NPC Natural Product Communications

2015
Vol. 10
No. 6
1075 - 1078

Comparative Chemical Composition and Antioxidant Properties of the Essential Oils of three *Sideritis libanotica* Subspecies

Carmen Formisano[a], Filomena Oliviero[a], Daniela Rigano[a,*], Nelly Apostolides Arnold[b] and Felice Senatore[a]

[a]*Department of Pharmacy, University of Naples Federico II, Via D. Montesano, 49, I-80131 Naples, Italy*
[b]*Faculty of Agronomical Sciences, University Saint Esprit, Kaslik, Beyrouth-Lebanon*

drigano@unina.it

Received: October 2nd, 2014; Accepted: December 12th, 2014

The phytochemical composition of the essential oils of three *Sideritis libanotica* subspecies, namely *S. libanotica* ssp. *libanotica*, *S. libanotica* ssp. *linearis* and *S. libanotica* ssp. *michroclamys*, all collected in Lebanon, was analyzed by GC and GC-MS. The diterpene sideridiol was recognized as the main constituent of both *S. libanotica* ssp. *libanotica* (50.8%) and *S. libanotica* ssp. *michroclamys* (18.4%) oils, while hexadecanoic acid (10.5%) prevailed in *S. libanotica* ssp. *linearis*. The antioxidant activity of the oils was studied in two cell free systems by DPPḢ radical scavenging and ferric ion reduction (FRAP) assays; only *S. libanotica* ssp. *linearis* showed a moderate activity when assayed by the FRAP test (0.6± 0.01 mmol TE/mL).

Keywords: *Sideritis libanotica* ssp. *libanotica*, *Sideritis libanotica* ssp. *linearis*, *Sideritis libanotica* ssp. *michroclamys*, Essential oil, Diterpenes, Antioxidant activity.

The genus *Sideritis*, family Lamiaceae, subfamily Lamioideae, has more than 150 species occurring mainly in the Eastern and Western Mediterranean regions [1]. Infusions of the aerial parts, known as “mountain tea” because some species grow in the high mountain areas, are used as tonics, carminatives, diuretics, and digestives; in addition, *Sideritis* spp. are used as culinary herbs and for producing flavoring substances [2]. The genus has been the subject of wide chemotaxonomic investigations for 40 years because of the presence of diterpenoids with many different carbon skeletons (mainly kaurane and labdane, but also beyerane, atisane, trachilobane, and rarely pimarane, rosane and abietane), occurring in almost all the species studied [3], and essential oils. Recently Pala-Paul *et al*. [4] summarized both yields and main components of essential oils from *Sideritis* species studied until now: most of these are richer in monoterpene hydrocarbons than in other terpenoid compounds, and diterpenes occur only in the oils of a few species [4].

In the present study, following our previous research on this genus [5-7], we contribute to the knowledge of the volatile compounds of *Sideritis* species describing the chemical composition of essential oils from three *S. libanotica* subspecies, namely: *S. libanotica* Labill. ssp. *libanotica* (Hand-Mazz.) Huber-Morath., *S. libanotica* Labill. ssp. *linearis* (Bentham) Borm. and *S. libanotica* ssp. *michroclamys* (Hand-Mazz.) Huber-Morath. *S. libanotica* is very popular to treat coughs, hypertension and the “worm in the eyes” syndrome (it is traditionally believed that pains in the eyes are caused by worms with a black head) [2]. Methanol extract of the aerial parts of *S. libanotica* subsp. *linearis* showed *in vitro* antiproliferative activities against Vero, HeLa and C6 cells [8], and antioxidant activity [9,10]. *S. libanotica* ssp. *libanotica* has previously been investigated for diterpenes; siderol and sideridiol were found [11], while the main volatile compounds of the three subspecies of *S. libanotica* from Turkey have been described by Kirimer *et al*. [12]. Along with the chemical composition of the essential oils from the title plants, here we describe also the antioxidant activity of the oils evaluated by two cell free systems, DPPḢ radical scavenging and ferric ion reduction (FRAP) assays.

