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Headspace Solid Phase Microextraction Analysis of Volatile Compounds of the Aerial Parts and Flowers of *Plectranthus neochilus* Schltr. and *Salvia farinacea* Benth.

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Abstract: The composition of the volatile compounds of the aerial parts (leaves and stems) and flowers (inflorescences) of *Plectranthus neochilus* Schltr. and *Salvia farinacea* Benth. growing in Egypt was analyzed by headspace solid phase microextraction (HS-SPME) coupled with gas chromatography/mass spectrometry (GC-MS). The analysis revealed that both the aerial parts and flowers of *Plectranthus neochilus* Schltr. were dominated by sesquiterpene hydrocarbons (79.9 % and 63.79 %), respectively. Concerning the aerial parts of *Plectranthus neochilus* Schltr., the major volatile components were *allo*-aromadendrene (19.35 %) and aromadendrene (18.3 %) followed by selin-3,7(11)-diene (10.2 %), while γ-cadinene (18.56 %) and aromadendrene (17.94 %) followed by β-myrcene (10.5 %) and E-β-ocimene (9.11 %) were the major components in the oil of the flowers. On the other hand, the analysis revealed that 1-octen-3-ol (46.51 %), 2-hexenal (18.02 %), benzaldehyde (8.8 %) and aromadendrene (7.24 %) were the main components of the aerial parts of *Salvia farinacea* Benth. Ethyl benzene (24.29 %) was identified as the major volatile component in the flowers followed by *m*-xylene (21.95 %), *o*-xylene (7.9 %), α-thujene (7.64 %) and α-pinene (6.11 %).

Key words: *Plectranthus*, *Salvia*, headspace solid phase microextraction, GC-MS, volatile compounds.

Introduction

Essential oil is one of the plant secondary metabolites with many applications in food flavoring [1]. Its composition varies with the species, extraction method and temperature variations [2]. Several methods have been used for the oil extraction as hydrodistillation and headspace-solid phase micro-extraction (HS-SPME) [1]. Headspace is a popular technique for the extraction of volatile compounds from medicinal plants as an alternative to other sampling techniques [3]. It is rapid, simple, easy to automate, consumes no solvent and uses small amount of samples [1,3]. Furthermore, it reduces the degradation of the volatile compounds minimizing the loss of these components [1].

Family Lamiaceae consists of several *genera* such as *Salvia*, *Thymus*, *Mentha* and *Plectranthus*. The plants belonging to this family are aromatic and easily cultivated [4]. *Plectranthus* is a large *genus* of about 350 species distributed throughout Africa, Asia and Australia [5]. Several *Plectranthus* species are cultivated as ornamentals or due to their essential oil content [5]. The essential oil of *genus Plectranthus* have been reported to have antimicrobial [6,7,8], anti-oxidant [9] and cytotoxic activities [9].

Genus Salvia, commonly known as sage, is the largest *genus* of family Lamiaceae with about 900 species distributed throughout the world [1]. The oil of *salvia* has been used as carminative, antiseptic and antispasmodic [10]. Many investigations have been performed for identifying the chemical composition of essential oils of numerous *Plectranthus*

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[6,8,9,11-14] and *Salvia* [15-20] species.

Plectranthus neochilus Schltr. is herbaceous aromatic plant, known as *boldo rasteiro* in Brazil [21]. It had been used in folk medicine to treat indigestion, dyspepsia, skin and respiratory diseases [21]. The essential oil displayed *in-vitro* shistosomicidal and insecticidal activities [21].

Salvia farinacea Benth. is a perennial herb known as mealy sage or mealycup sage [22]. Previous investigations reported the isolation and identification of flavonoids from its leaves [23] as well as diterpenes [24] and triterpenes [25] from its aerial parts. Anthocyanins were isolated from the flowers [26].

The present study used headspace analysis in combination with gas chromatography/mass spectroscopy for better understanding of the composition of the volatile compounds from the aerial parts and flowers of *Plectranthus neochilus* Schltr. and *Salvia farinacea* Benth. growing in Egypt and compared the findings of the previous investigations on the oil extracted by hydrodistillation from the aerial parts or leaves of both plants. To the best of our knowledge, no data was found on the chemical composition of the essential oils of the flowers of both plants.

