Progress in Essential Oils

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Dill Oil and Extract

Zhao et al. (1995) reported that a dill seed oil produced in China possessed the following composition:

limonene (27.67 percent)
α-p-dimethylstyrene (0.10 percent)
cis-dihydrocarvone (0.26 percent)
trans-dihydrocarvone (1.33 percent)
trans-carveol (0.10 percent)
carvone (65.8 percent)
(E)-anethole (0.10 percent)
apiole (4.16 percent)

Reichert and Mosandl (1999) confirmed by synthesis and enantiomeric distribution studies using chiral GC that dill ether had the stereochemistry (3S,3aS,7aR)-3,6-dimethyl-2,3,3a,4,5,7a-hexahydrobenzo[b]furan and was the only *cis*- or *trans*-fused ring oxide present in dill herb oil.

An oil produced from Indian dill seed (*Anethum sowa* Roxb.) was the subject of analysis by Shankaracharya et al. (2000). Using GC/MS and retention indices on a non-polar column as their analytical method, the authors found that the oil contained the following components:

α-thujene (0.04 percent)
α-pinene (0.13 percent)
sabinene (0.27 percent)
myrcene (0.68 percent)
α-phellandrene (1.01 percent)
p-cymene (0.08 percent)
limonene (42.67 percent)
γ-terpinene (0.63 percent)
α-p-dimethylstyrene (0.05 percent)
cis-limonene oxide (0.13 percent)
trans-limonene oxide (0.05 percent)
trans-dihydrocarvone (12.97 percent)
carvone (22.50 percent)
thymol (0.68 percent)
δ-cadinene (0.05 percent)
myristicin (0.12 percent)
dillapiole (15.92 percent)
heptadecane (0.16 percent)
hexadecanoic acid (0.17 percent)

Bonnländer and Winterhalter (2000) subjected a methanolic extract of dill herb to XAD-2 adsorption column chromatography followed by a technique known as multiplayer coil countercurrent chromatography and subsequent SiO_2 fractionation and preparative HPLC they isolated the following nine constituents in pure form:

8-hydroxygeraniol
β-D-glucopyranoside
(E)-2,6-dimethylocta-6-hydroxy-2,7-dienoic acid
3-hydroxy-α-ionol
3-hydroxy-β-ionol 3-O-β-D-gluco-pyranoside
chlorogenic acid
(Z)-3-hexenyl-β-D-glucopyranoside
quercitin 3-O-β-D-glucuronide
p-menth-2-ene-1,6-diol β-D-glucopyranoside
9-hydroxypiperitone β-D-glucopyranoside

The interesting part of this analysis is that the authors speculated that the 9-hydroxypiperitone β-D-glucopyranoside was a more likely precursor of dill ether than α-phellandrene. Also, they postulated that p-menth-2-ene-1,6-diol β-D-glucopyranoside could be considered an oxidation product of α-phellandrene, a major component of dill herb oil.

Hassanzadeh et al. (2000) analyzed oils produced from different aerial parts of *A. graveolens* grown in Iran. The authors used GC/MS as their method of analysis, the results of which can be seen in T-1.

Bailer et al. (2001) determined the oil yield and major component composition of oils produced from 24 different cultivars of dill seed from plants grown in Austria. The results of this study are shown in T-2.

Lisiewska et al. (2001) examined the difference in chlorophyll and oil content of the leafy parts of the 'Amat,' 'Ambrozia' and 'Lukullus' cultivars of *A.*

Comparative percentage composition of different aerial parts of *Anethum graveolens* **T-1**

Compound	Leaf/stem oil	Flower oil	Seed oil
α-thujene	0.96	0.48	—
α-pinene	4.36	2.32	—
sabinene	0.47	0.26	—
β-pinene	0.28	0.14	—
myrcene	1.93	0.99	0.20
α-phellandrene	27.80	23.11	1.23
p-cymene	29.61	12.97	0.87
limonene	15.53	22.40	28.85
terpinolene	0.26	0.20	—
cis-limonene oxide	14.33	8.59	—
cis-dihydrocarvone	—	3.49	0.02
trans-dihydrocarvone	—	1.04	7.74
trans-piperitol	0.26	0.12	—
isodihydrocarveol	—	0.24	—
neoisodihydrocarveol	—	0.51	—
cuminaldehyde	0.25	0.18	—
carvone	0.15	4.65	59.00
pulegone	0.24	0.10	—
carvacrol	1.29	0.52	—
β-caryophyllene	0.19	—	—
santalene*	0.68	0.21	—
δ-cadinene	—	—	0.05
myristicin	—	0.58	—
dillapiole	1.41	16.92	0.09

*incorrect identification

graveolens grown in Poland. Although they did not present any compositional data, they did report that the 'Amat' cultivar was richest in oil.

Arora and Srinivas (2002) used a γ-cyclodextrin chiral GC column and olfactory analysis to determine that (4R,5)-(+)-carvone (30 percent) was the main character impact component of Indian dill seed oil with an enantiomeric purity of greater than 99 percent (a well known piece of information). They also showed that the other components identified were limonene (35 percent), a dihydrovarvone (0.1 percent) and dillapiole (19 percent).

Zawirska-Wojtasiak and Wasowicz (2002) compared the limonene and carvone contents of the oils of the fruits of six cultivars of dill grown in Poland. The results of this comparison can be seen in T-3.

Gora et al. (2002) compared the composition of oils produced from the 'Corso' cultivar of *A. graveolens* harvested at different developmental times. They examined oils produced from plants with young leaves, young plants collected prior to umbel formation, plants collected at flowering commencement, plants in full bloom, plants with green fruits and plants with ripe umbels. The results of the analyses of these oils can be found in T-4. It should be noted that the oils were produced from fresh plant materials.

