Progress in Essential Oils

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Fennel Oil

Ravid et al. (1992) determined that the range of fenchone content of sweet fennel oil (*Foeniculum vulgare* var. *dulce*) was 2.2–5.2%, whereas in bitter fennel oil (*F. vulgare* var. *vulgare*) it was 7.2–20.4%. The authors further determined that the enantiomeric distribution of fenchone in both sweet and bitter fennel seed oil was (+)-fenchone (100%): (-)-fenchone (0%). As a result, fennel oil would make an excellent source of (+)-fenchone.

Gora et al. (1997) reported that Polish fennel seed oil contained fenchone (19.1%) and (E)-anethole (69.4%). This fenchone level indicates that the oil was produced from bitter fennel.

The major constituents of bitter fennel oil produced in the laboratory by Başer et al. (1997) from seeds of Uzbekistani origin were found to be:

limonene (0.78%)
γ-terpinene (0.39%)
fenchone (8.03%)
methyl chavicol (3.24%)
(E)-anethole (87.33%)

Aridogan et al. (2002) reported that fennel oil produced in Turkey contained the following major constituents:

α-pinene (0.3%)
limonene (7.7%)
1,8-cineole (1.6%)
γ-terpinene (0.9%)
fenchone (3.3%)
methyl chavicol (3.2%)
(E)-anethole (76.4%)
anisketone (1.2%)

Yamini et al. (2002) compared the composition of an oil produced from Iranian fennel seed with a volatile concentrate of the same batch of fennel seed produced by supercritical fluid CO_2 extraction (SFE). The SFE conditions used were varied for pressure (200–350 atmospheres), temperature (45°–55°C), dynamic time (30–45 min) and the use of a methanol modifier (80, 400 or 800 µL) in a few extractions. The constants were 8 mL extraction vessel volume, 2.5 g powdered fennel seed mixed with an unknown amount of inert sand, 25 min static extraction and CO_2 flow rate of 0.3–0.4 mL/min. After each static extraction, the vessel was flushed with ca. 16 mL of CO_2. Because a wide range of conditions were used in the 11 separate CO_2 extractions, only a summary of the volatile concentrate data is presented in T-1.

T-1 Comparative percentage composition of the oil and volatile concentrate of fennel seed of Iranian origin

Compound	Oil	Volatile concentrate
α-pinene	0.89	0–1.32
camphene	0.09	–
sabinene	0.15	0–0.15
myrcene	0.58	–
p-cymene	0.24	–
limonene	10.00	2.82–9.78
(Z)-β-ocimene	0.96	0–1.39
γ-terpinene	0.72	0–1.94
fenchone	11.00	6.18–9.50
terpinolene	0.13	–
camphor	0.24	–
methyl chavicol	4.45	0.79–3.15
p-anisaldehyde	0.57	–
(Z)-anethole	0.27	–
(E)-anethole	69.41	68.25–90.14
germacrene D	0.25	0–2.97

Comparative percentage composition of the hexane extract volatiles of fennel seed obtained from either their natural habitat or cultivated **T-2**