Material and methods

Plant material

The fresh aerial parts (leaves and stems) and flowers (10 g, each) of *Plectranthus neochilus* Schltr. and *Salvia farinacea* Benth. were collected in June during the flowering stage from the Experimental Station of Faculty of Pharmacy, Cairo University, Egypt (GPS location: 30°01'49.0"N 31°11'48.8"E). Voucher specimens for *Plectranthus neochilus* Schltr. (numbered 18.8.2016) and for *Salvia farinacea* Benth. (numbered 26.12.2016) were kept at the Museum of the Department of Pharmacognosy, Faculty of Pharmacy, Cairo University, Egypt. The plants were kindly identified by Dr. Reem Samir Hamdy, Associate professor of Taxonomy and Flora, Department of Botany, Faculty of Science, Cairo university and Mrs. Therese Labib, the former director of El-Orman botanical garden and the consultant of plant taxonomy at ministry of agriculture and national gene bank.

Extraction of the volatile compounds

Frozen aerial parts (leaves and stems) and flowers (1 g) each, were cut into small pieces (0.5-1 cm) and transferred to SPME screw cap vials (20 ml). Vials were rapidly closed and SPME fiber (stableflex coated with divinyl benzene/carboxen/polydimethylsiloxane (DVB/CAR/PDMS, 50/30 μm), Supelco Oakville, ON, Canada) left to sample the head space above the sample at 50°C for 30 min (these conditions were enough for the samples to thaw and reach equilibrium which was confirmed by comparing the number of peaks at time intervals (15, 20, 25 min), and the number of peaks was the same with no further increment and no decrease in peak areas as well). The fiber is then withdrawn into the needle and transferred to the injection port of the GC-MS instrument [27]. The extraction temperature and time were optimized as reported from previous work [28,29]. The extraction temperature (50°C) was found sufficient for volatiles extraction, in addition to avoiding the desorption of the compounds.

Analysis of the volatile compounds

GC-MS analyses were performed on Shimadzu model (Kyoto, Japan) GC-17A gas chromatograph equipped with SLB-5ms (Supelco Low Bleed - 5ms, 28471-U, SUPELCO, Sigma-Aldrich, Co. LLC) column (30 m x 0.25 mm x 0.25 μm film thickness) and coupled to Shimadzu QP5050A mass chromatograph. The temperature of injector and the interface was kept at 220°C. Temperature was kept at 40°C for 3 min, then increased to 180°C by rate of 12°C/min, kept at 180°C for 5 min and finally ramped at a rate of 40 °C/min to 240°C and kept at that final temperature for 5 min. Helium was the carrier gas with flow rate of 0.9 ml/min. Splitless injection was used and the first 5 min of the analysis were considered as solvent delay and omitted from the final chromatograms. SPME fiber was prepared to the next analysis by leaving it in the injection port for 2 min. The EIMS mode was 70 eV and electron multiplier was 130 V. The scan range was set at *m/z* 40-500. Volatile components were identified as described in Farag & Wessjohann[27] and peaks were deconvoluted using AMDIS software (Automatic Mass Spectral Deconvolution and Identification System) and identified by comparing their retention indexes (RI) relative to *n*-alkanes (C_6-C_{20}) and matching to spectral MS data from NIST (National Institute of Standards and Technology) mass spectral database and by comparing with the mass spectral literature data [30].

Results and discussion

HS-SPME led to the identification of eighty-five and sixty-five volatile components (**Table 1**) in the aerial parts and flowers of *Plectranthus neochilus* Schltr. representing 97.66 % and 95.51 %, respectively. The aerial parts included twenty-eight sesquiterpenes (79.9 %), five oxygenated sesquiterpenes (0.89 %), eighteen monoterpenes (5.17 %) and nineteen oxygenated monoterpene hydrocarbons (0.85 %). On the other hand, the flowers comprised twenty-one sesquiterpenes (63.79 %), eleven monoterpenes (21.41 %), and seven oxygenated monoterpene hydrocarbons (0.27 %). Sesquiterpene hydrocarbons were the dominating constituents of the aerial parts and flowers. Furthermore, the major components found in the volatile compounds of the aerial parts were *allo*-aromadendrene (19.35 %), aromadendrene (18.3 %) followed by selin-3,7(11)-diene (10.2 %), while γ-cadinene (18.56 %) and aromadendrene (17.94 %) followed by β-myrcene (10.5 %) and E-β-ocimene (9.11 %) were the major components in the flowers. Considerable amount of aliphatic alcohols (10.01 %) was detected in the aerial parts and the major constituent was 1-octen-3-ol (6.68 %). Other constituents were detected as well, in the flowers as

Table 1. Chemical composition of the volatile compounds from the aerial parts and flowers of *Plectranthus neochilus* Schltr.

