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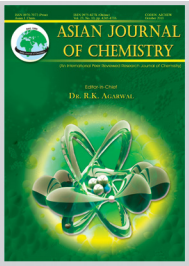

Volatile Constituents of the Aerial Parts of *Ferulago subvelutina* Rech. f., *Ferulago stellata* Boiss., Leaves and Flowers of *Prangos ferulacea* (L.) Lindle. and Leaves of *Ferula ovina* (Boiss.) Boiss.: Four Umbelliferae Herbs from Iran

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The composition of the essential oils from four umbelliferae species of Iran *i.e.*, *Ferulago subvelutina* Rech. f. (syn. *Ferulago turcomanica Schischk.*), *Ferulago stellata* Boiss. (syn. *Ferulago koeiziana* Rech. f.), *Prangos ferulacea* (L.) Lindle. (syn. *Prangos macrocarpa* Boiss., *Cachrys goniocarpa* Boiss., *Cachrys prangoides* Boiss.) and *Ferula ovina* (Boiss.) Boiss. obtained by hydrodistillation were analyzed by GC and GC/MS. The major constituents of the oil of *F. subvelutina* appeared to be limonene (27.0 %), α-phellandrene (23.1 %) and α-pinene (13.3 %) and the main composition of *F. stellata* was 2,4,5-trimethyl benzaldehyde (61.1%). β-Pinene (29.6 % and 20.6 %), α-pinene (19.8 % and 8.8 %), δ-3-carene (11.4 % and 10.4 %) and β-phellandrene (11.1 % and 8.1 %) were the main constituents in the leaf and flower oils of *P. ferulacea*, respectively. The leaf oil of *F. ovina* was characterized by higher amount of α-pinene (22.5 %), bornyl acetate (14.1 %) and camphene (11.0 %).

Key Words: *Ferulago subvelutina*, *Ferulago stellata*, *Prangos ferulacea*, *Ferula ovina*, Umbelliferae, Essential oil, Limonene, α-Phellandrene, α-Pinene, 2,4,5-Trimethyl benzaldehyde, β-Pinene, δ-3-Carene, β-Phellandrene.

INTRODUCTION

The genus *Ferulago* comprises of some 35 species, seven of which are found in Iran including two endemic *i.e.*, *F. contracta* Boiss. et Hausskn. and *F. phialocarpa* Rech. f. et. H. Riedl[1,2]. *Ferulago* species are used since ancient times in folk medicine for their sedative, tonic, digestive, aphrodisiac properties and have been used in the treatment of intestinal worms and homorrhoids in different regions of Turkey[3,4]. The chemical investigation of some *Ferulago* species have shown coumarins, sesquiterpenes and aromatic compounds[5-9]. A number of *Ferulago* species have previously been investigated for their essential oil composition and antimicrobial activities[10-18].

Fifteen species of the genus *Prangos* are found in Iran, among, which five are endemic[1,2]. *P. ferulacea* is a widespread species of *Prangos* genus that is distributed from east Europe to Turkey, Iran and Central Asia.[1] The plant has been used in Iran as a medicinal plant under the common name of Djashir. In traditional medicine, extracts of the roots and fruits of the plant have been used for the treatment of digestive disorders, healing scars and to stop bleeding in Iran, Turkey, India and central Asia.[19]

On the other hand, the aerial parts of *P. ferulacea* have high nutrient value and are used in different parts of Iran as an animal fodder. However, the number of wild plants has been declining rapidly due to the changing environmental conditions over the past decades and excessive harvesting of the wild plants from native fields by horticultural trades, herbalists and husbandries. Chemical investigation of some *Prangos* species have shown the presence of coumarins and its derivatives[20-27]. The oils of some *Prangos* species have been the subject of our previous studies.[28,29]

The oil from the fruits of *P. ferulacea* from Italy, contained γ-terpinene (27.8 %), *cis*-β-ocimene (26.8 %) and 4-terpineol (12.2 %) as the major components[30]. The essential oils, water-distilled from whole and crushed fruits of *P. ferulacea* (collected from Turkey), were analyzed by GC and GC/MS. Crushed and whole fruits yielded oils rich in γ-terpinene (30.2 % and 33.3 %, respectively) and α-pinene (16.7 % and 12.8 %, respectively). Germacrene B (30.3 %) and γ-terpinene (17.2 %) were the major constituents of the oil obtained following redistillation the already distilled whole fruits after crushing[31].