Santos et al. (2002) compared the composition of the oils obtained from the fruits, aerial plant parts and roots of *A. graveolens*. They found that the fruit oil contained the following constituents:

α-phellandrene (0.6 percent)
β-phellandrene (6.6 percent)
limonene (23.0 percent)
2,5-dimethylstyrene (t; <0.5 percent)
trans-dihydrocarvone (1.6 percent)
carvone (67.0 percent)

The authors also identified myrcene, p-cymene, (E)-β-ocimene, *cis*-dihydrocarvone and *trans*-carveol in the oil, but did not present data other than stating that the amounts were less thatn 2 percent. In contrast, the composition of the oil produced from the aerial parts of the same plants was determined to be as follows:

nonane (0.1 percent)
β-pinene (0.5 percent)
α-phellandrene (62.1 percent)
β-phellandrene (7.3 percent)
limonene (3.5 percent)
undecane (3.2 percent)
carvone (0.9 percent)
myristicin (6.6 percent)
dillapiole (9.7 percent)
apiole (0.2 percent)

Comparative percentage oil yield and selected component contents (mg/g) of dill seed **T-2**

Cultivar	Oil yield	Component content (mg/g) 1	2	3	4	5	6	7	8	9
30.013.13	3.7-4.0	13.44-16.38	0.53	0.03	0.20	1.26	0.22	12.18	-	-
Ambrozjia	3.9	13.29-15.70	0.58	0.08	0.19	0.97	0.27	11.96	-	-
Aneth 34-93	2.7-3.7	11.07-13.79	0.33	0.06	0.27	1.36	0.25	10.70	3.24	0.37
Arom	3.3-3.9	12.11-15.71	0.43	0.05	0.19	0.72	0.31	11.75	0.40	0.08
Aromatischer	3.6-3.9	13.07-14.87	0.56	0.08	0.21	1.14	0.20	11.80	-	0.51
Blattreicher	3.3-3.9	12.35-15.89	0.45	0.12	0.25	0.93	0.39	11.68	0.02	0.11
Delikat	3.3[a]	12.24	0.51	0.11	0.21	0.71	0.42	12.07	-	-
Dukat	3.4-4.1	11.95-15.37	0.50	0.08	0.23	0.97	0.32	11.39	-	-
Dura	3.8-4.1	13.33-15.68	0.41	0.06	0.21	0.94	0.32	11.98	0.12	0.07
Elefant	3.7[a]	12.91	0.61	0.08	0.26	0.83	0.47	12.45	-	-
Gowöhnlicher	3.1-4.2	12.45-17.03	0.44	0.03	0.18	1.12	0.25	12.68	-	-
Hanak	3.8-4.1	14.19-15.29	0.57	0.05	0.17	0.93	0.22	12.36	-	-
Herkules	3.6-4.2	12.60-16.75	0.48	0.08	0.23	1.11	0.33	11.85	-	-
Mammut	3.7-3.8	13.29-15.14	0.49	0.06	0.21	1.08	0.29	11.80	0.30	0.86
Pikant	3.2-3.7	12.46-15.39	0.54	0.12	0.23	0.93	0.33	11.60	0.16	-
Prager	3.5-4.0	13.25-15.63	0.48	0.03	0.23	1.29	0.28	11.96	-	-
Sari	3.7-4.6	13.88-16.73	0.36	0.08	0.16	0.72	0.25	13.00	0.39	-
Selektion Mammut	3.8	13.58-16.30	0.54	0.10	0.21	0.92	0.33	12.08	-	-
SP-980820	3.2[a]	11.95	0.50	0.08	0.25	0.78	0.43	11.39	-	-
Super Dukat	3.4[a]	12.47	0.50	0.08	0.25	0.81	0.43	11.86	-	-
Tetra A[b]	3.5[a]	12.68	0.56	0.09	0.28	0.88	0.47	12.20	-	-
Tetra B[b]	2.6-4.2	10.21-17.82	0.68	0.08	0.21	1.39	0.23	12.23	0.10	0.23
Tetra C[b]	3.3-4.0	12.67-15.77	0.56	0.03	0.28	1.30	0.27	12.11	-	-
Tetradill Goldkrone	3.5[a]	12.92	0.58	0.09	0.27	0.87	0.47	12.49	-	-
Vierling	3.4-3.8	12.86-15.03	0.64	0.17	0.23	0.98	0.36	11.75	-	-
Zwaans Treibdill	3.1-3.8	11.95-15.16	0.44	0.06	0.17	0.69	0.28	11.50	-	-

Components listed are: 1) limonene; 2) α-phellandrene; 3) dill ether; 4) *trans*-dihydrocarvone; 5) *cis*-dihydrocarvone; 6) *cis*- and *trans*-carveol; 7) carvone; 8) myristicin; 9) apiole; oil yield and limonene content over two seasons; [a]only a single season; [b]same cultivar, different supplier

Comparative limonene and carvone contents (mg/g) of dill seeds of different cultivars **T-3**

Cultivar	Limonene content	Carvone content
Ambrozjia	10.85	13.25
Amat	11.99	14.00
Common	9.41	13.90
Lukullus	10.35	13.95
Szmargd	9.16-12.10[a]	1455-1670[a]
Turkus	9.06-9.26[a]	13.24-13.95[a]

[a]results over two seasons

In addition, α-thujene, α-pinene, sabinene, myrcene, α-terpinene, p-cymene, (Z)-β-ocimene, (E)-β-ocimene, terpinolene, nonanal, dill ether, tridecane, dodecanal and germacrene D were also found in this oil with their amounts not exceeding
2 percent.

The authors also examined the composition of an oil produced from the roots of these same plants. This oil was found to contain the following components:

nonane (2.9 percent)
β-pinene (0.3 percent)
octanal (0.6 percent)
α-phellandrene (14.7 percent)
β-phellandrene (1.9 percent)
limonene (15.5 percent)
2,5-dimethylstyrene (0.2 percent)
undecane (3.7 percent)
trans-dihydrocarvone (0.8 percent)
carvone (27.8 percent)
myristicin (4.6 percent)
dillapiole (7.5 percent)
apiole (3.1 percent)
falcarinol (11.3 percent)

A few constituents not exceeding 2 percent were also identified in this same oil. They were α-thujene, α-pinene, sabinene, myrcene, α-terpinene, p-cymene, (Z)-β-ocimene, (E)-β-ocimene, terpinolene, nonanal, tridecane, dodecanal, germacrene D and β-bisabolene. Finally, an oil that was produced from a tissue culture

Comparative percentage composition of *Anethum graveolens* plants harvested at different developmental stages **T-4**