No.	RT [a]	RI [b]	Compound	Area percentage Aerial parts	Area percentage Flowers
1	5.40	809	Hexanal [5]	0.11	0.02
2	6.45	864	2-Hexenal [5]	0.41	1.32
3	6.49	866	2, 4-Octadiyne [5]	0.03	-
4	6.53	868	Ethyl benzene [5]	0.04	-
5	6.54	869	*p*-Xylene [5]	-	1.87
6	6.71	877	*o*-Xylene [5]	-	1.27
7	7.15	899	1, 3, 5-Cyclooctatriene [5]	-	0.63
8	7.55	921	(E,E)-2, 4-Hexadienal [5]	0.13	-
9	7.60	924	α-Thujene [1]	0.08	-
10	7.78	934	α-Pinene [1]	1.90	0.04
11	7.91	941	Tricyclene [1]	0.76	-
12	8.08	951	Thuja-2, 4(10)-diene [1]	0.11	-
13	8.24	959	Propyl benzene [5]	-	0.03
14	8.45	971	Benzaldehyde [5]	-	0.35
15	8.49	973	β-Thujene [1]	0.01	-
16	8.61	980	Sabinene [1]	0.84	0.44
17	8.72	990	1-Octen-3-ol [5]	6.68	0.87
18	8.86	994	β-Myrcene [1]	0.25	10.50
19	8.93	997	2-Octanol [5]	0.02	-
20	8.96	999	Mesitylene [5]	-	0.01
21	9.03	1003	(E,E)-2, 4-Heptadienal [5]	-	0.01
22	9.03	1003	6-Methyl-3-heptanol [5]	3.28	-
23	9.10	1008	Octanal [5]	-	0.03
24	9.12	1009	4-Hexenyl acetate [5]	0.06	-

table 1. (continued).

No.	RT [a]	RI [b]	Compound	Area percentage Aerial parts	Flowers
25	9.35	1024	α-Terpinene [1]	0.02	-
26	9.38	1026	*p*-Cymene [1]	0.01	-
27	9.46	1026	*o*-Cymene [1]	0.03	0.07
28	9.55	1036	D-Limonene [1]	0.12	0.39
29	9.59	1039	Z-β-Ocimene [1]	0.79	0.68
30	9.78	1051	E-β-Ocimene [1]	-	9.11
31	10.00	1065	γ-Terpinene [1]	0.07	0.02
32	10.23	1079	Z-Sabinene hydrate [2]	0.07	-
33	10.43	1091	Terpinolene [1]	-	0.06
34	10.44	1092	*p*-Mentha-2, 4(8)-diene [1]	0.01	-
35	10.50	1096	*p*-Cymenene [1]	0.06	-
36	10.54	1098	Hexenyl priopionate [5]	0.01	-
37	10.60	1103	β-Linalool [2]	0.01	-
38	10.67	1107	Nonanal [5]	0.03	0.39
39	10.71	1111	E-Sabinene hydrate [2]	0.01	-
40	10.72	1111	α-Phellandrene [1]	0.03	-
41	10.87	1121	Z-Sabinol [2]	0.03	-
42	10.91	1124	Methyl octanoate [5]	-	1.46
43	10.93	1125	1, 3, 8-*p*-Menthatriene [1]	0.04	0.08
44	10.95	1127	Thujone [2]	0.08	-
45	11.01	1131	*allo*-Ocimene [1]	0.04	0.02
46	11.07	1135	α-Campholenal [2]	0.01	-
47	11.33	1154	E-Pinocarveol [2]	0.02	-
48	11.39	1158	2E,6Z-Nonadienal [5]	-	0.31
49	11.43	1161	Camphor [2]	0.01	-
50	11.48	1164	2E-Nonenal [5]	-	0.11
51	11.58	1171	Methyl-2-octenoate [5]	-	0.06
52	11.64	1175	*p*-Cresol acetate [5]	0.01	-
53	11.87	1190	Terpinen-4-ol [2]	0.10	0.02
54	11.92	1195	*p*-Cymen-8-ol [2]	0.08	-
55	12.02	1202	Methyl salicylate [5]	-	0.04
56	12.05	1204	Dihydrocitronellol [2]	-	0.11
57	12.10	1208	Decanal [5]	0.26	0.17
58	12.37	1228	E-Carveol [2]	0.01	-
59	12.72	1255	Carvone [2]	-	0.02
60	12.75	1257	Thymoquinone [2]	-	0.01
61	12.78	1259	Unknown	-	0.95
62	12.82	1261	Carvotanacetone [2]	0.03	-
63	12.87	1266	Nonanoic acid [5]	0.01	0.04
64	12.96	1273	Geranial [2]	-	0.07
65	12.98	1274	Decanol [5]	0.03	-
66	13.09	1283	E-Pinocarvyl acetate [2]	0.01	-
67	13.13	1286	Cinnamaldehyde [5]	0.01	0.02

table 1. (continued).

