-	0.14	0.27	0.48	-	1.09	-	0.51	0.12
Pinocarvone	1165	0.10	0.25	-	-	-	0.73	-	-	0.28
Borneol	1169	1.45	0.99	0.20	0.25	1.97	0.57	-	0.65	23.41
p-Cymen-8-ol	1183	0.60	0.57	0.33	0.72	0.73	0.16	-	0.11	0.23
cis-Piperitol	1193	-	-	-	0.13	0.18	1.79	-	0.21	-
Myrtenol	1196	-	-	0.07	-	0.26	0.46	-	-	0.11
Verbenone	1205	0.07	0.12	-	0.51	0.38	0.18	0.23	0.08	1.56
cis-*p*-Mentha-1(7),8-diene-2-ol	1231	0.65	-	1.29	-	-	0.18	-	-	4.87
Carvone	1244	0.04	0.14	0.14	-	0.20	0.08	-	-	-
Perillol	1261	-	0.41	-	-	0.14	-	-	-	-
Verbenol acetate	1283	1.66	-	-	2.99	-	-	-	-	-
Bornyl acetate	1285	0.10	0.90	0.07	0.21	-	-	0.31	-	0.32
trans-Pinocarvyl acetate	1298	-	0.16	-	0.18	0.24	0.12	-	-	5.06
Durenol	1361	-	-	-	-	0.13	0.08	-	-	-
8-Hydroxylinalool	1366	0.17	0.33	0.26	-	-	-	-	0.07	0.28
β-Ionone	1489	-	0.14	0.09	0.21	-	0.45	-	-	-
trans-2-Menthenol	1571	0.23	0.53	0.85	0.26	0.35	0.23	0.40	-	-
		5.53	**5.60**	**3.92**	**6.76**	**5.45**	**10.30**	**0.94**	**2.02**	**42.30**
Sesquiterpene hydrocarbons										
α-Bourbonene	1344	0.10	0.18	0.90	0.21	0.43	2.42	-	0.14	0.34
β-Cubebene	1390	0.17	3.57	0.65	0.18	0.73	0.47	-	0.16	0.28
(Z)-Caryophyllene	1409	0.04	0.60	0.12	0.20	-	-	-	0.15	-
α-Gurjunene	1412	-	-	0.30	2.28	-	0.16	-	-	-
Longifolene	1416	0.08	0.27	0.32	-	0.36	0.41	0.26	2.69	0.11
(E)-*β*-Caryophyllene	1418	0.28	1.05	0.35	0.44	0.29	0.23	0.23	0.38	0.23
Allo-Aromadendrene	1461	0.54	-	0.18	1.69	-	0.56	0.33	0.40	-
Aromadendrene	1475	0.08	0.12	0.08	-	0.20	0.20	-	3.23	0.23
γ-Muurolene	1477	-	0.14	0.15	-	0.60	0.20	-	-	0.14
Valencene	1483	0.07	0.10	0.18	0.20	0.77	0.55	-	-	-
Germacrene-D	1485	-	0.47	0.27	0.76	0.44	0.73	-	-	-
β-Selinene	1490	0.12	0.43	0.08	0.43	-	0.34	2.59	-	-
β-Bisabolene	1498	0.90	1.36	1.91	1.60	1.36	0.55	6.82	0.43	-
δ-Cadinene	1524	0.21	0.18	0.13	-	0.39	0.19	-	-	-
Bicyclogermacrene	1755	-	1.07	-	-	0.48	-	0.35	-	-
		2.60	**9.53**	**5.62**	**7.97**	**6.05**	**7.01**	**10.58**	**7.58**	**1.33**