Compound	1N	1C	2N	2C	3N	3C	4N	4C	5N	5C	6N	6C	7N	7C
α-pinene	1.29	1.90	3.92	4.13	1.09	3.61	2.41	2.36	1.92	1.90	2.47	2.80	2.24	3.25
camphene	–	–	–	–	0.13	–	–	0.17	0.22	0.16	0.07	–	0.38	0.15
sabinene	–	–	0.33	–	0.19	–	0.24	0.17	0.12	–	0.21	0.17	0.22	0.65
β-pinene	0.95	1.42	–	3.03	–	0.88	0.15	0.12	0.28	2.02	0.30	0.60	–	–
myrcene	0.95	1.49	1.44	1.99	0.60	1.37	1.11	1.36	0.99	1.35	0.78	0.71	1.36	1.82
α-phellandrene	0.22	0.34	0.63	0.63	0.14	0.46	0.24	0.17	0.29	0.33	0.12	0.03	0.29	0.52
limonene	9.31	14.09	5.80	8.22	3.49	5.58	6.57	9.52	5.14	9.76	5.02	5.36	13.79	13.92
γ-terpinene	2.39	2.50	1.60	3.02	1.30	1.64	1.70	0.93	1.09	2.22	0.93	1.23	2.85	3.26
fenchone	15.60	22.06	24.32	27.25	11.45	21.64	15.09	14.17	17.42	16.52	8.23	7.99	19.33	23.55
allo-ocimene*	0.12	0.22	0.17	0.18	0.29	0.27	0.05	0.01	0.08	0.21	–	t	0.35	0.57
camphor	0.36	0.55	0.54	0.66	0.22	0.54	0.33	0.25	0.40	0.39	0.19	0.18	0.48	0.59
methyl chavicol	6.60	8.89	60.93	50.09	50.33	61.53	45.37	12.30	41.75	48.73	4.67	5.22	33.37	5.32
α-fenchyl acetate	–	–	–	–	–	0.12	–	–	–	0.08	0.04	0.01	0.09	0.21
(Z)-anethole	–	–	–	–	–	–	0.08	0.09	0.02	–	0.11	0.11	0.16	0.19
(E)-anethole	61.73	45.67	0.14	0.46	2.10	0.14	–	–	30.00	16.15	76.74	75.42	24.62	45.72
germacrene D	0.21	0.22	0.16	0.31	0.11	0.24	0.04	0.07	0.08	0.16	0.09	0.11	0.27	0.29

1 = Lohame-haGet'ot; 2 = Mount Dov; 3 = Mount Meron; 4 = Ma'alot-Tarshiha; 5 = Mount Tayyasim; 6 = Sede-Boker; 7 = Ramat-ha'Sharon; N = seed extract from natural population; C = seed extract from cultivated plants; *correct isomer not identified

Barazani et al. (2002) collected fennel seed from seven natural populations in Israel. They compared the composition of hexane extracts of the original collected seed with seed produced from the same plants grown under standard conditions in an experimental garden (Neve-Ya'ar). The results of this comparative study are summarized in T-2. It is of interest to note that the fenchone content of the hexane extract of cultivated fennel seed originating from Mount Meron was ca. double that of the seed obtained from the same origin. Also, the methyl chavicol content of hexane extracts from the original seed of Ma'alot-Tarshiha and Ramat-ha'Sharon were significantly different from the extracts obtained from the cultivated seed. Finally, analysis of the results revealed the existence of a methyl chavicol-chemotype and an (E)-anethole-chemotype among the fennel seed examined.

A comparison between an oil produced from Portuguese wild *F. vulgare* subsp. *piperitum* (Ucria) Coutinho and the supercritical fluid CO_2 extracts (SFE) of the same batch of fruit (seed) of different mesh sizes was performed by Coelho et al. (2003). The results of this comparative study are shown in T-3. In addition, the authors also examined the composition of an oil produced from the stalks of this same fennel plant. They found that the oil was very similar to the fruit oil, as can be seen as follows:

α-pinene (6.9%)
camphene (0.2%)
sabinene (0.1%)
β-pinene (1.5%)
myrcene (1.2%)
α-phellandrene (2.0%)
p-cymene (2.6%)
limonene (2.1%)

γ-terpinene (< 0.1%)
terpinolene (0.5%)
linalool (0.2%)
fenchone (15.8%)
camphor (0.3%)
menthol (0.2%)
methyl chavicol (18.9%)
(E)-anethole (42.5%)
piperitenone oxide (0.2%)

As part of an antimicrobial screening program, LoCantore et al. (2004) found that the oil of bitter fennel that they screened contained the following components:

α-pinene (2.7%)
camphene (0.2%)
sabinene (0.1%)
α-phellandrene (0.5%)
p-cymene (2.0%)
limonene (15.0%)
β-phellandrene (2.3%)
γ-terpinene (0.1%)
fenchone (12.6%)
terpinolene (0.2%)
methyl chavicol (0.9%)
α-fenchyl acetate (0.2%)
(Z)-anethole (0.5%)
(E)-anethole (59.2%)
eugenol (0.3%)
apiole (0.1%)

In addition, trace amounts (< 0.1%) of tricyclene, β-pinene and myrcene also were found in this same oil.

