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Micro-Distilled Volatile Compounds from *Ferulago* Species Growing in Western Turkey*

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Abstract

Twelve *Ferulago* (Apiaceae) species growing in Turkey, *viz*. *F. asparagifolia* Boiss., *F. aucheri* Boiss., *F. confusa* Velen., *F. galbanifera* (Miller) W. Koch., *F. humilis* Boiss., *F. idaea* N. Özhatay et E. Akalın, *F. macrosciadia* Boiss. et Bal., *F. mughlae* Peşmen, *F. sandrasica* Peşmen et Quezel., *F. silaifolia* (Boiss.) Boiss., *F. sylvatica* (Besser) Reichb., and *F. trachycarpa* Boiss. were investigated for their chemical compositions by using a new technique: microdistillation. Milligram quantities of dried materials were sufficient for characterizing the composition of the volatiles using a GC/MS system.

Keywords: Apiaceae, essential oils, *Ferulago* species, GC/MS, micro-distillation.

Introduction

The genus *Ferulago* W. Koch. (Apiaceae) is represented by 30 species; 16 of these are endemic in the flora of Turkey (Davis, 1972; Davis et al., 1988). The *Ferulago* species are known and used as "çakşırotu", "kişniş", "asaotu", "kuzu başı" and "kuzu kemirdi" in different regions of Turkey (Akalın, 1999). Since ancient times, *Ferulago* species have been used in folk medicine as sedative, tonic, digestive, aphrodisiac and in the treatment of intestinal worms and haemorrhoids. (Akalın, 1999; Baytop, 1999).

A number of the *Ferulago* species have previously been investigated for their chemical compositions. Monoterpenes and sesquiterpenes were reported from *Ferulago nodosa*, *F. sylvatica* and *F. antiochia* (Ruberto et al., 1999, 1994; Chalchat et al., 1992; Miski et al., 1990). The essential oils of *F. trachycarpa* and *F. asparagifolia* were previously investigated by our group (Başer et al., 1998, 2001). α- and β-Phellandrene were major constituents in the flower oil. *p*-Cymene and α-phellandrene were detected as major components in the stem oil of *F. contracta* from Iran (Rustaiyan et al., 1999). In a recent study, the hexane extracts and essential oil compositions of *F. thyrsiflora*, *F. sylvatica*, and *F. nodosa* have been investigated for their antimicrobial activities (Demetzos et al., 2000).

Recently, we have reported the main components of the hydrodistilled essential oils of *Ferulago asparagifolia*, *F. galbanifera*, *F. humilis* and *F. trachycarpa* and the antimicrobial activity of their oils for the first time (Demirci et al., 2000). In our continuing research, we report on the essential oils obtained by micro-distillation from the fruits of 12 *Ferulago* species, using an Eppendorf MicroDistiller® system. The subsequent volatiles were analyzed and characterized by GC/MS.

Materials and methods

Plant material

The plant materials and their collection sites are given in Table 1. Voucher specimens are kept at Herbarium of the Faculty of Pharmacy at Istanbul University in Istanbul (ISTE), Turkey.

Distillation method

The essential oils were obtained by micro-distillation from the fruits of 12 species of *Ferulago* by using an Eppendorf MicroDistiller®.

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Table 1. Plant Materials used in this study.

Code	*Ferulago* species	Collection Site	ISTE
A	*F. asparagifolia* Boiss.	Aydın: Ephesus	76428
B	*F. aucheri** Boiss.	Muğla: Sandras Mountain	74565
C	*F. confusa* Velen.	Tekirdağ-Hayrabolu	72427
D	*F. galbanifera* (Miller) W. Koch	Bilecik	72560
E	*F. humilis** Boiss.	Muğla: Sandras Mountain	74563
F	*F. idaea** N. Özhatay et E. Akalın	Balıkesir: Kazdağı	74485
G	*F. macrosciadia** Boiss. et Bal.	Balıkesir: Kazdağı	72514
H	*F. mughlae** Peşmen	Muğla: Köyceğiz	72535
I	*F. sandrasica** Peşmen et Quezel.	Muğla: Sandras Mountain	74528
J	*F. silaifolia** (Boiss.) Boiss.	Bursa: Mezitler	72530
K	*F. sylvatica* (Besser) Reichb.	Çanakkale: Çan, Kazdağı	72505
L	*F. trachycarpa* Boiss.	Balıkesir: Edremit	74661

* Endemic species.