No.	RT [a]	RI [b]	Compound	Area percentage Aerial parts	Flowers
68	13.23	1293	Bornyl acetate [5]	-	0.16
69	13.24	1294	Thymol [2]	0.02	-
70	13.29	1298	Tridecane [5]	-	0.16
71	13.33	1301	*p*-Cymen-7-ol [2]	0.01	-
72	13.42	1308	Myrtenyl acetate [2]	0.03	-
73	13.91	1348	Citronellyl acetate [2]	-	0.01
74	14.03	1358	α-Cubebene [3]	1.95	0.91
75	14.06	1362	Eugenol [2]	0.03	0.03
76	14.29	1379	Z-β- Hexenyl caproate [5]	-	0.06
77	14.35	1384	Hexyl hexanoate [5]	-	0.45
78	14.37	1386	β-Ylangene [3]	0.09	-
79	14.46	1393	β-Copaene [3]	2.85	2.89
80	14.49	1396	β-Elemene [3]	0.02	-
81	14.53	1399	Tetradecane [5]	-	0.17
82	14.55	1401	Sativene [3]	-	1.08
83	14.59	1404	β-Cubebene [3]	4.34	0.34
84	14.60	1405	β-Bourbonene [3]	5.15	-
85	14.63	1407	Unknown	0.36	-
86	14.83	1423	Z-Caryophyllene[3]	0.41	-
87	14.86	1426	β-Ylangene [3]	4.63	0.06
88	15.10	1445	*allo*-Aromadendrene [3]	19.35	-
89	15.10	1446	*neo*-Clovene [3]	4.20	-
90	15.11	1446	Aromaden drene [3]	18.30	17.94
91	15.16	1450	β-Copaene [3]	1.18	0.92
92	15.21	1454	β-Farnesene [3]	0.09	-
93	15.32	1463	γ-Muurolene [3]	0.46	0.03
94	15.35	1466	(+)-epi-Bicyclosesquiphellandrene [3]	-	0.06
95	15.37	1467	Z-Muurola-3, 5-diene [3]	0.01	0.34
96	15.41	1470	E-β-Famesene [3]	0.08	0.02
97	15.49	1477	Bicyclogermacrene [3]	1.34	-
98	15.66	1491	Germacrene D [3]	1.14	0.87
99	15.68	1492	β-Chamigrene [3]	0.74	3.39
100	15.82	1503	Unknown	2.08	-
101	15.85	1505	α-Farnesene [3]	-	6.34
102	15.93	1510	β-Selinene [3]	0.29	-
103	15.99	1515	α-Muurolene [3]	0.25	2.60
104	16.01	1516	α-Selinene [3]	0.18	-
105	16.03	1517	β-Bisabolene [3]	0.56	-
106	16.07	1520	β-Curcumene [3]	-	0.10
107	16.25	1521	σ-Cadinene [3]	0.09	6.56
108	16.28	1534	γ-Cadinene [3]	1.89	18.56
109	16.31	1536	Calamenene [3]	-	0.12
110	16.39	1541	Selina-3, 7(11)-diene [3]	10.20	-

table 1. (continued).

No.	RT [a]	RI [b]	Compound	Area percentage Aerial parts	Flowers
111	16.53	1551	α-Cadinene [3]	0.09	0.63
112	16.62	1557	α-Calacorene [3]	0.02	0.03
113	16.70	1563	E-Nerolidol [4]	0.29	-
114	17.20	1597	Caryophyllene oxide [4]	0.10	-
115	17.22	1598	Hexadecane [5]	0.05	-
116	17.26	1600	Spathulenol [4]	0.03	-
117	18.33	1656	*allo*-Aromadendrene oxide [4]	0.18	-
118	18.66	1673	Z-α-Santalol [4]	0.26	-
			Monoterpene hydrocarbons	5.17	21.41
			Oxygenated monoterpenes	0.85	0.27
			Sesquiterpene hydrocarbons	79.9	63.79
			Oxygenated sesquiterpenes	0.89	-
			Total identified compounds	97.66	95.51

[a]: Retention time in minutes
[b]: Retention index relative to standard mixtures of n-alkanes on SLB-5 column
[1]: Monoterpene hydrocarbons
[2]: Oxygenated monoterpenes
[3]: Sesquiterpene hydrocarbons
[4]: Oxygenated sesquiterpenes
[5]: Miscellaneous
Literature retention indices obtained from Adams [30]