Table 3 continued

Compounds*	**KI**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Oxygenated sesquiterpenes										
cis-Nerolidol	1527	0.11	-	0.06	0.95	1.62	4.79	-	0.09	-
Germacrene D-4-ol	1574	-	-	0.69	0.39	0.43	0.19	-	2.47	0.11
Isoaromadendrene epoxide	1579	0.16	3.74	1.30	0.28	0.40	1.37	-	1.35	-
Caryophyllene oxide	1581	0.37	3.90	2.82	2.03	0.68	2.52	-	1.17	0.37
Cubenol	1592	0.46	0.90	0.67	0.21	1.16	0.05	-	0.66	0.43
Humulene epoxide II	1607	0.94	1.15	0.59	0.79	2.25	6.53	0.59	1.21	0.59
Spathulenol	1619	0.04	2.96	1.51	0.11	7.99	1.23	0.73	0.58	0.23
Cedr-8-en-15-ol	1644	0.31	0.31	1.44	1.54	1.18	2.25	0.38	0.95	0.17
β-Eudesmol	1654	0.16	0.27	0.46	1.15	1.04	0.46	0.48	-	-
Cedr-8-en-13-ol	1689	0.54	0.58	1.61	-	1.32	2.66	-	0.25	-
Isolongifolol	1715	0.31	1.42	0.69	0.23	-	0.32	-	0.32	0.15
β-Santalol	1716	0.22	0.58	0.57	0.54	0.72	4.32	-	-	0.47
Cedryl propyl ether	1741	-	2.50	1.46	1.36	2.78	1.99	3.76	5.78	0.63
Longipinocarvone	1747	-	2.67	0.14	2.59	0.93	0.32	7.44	-	-
Cedrane-8,13-diol	1876	-	-	5.60	-	1.02	0.44	0.51	-	4.08
Sclareol oxide	1906	2.23	-	-	-	-	0.16	4.81	-	-
		5.84	**21.00**	**19.61**	**12.18**	**23.52**	**29.60**	**18.70**	**14.83**	**7.23**
Diterpene alcohols										
Cetyl alcohol	1876	1.04	5.79	1.90	3.28	1.14	0.27	1.05	2.96	-
Phytol	1943	0.40	-	1.09	0.63	0.50	0.30	0.23	-	-
Sclareol	2223	0.34	0.49	1.36	0.44	6.31	0.38	-	0.29	-
		1.78	**6.28**	**4.35**	**4.35**	**7.96**	**0.95**	**1.28**	**3.25**	**0.00**
Fatty acids and derivatives										
Lauric acid	1567	0.86	0.76	2.15	0.40	1.45	1.26	-	-	0.69
Myristic acid	1724	0.50	2.38	2.23	6.08	1.97	0.13	0.79	0.87	1.20
Palmitic acid	1922	0.77	1.23	5.21	3.58	3.87	0.41	0.74	17.79	7.93
Stearic acid, allyl ether	2251	-	0.72	1.06	-	0.24	-	25.38	0.98	2.08
		2.12	**5.09**	**10.65**	**10.07**	**7.53**	**1.80**	**26.91**	**19.64**	**11.90**
Phenolic compounds										
Thymol	1290	-		-	-	-	3.17	-	-	-
Carvacrol	1299	0.05	0.27	0.34	0.51	1.08	2.08	-	0.37	0.11
		0.05	**0.27**	**0.34**	**0.51**	**1.08**	**5.25**	**0.00**	**0.37**	**0.11**
Oxygenated triterpenes										
Betulin	1752	66.00	-	-	-	-	1.08	-	3.20	-
Oleanolic acid	3242	-	-	0.27	-	1.13	-	1.33	0.07	-
Myristyl oleate	3377	0.13	0.35	0.47	0.58	0.83	0.05	0.21	0.15	0.29
		66.13	**0.35**	**0.74**	**0.58**	**1.96**	**1.13**	**1.54**	**3.42**	**0.29**
Others compounds										
Tetraneurin D	2494	-	1.66	2.52	2.96	-	-	0.56	-	-
Isochiapin B	2577	1.27	-	0.15	0.11	5.39	0.44	2.18	1.75	0.29
Squalene	2914	-	-	-	-	-	0.04	-	-	-
24,25-Dihydroxycholecalciferol	3124	-	-	9.45	-	-	0.10	2.10	7.41	-
Stigmasterol	3170	-	-	-	-	-	-	0.27	-	-
		1.27	**1.66**	**12.12**	**3.07**	**5.39**	**0.58**	**5.11**	**9.16**	**0.29**
TOTAL		**92.60**	**85.63**	**84.50**	**83.26**	**81.95**	**94.90**	**84.62**	**86.42**	**77.76**