Micro-distillation

Crushed fruits (~250 mg) were placed in a sample vial together with 10 ml of water. NaCl (2.5 g) and water (0.5 ml) were placed in the collecting vial. *n*-Hexane (300 µl) was added into the collecting vial to trap volatile components. Sample vials were heated to 100 °C at a rate of 20 °C/min and then kept at 100 °C for 15 min. Then, heated to 112 °C at a rate of 20 °C/min and kept at this temperature for 35 min. Finally, the samples were subjected to post-run for 2 min under the same conditions. Collecting vials were cooled to −5 °C during distillation. After the distillation was completed, the organic layer in the collection vial was injected to GC/MS.

Analysis of essential oils

The essential oils were analysed using a Hewlett-Packard G1800A GCD system. Innowax FSC column (60 m × 0.25 mm Ø, with 0.25 µm film thickness). Helium (0.8 ml/min) was used as carrier gas. GC oven temperature was kept at 60 °C for 10 min and programmed to 220 °C at a rate of 4 °C/min and then kept constant at 220 °C for 10 min to 240 °C at rate of 1 °C/min. Mass range was recorded from *m/z* 35 to 425. Injections were applied splitless. The injection port temperature was at 250 °C. The MS were recorded at 70 eV. The relative percentage amounts of the separated compounds were calculated automatically from peak areas of the total ion chromatogram. Alkanes were used as reference points in the calculation of relative retention indices (RRI). Library search was carried out using "Wiley GC/MS Library" and "TBAM Library of Essential Oil Constituents".

Results and discussion

The volatiles were obtained from the fruits of the *Ferulago* species by micro-distillation for the first time. The results of their subsequent GC/MS analyses are given in Table 2. The main components were found as follows:

Ferulago asparagifolia Boiss.: 42 components were characterized representing 94.8% of the total components detected. 2, 3, 6-Trimethylbenzaldehyde (42.0%) was the main component of the oil obtained by micro-distillation. We have previously investigated hydro-distilled essential oil of *F. asparagifolia* fruits collected from Antalya by GC/MS and we found that 2, 3, 6-trimethylbenzaldehyde (38.9%) and myrcene (18.2%) were the main components (Başer et al., 2001). Its oil was previously tested against bacteria and fungi (Demirci et al., 2000).

Ferulago aucheri Boiss.: The composition of the essential oil of this endemic species has not been investigated previously. The isolation of flavonoids, coumarins and benzenoids were reported from the aerial parts of *Ferulago aucheri* (Doğanca et al., 1991, 1997). We have studied the essential oil composition of the 2 materials collected from 2 different regions in Turkey. Thirty-nine compounds, representing 81.6% of the oil, were identified with α-pinene (35.9%) as the main constituent.

Ferulago confusa Velen.: Thirty-five components were characterized representing 99.4% of the oil. The main constituent was 2,5-dimethoxy-*p*-cymene (63.4%). As far as we know, this is the first report on the essential oil composition of *F. confusa*.

Ferulago galbanifera (Miller) W. Koch: The main constituent of this oil was *trans*-chrysanthenyl acetate (17.2%). GC/MS analysis resulted in the characterization of 23 constituents representing 92.9% of the oil. *F. galbanifera* collected from Eskişehir showed a different essential oil profile with α-pinene (31.8%) and sabinene (15.8%) as main components. The oil of this species was previously evaluated for its antifungal and antibacterial activities (Demirci et al., 2000).

Ferulago humilis Boiss.: This endemic species was previously investigated by our group. (*Z*)-β-Ocimene (32.4%) was reported as the main component and its oil was also tested

Table 2. The composition of the essential oils of *Ferulago* species.