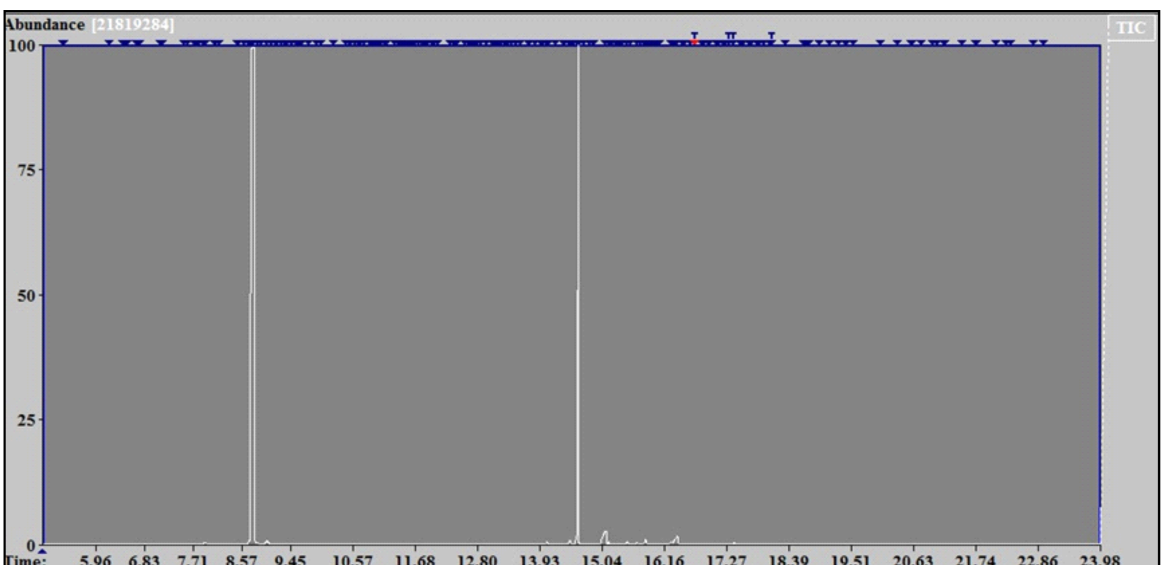

Figure 1. SPME-GC-MS chromatogram of the aerial parts of *Plectranthus neochilus* Schltr. headspace volatiles

aromatic hydrocarbons (3.2 %) and aldehydes (2.71 %). Thirty-five components were common in both aerial parts and flowers.

Regarding the aerial parts and flowers of *Salvia*

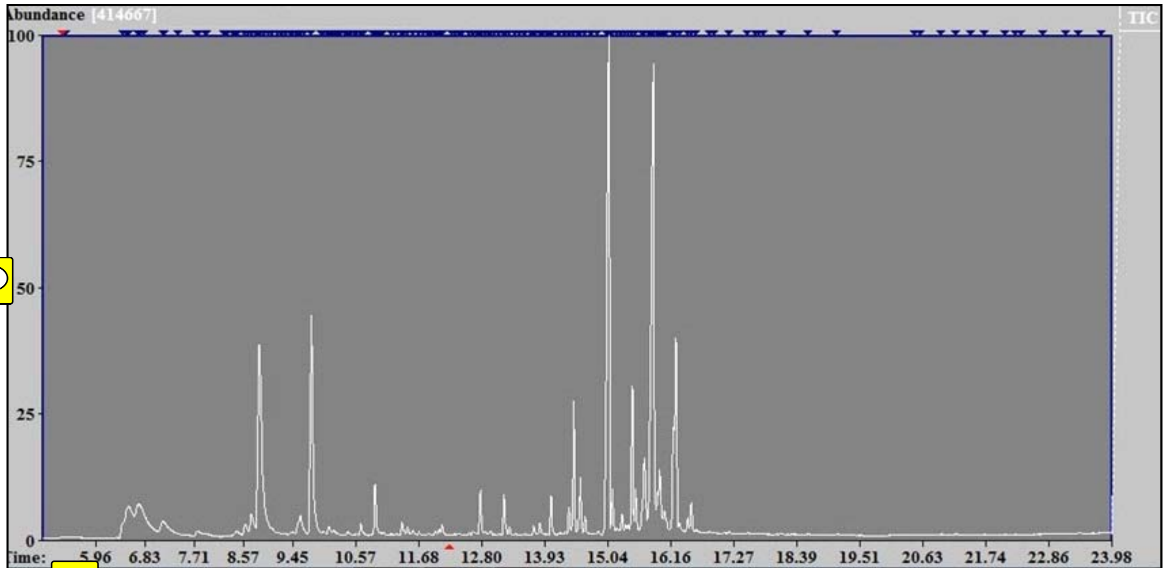

Figure 2. SPME-GC-MS chromatogram of the flowers of *Plectranthus neochilus* Schltr. headspace volatiles