The relative concentrations of the volatile components identified in the essential oils of the three subspecies of *S. libanotica* are presented in Table 1, according to their retention indices Ki on a HP-5 MS column. The oils presented different compositions and the identity of the most dominant components differed notably.

In *S. libanotica* ssp. *libanotica* (**Lb**) we identified 50 compounds, accounting for 91.9% of the total oil. Diterpenes (52.8%) represented the main fraction of the oil and sideridiol (50.8%) was recognized as the main constituent. Fatty acids and esters (8.9%) were quite abundant and were mainly constituted by (*Z*,*Z*)-9,12-octadecadienoic acid (4.3%) and hexadecanoic acid (3.2%). Oxygen containing monoterpenes contributed 6.1%; monoterpene hydrocarbons were completely absent.

As regards *S. libanotica* ssp. *linearis* (**Ln**), the oil was constituted of 50 compounds accounting for 90.2% of the total oil. The main compounds were hexadecanoic acid (10.5%), (*Z*,*Z*,*Z*)-9,12,15-octadecatrienoic acid (7.8%) and oplopanone (7.1%). Fatty acids and esters (32.2%) clearly prevailed but also phenols were abundant (13.4%) and generally oxygenated compounds. Also in this sample monoterpene hydrocarbons were absent and sesquiterpene hydrocarbons were scarce (1.6%). Diterpenes accounted only for 0.5%. The absence of monoterpene hydrocarbons in **Lb** and **Ln** is worthy of note if we consider that Kirimer *et al*. [12] classified these two oils as monoterpene hydrocarbon-rich oils, and particularly β- and α-pinene-rich oils. This confirms the wide variation in essential oil composition between different sites and populations observed previously [4].

Sideridiol (18.4%) was recognized as the main constituent of *S. libanotica* ssp. *michroclamys* oil (**Lm**), together with bicyclogermacrene (4.7%). Diterpenes were quite abundant (22.9%), followed by oxygenated monoterpenes (16.6%), fatty acids and esters (13.6%) and sesquiterpene hydrocarbons (12.6%). Again our results differ from those of Kirimer *et al*. [12] who found β-caryophyllene (12%) and germacrene D (10%) as main compounds, classifying this oil as sesquiterpene-rich and particularly β-caryophyllene-rich.

Table 1: Chemical composition of the essential oils from aerial parts of *S. libanotica* ssp. *libanotica* (**Lb**), *S. libanotica* ssp. *linearis* (**Ln**) and *S. libanotica* ssp. *michroclamys* (**Lm**)