Compound	Stage of development 1	2	3	4	5	6
α-thujene	0.41	0.57	0.17	0.22	t	t
α-pinene	2.13	3.08	1.38	1.21	t	t
camphene	0.03	t	t	t	t	t
sabinene	0.92	0.86	0.69	0.68	0.13	0.12
β-pinene	0.12	0.13	t	0.04	t	t
α-phellandrene	53.56	10.33	54.20	35.15	0.26	0.99
α-terpinene	0.43	0.56	1.69	0.42	0.67	0.37
limonene	3.52	5.34	7.95	33.69	40.81	36.67
β-phellandrene	7.77	6.36	7.60	4.83	0.06	0.05
p-cymene	6.45	32.75	2.88	4.25	0.28	0.31
1,8-cineole	0.05	t	t	t	t	t
p-cymenene	t	0.22	t	0.01	t	t
cis-p-menth-2-en-1-ol	0.04	0.44	t	0.01	t	t
dill ether	11.65	10.53	21.61	10.75	0.19	0.20
cis-dihydrocarvone	0.62	2.13	t	0.14	t	t
trans-dihydrocarvone	0.06	0.80	0.08	1.06	1.94	1.49
carvone	0.16	0.68	t	4.34	54.46	58.73
carvacrol	1.81	6.24	t	0.59	t	t
germacrene D	0.35	0.02	t	0.09	t	t
myristicin	0.03	0.18	t	t	t	t
apiole	t	t	t	t	t	t

t = trace (<0.01 percent); development stages: 1) plants with young leaves; 2) young plants prior to umbel formulation; 3) plants at flowering commencement; 4) plants in full bloom; 5) plants with green fruit; 6) plants with ripe fruit

of the hairy roots of *A. graveolens* that were grown in half strength Marashige Skoog medium was found to possess the following composition:

β-pinene (4.0 percent);
octanal (5.2 percent)
limonene (t)
undecane (t)
carvacrol (1.6 percent)
myristicin (7.9 percent)
dillapiole (14.0 percent)
apiole (39.6 percent)
falcarinol (21.0 percent)

t = trace (<0.5 percent)

As with two other oils, the authors also identified some other constituents whose amounts did not exceed 2 percent. These constituents were heptanal, α-pinene, sabinene, myrcene, p-cymene, (Z)-β-ocimene, terpinolene, nonanal, (E)-tagetone, (Z)-tagetone, decanal and cuparene.

Kubeczka and Formacek (2002) determined that a sample of dill seed oil (ex *A. graveolens*) possessed the following composition:

α-pinene (0.22 percent)
β-pinene (0.02 percent)
sabinene (0.27 percent)
δ-3-carene (0.04 percent)
myrcene (0.96 percent)

α-phellandrene (0.29 percent)
limonene (68.42 percent)
β-phellandrene (0.16 percent)
γ-terpinene (0.01 percent)
p-cymene (0.17 percent)
cis-limonene oxide (0.02 percent)
trans-limonene oxide (0.01 percent)
dill ether (1.72 percent)
linalool (0.02 percent)
cis-dihydrocarvone (0.09 percent)
trans-dihydrocarvone (0.19 percent)
carvone (27.29 percent)
trans-carveol (0.09 percent)
cis-carveol (0.01 percent)

An oil produced from *A. graveolens* seeds that had been in storage in Bulgaria for more than 30 years was the subject of analysis by Jirovetz et al. (2003). Although the authors stated that they wanted to evaluate the influence of uncontrolled storage time on the dill seed, they did not compare it to controlled storage conditions or oil from freshly produced dill seed. Nevertheless, the oil composition of the old dill seed was found to be as follows:

hexanal (0.1 percent)
(Z)-3-hexenol (0.1 percent)
(E)-2-hexenol (t)
hexanol (0.1 percent)
α-pinene (0.1 percent)
β-pinene (t)
sabinene (t)
myrcene (0.2 percent)
α-phellandrene (0.1 percent)
p-cymene (0.3 percent)
β-phellandrene (0.2 percent)
limonene (44.1 percent)
benzyl alcohol (t)
γ-terpinene (t)
artemisia ketone (0.1 percent)
artemisia alcohol (t)
linalool (0.1 percent)
trans-p-mentha-2,8-dien-1-ol (t)
cis-limonene oxide (0.2 percent)
trans-limonene oxide (0.1 percent)
methyl chavicol (0.2 percent)
α-terpineol (0.1 percent)
dihydrocarveol (t)
3,9-epoxy-p-menth-1-ene (t)
cis-dihydrocarvone (1.9 percent)
trans-dihydrocarvone (0.7 percent)
citronellol (0.1 percent)
isodihydrocarveol (t)
trans-carveol (0.4 percent)
cuminaldehyde (0.1 percent)
cis-carveol (t)
carvone (50.1 percent)
chavicol (0.2 percent)
geraniol (0.1 percent)
cumin alcohol (0.8 percent)
eugenol (0.1 percent)
geranyl acetate (0.1 percent)
methyl eugenol (t)
β-caryophyllene (t)
dillapiole (t)

t = trace (<0.1 percent)

The authors also examined two oils using olfactorial assessment by professional perfumers. It was not surprising that the fresh and spicy odors associated with the dill oil were the (4R)-(+)-limonene and (4R)-(+)-carvone (chirality determined by chiral GC).

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Lavandula stoechas Oil

A limited amount of oil produced from *Lavandula stoechas* L. of Spanish origin can be found on the international essential oil market, much of which finds it use in the aromatherapy field. The oil should be produced from *L. stoechas* ssp. *stoechas*, which is endemic to the Mediterranean region. However, there are a number of subspecies of *L. stoechas* that could be mistakenly harvested from the wild to produce *Lavandula stoechas* oil, e.g.:

L. stoechas ssp. *stoechas*
L. stoechas ssp. *sampaioana* Rozeira
L. stoechas ssp. *pedunculata* (Miller) Rozeria
L. stoechas ssp. *cariensis* (Boiss.) Rozeira
L. stoechas ssp. *luiseiri* (Rozeira) Rozeira
L. stoechas ssp. *atlantica* Braun-Bl.
L. stoechas ssp. *lineana* Rozeira

Granger et al. (1973) examined the composition of *L. stoechas* oil produced from plants collected in France (including Corsica), Spain and Turkey. They found that the oil contained α-pinene, camphene, β-pinene, limonene + 1,8-cineole, p-cymene, fenchone (35-88 percent), camphor (10-62 percent), linalool, bornyl acetate,

Major component composition (percent) of the oils of *Lavandula stoechas* ssp. *lineana* and *L. stoechas* ssp. *atlantica*

T-5

	Lavandula stoechas		
	ssp. *lineana*	ssp. *atlantica*	
Compound	***1***	***2***	***3***
α-pinene	1.9	5.7	0.6
camphene	3.1	4.0	3.6
β-pinene	0.5	4.5	t
1,8-cineole	3.8	3.0	t
fenchone	34.0	19.1	11.5
camphor	24.0	28.0	72.8
bornyl acetate	10.0	2.2	1.5
borneol	5.9	1.1	3.2
isoeugenol*	0.7	4.0	t
methyl isoeugenol*	0.7	2.4	t

*correct isomer not identified; t = trace (<0.1 percent); sample origins: 1. Témara, 2. Jebha and 3. Idni

borneol and carvacrol.