Compound	RRI	A	B	C	D	E	F	G	H	I	J	K	L
α-Pinene	1032	11.4	35.9	3.5	–	6.1	16.1	0.1	25.4	40.8	5.6	–	–
α-Thujene	1035	0.2	–	0.2	–	–	–	0.1	0.1	–	–	–	–
Isopropyl 2-methylbutyrate	1061	–	–	–	–	0.1	–	–	–	–	–	–	–
Camphene	1076	–	–	tr	–	0.2	0.4	–	1.7	1.1	–	–	0.7
β-Pinene	1118	0.5	1.5	0.2	4.0	0.4	0.7		1.3	1.5	0.4	0.1	tr
Sabinene	1132	6.2	0.2	0.4	0.7	0.2	–	0.2	0.7	0.2	0.1	0.4	0.5
δ-2-Carene	1146	–	–	–	–	–	–	–	0.5	–	–	–	–
δ-3-Carene	1159	–	–	tr	–	–	1.0	–	tr	0.1	–	–	8.1
Myrcene	1174	–	tr	0.5	–	2.3	1.2	0.2	3.9	0.6	0.6	0.9	19.9
α-Phellandrene	1176	4.3	–	–	10.9	–	–	–	–	–	–	–	–
Isobutyl 2-methylbutyrate	1185	0.4	–	–	–	–	–	–	–	–	–	–	–
α-Terpinene	1188	0.4	–	tr	–	–	–	–	0.2	–	–	–	–
Dehydro-1,8-cineole	1195	–	–	–	–	–	–	–	0.1	–	–	–	–
Limonene	1203	1.1	0.8	0.3	10.3	31.4	1.5	0.1	3.1	2.2	0.3	1.0	5.1
β-Phellandrene	1218	1.4	–	0.1	7.8	0.5	–	0.1	6.1	–	–	0.1	1.8
(*Z*)-β-Ocimene	1246	–	–	0.1	1.2	31.9	–	–	0.3	–	–	1.2	1.5
γ-Terpinene	1255	1.2	tr	0.3	–	4.1	3.4	1.0	0.2	0.1	–	2.8	27.8
(*E*)-β-Ocimene	1266	–	–	–	–	0.9	–	–	tr	–	–	–	–
p-Cymene	1280	2.7	0.9	24.0	11.9	7.0	18.4	19.4	2.4	0.5	0.5	45.8	21.6
Isoterpinolene	1286	–	–	–	–	–	–	–	–	–	–	–	0.4
Terpinolene	1290	–	–	0.2	–	2.0	–	–	0.2	–	0.1	1.4	1.2
1,2,4-Trimethyl benzene	1294	1.9	–	0.1	–	–	2.2	–	–	–	–	–	–
1,2,3-Trimethyl benzene	1355	0.4	–	–	–	–	0.6	–	–	–	–	–	–
cis-Alloocimene	1382	–	–	–	–	1.1	–	–	–	–	–	–	–
α-Pinene oxide	1384	–	0.3	–	–	–	–	–	–	–	–	–	–
trans-Alloocimene	1409	–	–	–	–	0.1	–	–	–	–	–	–	–
Pentyl benzene	1426	–	–	–	–	–	–	–	–	–	–	2.8	–
γ-Campholene aldehyde	1439	–	–	–	1.0	–	–	–	–	0.1	–	–	–
α,*p*-dimethylstyrene	1452	0.1	–	0.1	–	0.1	–	–	0.1	–	–	0.3	–
α-Cubebene	1466	–	tr	–	–	–	–	–	0.1	–	–	–	
trans-1,2-Limonene epoxide	1468	–	–	–	–	0.1	–	–	–	–	–	–	–
(*Z*)-β-Ocimene epoxide	1476	–	–	–	–	0.1	–	–	–	–	–	0.1	–
δ-Elemene	1479	–	–	–	–	–	–	–	1.6	–	0.2	–	–
α-Ylangene	1493	–	–	–	–	–	–	–	0.3	–	–	–	0.4
Bicycloelemene	1495	–	–	–	–	–	–	–	–	0.1	–	–	–
α-Copaene	1497	–	–	–	–	0.3	–	–	1.6	–	–	–	–
α-Campholene aldehyde	1499	0.2	4.3	0.1	–	–	1.4	–	–	1.1	0.1	–	–
α-Bourbonene	1528	–	0.3	–	–	–	–	–	–	–	–	–	–
β-Bourbonene	1535	–	1.4	–	1.0	–	–	–	0.1	0.5	–	–	0.4
β-Cubebene	1549	0.1	–	–	–	–	–	–	0.5	0.1	–	–	–
Linalool	1553	0.1	–	–	0.6	–	–	–	–	–	–	–	–
trans-*p*-Menth-2-en-1-ol	1571	–	–	–	–	–	–	–	0.3	–	–	–	–
trans-Chrysanthenyl acetate	1582	5.2	–	1.2	17.2	4.0	8.8	–	tr	5.3	83.5	0.1	–
Pinocarvone	1586	–	1.0	–	–	–	–	–	0.1	–	–	–	–
Aristolene	1589	–	–	–	–	–	–	–	0.3	–	–	–	–
α-Guaiene	1596	–	0.4	–	–	–	–	–	–	–	–	–	–
Bornyl acetate	1597	0.3	–	tr	5.0	0.6	1.4	–	0.1	1.4	0.2	–	3.1
β-Elemene	1600	–	–	0.1	0.9	0.5	–	–	0.9	0.7	–	–	–
Terpinen-4-ol	1611	1.6	–	0.2	–	–	–	0.1	–	–	–	0.2	–
β-Caryophyllene	1612	–	0.7	–	7.8	–	–	–	1.0	3.2	–	–	–
Carvacrol methyl ether	1614	–	–	0.9	–	0.8	13.4	78.1	tr	–	–	0.5	tr
6,9-Guaiadiene	1617	–	–	–	–	–	–	–	0.1	–	–	–	–
cis-*p*-Menth-2-en-1-ol	1638	–	–	–	–	–	–	–	0.3	–	–	–	–
trans-*p*-Mentha-2,8-dien-1-ol	1639	–	–	–	–	0.1	–	–	–	–	–	–	–
Myrtenal	1648	–	1.1	–	–	0.1	–	–	0.1	0.4	–	–	–
γ-Elemene	1650	–	–	–	–	–	–	–	0.1	–	–	–	–
trans-Pinocarvyl acetate	1661	1.0	–	0.1	0.5	–	–	–	–	0.1	0.5	–	–