R_i[a]	R_i[b]	Components	Id.[c]	Lb% [d]	Ln% [d]	Lm% [d]
				50 (91.9)	50 (90.2)	87 (93.1)
		Alcohols		**3.4**	**0.7**	**2.7**
1475	1973	Dodecanol	1. 2. 3	0.2	0.7	
2060	2693	(*Z*)-9-Octadecenol	1. 2	3.2		2.7
		Carbonylic compounds		**3.8**	**9.7**	**1.9**
1186	1690	Cryptone	1. 2	0.3		0.8
1302	1797	*p*-Methoxyacetophenone	1. 2. 3	1.6	1.6	0.9
1305	1779	(*E.Z*)-2.4-Decadienal	1. 2		0.2	
1382	1838	(E)-β-Damascenone	1. 2	0.3	1.4	
1517	1829	Tridecanal	1. 2		0.3	
1590	2512	Benzophenone	1. 2. 3	0.8		
1805	2203	2-Hexadecanone	1. 2		0.6	
1998	2695	(*Z*)-9-Octadecenal	1. 2	0.8		0.2
2023	2354	Octadecanal	1. 2		0.5	
2111	2367	9,12,15-Octadecatrienal[#]	1. 2		5.1	
		Diterpenes		**52.8**	**0.5**	**22.9**
1950	2622	(*Z*)-Phytol	1. 2		0.5	
1968	2286	Sandaracopimaradiene	1. 2			0.5
1973	2231	Sclarene	1. 2			0.9
1989	2346	α-Kaurene	1. 2			0.5
1990	2367	Manoyl oxide	1. 2	2.0		0.7
2035	2438	Phyllocladene	1. 2			1.2
2239		7α-Hydroxy-manool	1. 2			0.3
2271		Sandaracopimaradien-3β-ol	1. 2			0.4
2605		Sideridiol	1. 2	50.8		18.4
		Fatty acids and esters		**8.9**	**32.2**	**13.6**
1180	2053	Octanoic acid	1. 2. 3		0.7	
1566	2503	Dodecanoic acid	1. 2. 3		0.9	
1589	2149	(*Z*)-3-Hexenyl benzoate				0.6
1643	2366	(*Z*)-Methyl jasmonate				0.5
1767	2655	Benzyl benzoate	1. 2. 3		0.3	0.8
1769	2713	Tetradecanoic acid	1. 2. 3	1.4	4.2	0.7
1870	2822	Pentadecanoic acid	1. 2. 3		1.7	
1928	2208	Hexadecanoic acid methyl ester	1. 2. 3		0.9	
1957	2932	Hexadecanoic acid	1. 2. 3	3.2	10.5	2.1
2074	2975	Heptadecanoic acid	1. 2. 3	t	0.9	0.3
2099	3157	(*Z,Z,Z*)-9,12,15-Octadecatrienoic acid	1. 2. 3		7.8	3.2
2104	3160	(*Z,Z*)-9,12-Octadecadienoic acid	1. 2. 3	4.3	2.4	3.5
2117	3157	(*Z*)-9-Octadecenoic acid				1.1
2172	3152	Octadecanoic acid	1. 2. 3		1.9	0.8
		Phenols		**3.8**	**13.4**	**1.6**
1293	2198	Thymol	1. 2. 3	0.5	4.9	
1299	2239	Carvacrol	1. 2. 3		5.3	0.5
1313	2180	4-Vinylguaiacol	1. 2	1.7	2.1	0.9
1353	2186	Eugenol	1. 2. 3	1.6	1.1	0.2
		Hydrocarbons		**5.0**	**8.2**	**5.0**
1179	1763	Naphthalene	1. 2. 3	0.5	0.2	1.2
2000	2000	Eicosane	1. 2.l 3			0.3
2300	2300	Tricosane	1. 2. 3	0.7	0.4	1.2
2500	2500	Pentacosane	1. 2. 3	1.5	1.1	0.5
2700	2700	Heptacosane	1. 2. 3	1.2	2.8	0.6
2900	2900	Nonacosane	1. 2. 3	0.8	2.2	0.8
3100	3100	Hentriacontane	1. 2	0.3	1.5	0.4
		Monoterpene hydrocarbons				**8.1**
938	1075	α-Pinene	1. 2. 3			1.3
978	1118	β-Pinene	1. 2. 3			2.1
993	1174	Myrcene	1. 2. 3			0.4
1005	1150	α-Phellandrene	1. 2. 3			0.5
1029	1218	β-Phellandrene	1. 2. 3			2.2
1030	1205	Limonene	1. 2			0.7
1049	1262	(*E*)-β-Ocimene	1. 2			0.1
1057	1256	γ-Terpinene	1. 2. 3	t		0.4
1086	1265	Terpinolene	1. 2. 3			0.4
		Others		**1.1**	**0.3**	**T**
1483	2354	Dihydroactinidiolide	1. 2	0.6		
1898		7,9-Di-*tert*-butyl-1-oxaspiro[4,5]deca-6,9-diene 2,8-dione	1. 2	0.5		
2824	3047	Squalene	1. 2	t	0.3	t
		Oxygenated monoterpenes		**6.1**	**11.2**	**16.6**
1064	1555	*cis*-Sabinene hydrate	1. 2	0.5		0.3
1086	1406	Fenchone	1. 2	0.3		
1098	1553	Linalool	1. 2. 3		0.3	
1128	1637	*cis*-*p*-Menth-2-en-1-ol	1. 2			0.7
1137	1648	*trans*-Pinocarveol	1. 2		0.2	1.4
1141	1603	Nopinone	1. 2	0.3		1.1
1144	1663	*cis*-Verbenol	1. 2	0.6	0.4	
1145	1532	Camphor	1. 2. 3	0.6		
1154	1587	Pinocarvone	1. 2	0.4	0.4	2.5
1164	1737	α-Phellandren-8-ol	1. 2		1.9	
1176	1611	Terpineol-4	1. 2. 3		0.2	1.2
1185	1856	*p*-Cymen-8-ol	1. 2	0.2	1.9	0.3
1190	1815	*p*-Menth-8-en-2-ol	1. 2			0.3
1193	1648	Myrtenal	1. 2	0.6		1.1
1194	1685	trans-Verbenol	1. 2		3.4	2.6
1195	1624	*cis*-Dihydrocarvone	1. 2	0.2		0.4
1196	1804	Myrtenol	1. 2	0.5	0.3	0.5
1206	1723	*cis*-Verbenone	1. 2	0.8	1.4	1.3