The fenchone and camphor contents were found to vary in seven oils produced from plants collected in a specific area in France in amounts of 60-70 percent and 12-37 percent, respectively. In addition, they also found that fenchone isolated from *L. stoechas* oil existed almost exclusively as the (+)-enantiomer, whereas the (-)-enantiomer of camphor was minimally most prevalent.

Tanker et al. (1977) determined that two samples of Turkish *L. stoechas* oil contained the following:

α-pinene(3.70-4.80 perccent)
camphene (3.32-6.30 percent)
β-pinene (1.11-7.90 percent)
limonene (24.0-13.30 percent)
1,8-cineole (3.30-4.07 percent)
fenchone (7.60-12.94 percent)
linalool (1.48-10.80 percent)
linalyl acetate (t-11.80 percent)
camphor (13.00-23.29 percent)
borneol (6.87-19.80 percent)

t = trace (<0.1 percent)

Bellakhdar et al. (1984) determined the major components of oils produced from *L. stoechas* ssp. *lineana* (one accession) and *L. stoechas* ssp. *atlantica* (two accessions) collected in Morocco using GC and modern spectroscopic techniques. The results of this study are shown in T-5.

A sample of *L. stoechas* oil produced from the Chalkidiki Peninsula (Greece) was the subject of GC and GC/MS analysis by Kokkalou (1988). The composition of this oil was found to be as follows:

apopinene† (0.05 percent)
α-pinene (0.75 percent)
camphene (0.08 percent)
verbenene (0.09 percent)
1,8-cineole (8.12 percent)
p-cymene (0.25 percent)
fenchone (30.85 percent)
2,2-3-trimethyl-3-cyclopentene-1-acetaldehyde° (0.06 percent)
p-cymene (0.06 percent)
1-octen-3-ol (0.18 percent)
2-(2'-propan-2'-ol)-5-methyl-5-vinyltetrahydrofuran† (0.04 percent)
1-(benzyloxy)-propane† (0.08 percent)
2,3-epoxypinane† (0.08 percent)
chrysanthenone (0.02 percent)
camphor (9.58 percent)
pinocamphone (0.42 percent)
α-fenchyl acetate (0.17 percent)
2,4-dimethyl-2,7-octadiene† (0.1 percent)
cis-sabinene hydrate (0.04 percent)
trans-3-caranol† (0.01 percent)
α-humulene† (0.05 percent)
α-fenchol (2.72 percent)
myrtenal (2.85 percent)
α-copaene (0.08 percent)
bornyl acetate (0.68 percent)
trans-pinocarveol (0.76 percent)
p-mentha-1,5-dien-8-ol (0.12 percent)
verbenol† (0.41 percent)
p-mentha-2,8-dien-1-ol† (0.01 percent)
cis-verbenol (3.81 percent)
3,6,6-trimethylbicyclo[3.1.0]hex-2-en-2-carbaldehyde† (0.94 percent)
p-mentha-1(7)-en-8-ol (0.50 percent)
p-mentha-1(8)-dien-8-ol‡ (0.62 percent)
carvone (0.17 percent)
pinocarvyl acetate* (10.20 percent)
cis-isopiperitenone‡ (0.02 percent)
cuminaldehyde (0.02 percent)
myrtenol (4.65 percent)
p-cymen-8-ol (2.52 percent)
trans-carveol (2.01 percent)
α-muurolene (0.10 percent)
2-(p-tolyl)-propanol† (0.04 percent)
cadinene* (2.39 percent)
calamenene* (1.38 percent)
myrtenyl propionate (1.65 percent)
ledol (2.04 percent)
copaborneol (2.52 percent)
muskatone (2.10 percent)

*correct isomer not identified
† incorrect identification
‡ impossible compound name
° usually known as α-campholenal

Garcia-Vallejo et al. (1989) used a combination of modern analytical techniques to analyze the oils of *L. stoechas* subspecies produced from plants collected in the wild in Spain. A summary of the analytical results can be seen in T-6.

Garcia Vallejo (1992) reported the results of the analysis of the oils of *L. stoechas* produced from plants harvested in Almeria (2), Barcelona (3), Cadiz (3), Gerona (1), Granada (2), Huelva (2), Malaga (7),

Comparative percentage composition of the oils of subspecies of *Lavandula stoechas* of Spanish origin **T-6**

	Oils of *Lavandula stoechas*				
	ssp. *stoechas*	ssp. *sampaioana*		ssp. *pedunculata*	
Compound	**A**	**A**	**B**	**A**	**B**
α-pinene	0.2-8.6	0.2-18.6	5.9-23.0	2.2-21.1	12.9-16.9
camphene	0.1-3.6	0.1-14.5	0.4-1.5	0.5-8.3	0.5-2.7
β-pinene	t-0.3	t-8.0	13.4-31.0	t-6.8	20.2-26.0
sabinene	-	t-0.8	1.3-2.4	0.1-0.8	1.5-2.2
δ-3-carene	-	0-5.5	0-t	0-13.7	-
myrcene	0-0.3	t-0.6	0.1-0.6	t-0.8	0.2-0.3
limonene	0.4-3.1	0.3-3.2	1.4-2.8	0.2-3.3	1.3-1.9
1,8-cineole	0.3-52.7	5-25.8	5.1-16.0	0.1-67.7	9.6-22.5
(Z)-β-ocimene	-	0-1.7	0.1-1.4	0-1.2	0.1-0.4
3-octanone	0-0.4	0.1-0.9	0.3-1.0	t-2.6	0.4-0.6
p-cymene	0-0.6	0-1.5	t-0.3	0-1.6	t-0.1
fenchone	23.6-68.2	0.4-56.0	5.0-28.2	0.9-44.5	1.3-18.8
1-octen-3-ol	0.1-1.1	t-1.7	0.1-0.5	t-1.3	t-0.1
camphor	1.5-51.6	4.4-84.4	2.0-7.2	7.3-55.7	3.4-10.7
linalool	0.1-3.7	0.5-12.2	1.5-5.1	0.3-10.1	3.6-4.9
β-caryophyllene	0.1-5.5	t-8.0	t-0.5	t-3.4	0.3-1.5
pinocarvone	-	0-1.5	0.3-3.6	0-0.9	1.1-1.8
α-fenchyl alcohol	0.2-3.3	t-1.5	0.1-0.2	t-1.7	0-0.2
terpinen-4-ol	t-0.5	t-1.8	0.1-1.3	0.1-1.7	0.3-1.1
myrtenal	t-0.8	0-1.3	0.7-4.1	t-0.9	1.4-2.2
trans-pinocarveol	t-0.6	t-1.9	1.0-6.3	t-1.1	1.5-2.6
verbenyl acetate*	0-0.8	0-1.9	0.2-0.7	0-1.5	0-0.3
myrtenyl acetate	t-5.3	-	-	-	-
trans-verbenol	t-1.2	t-0.3	0.6-2.0	0.3-2.7	0.5-1.2
borneol	0-1.2	t-1.9	t-0.2	t-1.5	t-0.2
α-terpineol	t-0.7	t-1.0	0.2-0.8	0.2-0.9	t-0.6
verbenone	0-0.9	0-1.7	1.5-3.4	t-3.6	1.3-2.6
myrtenol	t-3.1	0-0.7	0.2-2.3	0-0.6	0.4-1.3
p-cymen-8-ol	0.2-1.8	t-5.5	t-0.3	t-2.7	t-0.3
caryophyllene oxide	t-0.8	0-2.5	0-0.4	0-1.6	0.1-0.7
viridiflorol	t-2.7	0-0.5	0.2-0.6	0-0.5	0.2-0.5
dihydrocaryophyllenol*	t-1.3	-	-	-	-
α-cadinol	0-0.3	0-6.0	t-0.2	t-11.7	0.1-0.3