Table 2. (*Continued*)

Compound	RRI	A	B	C	D	E	F	G	H	I	J	K	L
cis-Verbenol	1663	0.5	0.1	–	–	–	–	–	–	–	0.6	–	–
trans-Pinocarveol	1664	–	3.4	–	–	0.4	–	–	0.3	1.4	–	–	–
p-Mentha-1,5-dien-8-ol	1674	0.3	0.5	–	–	0.1	–	–	0.1	0.5	–	–	–
cis-*p*-Mentha-2,8-dien-1-ol	1678	–	–	–	–	0.1	–	–	–	–	–	–	–
trans-Verbenol	1683	1.3	6.4	0.4	–	1.1	1.1	–	0.7	1.4	2.8	–	–
α-Humulene	1687	–	3.4	–	0.7	0.1	–	–	1.8	5.8	–	–	–
γ-Terpinyl acetate	1696	0.2	–	–	–	–	–	–	–	–	–	–	–
Myrtenyl acetate	1698	0.3	–	–	–	–	–	–	–	–	–	–	–
p-Mentha-1,8-dien-4-ol (=Limonen-4-ol)	1700	–	–	0.1	–	0.1	–	–	0.1	–	–	0.2	–
γ-Muurolene	1704	–	0.3	–	–	–	–	–	0.6	0.1	–	–	–
α-Terpineol	1706	–	0.1	–	–	–	–	–	–	0.2	–	–	–
δ-Selinene	1707	–	–	–	–	–	–	–	1.4	–	–	–	–
Borneol	1719	–	–	–	–	–	–	–	0.1	–	–	–	–
Verbenone	1725	–	0.8	–	–	–	–	–	–	–	–	–	–
Germacrene D	1726	0.2	1.0	–	2.3	0.2	–	–	3.9	8.1	–	–	1.4
α-Zingiberene	1726	–	–	–	–	–	–	–	–	–	0.3	–	–
Thujol	1729	–	–	–	–	–	–	–	0.1	–	–	–	–
β-Bisabolene	1741	–	–	–	–	–	–	–	–	–	0.2	–	–
β-Selinene	1742	–	–	–	–	–	–	–	0.4	–	–	–	–
α-Selinene	1744	–	0.7	–	–	–	–	–	tr	1.4	–	–	–
Carvone	1751	–	0.1	–	–	0.4	–	–	–	–	–	–	–
Bicyclogermacrene	1755	1.6	–	–	1.8	–	–	–	0.4	0.4	–	–	2.6
cis-Piperitol	1758	–	–	–	–	–	–	–	0.2	–	–	–	–
cis-Chrysanthenol	1764	–	–	–	–	–	–	–	–	–	0.6	–	–
δ-Cadinene	1773	0.4	0.8	tr	–	0.4	–	0.1	4.5	0.3	–	–	1.5
γ-Cadinene	1776	–	0.3	–	–	–	–	–	1.9	0.2	–	–	–
β-Sesquiphellandrene	1783	–	–	–	–	–	–	–	–	–	0.2	–	–
Kessane	1786	0.2	–	–	–	–	–	–	–	–	–	–	–
ar-Curcumene	1786	–	–	–	–	–	–	–	tr	–	0.4	–	–
Selina-3(7),11-diene	1796	–	–	–	0.8	–	–	–	–	0.4	–	–	–
Myrtenol	1804	–	–	–	–	–	–	–	0.1	0.4	–	–	–
3,7-Guaiadiene	1810	–	–	–	–	–	–	–	0.1	–	–	–	–
p-Mentha-1(7),5-dien-2-ol	1823	0.1	–	–	–	–	–	–	0.2	–	–	–	–
trans-Carveol	1845	0.2	–	–	–	0.2	tr	–	–	0.4	–	–	–
Germacrene-B	1854	0.4	–	–	0.7	–	–	–	0.5	–	–	–	–
p-Cymen-8-ol	1864	0.1	0.2	0.5	–	0.1	0.5	0.1	0.2	0.1	0.1	1.0	–
2,5-Dimethoxy-*p*-cymene	1878	–	–	63.4	–	0.1	13.2	–	–	–	–	40.2	–