farinacea Benth., twenty-eight and thirty-two volatile components were identified representing 95.43 % and 96.7 % of the composition of total volatile compounds, respectively **(Table 2)**. The aerial parts were characterized by the presence of appreciable amount of aliphatic alcohols constituting 47.2 % of the total composition, whereas 1-octen-3-ol (46.51 %) was considered the most abundant constituent. Seven sesquiterpenes (13.26 %) and six monoterpene hydrocarbons (1.78 %) were identified in the aerial parts, while ten monoterpenes (22.19 %), ten sesquiterpenes (12.74 %) and one oxygenated monoterpene hydrocarbon (0.56 %) were found in the flowers. Aldehydes were found in high percentage (29.67 %) represented by 2-hexenal (18.02 %) and benzaldehyde (8.8 %) as the major components. Moreover, aromatic hydrocarbons were the main class present in the volatile compounds of the flowers representing 54.4 % of the total composition with ethyl benzene (24 %) as the major component. Monoterpenes were dominating over the sesquiterpenes in the flowers. Conversely, sesquiterpenes were the abundant hydrocarbons in the aerial parts. No oxygenated sesquiterpenes were found in both organs.

Comparison with data from the available literature, Lawal *et al.*,[31] reported that thirty six components are identified in the oil obtained by hydrodistillation from the leaves of *Plectranthus neochilus* Schltr. collected in South Africa where citronellol (29 %), citronellyl formate (11 %), linalool (9.8 %) and isomenthone (9.2 %) are the major components. Caixeta *et al.*,[21] found that the major components in the oil of the leaves collected in Brazil are β-caryophyllene (28.23 %), α-pinene (12.63 %) and α-thujene (12.22 %). The hydrodistilled oil from the plant collected in Brazil was also studied by Crevelin *et al.,*[32]. Thirty-one components are detected where *trans*-caryophyllene (29.8 %), α-pinene (14.1 %) and caryophyllene oxide (12.8 %) are the dominant components. Unlike previous investigations of the oil, our results showed that the major components in the oil of the aerial parts extracted by HS-SPME are different from that extracted from the leaves by hydrodistillation. However, aromadendrene and *allo*-aromadendrene are found as described by Lawal *et al.,*[31] but in trace amounts. In addition, HS-SPME showed larger number of volatile components compared to hydrodistillation. The observed variation might be attributed to the geographical origin [33] and the extraction methods [34] as they could affect the type of compounds extracted [35].

Regarding *Salvia*, Pãdure *et al.,*[36] reported that the essential oil of the aerial parts of *Salvia farinacea* Benth. in Romania extracted by

Table 2. Chemical composition of the volatile compounds from the aerial parts and flowers of *Salvia farinacea* Benth.

No.	RT[a]	RI[b]	Compound	Area percentage Aerial parts	Flowers
1	5.30	806	Hexanal [5]	0.52	-
2	6.37	860	2-Hexenal [5]	18.02	1.38
3	6.48	865	Ethyl benzene [5]	1.02	24.29
4	6.65	874	*m*-Xylene [5]	-	21.95
5	6.70	897	*o*-Xylene [5]	1.25	7.90
6	6.77	880	Hexanol [5]	0.39	-
7	7.09	896	*p*-Xylene [5]	0.66	-
8	7.56	922	2E,4E-Hexadienal [5]	-	0.04
9	7.68	929	Cumene [1]	-	0.14
10	7.73	931	α-Thujene [1]	-	7.64
11	7.88	940	α-Pinene [1]	-	6.11
12	8.23	959	1-Propyl benzene [5]	-	0.30
13	8.44	969	Benzaldehyde [5]	8.80	0.12
14	8.58	978	Sabinene [1]	0.08	3.64
15	8.69	984	β-Pinene [1]	-	2.05
16	8.70	984	Unknown	-	0.87
17	8.72	985	1-Octen-3-ol [5]	46.51	1.80
18	8.83	992	β-Myrcene [1]	0.59	0.30
19	8.94	998	Mesitylene [5]	0.22	-
20	9.00	1001	3-Octanol [5]	0.30	0.62
21	9.02	1003	(E,E)-2, 4-Heptadienal [5]	1.76	-
22	9.10	1008	Z-3-Hexenyl acetate [5]	-	0.42
23	9.40	1027	Unknown	4.60	-
24	9.45	1030	*o*-Cymene [1]	0.37	0.25
25	9.53	1035	Limonene [1]	0.52	0.40
26	9.58	1038	E-β-Ocimene [1]	-	0.25
27	9.65	1043	Benzyl alcohol [5]	0.26	-
28	9.76	1049	β-Ocimene [1]	0.18	1.41
29	9.78	1051	Benzene acetaldehyde [5]	0.49	-
30	10.40	1089	1, 3 ,8-*p*-Menthatriene [1]	0.04	-
31	10.60	1102	β-Linalool [2]	-	0.56
32	10.67	1107	Nonanal [5]	0.08	-
33	10.74	1112	Unknown	-	2.02
34	12.10	1208	Decanal [5]	-	2.39
35	14.04	1359	α-Cubebene [3]	-	0.13
36	14.09	1363	Unknown	-	0.05
37	14.44	1392	α-Copaene [3]	0.21	0.20
38	14.53	1399	β-Bourbonene [3]	0.03	-
39	14.56	1401	α-Bourbonene [3]	-	0.54
40	15.02	1438	Caryophyllene [3]	-	4.59
41	15.02	1439	Aromadendrene [3]	7.24	-
42	15.06	1442	E-α-Bergamotene [3]	-	0.40