A and B refers to different chemotypes within a subspecies; *correct isomer not identified; t = trace (<0.1 percent)

Murcia (2), Pontevedra (2) and Sevilla (3), in various regions of Spain. The results of these analyses can be seen in T-7. From these results, it can be readily seen that the major components of the oils, such as 1,8-cineole, fenchone, camphor and myrtenyl acetate, varied widely. Also, there did not appear to be a geographic relationship between the area in which the plants were found and the chemical composition of the oil even though this was not a very large sampling size from each region.

Valentini et al. (1993) collected *L. stoechas* from Delikipo, Ora-Laya, Ora-Ayii and Stavrovouni (Cyprus), and separated the leaves and flowers of each collection and subjected them to separate water distillation to yield oils that were analyzed by GC and GC/MS. The oils compositions can be seen summarized in T-8.

Malik et al. (1993) analyzed an oil of *L. stoechas* produced from plants grown in Pakistan. They found that the oil contained the following components:

α-pinene (0.42 percent)
camphene (0.50 percent)
β-pinene (0.45 percent)
1,8-cineole (2.51 percent)
fenchone (0.43 percent)
α-thujone (0.33 percent)
linalool (0.61 percent)
α-fenchyl alcohol (0.79 percent)
camphor (47.06 percent)
isoborneol (t)
borneol (5.37 percent)
menthol (0.35 percent)
β-terpineol* (0.39 percent)
α-terpineol (1.09 percent)

Comparative percentage composition of *Lavandula stoechas* oils produced from plants harvested from different regions of Spain **T-7**

Compound	Almeria	Barcelona	Cadiz	Gerona	Granada	Huelva	Malaga	Murcia	Pontevedra	Sevilla
α-thujene	0.1-0.2	t-0.2	t-0.1	t	t	t-0.1	0-0.1	t-0.1	t	t
α-pinene	0.8-3.1	1.4-2.2	0.2-0.8	8.6	1.5-1.9	0.6-1.0	0.3-4.4	0.8-1.3	1.3-2.0	0.9-3.7
camphene	0.2-4.4	0.3-3.6	0.1-2.4	0.6	0.5-2.8	0.1-0.3	t-2.3	0.8-2.0	1.2-1.3	0.2-1.5
β-pinene	0.3	t-0.2	0.1-0.2	0.1	0.1	t	t-0.2	0.1	0.2	t-0.1
sabinene	0.1-0.3	t-0.1	t-0.4	0.2	t	0.2-1.5	t-0.6	t-0.1	t-0.1	t-0.1
δ-3-carene	0.3-0.7	0.t	-	-	t-0.2	t	0-t	0-t	0-t	0-t
myrcene	t-0.3	0.1-0.3	0-t	0.2	0.1	t	t-0.1	t	0.1	t-0.2
limonene	0.5-2.2	1.4-2.3	0.2-0.7	1.5	1.4	0.3-0.5	0.7-1.2	0.5-1.0	1.6-1.9	0.4-3.1
1,8-cineole	7.4-52.7	3.7-10.2	3.6-48.4	5.2	4.8-9.7	9.2-10.2	0.4-17.8	4.6-10.3	6.7-9.6	0.3-6.6
terpinolene	0.3-0.6	0.1-0.3	0.3-0.7	0.1	t-0.2	0.3-0.4	t-0.4	t	0.1	0.1-0.5
fenchone	23.6-40.6	29.8-60.0	0.1-55.8	61.9	30.7-40.8	33.0-71.9	7.3-68.2	29.5-40.5	27.9-30.2	30.7-65.4
1-octen-3-ol	t-0.1	0-t	t-0.7	-	t-0.2	t	t-0.6	t-0.2	t	0-0.1
trans-sabinene hydrate	0.3-0.5	0.2-0.8	0.4-1.0	0.2	0.1-0.5	t-1.0	0.1-1.2	0.2	0.5-1.0	0.2-1.1
α-copaene	t-0.3	0.3-0.4	0-0.4	0.1	0-t	0.9-1.2	0-0.5	0-0.1	0-t	0-t
α-gurjunene	t-0.1	t-0.1	t-0.4	-	t	0.1-0.3	0-0.6	-	0-t	0-0.2
camphor	1.5-18.8	1.8-40.4	6.7-19.2	5.0	14.3-39.8	1.9-3.6	2.7-44.6	21.0-46.7	35.6-43.7	2.6-51.6
linalool	1.4-2.0	0.4-1.6	0.4-5.1	0.1	1.1-2.9	0.1-0.8	0.2-3.7	0.4-1.1	0.2-0.3	0.2-1.2
linalyl acetate	t	0-t	t-2.1	0.1	0.1-0.2	t	t-0.3	t-0.2	t	0-0.1
bornyl acetate	0.1-4.7	0.2-2.5	t-9.2	0.2	0.9-4.0	t-0.4	0.3-2.9	0.4-5.3	1.6-1.8	0.2-0.4
α-fenchol	0.4-0.5	0.3-0.5	0-0.4	0.5	0.2-0.8	0.4-0.5	t-0.8	0.4-1.1	1.3-3.3	0.3-1.2
trans-α-nec rodyl acetate	-	t	0-4.8	t	t	0.6-4.3	0-2.3	0-0.2	t	t
lavandulyl acetate	0.4-0.5	0.1-0.3	t-1.8	t	0.2-0.3	0.1-2.6	0.1-1.1	0.2-0.3	0.1	t-0.2
myrtenal	0.3-0.5	0.4-0.7	0.3-1.1	0.3	0.3-0.8	0.2-0.5	0.5-1.5	t-0.4	0.1-0.2	t-0.7
trans-pinocarveol	0.1-0.3	t-0.1	0.1-1.1	0.4	0.1-0.2	0.2-4.5	t-0.7	0.2-0.6	0.1-0.2	t-0.2
trans-α-necrodol	0-t	-	0-2.4	t	0-t	0.1-2.6	t-22	t-0.3	t-0.1	0-t
lavandulol	t	t	t-1.0	t	t-0.1	0.1-0.3	t-1.3	0.1-0.3	0.1	t-0.1
myrtenyl acetate	2.1-4.8	2.4-5.0	1.8-13.9	2.3	1.5-3.8	1.8-3.0	1.5-19.8	0.2-1.6	0.7-1.3	t-5.3
trans-verbenol	0.3	t-0.4	0.1-0.9	0.7	0.3-0.8	t-0.4	0.2-1.7	0.3-1.2	0.1-0.4	0.3-0.6
α-terpineol	t-0.6	0.2-0.6	t-0.5	0.1	t-0.7	0.2-0.8	t-0.4	0.2-0.6	0.5-1.2	t-0.4
borneol	0.6-0.7	t-0.1	0.1-1.3	0.6	0.2-0.5	0.1-0.5	0.1-0.9	0.3-0.4	0.4-0.6	t-0.5
α-necrodol*	t-0.1	0.4-0.9	0-0.7	t	0-0.1	0.6-0.8	0-1.7	0-0.1	0.1	0-t
α-farnesene*	0.2-0.3	0.1-0.2	t-0.5	0.2	0.1-0.3	t-1.2	0.2-0.4	0.3-0.5	0.2-0.3	0.2-0.3
myrtenol	0.4-1.0	1.3-1.9	0.8-1.7	0.7	1.6-2.2	0.1-0.2	0-4.1	-	-	0-0.1
p-cymen-8-ol	0.3	t-0.2	0.1-0.5	0.2	0.3-0.5	t	0.1-0.7	0.4-0.5	0.2-0.4	0.3-1.8
nerolidol*	0.1-0.2	0.2-0.3	0.2-0.5	0.2	0.1-0.6	t-0.2	0.1-0.8	0.2-0.3	0.2-0.3	t-0.2
viridiflorol	0.4-1.0	1.0-2.0	1.2-5.8	1.4	0.9-1.3	0.8-1.7	0.9-4.2	1.0-1.4	0.8-1.0	t-1.4
dihydrocaryo-phyllenol	0.2-0.4	0.3-0.8	0.6-2.8	0.5	0.5-0.7	0.4-0.8	0.4-2.1	0.4-0.7	0.3-0.5	t-0.5
α-cadinol	t	t-0.1	0.1-0.7	t	t-0.2	0.3	t-0.3	0.1	0.2	0-t