epi-Cubebol	1900	–	–	–	–	–	–	–	0.1	–	–	–	–
Thymoquinone	1908	0.4	–	0.1	–	–	–	–	–	–	–	–	–
2,3,4-Trimethylbenzaldehyde	1925	3.7	–	0.2	2.2	–	–	–	–	–	–	–	–
α-Calacorene	1941	–	0.4	–	–	–	–	–	0.5	–	–	–	–
1,5-Epoxy-salvial-4(14)-ene	1945	–	1.9	–	–	–	–	–	0.1	0.6	–	–	–
γ-Calacorene	1984	–	0.1	–	–	–	–	–	0.3	–	–	–	–
Caryophyllene oxide	2008	–	2.6	0.1	–	–	–	–	0.4	3.0	–	–	–
2,3,6-Trimethylbenzaldehyde	2019	42.0	–	1.7	–	–	14.1	–	0.4	–	0.2	–	–
Salvial-4(14)-en-1-one	2037	–	0.7	–	–	–	–	–	0.1	0.3	–	–	–
Humulene epoxide-I	2045	–	0.7	–	–	–	–	–	–	0.3	–	–	–
(*E*)-Nerolidol	2050	–	0.4	–	–	–	–	–	–	–	–	–	–
Humulene epoxide-II	2071	–	7.3	–	–	–	–	–	0.4	3.0	–	–	–
Cubenol	2080	–	–	–	–	–	–	–	12.7	0.3	–	–	–
Humulene epoxide-III	2081	–	0.6	–	–	–	–	–	–	0.2	–	–	–
Elemol	2096	–	–	–	–	–	–	–	0.3	–	–	–	–
Guaiol	2103	–	–	–	–	–	–	–	0.1	–	–	–	–
Spathulenol	2144	1.6	–	–	2.6	0.6	–	–	1.0	1.3	–	–	2.0
T-Cadinol	2187	–	–	–	–	–	–	–	0.1	–	–	–	–
Thymol	2198	–	–	tr	–	–	–	0.1	–	–	–	–	–

Table 2. (*Continued*)

Compound	RRI	A	B	C	D	E	F	G	H	I	J	K	L
1,6-Germacradien-5α-ol (=*Germacrene D-4α-ol*)	2202	–	–	–	–	–	–	–	0.5	–	–	–	–
T-Muurolol	2209	0.1	–	–	–	–	–	–	0.1	–	–	–	–
δ-Cadinol	2219	–	–	–	–	–	–	–	0.2	–	–	–	–
Isocarvacrol (=4-isopropyl-2-methyl phenol)	2221	–	–	0.1	–	–	–	–	–	–	–	–	–
Methyl hexadecanoate	2226	–	–	–	1.0	–	–	–	–	–	–	–	–
Carvacrol	2239	0.1	–	0.2	–	–	–	0.1	tr	–	–	0.2	–
trans-α-Bergamotol	2247	0.1	–	–	–	–	–	–	0.1	–	–	–	–
α-Cadinol	2255	0.3	–	–	–	–	–	–	0.4	0.7	–	–	–
4-Isopropyl-6-methyl-1,2,3,4-tetrahydronapthalen-1-one	2419	–	–	–	–	–	–	–	0.1	–	–	–	–
Monoterpenes		29.4	39.3	29.8	46.8	88.2	42.7	21.2	46.1	47.1	7.6	53.7	88.6
Oxygenated Monoterpenes		57.6	17.5	69.2	26.5	8.4	53.9	78.5	3.5	12.8	88.6	45.6	3.1
Sesquiterpenes		2.7	11.0	0.2	16.0	1.5	–	0.1	22.9	21.3	1.3	–	6.3
Oxygenated Sesquiterpenes		2.3	13.8	0.1	2.6	0.6	–	–	16.6	9.7	–	–	2.0
Others		2.8	–	0.1	1.0	0.2	2.8	–	0.2	–	–	–	–
Total		94.8	81.6	99.4	92.9	98.9	99.4	99.8	89.3	90.9	97.5	99.3	100