*Identification via MS data and KI (on DB-5 column)

Table 4. The ratio of monoterpenes to sesquiterpenes of *Salvia* species

Total	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Monoterpenes	16.75	37.77	5.79	31.98	12.57	53.77	54.15	35.58	9.65	25.92	36.00	7.71	5.40	47.00	64.30
Sesquiterpenes	12.20	28.09	33.92	55.52	42.56	34.04	6.37	32.60	23.74	13.71	22.06	32.11	28.01	12.10	8.20
Ratio$_{Monoterpenes/Sesquiterpenes}$	**1.37**	**1.34**	**0.17**	**0.58**	**0.30**	**1.58**	**8.50**	**1.09**	**0.41**	**1.89**	**1.63**	**0.24**	**0.19**	**3.88**	**7.84**
Total	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Monoterpenes	12.95	8.82	19.85	29.76	8.59	76.30	5.60	15.81	18.56	9.81	3.68	31.20	42.73	7.29	49.18
Sesquiterpenes	19.10	17.76	12.40	26.93	32.81	1.00	20.56	55.61	23.81	21.94	30.73	29.44	30.21	17.73	34.01
Ratio$_{Monoterpenes/Sesquiterpenes}$	**0.68**	**0.50**	**1.60**	**1.11**	**0.26**	**76.30**	**0.27**	**0.28**	**0.78**	**0.45**	**0.12**	**1.06**	**1.41**	**0.41**	**1.45**
Total	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
Monoterpenes	1.44	42.13	7.04	26.77	49.04	56.77	7.19	10.18	4.19	7.46	7.15	39.49	1.23	3.14	44.79
Sesquiterpenes	41.06	29.14	16.29	32.52	17.54	18.09	8.44	30.53	25.23	20.15	29.56	36.61	29.28	22.41	8.56
Ratio$_{Monoterpenes/Sesquiterpenes}$	**0.04**	**1.45**	**0.43**	**0.82**	**2.80**	**3.14**	**0.85**	**0.33**	**0.17**	**0.37**	**0.24**	**1.08**	**0.04**	**0.14**	**5.23**

Table 5. Essential oil compositions, and uses of *Salvia* species around the world

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
3	*Salvia aethiopis*	*α*-copanene, germacreneD *β*-caryophyllene, caryophyllene oxide and humulene	Folk medicine	Cytotoxic, antioxidant, antimicrobial, inhibition of 5-lipoxygenase activity, anti-inflammatory, antibacterial, analgesic, antipyretic, haematological effects and acetylcholinesterase	Iran, Turkey, Serbia, Lithuania, Spain	[16-25]	0.23
4	*Salvia aramiensis*	*β*-pinene, 1,8-cineole, camphor and borneol	Herbal tea	Antimycobacterial, antioxidant, antibacterial and acetylcholinesterase	Turkey	[26-29]	2.20
5	*Salvia atropatana*	caryophyllene oxide, *α*-cubebene, *β*-caryophyllene, germacrene D, phytol, longifololacetate and δ-cadinene	No report	Antioxidant, antiproliferative, antimicrobial and cytotoxic	Iran, Poland, Turkey	[16-17], [25], [30-33]	0.20
6	*Salvia aucheri* var. *aucheri*	1,8-cineole, camphor, *α*-pinene, camphene, *β*-pinene and borneol	Herbal tea	Antimycobacterial, antibacterial, antifungal, acetylcholinesterase and antioxidant	Turkey	[25], [27-29], [34]	0.70
7	*Salvia blepharochlaena*	*α*-pinene, *α*-copaene, camphor, spathulenol, *β*-phellandrene, *β*-pinene and 1,8-cineole	No report	Acetylcholinesterase, antioxidant and antibacterial	Turkey	[5], [25], [35-36]	0.10