*correct isomer not identified; t = trace (<0.1 percent)

citronellol (0.79 percent)
nerol (0.35 percent)
neral + pulegone (0.85 percent)
linalyl acetate + geranial (2.98 percent)
β-caryophyllene (2.37 percent)

*correct isomer not identified
t = trace (<0.1 percent)

It should be noted that this is an atypical oil of *L. stoechas*.

Skoula et al. (1996) collected *L. stoechas* plants from across Crete (Greece) from which oils were produced and subjected to analysis using GC and GC/MS. The flowers were separated from the leaves so that two oils (a leaf oil and flower oil) were produced. The results of the comparative analysis of these two oils can be seen in T-9.

Baldovini et al. (1998) analyzed a number of oils of *L. stoechas* ssp. *stoechas*, which were produced from plants collected all over Corsica. They found that the oils were qualitatively similar, but there were quantitative differences. As a result, the authors were able to

Comparative percentage composition of the leaf and flower oils of *Lavandula stoechas* from different regions of Cyprus **T-8**

Compound	Delikipo		Ora-Laya		Ora-Ayii		Stavrovouni	
	L	F	L	F	L	F	L	F
apopinene‡	0.1	0.2	t	-	0.1	0.3	0.1	0.1
α-thujene	0.2	-	0.3	-	0.3	0.3	0.3	0.1
α-pinene	0.9	4.4	0.5	2.1	0.6	3.3	1.0	1.4
camphene	-	-	0.1	-	-	-	-	0.2
β-pinene	2.6	1.6	3.6	0.7	3.8	4.9	3.8	1.6
cis-pinen-3-ol‡	0.1	-	0.1	0.2	-	0.2	0.1	0.1
limonene	0.2	1.1	0.1	0.7	-	0.7	1.2	0.3
1,8-cineole	9.1	3.1	5.7	1.5	6.0	2.7	12.1	3.6
γ-terpinene	-	-	t	-	-	0.1	-	-
p-cymene	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4
fenchone	44.1	35.8	36.2	30.0	41.0	31.0	44.8	51.8
cis-linalool oxide†	0.5	-	0.1	-	0.2	0.1	0.5	0.2
1-octen-3-ol	0.1	-	0.3	-	t	0.3	-	0.3
α-fenchyl alcohol	0.9	-	0.3	0.4	t	0.6	0.8	0.9
chrysanthenone	0.5	0.5	t	-	-	0.5	0.1	0.3
camphor	20.3	18.5	26.0	30.0	28.3	21.8	18.1	7.4
linalool	0.4	0.9	0.1	0.4	-	0.4	1.4	1.0
linalyl acetate	0.1	-	-	0.3	-	0.2	-	t
bornyl acetate	3.9	3.3	8.5	3.7	8.9	6.6	4.4	5.2
β-caryophyllene	0.2	2.2	0.2	1.4	t	1.6	0.3	0.3
terpinen-4-ol	0.1	-	0.2	-	0.5	-	0.3	0.6
myrtenal	0.5	0.8	0.3	1.7	0.2	1.0	0.3	1.0
verbenone	0.2	2.6	1.0	3.6	0.8	0.4	0.5	0.7
myrtenyl acetate	1.1	-	1.5	-	1.5	1.8	2.5	10.4
α-terpineol	1.9	12.9	1.7	13.4	1.6	8.5	1.1	0.9
isoborneol	-	1.1	0.4	-	-	0.7	-	0.7
cis-verbenol	0.5	0.7	-	0.7	0.3	0.9	0.6	2.9
carvone	0.2	-	1.2	0.2	t	0.3	0.3	0.5
γ-cadinene	1.1	5.1	0.7	2.2	0.7	2.9	1.2	0.5
geranyl acetate	0.3	0.7	0.4	0.7	0.5	0.6	0.5	0.2
geraniol	0.5	0.7	0.5	0.6	0.4	0.5	0.5	0.3
caryophyllene oxide	0.5	t	0.4	t	0.2	0.3	0.3	0.4
methyl eugenol	0.9	t	0.4	0.1	0.2	0.1	0.3	0.2
myrtenol	2.1	1.9	2.0	1.3	1.9	1.3	1.8	0.2
thymol	1.4	0.6	1.5	0.6	0.9	0.9	0.5	1.2
β-guaiene‡	0.5	-	0.2	t	-	0.2	t	0.4
farnesol*	0.4	t	0.5	0.2	0.4	0.2	t	0.5
γ-gurjunene‡	-	0.1	-	-	-	-	-	0.2