T-3 Percentage composition of the oil and volatile concentrate (SFE) of *Foeniculum vulgare* subsp. *piperitum* seed

Compound	Oil	SFE	
	0.55[a]	0.55	0.35
α-pinene	4.6	3.5	2.8
camphene	0.2	0.2	0.1
sabinene	0.2	0.2	0.2
β-pinene	1.0	0.8	0.7
myrcene	1.4	1.4	1.3
α-phellandrene	2.2	2.2	1.9
p-cymene	1.0	0.9	0.9
limonene	3.6	3.5	3.1
γ-terpinene	0.1	t	t
terpinolene	0.6	0.6	0.6
linalool	0.9	0.8	0.7
fenchone	16.8	16.2	17.1
camphor	0.6	0.4	0.5
menthol	0.1	t	t
methyl chavicol	20.9	21.0	21.9
(E)-anethole	42.2	42.5	44.6
piperitenone oxide	0.2	0.3	0.3

[a]mesh size of ground fruits; t = trace (< 0.1%)

An oil of fennel produced from seeds (fruit) grown in Turkey was subjected to antibacterial analysis. The main components of this oil were determined by Dadalioglu and Evrendilek (2004) to be as follows:

α-pinene (0.27%)
limonene (2.77%)
α-thujone (1.23%)
methyl chavicol (5.12%)
carvone (0.94%)
p-anisaldehyde (2.61%)
(E)-anethole (83.13%)

It should be noted that the characterization of α-thujone in sweet fennel oil was in error. It is presumed that the authors should have characterized fenchone (1.23%), not α-thujone.

Osée Muyima et al. (2004) screened three oils produced from plants grown in South Africa (among which was *F. vulgare*) for their antimicrobial and antioxidant properties. The found that the oil contained:

α-thujene (2.82%)
α-pinene (13.15%)
β-pinene (12.32%)
sabinene (26.18%)
myrcene (14.62%)
α-terpinene (3.52%)
limonene (13.05%)
1,8-cineole (8.71%)
γ-terpinene (2.51%)
terpinolene (0.60%)
cis-sabinene hydrate (0.59%)
terpinen-4-ol (0.90%)

This reviewer has no idea why the authors believed that the oil they analyzed was of *F. vulgare* origin because it can be seen from their analysis that the oil does not contain the characteristic constituents of fennel oil.

Agrawal and Singh (2004) examined the major components in oils produced from a number of bitter fennel cultivar hybrids grown in India. They found that the range for fenchone, methyl chavicol and (E)-anethole was:

fenchone (12.67–18.87%)
methyl chavicol (15.65–40.87%)
(E)-anethole (12.67–41.33%)

Raina et al. (2004) used GC and GC/MS to analyze oils produced in the laboratory by hydrodistillation of three seed sources (one research sample and two commercial samples) of bitter fennel of Indian origin. The composition of the three oils can be seen summarized in T-4.

Damianova et al. (2004) determined that a supercritical fluid CO_2 extract of sweet fennel (*F. vulgare* var. *dulce* 'Shumen') contained the following constituents:

α-pinene (0.8%)
camphene (0.1%)

sabinene (0.1%)
β-pinene (0.2%)
myrcene (0.1%)
p-cymene (0.5%)
limonene (1.8%)
1,8-cineole (0.1%)
γ-terpinene (0.1%)
fenchone (11.3%)
methyl chavicol (4.3%)
(Z)-anethole (4.7%)
(E)-anethole (72.3%)

With such a high fenchone content, the origin of the seed should have been *F. vulgare* var. *vulgare* (bitter fennel).