1217	1845	*trans*-Carveol	1. 2		0.3	0.8
1218	1802	Cuminaldehyde	1. 2			0.3
1230	1878	*cis*-Carveol	1. 2		0.2	0.3
1236	1582	*trans*-Chrysanthenyl acetate	1. 2	0.5		
1238	1694	Neral	1. 2			0.3
1241	1752	Carvone	1. 2	0.6		0.4
1275	1744	Phellandral	1. 2			0.3
1286	1567	Bornyl acetate	1. 2. 3			0.2
1288	2112	Cumin alcohol	1. 2	t	0.3	0.3
		Oxygenated sesquiterpenes		**4.0**	**12.4**	**8.1**
1565	2057	Ledol				0.7
1577	2150	Spathulenol	1. 2	1.9		2.7
1579	2208	Caryophyllene oxide	1. 2. 3		1.2	
1593	2103	Viridiflorol				0.6
1613	2108	β-Oplopenone	1. 2		0.9	
1628	2185	Isospathulenol				0.3
1640	2185	t-Cadinol				0.4
1641	2209	t-Muurolol				0.3
1648	2399	Aromadendrene oxide				0.2
1668	2392	Caryophyllenol II	1. 2			0.5
1676	2219	α-Bisabolol	1. 2	0.5		0.5
1720	2354	(*E.E*)-Farnesol	1. 2		0.6	
1741	2565	Oplopanone	1. 2		7.1	
1845	2131	Hexahydrofarnesylacetone	1. 2	1.6	2.6	1.4
1918	2389	(*E.E*)-Farnesyl acetone	1. 2			0.5
		Sesquiterpene hydrocarbons		**3.0**	**1.6**	**12.6**
1339	1494	Bicycloelemene	1. 2			0.8
1377	1497	α-Copaene	1. 2			1.3
1387	1600	β-Elemene	1. 2			0.2
1414	1612	(*E*)-Caryophyllene	1. 2. 3	0.9		1.7
1432	1651	γ-Elemene	1. 2	0.5		
1437	1628	Aromadendrene	1. 2	0.3		0.2
1438	1573	*trans*-α-Bergamotene				0.3
1452	1672	(*E*)-β-Farnesene				0.4
1455	1689	α-Humulene				0.2
1463	1661	*allo*-Aromadendrene	1. 2	0.1		0.4
1477	1726	Germacrene D				0.3
1491	1726	Bicyclogermacrene	1. 2			4.7
1510	1743	β-Bisabolene	1. 2	t		1.4
1526	1773	δ-Cadinene	1. 2	0.7		0.7
1541	1918	α-Calacorene	1. 2	0.5	1.6	

a: Retention index on a HP-5MS column; b: Retention index on a HP-Innowax column; c Identification: 1 = comparison of retention index; 2 = comparison of mass spectra with MS libraries; 3 = comparison with authentic compounds; d t = trace; less than 0.05 %. #: correct isomer not identified.