A: *F. asparagifolia* B: *F. aucheri* C: *F. confusa* D: *F. galbanifera* E: *F. humilis* F: *F. idaea* G: *F. macrosciadia* H: *F. mughlae* I: *F. sandrasica* J: *F. silaifolia* K: *F. sylvatica* L: *F. trachycarpa*
RRI = Relative retention indices on a polar column
tr = Trace (<0.1%)

for its antifungal and antibacterial activities (Demirci et al., 2000). In the microdistilled oil, 38 components were identified representing 98.9% of the oil. The main component was (*Z*)-β-ocimene (31.9%).

Ferulago idaea N. Özhatay et E. Akalın: This plant has recently been described as a new species (Akalın, 1999; Özhatay & Akalın, 2000). GC/MS analysis resulted in the characterization of 19 constituents representing 99.4% of the oil. The main component was *p*-cymene (18.4%).

Ferulago macrosciadia Boiss. et Bal.: Fourteen compounds were identified representing 99.8% of the oil with carvacrol methyl ether (78.1%) as main constituent of this endemic species.

Ferulago mughlae Peşmen: This endemic species has not been investigated previously. GC/MS analysis of the oil resulted in the characterization of 78 compounds representing 89.3% of the oil with α-pinene (25.4%) as the main component.

Ferulago sandrasica Peşmen et Quezel.: α-Pinene (40.8%) was the main constituent in the essential oil of this endemic species. It was among the 44 characterized compounds representing 90.9% of the oil.

Ferulago silaifolia (Boiss.) Boiss.: Twenty-one compounds representing 97.5% of the oil of this endemic species were identified with *trans*-chrysanthenyl acetate (83.5%) as the main constituent.

Ferulago sylvatica (Besser) Reichb.: This species has been the subject of a previous study. Monoterpenes and sesquiterpenes were reported from aerial parts of the essential oil of *F. sylvatica* (Chalchat et al., 1992). GC/MS analysis has resulted in the characterization of 19 compounds representing 99.3% of the oil with *p*-cymene (45.8%) as the main constituent.

Ferulago trachycarpa Boiss.: Essential oil from fresh fruits of *F. trachycarpa*, collected from Karaman in Turkey, was previously investigated by our group. (*Z*)-β-Ocimene was reported as the main component (30.7%) (Başer et al., 1998). More recently, (*Z*)-β-ocimene (34.1%) was reported by us as the main of the essential oil from aerial parts of *F. trachycarpa* from Konya. Its antifungal and antibacterial activities were also reported (Demirci et al., 2000). In the scope of this work, we have studied the essential oil composition of the fruits collected from another region. GC/MS analysis resulted in the characterization of all 20 compounds of the oil with γ-terpinene (27.8%) as the main component.

In summary, the following compounds were identified in relative percentage amounts indicated in parantheses as major components, respectively: α-pinene: *F. aucheri* (36%), *F. mughlae* (25%), *F. sandrasica* (41%); 2,5-dimethoxy-*p*-cymene: *F. confusa* (63%); 2, 3, 6-trimethylbenzaldehyde: *F. asparagifolia* (42%); *p*-cymene: *F. sylvatica* (46%), *F. idaea* (18%); carvacrol methyl ether: *F. macrosciadia* (78%); *trans*-chrysanthenyl acetate: *F. silaifolia* (84%), *F. galbanifera* (17%); γ-terpinene: *F. trachycarpa* (28%); (*Z*)-β-ocimene: *F. humilis* (32%).

The microdistillation technique enabled the isolation of volatiles of a few seeds/fruits in a rapid and efficient manner.

It gave quite comparable results with those of hydrodistilled oils (Briechle et al., 1997; Brunn et al., 1997). The method can particularly be useful in studying the essential oil composition of herbarium materials.

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