Comparative percentage composition of the fennel seed oils **T-4**

Compound	1	2	3
δ-3-carene	0.3	0.2	0.1
α-terpinene	0.1	t	t
limonene	3.7	2.9	2.1
fenchone	8.5	7.0	11.6
camphor	0.2	0.2	0.2
methyl chavicol	10.8	3.1	3.4
trans-carveol	t	t	t
carvone	–	–	t
α-fenchyl acetate	0.1	0.1	0.1
p-anisaldehyde	1.1	2.8	1.0
safrole	–	–	t
(E)-anethole	73.2	80.4	79.9
α-copaene	t	t	t
tetradecane	0.3	0.9	0.2
anisketone	0.3	0.9	0.2
hexadecane	t	0.2	t
dillapiole	0.1	t	t
apiole	–	t	–

1 = research experimental garden seed oil; 2 = local market-selected small seed oil; 3 = local market commercial seed oil; t = trace (< 0.1%)

The composition of an oil of *F. vulgare* var. *vulgare* cv. Soroksari was the subject of analysis by Raouffard and Omidbaigi (2005). The oil, which was produced in the laboratory by hydrodistillation, was obtained from seeds of Hungarian origin grown in an experimental garden in Iran. The components identified in the oil were:

α-pinene (2.9%)
camphene (0.2%)
sabinene (0.2%)
β-pinene (0.3%)
myrcene (1.1%)
α-phellandrene (0.5%)
p-cymene (0.3%)
limonene (2.6%)
(Z)-β-ocimene (0.1%)
γ-terpinene (1.5%)
fenchone (17.6%)
camphor (0.4%)
methyl chavicol (3.7%)
(E)-anethole (67.0%)
dihydrocarvyl acetate (0.2%)
cis-pinocarvyl acetate (0.1%)
γ-himachalene (0.2%)
germacrene D (0.2%)
nonadecane (0.6%)

An oil from dried fennel seeds was produced by simultaneous distillation and extraction using methylene chloride as the solvent. The same batch of seeds was subjected to supercritical fluid CO_2 extraction, and both sets of volatiles were analyzed by Diaz-Maroto et al. (2005). The results of this comparative study can be seen in T-5. Furthermore, the authors determined that (E)-anethole, methyl chavicol, fenchone and 1-octen-3-ol possessed the strongest odors in the oil and volatile concentrate of fennel.

Zeller and Rychlik (2006) determined that the concentration of volatiles in fennel fruits (*F. vulgare* var. *vulgare*) was found to be:

α-pinene (1,800)[a]
myrcene (1,150)
limonene (690)
1,8-cineole (170)
fenchone (6,500)

Comparative percentage composition of an oil and a volatile concentrate of fennel seed **T-5**

Compound	Oil	Volatile concentrate
α-pinene	0.62	0.31
camphene	0.07	t
sabinene	0.04	t
β-pinene	0.04	t
myrcene	0.17	0.13
α-phellandrene	0.09	0.07
α-terpinene	0.01	t
p-cymene	0.18	0.05
1,8-cineole + limonene	1.01	0.87
γ-terpinene	0.12	0.23
trans-sabinene hydrate	0.08	t
fenchone	19.33	12.71
terpinolene	0.06	0.05
linalool	0.04	0.03
camphor	0.49	0.32
terpinen-4-ol	0.04	0.02
methyl chavicol	25.84	20.33
p-anisaldehyde	1.90	0.99
(Z)-anethole	0.12	0.10
(E)-anethole	49.71	63.80

t = trace (< 0.01%)

2-isopropyl-3-methoxypyrazine (0.0007)
camphor (180)
linalool (1.8)
methyl chavicol (1,080)
carvone (19)
(Z)-anethole (68)
(E)-anethole (23,000)
guaiacol (0.027)
β-ionone* (0.058)
anisaldehyde (130)
anisketone (45)
eugenol (0.067)
methyl isoeugenol* (10)
sotolone (0.15)
myristicin (14)
anisyl alochol (2.8)
vanillin (0.5)

[a]mg/g of fruits; *correct isomer not identified

In addition, the authors determined that the enantiomeric ratios of four fennel constituents were as follows:

(1R,5R)-(+)-α-pinene (100%):(1S,5S)-(-)-α-pinene (0%)
(4R)-(+)-limonene (64%):(4S)-(-)-limonene (36%)
(3S)-(+)-linalool (100%):(3R)-(-)-linalool (0%)
(3R)-(+)-camphor (0%):(3S)-(-)-camphor (100%)

Finally, using aroma extract dilution analysis, the authors determined that (E)-anethole, anisaldehyde, fenchone, 1,8-cineole, α-pinene, methyl chavicol and myrcene were the most important contributors to the aroma of fennel fruits.

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Patchouli Oil

Rakotonirainy et al. (1997) determined that four sesquiterpene hydrocarbons found in patchouli oil (ex *Pogostemon cablin* Benth.) were α-guaiene, α-bulnesene, α-patchoulene and seychellene.

A supercritical CO_2 extract of *P. cablin* leaves was analyzed by GC/MS (Huang et al. 2001) and found to contain the following constituents:

β-patchoulene (0.94%)
β-elemene (0.24%)
β-caryophyllene (1.88%)
α-guaiene (15.31%)
α-humulene (0.22%)
α-patchoulene (4.81%)
10-epi-α-selinene (0.29%)
β-selinene (0.44%)
γ-gurjunene (0.27%)
valencene (0.21%)
α-selinene (2.30%)
δ-guaiene (15.22%)
7-epi-α-selinene (0.20%)
7,8-dihydroxy-4,5-dimethyl-3,4-dihydronaphthalen-1(2H)-one† (0.53%)

nerolidol* (0.20%)
caryophyllene oxide (1.10%)
4,4-dimethylthiochroman† (0.17%)
isospathulenol (0.68%)
globulol (0.79%)
allo-aromadendrene‡ (0.46%)
patchouli alcohol (48.77%)
patchoulione† (0.18%)
aristolone (0.56%)
9-aristolen-2-one (0.55%)

†doubtful constituent; *correct isomer not identified; ‡incorrect identity based on GC elution order

Zhang et al. (2002) determined that a Chinese patchouli oil was found to possess the following constituents:

α-pinene (0.08%)
β-pinene (0.11%)
β-patchoulene (3.49%)
β-elemene (1.16%)
β-caryophyllene (3.41%)
α-guaiene (19.78%)
α-patchoulene (7.51%)
trisubstituted cyclohexene* (3.09%)
patchoulene* (1.19%)
trisubstituted cyclohexane* (3.51%)
α-guaiene‡ (0.25%)
α-gurjunene (0.23%)
caryophyllene oxide (0.73%)
γ-patchoulene (0.28%)
erimophilene (0.62%)
patchouli alcohol (31.47%)
pogostone† (0.49%)

*correct isomer not identified; ‡incorrect identification based on GC elution order; †probably patchoulenone

A commercial sample of patchouli oil was analyzed by a combination of capillary GC and ^{13}C-NMR (Kubeczka and Formacek 2002). The oil composition was found to be as follows:

α-pinene (0.07%)
β-pinene (0.19%)
δ-elemene (0.07%)
β-patchoulene (2.37%)
α-copaene (0.33%)
cycloseychellene (0.70%)
α-guaiene (15.44%)
β-caryophyllene (3.16%)
α-patchoulene (5.66%)
seychellene (8.94%)
γ-patchoulene (1.08%)
α-humulene (1.04%)
trans-β-bergamotene (0.57%)
aciphyllene (2.62%)
α-bulnesene (17.49%)
α-bulnesene epoxide (0.32%)
caryophyllene oxide (0.41%)
norpatchoulenol (0.94%)
patchouli alcohol (32.43%)
pogostol (2.36%)

Narayanan (2003) compared the major constituents found in patchouli oil of Indonesian and Indian origins. He also showed that an Indian market sample (adulterated oil) contained diethyl phthalate as an adulterant. The results of this study can be seen in T-6.