† furanoid form; ‡ incorrect identification; L = leaf oil; F = flower oil

categorize the oils into three groups based on their quantitative compositions. A summary of these groupings can be seen in T-10. In addition to presenting the same results as was found in the paper by Baldovini et al., Ristorcelli et al. (1998) showed that the enantiomeric distribution of camphor was approximately:

(+)-camphor (59 percent) : (-)-camphor (41 percent)

They also found that fenchone existed in *L. stoechas* oil exclusively as the (+)-enantiomer.

Akgün et al. (2001) compared the composition of a supercritical fluid CO_2 extract (SFE) of *L. stoechas* ssp. *cariensis* with a methylene chloride extract of the flowers of the same plant which was collected in the wild in the Mugla region of Turkey. The results of this study, in which the extracts were analyzed by GC/MS, can be seen in T-11. It should be noted that the conditions used to prepare the SFE were 80 bar and 35°C.

An oil of *L. stoechas* of Lebananese origin was reported by Traboulsi et al. (2002) to possess the following major constituents:

α-pinene (2.0 percent)
1,8-cineole (11.7 percent)
fenchone (40.1 percent)

Comparative percentage composition of the leaf and flower oil of *Lavandula stoechas* ssp. *stoechas* of Cretan origin **T-9**

Compound	Leaf oil	Flower oil	Compound	Leaf oil	Flower oil
apopinene†	0.1	0.3	3,6,6-trimethylbicyclo[3.1.0] hex-2-en-2-carbaldehyde†	0.1	0.3
α-pinene	2.2	3.0	*trans*-verbenol	t	t
α-fenchene	0.2	0.3	elemol†	t	t
camphene	0.4	0.5	myrtenal	0.5	1.0
β-pinene	0.1	0.1	pinocarvyl acetate*	0.2	0.2
verbenene	0.2	0.1	*trans*-pinocarveol	0.2	0.2
myrcene	t	t	p-mentha-1(7),2-dien-8-ol	0.3	0.2
β-phellandrene†	t	0.1	α-terpineol	0.1	t
α-terpinene	0.1	t	myrtenyl acetate	2.1	9.4
limonene	0.6	1.8	myrtenyl acetate†	1.5	1.1
1,8-cineole	16.7	5.9	borneol	t	t
γ-terpinene	0.1	0.1	α-muurolene	t	t
p-cymene	0.4	0.4	4,6,6-trimethylbicyclo[3.1.0] hept-3-en-2-one†	t	
terpinolene	t	0.1	carvone	0.1	t
fenchone	44.8	48.7	δ-cadinene	0.9	0.9
2,2,3-trimethyl-3-cyclopenten-1-acetaldehyde°	t	t	γ-cadinene	0.1	t
1-octen-3-ol	t	t	ledene†	0.4	t
p-cymene	0.1	t	myrtenol	0.6	0.6
cis-verbenyl acetate	t	t	2-phenethyl acetate	0.2	0.1
α-cubebene	t	t	*trans*-carveol	0.9	0.6
sabinene hydrate*	0.2	0.1	p-cymen-8-ol	0.2	0.6
β-fenchyl acetate	0.1	0.2	myrtenyl propionate	0.4	0.4
α-copaene	0.2	0.1	4-isopropylbenzyl alcohol	0.4	0.5
2,3-epoxypinane†	0.2	0.4	tetrahydrospirol†	0.4	0.2
camphor	6.2	4.7	globulol	0.5	0.3
linalool	t	t	copaborneol	0.7	0.6
linalyl acetate	t	t	epi-globulol	1.6	0.9
bornyl acetate	t	t	α-cadinol	7.4	8.0
β-fenchyl alcohol	0.4	0.4	mustakone	1.2	1.1
β-caryophyllene	0.1	t			
terpinen-4-ol	0.3	0.3			

*correct isomer not identified; °also known as α-campholenal; ‡incorrect identification; t = trace (<0.1 percent)

Comparative percentage composition of the three groups of oil of *Lavandula stoechas* ssp. *stoechas* obtained from plants collected in Corsica **T-10**

Compound	Group 1	Group 2	Group 3	Compound	Group 1	Group 2	Group 3
tricyclene	0-0.6	0-0.7	0-0.7	bornyl acetate	0.3-4.6	1.3-4.6	1.1-8.7
α-pinene	2.4-10.4	0.9-5.9	1.8-4.3	terpinen-4-ol	0-0.6	0-0.8	0-0.3
camphene	0.5-6.2	3.6-7.3	3.0-7.7	myrtenal	0-1.2	0-0.6	0-0.9
δ-3-carene	0-7.8	0-1.9	0.4-1.3	*trans*-verbenol	0-2.1	0-1.2	0-1.0
limonene	0.6-2.5	0-1.4	0.5-1.5	myrtenyl acetate	0-5.0	0.6-3.4	1.6-4.9
1,8-cineole	0-17.7	4.0-17.8	0.5-13.5	borneol	0-1.7	-	0.5-1.1
p-cymene	0-1.0	0-0.9	0-0.3	α-terpineol	0-1.0	0-0.3	-
fenchone	39.2-75.5	22.9-39.1	13.5-27.2	myrtenol	0-3.5	0-0.9	0.6-2.4
camphor	2.5-28.4	29.8-43.0	39.1-56.2	viridiflorol	0-1.9	0-1.3	0-1.2
linalool	0-5.2	0-2.1	0.3-1.6				