The main constituents of the essential oil of aerial parts of *P. ferulacea* from Iran, were β-pinene (22.9 %) and δ-3-carene (16.0 %) and the seed oil of the plant contained β-pinene (33.0 %) and α-pinene (10.1 %)[32].

In the essential oil from the fruits of *P. ferulacea* from Tehran, Iran, chrysanthenyl acetate (26.5 %), limonene (19.6 %) and α-pinene (19.5 %) were predominated, also the essential oil of the plant showed activity against *Staphylococus aureus, S. epidermis, Eschrechia coli* and *Pseudomonas aeroginosa*[33].

In another investigation on the essential oils of fruits and umbels of *P. ferulacea*, growing in Iran, α-pinene and *cis*-ocimene were the major components the oils. The essential oils show high antibacterial effect against *Bacillus cereus*[34].

Chemical composition and antibacterial activity of essential oils from leaves, stems and flowers of *Prangos ferulacea* growing in Esfahan, Iran, have been reported. In the oil from the leaf, 10 components were identified, dominated by oxygenated monoterpenes. The three major constituents identified were linalool (36.7 %), caryophyllene oxide (16.3 %) and α-pinene (12.1 %). In the stem oil, 11 compounds were identified, with oxygenated monoterpenes again predominating. The two major constituents identified were 1,8-cineole (19 %) and α-pinene (10.3 %) of the 17 compounds found in the flower oil, the five main components identified were oxygenated monoterpenes *i.e.*, linalool (19 %), lavandulyl acetate (16 %), 1,8-cineole (14.5 %), α-pinene (12.4 %) and geranyl isobutyrate (12.2 %). It was found that the oil from leaves, stems and flowers of *P. ferulacea* and especially that of leaves, exhibited remarkable antibacterial activity[35].

The genus *Ferula*, includes about 170 species occurring from central Asia westward throughout the Mediterranean region to northern Africa[1]. The flora of Iran comprises 30 species of *Ferula* of which 15 are endemic.[2] The *Ferula* genus has been found to be a rich source of gum-resin.[36] This resin enjoys a reputation as a folklore medicine.[37] It is considered to be a sedative, carminative, antispasmodic digestive, expectorant, laxative, analgestic, anthelminitic, antiseptic and a diuretic in its properties. It is also believed to have aphrodisiac properties and increase sexual appetite.[38]

This genus presents interesting phytochemical features, such as the occurrence of sesquiterpenes and sesquiterpene coumarins.[39-42] Conversely, only a few studies have reported the chemical composition of *Ferula* essential oils. We already reported the oils composition of some species of this genus found in Iran.[43-50]

A water-distilled oil obtained from the aerial parts of *F. ovina*, collected from Abe-Ali road, east of Tehran, has been the subject of our previous studies. *Ferula ovina* oil contained α-pinene (50 %), limonene (11.5 %) followed by β-pinene (9.7 %), α-fenchyl acetate (7.4 %) and bornyl acetate (6 %) among the 19 constituents characterized, comprising 90 % of the total components detected. Monoterpenes (87.5 %) predominated over sesquiterpenes (2.3 %)[50].

In another previous investigation on the essential oil from aerial parts of *F. ovina* from Iran, 43 components consisting 86.7 % of the total components were identified, among them, carvacrol (9.0 %), α-pinene (8.2 %), geranyl isovalerate (7.2 %) and geranyl propionate (7.0 %) were the major components.[51] In this article we report the oils from the aerial parts of *Ferulago subvelutina*, *Ferulago stellata*, leaves and flowers of *Prangos ferulacea* and leaves of *Ferula ovina* grown wild in Iran.

EXPERIMENTAL

The aerial parts of *Ferulago subvelutina* and *Ferulago stellata*, were collected from Kashmar to Neishabour, Province of Khorrasan and Khosh-Ghadam area, Province of Eylam, west of Iran, both in July 2009, respectively. The leaves and flowers of *Prangos ferulacea* were collected from Sanandaj, Province of Kordestan, west of Iran, in July 2010. The leaves of *Ferula ovina* were collected from Haraz road, Province of Mazandaran, North of Iran, in July 2010. Voucher specimens have been deposited at the Herbarium of the Research Institute of Forests and Rangelands (TARI), Tehran, Iran.