table 2. (continued).

No.	RT[a]	RI[b]	Compound	Area percentage Aerial parts	Flowers
43	15.13	1448	Z-Muurola-4(14), 5-diene [3]	0.10	-
44	15.22	1455	α-Himachalene [3]	-	1.55
45	15.40	1469	β-Farnesene [3]	-	0.51
46	15.48	1476	α-Humulene [3]	1.46	-
47	15.66	1491	Z,E-α-Farnesene [3]	-	0.15
48	15.79	1501	Germacrene D [3]	3.84	0.95
49	15.81	1502	Unknown	-	0.26
50	16.00	1515	β-Bisabolene [3]	-	3.72
51	16.23	1531	δ-Cadinene [3]	0.38	-
52	16.70	1562	Unknown	-	0.11
			Monoterpene hydrocarbons	1.78	22.19
			Oxygenated monoterpenes	-	0.56
			Sesquiterpene hydrocarbons	13.26	12.74
			Total identified compounds	95.43	96.7

[a]: Retention time in minutes
[b]: Retention index relative to standard mixtures of n-alkanes on SLB-5 column
[1]: Monoterpene hydrocarbons
[2]: Oxygenated monoterpenes
[3]: Sesquiterpene hydrocarbons
[4]: Oxygenated sesquiterpenes
[5]: Miscellaneous
Literature retention indices obtained from Adams [30]

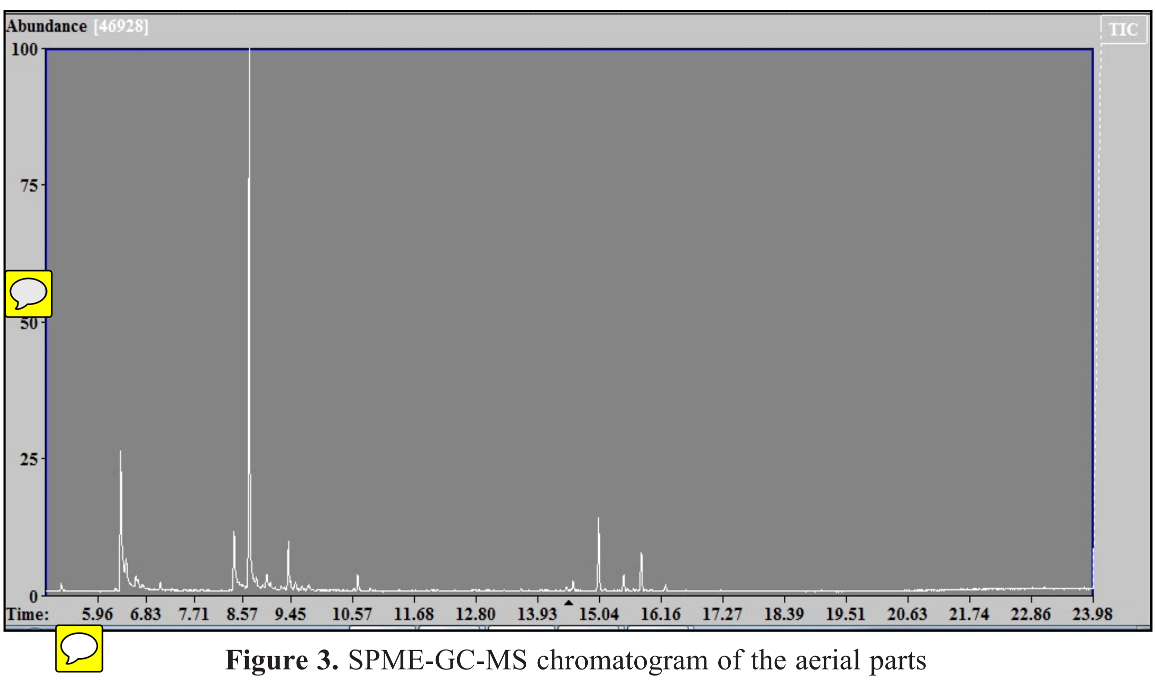

Figure 3. SPME-GC-MS chromatogram of the aerial parts of *Salvia farinacea* Benth. headspace volatiles