Generally, **Lb** and **Lm** consisted especially of terpenoids (65.9 and 68.3% respectively), but while **Lb** was rich of diterpenes (52.8%), in **Lm** there were similar amounts of monoterpenes (24.7%) sesquiterpenes (20.7%) and diterpenes (22.9%). Differently, in **Ln** terpenoids were scarce (25.7%), while fatty acids and esters (32.2%) and phenols (13.4%) were present in major percentages. The composition of the investigated samples differed greatly from the results reported earlier for other species of *Sideritis*, which generally contain essential oils rich in monoterpene hydrocarbons such as α-pinene, β-pinene, sabinene, myrcene, and limonene, or, to a lesser extent, in sesquiterpene hydrocarbons such as δ-cadinene and β-caryophyllene [4,13]. The quantitative prevalence of diterpenoids in **Lb** and **Lm** is worth mentioning as they do not appear very often in the essential oil of *Sideritis* species because of their low volatility. So, *S. libanotica* ssp. *michroclamys* and *S. libanotica* ssp. *libanotica* essential oils could both be classified as diterpene-rich essential oils, which is the most rare type [4].

In fact, only five species of this genus, *S. hirsuta* from Spain [4], *S. italica* from Sicily (South Italy) [6] and Camerino (Central Italy) [13], *S. perfoliata* and *S. dichotoma* from Turkey [12] and *S. scardica* from Bulgaria [14] have been previously described to present diterpenes as major or particularly abundant constituents. Different phytochemical studies have revealed that *ent*-kaurene type diterpenoids are the most frequently found in *Sideritis* species, particularly those growing in the Eastern Mediterranean Basin [3], and sideridiol in particular has been already isolated from the acetone extract of *S. libanotica* ssp. *libanotica* [11]. The presence of diterpenes in our samples is significant as this class of molecules is responsible for the different biological activities shown by *Sideritis* species [2]. The main compound characterizing *S. libanotica* ssp. *linearis*, hexadecanoic acid, is also present in high percentages in *S. italica* from Sicily [6] and the Sibilline Mountains [15], *S. lanata* (10.7%) [12] and *S. syriaca* (31.1%) [16]. Such results could have a taxonomic significance, suggesting further investigations.

The essential oils of the three *S. libanotica* subspecies were subjected to screening for their possible antioxidant activity by means of two spectrophotometric methods (DPPH and FRAP tests) and expressed as Trolox equivalents (TEs). According to the DPPH test, the essential oils did not show any antiradical activity, while the FRAP test revealed that our samples exerted a weak capacity to scavenge free radicals (0.60± 0.01, 0.32± 0.02 and 0.22± 0.02 mmol TE/L for **Ln, Lm** and **Lb** respectively); these values are very low in comparison with artificial antioxidants such as butylhydroxytoluene BHT assayed at the same dose (3.90± 0.02 mmol TE/L). The major activity showed by **Ln** is probably due to the higher amount of phenols (13.4%), particularly thymol (4.9%) and carvacrol (5.3%), both scarce in the other two samples. The antioxidant activities of the methanol extract of *S. libanotica* ssp. *linearis* [8] and of the aqueous extract of *S. libanotica* ssp. *libanotica* [2] were already shown, but this is the first time that the essential oils of the three title plants have been studied for their possible antioxidant activity.

Experimental

Plant material: Aerial parts of flowering *S. libanotica* ssp. *libanotica* and *S. libanotica* ssp. *linearis* were collected in July 2010 at Ras Baalbek, 1000 m asl; aerial parts of flowering *S. libanotica* ssp. *michroclamys* were collected in July 2010 at El Kneisse, Mohafazat Mont-Liban, from a rocky soil, 1700 m asl. The samples were authenticated by one of us (N. Arnold) and voucher specimens were deposited in the Herbarium of the Botanischer Garten, Berlin Universität (leg. & det. N. Arnold *S.* n., confirm. Th. Raus, No. NAP #167, NAP #168 and NAP #169).

Isolation of the essential oil: For the isolation of the essential oils, the air-dried samples (lots of 25 g) were ground in a Waring blender and then subjected to hydrodistillation for 3 h using *n*-hexane as a solvent, according to the standard procedure previously described [6]. The oils were dried over anhydrous sodium sulfate and stored under N_2 at +4°C in the dark until tested and analyzed. The hydrodistillation yielded 0.06% (**Ln**), 0.10% (**Lb**), and 0.08% (**Lm**), respectively, of yellowish oils.