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
8	*Salvia bracteata*	*β*-pinene, camphor, terpinen-4-ol, pulegone, carvacrol, *α*-copaene, caryophyllene and caryophyllene oxide	No report	Antimicrobial, anticholinesterase, antioxidant and antibacterial	Lebanon, Turkey, Iran	[19], [29], [37-40]	0.20
9	*Salvia cadmica*	cryptone, 1,8-cineole, *β*-phellandrene, camphor and carvacrol	No report	Acetylcholinesterase, butyrylcholinesterase, lipoxygenase, tyrosinase and antioxidant	Turkey, Poland	[25], [33], [41-42]	0.17
10	*Salvia caespitosa*	*α*-pinene, *β*-pinene, 1,8-cineol, camphor, *β*-caryophyllene and caryophyllene oxide	No report	Amoebicidal, cytotoxic, antibacterial, antioxidant and anticholinesterase	Turkey	[8], [36], [38], [43-46]	0.20
11	*Salvia candidissima* subsp. *candidissima*	α-pinene, 1,8-cineole, *p*-cymene, myrtenal, pinocarvone and camphene	No report	Antioxidant, anticholinesterase and antimicrobial	Greece, Turkey	[18-19], [46-49]	0.70
12	*Salvia chionantha*	germacrene D, *β*-caryophyllene, spathulenol and *α*-humulene	No report	Acetylcholinesterase and antioxidant	Turkey	[25], [50-51]	1.30
13	*Salvia cilicica*	spathulenol, caryophyllene oxide and hexadecanoic acid	No report	Antimycobacterial and antifungal activities	Turkey	[52]	1.40
14	*Salvia cryptantha (Salvia absconditiflora)*	*β*-pinene, 1,8-cineole, camphor and isoborneol	No report	Antiproliferative, antitumor, anticancer, anticholinesterase, antioxidant, tyrosinase inhibitory, antibacterial and antimicrobial	Turkey	[29], [38], [53- 57]	0.90
15	*Salvia divaricata*	1,8-cineole, α-pinene and camphor	No report	Acetylcholinesterase and antioxidant	Turkey	[25], [36]	0.80

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
16	*Salvia euphratica* var. *leiocalycina*	1,8-cineole, linalool, *trans*-pinocarveol, myrtenol, *trans*-pinocarvyl acetate and myrtenyl acetate	No report	Antioxidant and anticholinesterase	Turkey	[25], [46], [58-59]	0.60
18	*Salvia glutinosa*	butyl butyryl lactate, sclareol, caryophyllene oxide and manool	No report	Antioxidant, antiproliferative, anticholinesterase, antimicrobial and cytotoxic	Greece, Iran, Turkey, Serbia, Poland, Lithuania, Hungary	[20-21], [31], [33], [38], [47], [60-65]	0.40
19	*Salvia heldreichiana*	linalool, α-pinene, 1,8-cineole, borneol, cryptone, linayl acetate, α-terpineol, camphor, terpinene-4-ol, *trans*-linalool oxide, *trans*-verbenol, geranyl acetate and *cis*-linalool oxide	No report	Cytotoxic, antioxidant, antibacterial and acetylcholinesterase	Turkey	[56], [66-69]	0.22
20	*Salvia huberi*	α-pinene, β-pinene, 1,8-cineole and camphor	No report	Anti-inflammatory, anti-angiogenic, acetylcholinesterase inhibitory and antioxidant	Turkey	[25], [35]	0.20
21	*Salvia hydrangea*	camphor, α-humulene, *cis*-sesquisabinene hydrate, myrtenol, β-bisabolol and 1,8-cineole	No report	Antimicrobial, insecticidal, hypoglycemic, hypolipidemic, antioxidant, antiproliferative, antiplasmodial, antibacterial, alpha-amylase inhibitory activities, antitumor and acetylcholinesterase	Turkey, Iran, Armenia	[25], [31], [70-79]	0.53