Comparative percentage composition of three samples of patchouli oil T-6			
Compound	**Indonesian oil**	**Indian oil**	**Adulterated oil**
β-patchoulene	2.40	3.71	2.15
β-caryophyllene	3.54	3.63	5.14
α-guaiene	13.59	14.08	10.92
seychellene	6.87	7.39	5.71
α-patchoulene	6.71	7.87	6.85
α-bulnesene	17.17	17.34	13.47
unknown compound	–	–	0.46
patchouli alcohol	32.61	30.47	27.54
diethyl phthalate[†]	–	–	7.93

[†]not a naturally occurring constituent

Comparative percentage composition of three commercial samples of patchouli oil T-7			
Compound	**Chinese oil**	**Indonesian (30%) oil**	**Indonesian (35%) oil**
β-patchoulene	9.3	2.3	2.1
β-elemene	1.3	0.9	0.7
β-caryophyllene	3.1	3.8	3.1
α-guaiene	15.3	14.6	13.8
γ-patchoulene	6.7	6.3	6.7
α-patchoulene	5.9	5.1	5.1
allo-aromadendrene	5.0	2.4	2.3
ledene	3.9	3.7	3.4
δ-guaiene	20.7	18.8	16.7
nor-patchoulenol	0.4	0.6	0.6
pogostol	1.5	2.2	2.4
patchouli alcohol	17.5	28.2	32.7
pogostone	0.1	1.1	1.0

Zhu et al. (2003) characterized seychellene, α-patchoulene, α-guaiene, α-bulnesene and patchouli alcohol in patchouli oil. Furthermore, the authors reported that patchouli alcohol (the main component of patchouli oil) and patchouli oil were found to be both toxic and repellent against the Formosan subterranean termite.

Milchard et al. (2004) analyzed a sample of Chinese patchouli oil and compared it with two grades of Indonesian oil (so-called 30% and 35%), depending upon the patchouli alcohol content. A summary of the results of this study can be seen in T-7.

Buré and Sellier (2004) analyzed a commercial oil of patchouli purchased in France by GC and GC/MS. The composition of this oil was found to be as follows:

α-pinene (0.1%)
β-pinene (0.3%)
limonene (0.1%)
δ-elemene (0.2%)
α-copaene (0.2%)
α-patchoulene (2.3%)
β-elemene (1.1%)
cycloseychellene (0.7%)
β-caryophyllene (3.3%)
α-guaiene (15.6%)
seychellene (5.3%)
α-humulene (0.8%)
α-patchoulene (5.5%)
γ-gurjunene (2.2%)
germacrene D (0.2%)
δ-patchoulene (0.4%)
aciphyllene (3.4%)
δ-guaiene (16.7%)
7-epi-α-selinene (0.2%)
norpatchoulenol (0.6%)
1,10-epoxy-11-bulnesene (0.2%)
caryophyllene oxide (0.4%)
nortetrapatchoulol (0.3%)
patchouli alcohol (32.2%)
patchoulenone (0.2%)
9-oxopatchoulol (0.1%)
pogostol (0.2%)
isopatchoulenone (0.1%)

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Spanish Sage Oil

A commercial sample of Spanish sage oil (ex *Salvia lavandulaefolia* Vahl) was analyzed using GC and ^{13}C-NMR by Kubeczka and Formacek (2002). It was found to contain the following constituents:

tricyclene (0.46%)
α-thujene + α-pinene (24.54%)
camphene (7.69%)
β-pinene (2.23%)
sabinene (0.34%)
myrcene (1.34%)
α-phellandrene (0.10%)
α-terpinene (0.13%)
limonene (2.65%)
1,8-cineole (11.83%)
(Z)-β-ocimene (0.22%)
γ-terpinene (0.16%)
(E)-β-ocimene (0.11%)
p-cymene (0.84%)
terpinolene (0.18%)
camphor (30.11%)
linalool (3.10%)
linalyl acetate (0.34%)
bornyl acetate (0.21%)
β-caryophyllene + terpinen-4-ol (0.61%)
α-terpineol (1.89%)
borneol + α-terpinyl acetate (3.73%)
δ-cadinene (0.23%)
manool† (1.72%)

†tentative identification

Vincenzi et al. (2002) reported that the 1,8-cineole content of Spanish sage oil ranged between 11.8–41.2%.