Isolation of the essential oils: Air-dried aerial parts of *Ferulago subvelutina* (170 g) and *F. stellata* (150 g), leaves (120 g) and flowers (90 g) of *Prangos ferulacea* and leaves (100 g) of *Ferula ovina* were separately subjected to hydrodistillation using a Clevenger-type apparatus for 3 h. After decanting and drying of the oils over anhydrous sodium sulfate, the corresponding yellowish coloured oils were recovered [in the yield of 1.08, 0.58, 0.25, 0.40 and 0.10 % (w/w) respectively].

Gas chromatography: GC analysis was performed on Schimadzu 15 A gas chromatograph equipped with a split/splitless injector (25 ºC) and a flame ionization detector (250 ºC). Nitrogen was used as carrier gas (1 mL/min) and the capillary column used was DB-5 (50 m × 0.2 mm, film thickness 0.32 μm). The column temperature was kept at 60 ºC for 3 min and then heated to 220 ºC with a 5 ºC/min rate and kept constant at 220 ºC for 5 min. Relative percentage amount were calculated from peak area using a Shimadzu C-R4A chromatopac without the use of correction factors.

Gas chromatography-mass spectrometry: Analysis was performed using a Hewlett-Packard 5973 with a HP-5MS column (30 m × 0.25 mm, film thickness 0.25 μm). The column temperature was kept at 60 ºC for 3 min and programmed to 220 ºC at a rate of 5 ºC/min and kept constant at 220 ºC/min for 5 min. The flow rate of Helium as carrier gas with (1 mL/min). Mass spectrometry were taken at 70 eV. The retention indices for all the components were determined according to the Van Den Dool method, using *n*-alkanes as standards.[52]

The compounds were identified by (RRI, DB5) with those reported in the literature and by comparison of their mass spectra with the Wiley library or with the published mass spectra[53,54].

RESULTS AND DISCUSSION

The composition of the essential oils from aerial parts of *Ferulago subvelutina* and *Ferulago stellata*, leaves and flowers of *Prangos ferulacea* and leaves of *Ferula ovina* are listed in Tables 1-3, respectively, in which the percentage and relative retention indices of components are given.

As it is shown from the Table-1, about 97.8 % (41 components) of the oil of *F. subvelutina* and 98.5 % (38 components) of the oil of *F. stellata* were identified. The oil of *F. subvelutina* consists of twelve monoterpene hydrocarbons (80.1 %), twelve oxygenated monoterpenes (6.6 %), seven sesquiterpene hydrocarbons (1.6 %), six oxygenated sesquiterpenes (3.1 %)

TABLE-1
PERCENTAGE COMPOSITION OF THE OILS OF *Ferulago subvelutina* AND *Ferulago stellata*

Compound	RI[a]	*F. subvelutina*	*F. stellata*
α-Thujene	931	-	0.2
α-Pinene	939	13.3	4.1
Camphene	953	2.7	0.1
Sabinene	976	3.0	0.3
Myrcene	991	5.0	0.8
Mesitylene	994	-	3.2
α-Phellandrene	1005	23.1	0.3
δ-3-Carene	1011	t*	-
1,2-4-trimethyl Benzene	1023	-	0.3
ρ-Cymene	1026	-	0.3
Limonene	1031	27.0	1.5
(Z)-β-Ocimene	1040	t	-
(E)-β-Ocimene	1050	1.6	-
γ-Terpinene	1062	1.7	0.6
Terpinolene	1088	2.2	-
6-Camphenone	1093	-	2.9
Linalool	1098	0.7	-
endo-Fenchol	1112	-	t
Chrysanthenone	1123	-	2.1
allo-Ocimene	1129	0.5	-
trans-Pinocarveol	1139	-	t
cis-Verbenol	1140	0.8	0.2
trans-Verbenol	1144	t	t
Pinocarvone	1162	-	1.1
α-Phellandrene-8-ol	1166	0.3	-
Terpinen-4-ol	1177	0.3	-
ρ-ethyl-Benzaldehyde	1182	-	0.7
α-Terpineol	1189	t	-
Myrtenal	1193	-	1.2
Methyl chavichol	1195	2.5	-
Verbenone	1204	-	0.2
trans-Carveol	1217	-	t
Citronellol	1228	0.8	-
Neral	1240	t	-
Carvacrol methyl ether	1244	-	1.7
Piperitone	1252	0.2	-
Bornyl acetate	1285	3.0	-
Carvacrol	1298	0.5	-
2,4,6-trimethyl Benzaldehyde	1327	-	7.5
δ-Elemene	1339	-	t
Citronellyl acetate	1354	t	-
Eugenol	1356	t	-
α-Copaene	1376	-	t
2,4,5-trimethyl Benzaldehyde	1380	-	61.1
Daucene	1380	0.1	-
β-Bourbonene	1384	0.3	-
β-Elemene	1391	-	t
α-1,7-di-epi-Cedrene	1397	t	-
Methyl eugenol	1401	3.2	-
β-Caryophyllene	1418	-	0.7
α-Himachalene	1447	0.6	-
α-Humulene	1454	-	t
γ-Curcumene	1480	0.5	-
Germacrene D	1480	-	0.5
Bicyclogermacrene	1494	t	-
(E)-methyl iso Eugenol	1495	0.7	-
δ-Cadinene	1524	-	t
Kessane	1528	0.2	1.3
Elemol	1549	0.1	-
Germacrene B	1556	0.1	-
Longipinanol	1566	2.0	-
Spathulenol	1576	-	0.3
Caryophyllene oxide	1581	-	2.2
Guaiol	1595	0.4	-
Iso spathulenol	1636	-	0.4
β-Eudesmol	1649	0.2	-
Valeranone	1672	0.2	-
Khosinol	1674	-	0.2
Deodarone	1694	-	2.5
Monoterpene hydrocarbons		80.1	8.2
Oxygenated monoterpenes		6.6	9.4
Sesquiterpene hydrocarbons		1.6	1.2
Oxygenated sesquiterpenes		3.1	6.9
Others		6.4	72.8
Total		97.8	98.5