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
22	*Salvia hypargeia*	α-pinene, β-pinene, pulegone and β-ylangene	No report	Antioxidant, antimicrobial, cytotoxic, anticholinesterase, antibacterial and antimycobacterial	Turkey	[25], [36], [46], [80-84]	0.02
23	*Salvia kronenburgii*	limonene, 2-cyclohexen-1-ol, *trans*-verbenol and *trans*-carveol	No report	Antimicrobial, antioxidant, acetylcholinesterase and cytotoxic	Turkey	[25], [85-87]	0.70
24	*Salvia limbata*	germacrene D, 7-*epi*-α-selinene, β-elemene, β-pinene	Herbal tea	Anticholinesterase, antioxidant antimicrobial, antiviral, antibacterial, antinociceptive, anticandidal, antidiabetic, antimutagenic, antiobesity and cytotoxic	Iran, Turkey	[17-18], [25], [88-98]	0.30
25	*Salvia macrochlamys*	camphene, 1,8-cineole, camphor, β-caryophyllene, borneol and caryophyllene oxide	No report	Antifungal, allelopathic, anticholinesterase and antioxidant	Turkey	[25], [99-102]	0.15
26	*Salvia microstegia*	pulegone, caryophyllene oxide, 4-vinylguaiacole, hexadecanoic acid and menthone	No report	Anticholinesterase, antioxidant and antimicrobial	Lebanon, Turkey	[18], [29], [38], [86] [103-104]	0.10
28	*Salvia multicaulis*	1,8-cineole, camphor, α-pinene, valeranone and α-eudesmol	No report	Antioxidant, anticholinesterase, antibacterial, antifungal, hepatoprotective, antileishmanial, antimicrobial and antituberculos	Turkey, Iran, Lebanon, Egypt	[6], [38], [57], [86], [105-112]	0.40

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
29	*Salvia nemorosa*	*β*-caryohpyllene, germacrene B, caryophyllene oxide, cis-*β*-farnesene and germacrene D	No report	Antioxidant, antimicrobial, antibacterial, antiproliferative, cytotoxic, pyrophosphate-D-fructose-6-phosphate l-phosphotransferase, phosphofructokinase and peroxidase	Bulgaria, Iran, Romania, Hungary, Serbia, Turkey	[17-18], [32], [63], [78], [91], [113-119]	0.48
31	*Salvia palestina*	caryophyllene oxide, *β*-caryophyllene terpinen-4-ol, *β*-pinene and camphor	No report	Antioxidant, acetylcholinesterase, antibacterial, antiproliferative and antimicrobial	Turkey, Jordan, Syria, Lebanon, Iran	[25], [29], [75], [120-125]	0.30
32	*Salvia pisidica*	*α*-pinene, *β*-pinene, 1,8-cineole, sabinol, thujone, camphor and borneol	Herbal tea	Acetylcholinesterase, antitumoral, antioxidant, antimicrobial, anti-inflammatory and anti-angiogenic	Turkey	[25], [35], [126-127]	0.40
34	*Salvia potentillifolia*	*α*-pinene, *β*-pinene, 1,8-cineole, sabinene, *β*-myrcene, limonene, camphor, borneol, terpinen-4-ol, caryophyllene oxide	Folkloric drug, tea	Antioxidant, antimicrobial acetylcholinesterase, butyrylcholinesterase, lipoxygenase, tyrosinase and anticandidal	Turkey	[25], [29], [128-131]	0.40
35	*Salvia recognita*	*α*-pinene, camphene, 1,8-cineole, camphor and borneol	No report	Antiproliferative, antioxidant, antifungal and anticholinesterase	Hungary, Turkey	[25], [99], [116], [132]	0.33