Percentage composition of *Salvia lavandulaefolia* oil produced in two different locations in Morocco **T-8**

Compound	Ait Oufela oil	Ifrane oil
α-thujene	0.3	0.6
α-pinene	4.8	5.0
camphene	5.4	10.9
sabinene	0.5	0.8
β-pinene	12.5	7.9
myrcene	2.4	1.3
p-cymene	0.8	0.9
limonene	2.8	3.5
1,8-cineole	13.3	18.7
γ-terpinene	0.1	0.3
camphor	16.3	30.4
camphene hydrate	–	0.2
borneol	5.8	4.7
terpinen-4-ol	0.5	0.9
myrtenal	0.3	0.3
verbenone	0.3	0.3
bornyl acetate	2.4	0.5
cis-α-bergamotene	0.2	0.1
β-caryophyllene	6.1	1.6
trans-α-bergamotene	0.3	0.2
α-humulene	3.7	0.7
allo-aromadendrene	0.4	0.2
ar-curcumene	0.4	0.2
α-selinene	0.1	0.1
viridiflorene	0.2	0.2
γ-cadinene	–	0.1
δ-cadinene	0.1	0.3
spathulenol	0.7	0.7
caryophyllene oxide	2.2	1.5
viridiflorol	11.8	0.4
humulene oxide II	1.3	3.1
epi-α-cadinol	0.2	0.4
β-eudesmol	0.4	0.5
β-bisabolol	0.1	0.3

Comparative percentage composition of the leaves, twigs and flower oils of *Salvia lavandulaefolia* grown in Ifrane **T-9**

Compound	Leaf oil	Twig oil	Flower oil
α-thujene	0.5	0.5	0.8
α-pinene	5.1	6.1	11.2
camphene	10.7	11.8	8.7
sabinene	0.6	0.4	0.6
β-pinene	9.4	10.2	37.8
myrcene	1.6	0.8	1.0
p-cymene	1.0	0.9	0.6
limonene	3.4	3.2	4.7
1,8-cineole	19.5	18.0	14.4
γ-terpinene	0.1	0.1	0.1
camphor	29.0	31.9	10.8
camphene hydrate	0.1	–	0.1
borneol	4.9	5.3	2.5
terpinen-4-ol	0.6	0.4	0.4
myrtenal	0.2	0.1	0.1
verbenone	0.2	0.1	0.1
bornyl acetate	0.5	0.4	0.2
cis-α-bergamotene	0.2	0.1	–
β-caryophyllene	2.0	0.9	0.6
trans-α-bergamotene	0.3	0.1	0.1
α-humulene	0.5	0.3	0.2
allo-aromadendrene	0.2	0.1	–
ar-curcumene	0.1	0.3	0.2
α-selinene	0.1	–	0.2
viridiflorene	0.3	0.1	0.3
γ-cadinene	0.1	–	0.2
δ-cadinene	0.3	0.1	0.3
spathulenol	1.3	0.7	0.2
caryophyllene oxide	1.6	1.2	0.5
viridiflorol	0.3	0.3	0.5
humulene oxide II	0.3	0.2	0.1
epi-α-cadinol	0.5	0.2	0.1
β-eudesmol	0.1	0.1	0.1
β-bisabolol	0.1	0.1	–

Two oils of Moroccan-grown *S. lavandulaefolia* were analyzed by Zrira et al. (2004). One of the oils was produced from plants grown in the Ifrane region, while the other was produced from plants grown in the Ait Oufela region. As can be seen from the results presented in T-8, there were some distinct quantitative differences between the oils. The authors also compared the composition of oils of the Ifrane plants produced from the leaves, twigs and flowers, the results of which are presented in T-9.

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