[a]Retention indices as determined on a DB-5 column using the homologous series of *n*-alkanes; * trace < 0.1

and four non terpenoid compounds (6.4 %). Limonene (27 %), α-phellandrene (23.1 %) and α-pinene (13.3 %) were the major components in this oil.

The oil of *F. stellata* consisted of nine monoterpene hydrocarbons (8.2 %), eleven oxygenated monoterpenes (9.4 %), seven sesquiterpene hydrocarbons (1.2 %), six oxygenated sesquiterpenes (6.9 %) and five non terpenoid aromatic compounds (72.8 %). The major component of this oil was 2,4,5-trimethyl benzaldehyde (61.1 %) followed by 2,4,6-trimethyl benzaldehyde (7.5 %).

As can be seen from the above information the oil of *F. subvelutina* was characterized by higher amount of monoterpenes and small percentage of sesquiterpenes while, in the oil of *F. stellata* non terpenoid aromatic compounds predominated over monoterpenes and sesquiterpenes. Thus, the composition of both oils differs quantitatively and qualitatively. The main component identified in the essential oils of *F. angulata*, *F. phialocarpa, F. bernardii* and *F. carduchorum* from Iran, were β-phellandrene (32.0 %), α-pinene (40.9 %), 2,4,5-trimethyl benzaldehyde (21.2 %) and (Z)-β-ocimene (21.2 %), respectively[10-13].

While oils of *F. asparagifolia, F. thirkeana* and *F. trachycarpa* from Turkey were rich in 2,3,6-trimethyl benzaldehyde (38.9 %), ferulagone (63.5 %) and (Z)-β-ocimene (30.7 %), respectively.[14-16] The essential oils of *F. nodosa, F. sylvatica* and *F. thyrsiflora* from Greece contain α-pinene (31.1 %), spathulenol (13.0 %) and spathulenol (31.1 %), respectively[17].

Recently we reported the composition and antibacterial activity of the essential oils from aerial parts, stems, flowers and leaves of *Ferulago* contracta. β-Phellandrene (15.1 %, 15.3 % and 25.0 %) and α-phellandrene (14.4, 11.5 and 25.0 %) were the main constituents in the aerial parts, stem and flower oils of *F. contracta* respectively.

The other main components of the aerial part oil of the plant were β-eudesmol (10.9 %) and (E)-β-ocimene (10.0 %) and in the stem oil was also (E)-β-ocimene (11.3 %). The leaf oil of the plant was characterized by higher amount of β-eudesmol (24.5 %), spathulenol (16.2 %) and citronellol (11.9 %). The stem oil of the plant showed significant activity against some Gram-Positive and Gram-Negative bacteria[18].