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
36	*Salvia rosifolia*	*α*-pinene, *β*-pinene, 1,8-cineole, *p*-cymene, camphor, *β*-caryophyllene and caryophyllene oxide	No report	Antibacterial, antifungal, anticancer, antioxidant, cytotoxic, opioid receptor binding activitiy, and acetylcholinesterase	Turkey	[25], [133-134]	0.39
37	*Salvia russellii*	*γ*-terpinene, *α*-terpineol, thymol and carvacrol	No report	Antioxidant and acetylcholinesterase inhibitory activity	Turkey	[135-136]	0.80
38	*Salvia sclarea*	germacrene D, *β*-caryophyllene, linalool, spathulenol, *α*-copaene and sclareoloxide	Clary or muscatel sage	Antioxidant, antifungal, cytotoxic, antioxidative stress-induced apoptosis, antiproliferative, antimicrobial, antibacterial and antibiotic resistance modifying activity, larvicidal, opioid receptor binding activity, antibrucella, neuroprotection and antiprotozoal	Iran, Himalayas, Poland, Slovakia, Turkey, Greece, Tajikistan, Uruguay, Spain, Hungary, Germany	[16-17], [29], [31], [33], [74], [113], [134], [137-152]	1.20
39	*Salvia staminea*	germacrene D, hexahydrofarnesyl acetone and *α*-copaene	No report	Antioxidant, amoebicidal, cytotoxic and anticholinesterase	Iran, Poland, Turkey	[7], [25], [33], [44], [153-154]	2.90
40	*Salvia suffruticosa*	camphor, 1,8-cineole and camphene	No report	Antioxidant, antimicrobial, acetylcholinesterase, butyrylcholinesterase, lipoxygenase and tyrosinase inhibitory	Iran, Turkey	[25], [42], [155-156]	0.27

Table 5 continued

	Plant species	Main essential oil components	Used in	Widespread medicinal activity	Country	References	Oil yield (% v/dry weight)
41	*Salvia syriaca*	spathulenol, borneol, bicyclogermacrene and germacrene D	Animal food	Antioxidant, antibacterial, cytotoxic, antiproliferative, antiangiogenic, antimicrobial, anticholinesterase, antinociceptive, anti-inflammatory, larvicidal, antifungal and cardioactive	Iran, Jordan, Turkey	[17], [38], [49], [108], [136], [147], [157-164]	2.50
42	*Salvia tomentosa*	α-pinene, 1,8-cineole, camphor and borneol	Dark tea	Antibacterial, antifungal, antioxidant, insecticidal, fumigant activity, antitumor, antiprotozoal, larvicidal, opioid receptor binding activities, antimycobacterial, antimicrobial, polyphenol oxidase activity	Turkey, Greece	[27], [29], [68], [134], [147], [152], [165-175]	1.00
43	*Salvia trichoclada*	*β*-pinene, camphor, caryophyllene oxide and *β*-caryophyllene	No report	Antioxidant, antcholinesterase, antibacterial, anti-inflammatory and antimicrobial	Turkey	[29], [105], [176-180]	0.30
44	*Salvia verticillata* subsp. *amasiaca*	*β*-pinene and 1,8-cineole	No report	Anticholinesterase, antioxidant, antibacterial, antitumor, antimicrobial and antimycobacterial	Turkey	[25], [27], [49], [86], [170], [181-184]	0.22
45	*Salvia virgata*	*α*-thujene, sabinene, 1-octene-3-ol, terpinen-4-ol, *β*-caryophyllene and caryophyllene oxide	Dark tea	Antimicrobial, antioxidant, alphaamylase, GSH-Px activities, antinociceptive, anti-inflammatory, peroxidase activity, polyphenol oxidase activity and acetylcholinesterase	Iran, Turkey	[18], [25], [86], [113], [118], [174], [185-192]	2.90