Gas chromatography-mass spectrometry: Analytical gas chromatography was carried out on a Perkin-Elmer Sigma 115 gas chromatograph fitted with a HP-5 MS capillary column (30 m x 0.25 mm, 0.25 μm film thickness), as described previously [6].

Identification of components: Most constituents were identified by GC by comparison of their retention indices (LRI) with either those of the literature [17-19] or with those of authentic compounds available in our laboratories. The linear retention indices were determined in relation to a homologous series of *n*-alkanes (C_8-C_{28}) under the same operating conditions. Further identification was achieved by comparison of their MS on both columns, either with those stored in NIST 02 and Wiley 275 libraries or with MS from the literature [18, 19] and our home-made library.

Antioxidant activity: Essential oils were dissolved in methanol in order to obtain 1 mg/10 mL solutions. For each antioxidant assay, a Trolox aliquot was used to develop a 0.5-10 mmol/L standard curve. All data were then expressed as Trolox Equivalents (mmol/L) and antioxidant activity referred to as Trolox Equivalents Antioxidant Capacity (TEAC).

Free radical scavenging ability (DPPH method): The ability of essential oils and extracts to scavenge the DPPH radical was measured as described in [20]. Aliquots (40 μL) of samples were added to 3 mL of DPPH solution ($6x10^{-5}$ mol/L) and the absorbance was determined at 515 nm after 60 min.

Ferric reducing/antioxidant power (FRAP method): The total antioxidant potential of extracts were determined by using the ferric reducing antioxidant power (FRAP) assay, as described in [20]. A solution of 10 mmol/L TPTZ in 40 mmol/L HCl and 12 mmol/L ferric chloride was diluted in 300 mmol/L sodium acetate buffer (pH 3.6) at a ratio of 1:1:10. Aliquots (40 μL) of sample solutions were added to 3 mL of the FRAP solution and allowed to react for 60 min before reading the absorbance at 593 nm.

Statistics: Triplicate analyses for each measurement were conducted for each sample. Differences between the means were evaluated with ANOVA, using the Graf Pad Instat 3 (Microsoft Software) statistics program. The significance of the model was evaluated by ANOVA. The significance level was fixed at 0.05 for all the statistical analysis.

Acknowledgments – The GC and GC-MS analyses were performed at the "C.*S*.I.A.S." of the University "Federico II" of Napoli. The assistance of the staff is gratefully appreciated.

References

[1] Tomas-Barberan A, Rejdali M, Harborne JB, Heywood VH. (**1988**) External and vacuolar flavonoids from Ibero-North African *Sideritis* species. A chemosystematic approach *Phytochemistry*, ***27***, 165-170.

[2] Gonzalez-Burgos E, Carretero ME, Gomez-Serranillos MP. (**2011**) *Sideritis* spp.: Uses, chemical composition and pharmacological activities—A review. *Journal of Ethnopharmacology*, ***135***, 209-225.

[3] Piozzi F, Bruno M, Rosselli S, Maggio A. (**2006**) The diterpenoids from the genus *Sideritis. Studies in Natural Products Chemistry*, ***33***, 493-540

[4] Pala-Paul J, Perez-Alonso MJ, Velasco-Negueruela A, Ballesteros MT, Sanz J. (**2006**) Essential oil composition of *Sideritis hirsuta* L. from Guadalajara Province, Spain. *Flavour and Fragrance Journal*, ***21***, 410-415.

[5] Basile A, Senatore F, Gargano R, Sorbo S, Del Pezzo M, Lavitola A, Ritieni A, Bruno M, Spatuzzi D, Rigano D, Vuotto ML. (**2006**). Antibacterial and antioxidant activities in *Sideritis italica* (Miller) Greuter et Burdet essential oils. *Journal of Ethnopharmacology*, ***107,*** 240-248.

[6] Formisano C, Rigano D, Senatore F, Tenore G, Bruno M, Piozzi F. (**2010**) Volatile compounds of flowers and leaves of *Sideritis italica* (Miller) Greuter et Burdet (Lamiaceae), a plant used as mountain tea. *Natural Product Research*, ***24,*** 640-646.