As it is shown from the Table-2 in *P. ferulacea* we identified 65 components representing 96.2 % and 52 constituents representing 91.5 % of the leaf and flower oils, respectively. The main components in leaf and flower oils were β-pinene (29.6 %

and 20.6 %), α-pinene (19.8 % and 8.8 %), δ-3-carene (11.4 % and 10.4 %) and β-phellandrene (11.1 and 8.1 %), respectively.

According to these results, the composition of the leaf and flower oils of *P. ferulacea* show significant similarity for the concentration of the main components. Both oils were rich in regard to monoterpenes (85.6 % and 64.0 %, respectively), the sesquiterpene fraction of the oils was relatively small, representing (10.2 % and 27.4 %) of the total oils, respectively.

TABLE-2
COMPARATIVE PERCENTAGE COMPOSITION OF THE LEAF AND FLOWER OILS OF *Prangos ferulacea*

Compound	RI[a]	Leaf Oil (%)	Flower Oil (%)
α-Thujene	931	0.2	-
α-Pinene	939	19.8	8.8
Camphene	953	0.6	0.1
Thuja-2,4(10)-tiene	957	0.1	-
β-Pinene	980	29.6	20.6
6-methyl-5-Hepten-2-one	987	t*	-
dehydro-1,8-Cineole	991	t	-
Myrcene	991	2.3	2.7
α-Phellandrene	1005	2.2	2.2
δ-3-Carene	1011	11.4	10.4
α-Terpinene	1018	0.1	-
ρ-Cymene	1026	2.2	3.8
β-Phellandrene	1031	11.1	8.1
(Z)-β-Ocimene	1040	t	0.4
(E)-β-Ocimene	1050	0.2	-
3,3,5-trimethyl-1,5-Heptadiene	1053	t	-
γ-Terpinene	1062	0.2	0.1
Terpinolene	1088	1.6	1.9
6-Camphenone	1093	-	0.1
Linalool	1098	t	-
Nonanal	1098	0.1	-
end-Fenchol	1112	0.1	-
cis-ρ-Menth-2-en-1-ol	1121	0.1	-
α-Campholenal	1125	0.1	-
allo-Ocimene	1129	-	t
Nopinone	1137	0.1	0.1
trans-Pinocarveol	1139	0.3	0.4
cis-Verbenol	1140	t	-
Camphor	1143	-	0.1
trans-Verbenol	1144	0.2	0.2
Pinocarvone	1162	-	0.6
Borneol	1165	0.1	-
α-Phellandrene-8-ol	1166	0.1	0.2
Terpinen-4-ol	1177	0.3	0.3
ρ-Cymene-8-ol	1183	1.0	0.8
α-Terpineol	1189	0.4	0.4
Myrtenal	1193	0.3	0.3
Myrtenol	1194	0.4	0.3
Verbenone	1204	0.1	-
trans-Carveol	1217	0.1	0.2
Cumin aldehyde	1239	t	0.3
Neral	1240	t	-
(E)-2-Decanal	1261	0.1	-
Geranial	1270	t	-
Dehydro linalool acetate	1275	t	0.1
Bornyl acetate	1285	0.3	-
Thymol	1290	0.1	-
trans-Sabinyl acetate	1291	-	0.2
Carvacrol	1298	t	0.3
cis-Pinocarvyl acetate	1309	-	0.1
δ-Elemene	1339	0.1	0.1
cis-Carvyl acetate	1362	t	-
α-Copaene	1376	t	-
β-Bourbonene	1384	t	-
β-Cubebene	1390	0.1	-
β-Elemene	1391	0.3	0.5
β-Cedrene	1418	-	0.6
β-Caryophyllene	1418	3.7	-
β-Gurjunene	1432	-	0.2
γ-Elemene	1433	-	1.4
α-Humulene	1454	0.4	5.3
γ-Muurolene	1477	-	0.1
Germacrene D	1480	0.4	5.9
β-Selinene	1485	t	-
Bicyclogermacrene	1494	0.3	0.4
α-Muurolene	1499	-	0.4
γ-Cadinene	1513	-	0.5
δ-Cadinene	1524	0.1	3.3
α-Cadinene	1538	-	0.2
Germacrene B	1556	-	0.7
(E)-Nerolidol	1564	0.1	-
Germacrene D-4-ol	1574	-	0.9
Spathulenol	1576	2.0	0.7
Caryophyllene oxide	1581	1.8	-
Salvial-4(14)en-1-one	1590	-	0.2
Humulene epoxide II	1606	0.3	1.1
β-Oplopenone	1606	0.1	-
1-epi-Cubenol	1627	-	0.2
Iso spathulenol	1636	0.2	-
epi-α-Muurolol	1641	-	1.7
Cedr-8(15)-en-9-α-ol	1644	0.2	-
α-Muurolol	1645	-	0.4
α-Cadinol	1653	-	2.6
Khusinol	1674	0.1	-
6,4,10-Trimethyl-2-pentadecanone	1840	0.1	-
Monoterpene hydrocarbons		81.6	59.1
Oxygenated monoterpenes		4.0	4.9
Sesquiterpene hydrocarbons		5.4	19.6
Oxygenated sesquiterpenes		4.8	7.8
Others		0.4	0.1
Total		96.2	91.5