Altough Lamiaceae (Labiatae) plants grow throughout the world, especially in the Mediterranean region it has a very intense expansion [1,193]. Two hundred thirty-six genera and approximately 7200 species are represented by cosmopolitan type. The Lamiaceae family has 45 genera, 574 species and 256 of which are endemic the flora of Turkey [194]. *Salvia* is the largest genus in the Lamiaceae, which represents a broad and cosmopolitan distribution, and exhibits a considerable range of variation. Most of the studies on biological activity and essential oil composition of *Salvia* species were conducted on the plants growing in Iran, Turkey, Serbia, Lithuania, Spain, Poland, Lebanon, Greece, Hungary, Armenia, Egypt, Bulgaria, Romania, Jordan, Syria, Himalayas, Slovakia, Tajikistan, Uruguay and Germany. The essential oils were in the range of 0.02-2.90 % (Table 5). Altough common consumption as herbal teas in these regions, there is restricted reports for use as foods. Morever, the *Salvia* species have been reported to have cytotoxic, antioxidant, antimicrobial, antiinflammatory, antibacterial, analgesic, antipyretic, anticholinesterase, antimycobacterial, antiproliferative, antifungal, lipoxygenase, tyrosinase, amoebicidal, antitumor, antiangiogenic, insecticidal, hypoglycemic, hypolipidemic, antiplasmodial, alpha amylase, antinociceptive, anticandidal, antidiabetic, antimutagenic, antiobesity, allelopathic, hepatoprotective, antileishmanial, antituberculos, pyrophosphate-D-fructose-6-phosphate l-phosphotransferase, phosphofructokinase opioid receptor binding, antioxidative stress-induced apoptosis, antibiotic resistance modifying, larvicidal, antibrucella, neuroprotecttion, antiprotozoal and cardioactive activities (Table 5).

Previous reports on *Salvia* species [16-192] investigated in the present article are shown in Table 5. According to the literature, most of the essential oil compositions of *S. aethiopis, S. atropatana, S. bracteata, S. glutinosa, S. hydrangea, S. multicaulis, S. nemorosa, S. palestina, S. staminea* and *S. suffruticosa* are from Iran. Hovewer, these species do not appear to have a significant use as food or tea. While *S. limbata* is used as an antidiabetic tea, *S. palestina* and *S. virgata* are consumed as an animal food and dark tea, respectively (Table 5).

S. nemorosa and *S. recognita* from Hungary were reported without any information on their consumption. However, *S. sclarea* is known to be used as clary or muscatel sage. In Greece, while the essential oil compositions of *S. candidissima* and *S. glutinosa* were reported without any consumption, *S. tomentosa* was reported to be consumed as a dark tea.

Not enough reports were found for the uses of the endemic Anatolian *Salvia* species such as *S. blepharochlaena, S. caespitosa, S. chionantha, S. cryptantha, S. divaricata, S. euphratica, S. heldreichiana, S. huberi, S. hypargeia, S. kronenburgii, S. macrochlamys, S. potentillifolia, S. rosifolia, S. russellii, S. trichoclada, and S. verticillata* subsp. *amasiaca.* However, *S. aucheri* var. *aucheri, S. pisidica, S. tomentosa* and *S. aramiensis* were reported to be used as herbal tea and *S. potentillifolia* is consumed as folkloric drug and tea. Among all of them, some species are going to be utilized in the food, cosmetic, perfumery and pharmaceutical industries [195].

The Egyptian essential oil of *Salvia* consisting of thujone and limonene, showed antibacterial activity against Gram-positive *Sarcina* spp., *Staphylococcus aureus*, *Bacillus subtilis* and *Saccharomyces cerevisiae* yeast [196].

In vitro studies on *S. guaranitica*, used by Amazonian Indians as sedative and hypnotic, indicated that its constituents cirsiliol and caffeic acid ethyl ester are competitive benzodiazepine (GABA) receptor ligands [197]. The reports are available on anti-epileptic properties of *Salvia* species, particularly, of *S. officinalis* and monoterpenoid linalool, present in the essential oils of various species. It demonstrated an anticonvulsant action via inhibition of glutamate binding, which is the main excitatory neurotransmitter in CNS [198-199]. *S. lavandulaefolia* showed acetylcholinesterase activity, and the compounds responsible for the activity were found to be monoterpenois such as limonene, linalool and *p*-cymene. Chromatographic fractionation of *S. lavandulaefolia* essential oil yielded 25 components, among them, monoterpene derivatives inhibited human erythrocyte AChE activity, such as limonene, linalool and *p*-cymene at relatively high concentrations [200].