[7] Basile A, Castaldo Cobianchi R, Rigano D, Senatore F, Bruno M, Rosselli S, Conte B, Sorbo *S.* (**2011**)**.** Potential allelopathic activity of *Sideritis italica* (Miller) Greuter et Burdet essential oil. *Plant Biosystems*, ***145,*** 241-247.

[8] Demirtas I, Sahin A, Ayhan B, Tekin S, Telci I. (**2009**) Antiproliferative effects of the methanolic extracts of *Sideritis libanotica* Labill. subsp. *linearis. Records of Natural Products*, ***3***, 104-109.

[9] Demirtas I, Ayhan B, Sahin A, Aksit H, Elmastas M, Telci I. (**2011**) Antioxidant activity and chemical composition of *Sideritis libanotica* Labill. ssp. *linearis* (Bentham) Borm. (Lamiaceae). *Natural Product Research*, ***25***, 1512-1523.

[10] Tepe B, Sokmen M, Akpulat HA, Yumrutas O, Sokmen A. (**2006**) Screening of antioxidative properties of the methanolic extracts of *Pelargonium endlicherianum* Fenzl., *Verbascum wiedemannianum* Fisch. & Mey., *Sideritis libanotica* Labill. subsp. *linearis* (Bentham) Borm., *Centaurea mucronifera* DC. and *Hieracium cappadocicum* Freyn from Turkish flora. *Food Chemistry*, ***98***, 9-13.

[11] Bruno M, Piozzi F, Arnold AN, Başer KHC, Tabanca N, Kirimer N. (**2005**) Kaurane diterpenoids from three *Sideritis* species. *Turkish Journal of Chemistry*, ***29***, 61-64.

[12] Kirimer N, Başer KHC, Demirci B, Duman H. (**2004**). Essential oils of *Sideritis* species of Turkey belonging to the section *Empedoclia. Chemistry of Natural Compounds*, ***40***, 19-23.

[13] Giuliani C, Maleci Bini L, Papa F, Cristalli G, Sagratini G, Vittori S, Lucarini D, Maggi F. (**2011**) Glandular trichomes and essential oil composition of endemic *Sideritis italica* (Mill.) Greuter et Burdet from Central Italy. *Chemistry & Biodiversity*, ***8***, 2179-2194.

[14] Kostadinova E, Nikolova D, Alipieva K, Stefova M, Stefkov G, Evstatieva L, Matevski V, Bankova V. (**2007**) Chemical constituents of the essential oils of *Sideritis scardica* Griseb. and *Sideritis raeseri* Boiss and Heldr. from Bulgaria and Macedonia. *Natural Product Research*, ***21***, 819-823.

[15] Tirillini B, Pellegrino R, Menghini L, Pagiotti R, Meneghini A. (**2001**). Composition of the oil of *Sideritis syriaca* L. from Italy. *Journal of Essential oil Research*, ***13***, 444-445.

[16] Ertas A, Ozturk M, Boga M, Topcu G. (**2009**) Antioxidant and anticholinesterase activity evaluation of *ent*-kaurane diterpenoids from *Sideritis arguta*. *Journal of Natural Products*, ***72***, 500-502.

[17] Jennings W, Shibamoto T. (**1980**) *Qualitative Analysis of Flavour and Fragrance Volatiles by Glass Capillary Gas Chromatography*. Academic Press, New York.

[18] Davies NW. (**1990**) Gas chromatographic retention indices of monoterpenes and sesquiterpenes on methyl silicone and Carbowax 20M phase*S. Journal of Chromatography A*, ***503***, 1-24.

[19] Adams RP. (**2007**) *Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry*. Allured Publishing Corp., Carol Stream, IL.

[20] Tenore GC, Ciampaglia R, Arnold NA, Piozzi F, Napolitano F, Rigano D, Senatore F. (**2011**) Antimicrobial and antioxidant properties of the essential oil of *Salvia lanigera* from Cyprus. *Food and Chemical Toxicology*, ***49***, 238-243.