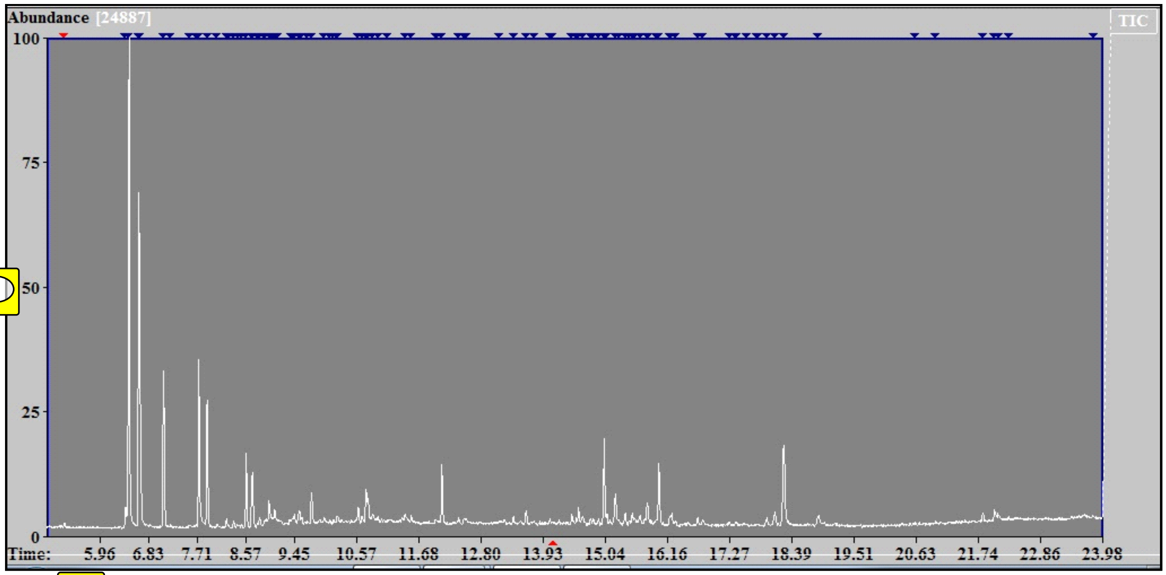

Figure 4. SPME-GC-MS chromatogram of the flowers of *Salvia farinacea* Benth. headspace volatiles

hydrodistillation and analyzed by capillary GC-MS revealed the presence of D-germacrene (40.67 %) and β-caryophyllene (23.20 %) as the major components. It also contains terpinolene, metil cavicol, α-copaene, α-caryophyllene, γ-cadinene and patchoulene. Tabanca *et al.,*[22] stated that the abundant constituents of the essential oil extracted by microdistillation from the aerial parts of the same plant in Texas are 1-octen-3-ol (30.1 %) and (Z)-3-hexenal (23.3 %). Other compounds are also detected as 1, 8-cineole, nonanal, β-caryophyllene, borneol, caryophyllene oxide, eugenol and 1-octadecanol.

Our results are partly in agreement with those of Tabanca *et al.,*[22] showing that 1-octen-3-ol is the major component identified. In addiiton, some components detected by HS-SPME were found in common but with different percentages as limonene, hexenal, benzaldehyde, nonanal, heptadienal and germacrene D.

Conclusion

In conclusion, headspace coupled to GC/MS is an advanced, simple, effective and rapid analytical technique using small amounts of plant samples. A large number of volatile compounds were identified in both studied plants with the aid of this technique. The volatile compounds of the flowers of both plants were studied for the first time. The major components in the aerial parts of *Plectranthus neochilus* Schltr. were *allo*-aromadendrene, aromadendrene and selin-3,7(11)-diene, while γ-cadinene and aromadendrene, β-myrcene and tra[illegible]β-ocimene were the major components in [illegible] flowers. 1-Octen-3-ol, 2-hexenal, benzaldehyde and aromadendrene were the main components of the aerial parts of *Salvia farinacea* Benth. Ethyl benzene was the major component in its flowers followed by *m*-xylene, *o*-xylene, α-thujene and α-pinene.

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