As mentioned before, the composition of the leaf and flower oils of plant, collected from Isfahan, central of Iran, show differentially to our results for the concentration of main components.[35] The oil of *P. latiloba* contained α-pinene (25.1 %) and limonene (16.1 %) and in the oil of *P. acaulis* *cis*-sesquisabinene hydrate (25.6 %) and α-pinene (12.5 %) were the major constituents.[28,29]

The oils from the crushed dry stems, leaves and roots of *P. latiloba*, from Iran, have been previously studied. The main components of stem oil were γ-cadinene (30.4 %), α-pinene (25.5 %) and sabinene (12.6 %); leaf oil germacrene D (27.8 %), α-pinene (17.8 %), β-caryophyllene (12.8 %) and β-pinene (11.2 %) and root oil, spathulenol (29.5 %), 1,8-cineole (19.4 %), γ-cymene (17.0 %) and α-bisabolol (15.3 %)[55].

Chemical composition of the essential oils obtained of stems, leaves and flowers of *Prangos* acaulis, grown wild in Iran, were analyzed by GC/MS. The major components of stem oil were 3-ethylidene-2-methyl-1-hexen-4-yne (56.8 %) and α-pinene (34.2 %); leaves oil, α-pinene (39.5 %), 3-ethylidene-2-methyl-1-hexen-4-yne (37.9 %) and α-terpinene (10.9 %) and in flowers oil, 3-ethylidene-2-methyl-1-hexen-4-yne (23.5 %), α-terpinene (17.3 %) and limonene (13.6 %)[56].

The essential oils of the fruits and inflorescence of Iranian *P. scabra* have been reported. The two most abundant components of the fruits oil were identified as β-elemene (19.9 %) and β-farnesene (16.2 %), wheras the inflorescence oil consisted of epi-globulol (21.1 %) and β-elemene (19.7 %) as the

TABLE-3
PERCENTAGE COMPOSITION OF THE LEAF OIL OF *Ferula ovina*

Compound	RI[a]	(%)	Compound	RI[a]	(%)
Tricyclene	926	0.6	Citronellol	1228	0.2
α-Pinene	939	22.5	*cis*-Carveol	1229	t*
Camphene	953	11.0	Carvone	1242	0.1
Thuja-2,4(10)-tiene	957	0.2	Linalool acetate	1257	0.1
Verbenene	967	0.1	Bornyl acetate	1285	14.1
Sabinene	976	2.4	*trans*-Sabinyl acetate	1291	t
β-Pinene	980	3.3	*trans*-Pinocarvyl acetate	1297	0.1
Dehydro-1,8-cineole	991	0.1	Terpin-4-ol acetate	1340	1.1
Myrcene	991	3.1	Citronellyl acetate	1354	0.3
α-Phellandrene	1005	0.2	*cis*-Carvyl acetate	1362	0.4
δ-3-Carene	1011	1.3	Davcene	1380	0.1
α-Terpinene	1018	0.3	Geranyl acetate	1383	0.3
ρ-Cymene	1026	0.8	β-Elemene	1391	0.1
Limonene	1031	6.4	1,7-diepi-β-Cedrene	1410	0.3
(E)-β-Ocimene	1050	0.1	β-Caryophyllene	1418	1.2
γ-Terpinene	1062	0.7	β-Gurjunene	1432	t
cis-Sabinene hydrate	1068	0.2	α-Humulene	1454	t
Fenchone	1087	0.1	γ-Curcumene	1480	0.2
Terpinolene	1088	0.6	*ar*-Curcumene	1483	0.1
6-Camphenone	1093	0.2	*epi*-Cubebol	1493	0.2
trans-Sabinene hydrate	1097	0.2	α-Selinene	1494	0.1
Linalool	1098	0.4	Cubebol	1514	0.3
cis-Thujone	1102	0.2	Myristicine	1520	0.1
endo-Fenchol	1112	0.9	δ-Cadinene	1524	0.3
cis-ρ-Menth-2-en-1-ol	1121	0.2	(E)-γ-Bisabolene	1533	0.2
α-Campholenal	1125	0.7	Caryophyllene oxide	1581	2.0
trans-Pinocarveol	1139	0.8	Geranyl isovalerate	1603	0.2
Camphor	1143	0.8	Gossonorol	1638	0.2
trans-Verbenol	1144	1.5	*epi*-α-Cadinol	1640	0.1
Pinocarvone	1162	0.6	Khusinol	1672	0.1
Terpinen-4-ol	1177	0.6	6,4,10-trimethyl-2-Pentadecanone	1844	0.2
Myrtenal	1193	0.5	Tricosane	2300	0.1
Myrtenol	1194	0.3	Monoterpene hydrocarbons		53.6
Borneol	1195	6.5	Oxygenated monoterpenes		34.2
Verbenone	1204	0.1	Sesquiterpene hydrocarbons		2.5
endo-Fenchyl acetate	1220	2.4	Oxygenated sesquiterpenes		3.1
			Others		0.4
Total					93.8