Recent reports represented a monoterpenoid carvacrol in *S. lavandulaefolia* and *S. fruticosa* as an antioxidant and antifungal agent [201-202]. Moreover, diverse activities of carvacrol such as antimicrobial, antitumor, antimutagenic, antigenotoxic, analgesic, antispasmodic, anti-inflammatory, angiogenic, antiparasitic, antiplatelet, AChE inhibitory, antielastase, insecticidal, antihepatotoxic and hepatoprotective along with its use as feed additive in honeybee breeding and in gastrointestinal ailments were demonstrated [203]. The diterpenoid aethiopinone from *S. aethiopis* has central and peripheral analgesic properties [204], and tanshinones from *S. miltiorrhiza* root showed anti-inflammatory activity in mice [205]. All of these

Salvia species could be considered useful in the treatment of CNS inflammatory disorders. Other constituents of *Salvia* species having anti-inflammatory effects include the flavonoids (carvacrol, cirsimaritin, eugenol, genkwanin, luteolin, quercetin and salvigenin), the monoterpenoids (carvacrol, eugenol, thymol, *α*-pinene and *β*-pinene) and a stilbene rosmarinic acid [206-211].

The reports, particularly in Spain, on the oestrogenic activity of *Salvia* species, such as *S. officinalis*, *S. sclarea* and *S. lavandulaefolia* indicated to treat gynecological disorders [206], [212-213]. 1,8-Cineole, also known as eucalyptol, which is a monoterpene oxide, showed a very strong activity against the tested Gram (-) and Gram (+) bacteria, and a significant activity against the three tested fungi [214]. Furthermore, Sonboli and coworkers [78] found that the antimicrobial activity of the oils from *Salvia* species probably due to the existence of synergy among the six compounds (linalool, 1,8-cineole, *α*-pinene, *β*-pinene, *β*-caryophyllene and limonene). Among them, linalool and 1,8-cineole had the highest antimicrobial activities. Similarly, *β*-caryophyllene, caryophyllene oxide, *α*-pinene, *p*-cymene, borneol, carvacrol, thymol, linalool, 1,8 cineole, limonene, *α*-terpineol, fenchone, piperitone and camphor are known to have moderate to high antimicrobial activities [215].

Squalene derived triterpenoids, ursolic and oleanolic acids, had anti-inflammatory activity and inhibited tumorigenesis in mouse skin [216-218]. Moreover, they had antihyperlipidemic properties and were shown to be effective in protecting against chemically induced liver injury in laboratory animals [219]. In the present study, oleanolic acid was found to be the most abundant compound in the volatile organic compounds of *S. limbata* (2.33%). Because of this, *S. limbata* can be expected to have potential hepatoprotective activity.

According to Taddei and coworkers, some of sage essential oil components like pinene [220] and borneol [221] exhibited spasmogenic and dose-dependent antispasmodic activities in vitro and in vivo [222]. Camphor and borneol from the essential oil of *S. lavandulifolia* Vahl. were tested for spasmolytic activity on isolated rat duodenal tissue, which demonstrated a significant inhibitory activity against at least one of the chemical spasmogenic agents ($BaCl_2$ and acetylcholine) [221].

In conclusion, we examined the main volatile organic compounds of fourty-five species, and reported chemotaxonomic evaluation of 45 different *Salvia* taxa from Turkey. The volatile organic compounds of the *S. adenocaulon* (**1**), *S. adenophylla* (**2**), *S. frigida* (**17**), *S. modesta* (**27**), *S. pachystachys* (**30**) and *S. poculata* (**33**) were studied, to the best of our knowledge, for the first time. It has been been shown that the oils of fourty five *Salvia* species are rich in monoterpenes, sesquiterpenes and diterpenes. Besides, the literature survey of the *Salvia* species indicated their common use as tea and alternative medicinal drug for many purposes throughout the world.

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Supporting Information

Supporting Information accompanies this paper on http://www.acgpubs.org/RNP

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