[a]Retention indices as determined on a DB-5 column using the homologous series of *n*-alkanes; * trace < 0.1

two major components[57]. The volatile constituents of *P. pabularia* fruits were obtained by hydrodistillation and microdistillation techniques, were analyzed by GC and GC/MS.

α-Humulene (16.6 % and 15.5 %), bicyclogermacrene (16.1 % and 7.9 %), spathulenol (10.6 % and 5.7 %) were found to be the major constituents of hydrodistilled and microdistilled oils, respectively[58]. As it is shown from Table-3. Sixty-eight constituents, representing 93.8 % of the total components in the leaf oil of *Ferula ovina* were characterized by α-pinene (22.5 %), bornyl acetate (14.1 %) and camphene (11.0 %) as the main compounds, followed by borneol (6.5 %) and limonene (6.4 %).

Thus, the leaf oil of *F. ovina* consists of sixteen monoterpene hydrocarbons (53.6 %), thirty-two oxygenated monoterpenes (34.2 %), ten sesquiterpene hydrocarbons (2.5 %), seven oxygenated sesquiterpenes (3.1 %) and three non terpenoid compounds (0.4 %). The leaf oil of *F. ovina* was rich in regard to monoterpenes (87.8 %), small amount of sesquiterpenes (5.6 %) and very few non terpenoid compounds (0.4 %).

According to these results, the composition of the leaf oil of *F. ovina* shows more different quantitatively than qualitatively for the main components to previous report and also quite different on major compounds to the other report on the aerial parts oil of the plant[50,51].

α-Pinene (48.8, 19.2, 15.4 and 50.0 %), one major compounds of the leaf oil of *F. ovina*, was also found to be the major component of some other *Ferula* species such as *F. stenocarpa*[44], *F. microclea, F. hirtella*[47] and *F. szowitsiana*[48], respectively. The dominant compound in the stem and root oils of *F. glabanifolia* and aerial parts of *F. macrocolea* was β-pinene (46.4, 58.8 and 15.9 %) respectively.[45,46]

The main component identified in the essential oils of *F. flabolliloba*[43], *F. latisecta*[49], *F. persica*[59], from Iran, was δ-cadinene (13.2 %), (Z)-ocimenone (32.4 %) and dillapiole (57.3 %), respectively. Neryl acetate (33.0 % and 41.5 %) was the major component in the essential oil obtained from stem/leaves and flowers/fruits of *F. szovitsiana*, respectively[60]. The dominant compound in the root oil of *F. persica* and aerial parts of *F. assa-foetida* were dimethyl trisulphide (18.2 %) and E-1-propenyl *sec*-butyl disulfide (40.0 %)[61].

The essential oil obtained from different parts of *F. glauca* growing in Italy, was analyzed by GC and GC/MS. The major volatiles were β-caryophyllene and caryophyllene oxide in leaves, α-pinene, myrcene and germacrene D in flowers, a

and β-pinene in fruits, (E)-β-farnesene, myristicin and elemicin in roots, respectively. The oil was assayed for its antimicrobial activity by the broth microdilution method. *B. subtillis* was found to be the most sensitive microorganism[62].

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