Comparative percentage composition of the extracts of *Lavandula stoechas* ssp. *cariensis* **T-11**

Compound	Methylene chloride extract	Supercritical fluid CO_2 extract	Compound	Methylene chloride extract	Supercritical fluid CO_2 extract
α-pinene	2.6	3.5	linalool	1.1	0.5
camphene	1.5	1.8	linalyl acetate	1.0	0.4
limonene	0.6	0.6	α-fenchyl acetate	1.3	1.1
1,8-cineole	4.3	-	borneol	0.4	0.3
fenchone	31.3	33.0	caryophyllene oxide	0.2	-
cis-linalool oxide†	0.3	0.2	α-cadinol	11.7	0.2
acetic acid	0.3	-	*trans*-sobrerol	0.5	-
α-fenchyl alcohol	0.1	-	viridiflorol	0.1	-
trans-linalool oxide†	0.4	0.5	glubolol	0.2	-
camphor	41.3	55.8	limonendiol*	0.2	-

*correct isomer not identified; † furanoid form

bornyl acetate (5.8 percent)
myrtenyl acetate (2.8 percent)
myrtenol (2.1 percent)
viridiflorol (1.9 percent)

Although the oil of *L. stoechas* ssp. *stoechas* is usually found to be fenchone-rich, Goren et al. (2002) collected some plants from Ayvalik-Cunda Island (western Turkey) and determined that an oil produced from them had a different composition as can be seen below.

α-thujene (0.1 percent)
α-pinene (1.2 percent)
camphene (0.4 percent)
sabinene (0.3 percent)
β-pinene (3.2 percent)
myrcene (0.3 percent)
α-terpinene (0.1 percent)
p-cymene (1.4 percent)
limonene (1.3 percent)
β-phellandrene (0.1 percent)
1,8-cineole (3.9 percent)
δ-3-carene* (0.3 percent)
δ-terpinene (0.4 percent)
isolimonene (0.1 percent)
isoterpinolene (0.1 percent)
β-terpineol** (2.3 percent)
cis-verbenol (0.2 percent)
trans-p-mentha-2,8-dien-1-ol (0.1 percent)
trans-dihydrocarvone (0.9 percent)
menthone (12.6 percent)
isopulegol (0.4 percent)
menthol (18.1 percent)
borneol (0.5 percent)
2,6,6-trimethyl-1-cyclohexene-1-carboxaldehyde (3.2 percent)
α-terpineol (0.4 percent)
cis-carveol (0.1 percent)
piperitenone (0.1 percent)
pulegone (40.4 percent)
piperitone (0.2 percent)
geranial (0.1 percent)
thymol (0.2 percent)
bornyl acetate (0.1 percent)
carvacrol (0.6 percent)
p-mentha-1(7),8(10)-dien-9-ol (0.6 percent)
β-caryophyllene (0.1 percent)
nerolidol* (0.1 percent)
spathulenol (0.4 percent)
caryophyllene oxide (0.1 percent)
β-cadinene* (0.1 percent)

*incorrect identification based on elution order from non-polar capillary column; **correct isomer not identified

Zrira and Benjilali (2003) compared the composition of oils of *L. stoechas* ssp. *atlantica* and *L. stoechas* ssp. *stoechas* collected in the wild in Morocco. Their results are summarized in T-12.

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Comparative percentage composition of oils of *Lavandula stoechas* ssp. *stoechas* and *L. stoechas* ssp. atlantica of Moroccan origin **T-12**

Compound	*L. stoechas* ssp. *stoechas*	*L. stoechas* ssp. *atlantica*	Compound	*L. stoechas* ssp. *stoechas*	*L. stoechas* ssp. *atlantica*
tricyclene	-	0.6	myrtenal	0.5	-
α-pinene	0.4	6.5	myrtenol	0.4	0.4
camphene	3.5	6.7	carvone	0.3	-
β-pinene	0.2	0.3	linalyl acetate	0.2	0.3
myrcene	0.2	0.2	isobornyl acetate	0.7	0.6
α-phellandrene	-	0.2	α-cubebene	1.8	-
p-cymene	0.5	0.3	α-copaene	0.2	-
limonene	-	0.8	β-cubenene	0.2	0.5
1,8-cineole	8.6	-	β-caryophyllene	0.7	0.5
(Z)-β-ocimene	-	0.4	aromadendrene	0.2	-
camphenilone	-	0.4	α-guaiene	0.4	0.9
fenchone	30.5	9.2	allo-aromadendrene	0.5	-
terpinolene	0.6	-	γ-muurolene	-	0.4
linalool	0.9	2.5	valencene	0.2	-
camphor	18.2	39.2	α-selinene	-	2.2
pinocarvone	0.9	-	*cis*-calamenene	-	0.8
borneol	1.4	2.5	δ-cadinene	1.1	2.2
terpinen-4-ol	0.5	0.6	cadalene	0.6	0.5

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Verbena, or Lemon Verbena, Oil

The oil of lemon verbena is produced from *Aloysia triphylla* (L'Herit.) Britton syn. *Lippia citriodora* (Lam.) O. Kuntze or *L. triphylla* (L'Herit.) O. Kuntze. Oils produced from plants that were harvested in two separate years and cultivated in Cumaovasi (Izmir, Turkey) were analyzed by Özek et al. (1996). The oil compositions as determined by GC/MS can be seen in T-13.

Zrira and Benjilali (1998) obtained leaves of *A. triphylla* from the Moroccan distribution market where many dozen kg were readily available. Lab-distilled oils from various lots of leaves were analyzed by a combination of GC and GC/MS. These oils were found to range in composition as follows:

α-pinene (0.2-0.6 percent)
sabinene (0.4-1.6 percent)
6-methyl-5-hepten-2-one (0.3-1.4 percent)
1-octen-3-ol (0.1-3.1 percent)
limonene (11.1-34.3 percent)
1,8-cineole (t-21.7 percent)
δ-3-carene® (0.3-0.7 percent)
terpinen-4-ol (0.3-0.9 percent)
α-terpineol (1.1-1.5 percent)
nerol (0.2-0.7 percent)
neral (7.1-22.5 percent)
piperitone (0.2-0.3 percent)
geranial (12.1-22.9 percent)
α-copaene (t-0.3 percent)
geranyl acetate (t-0.2 percent)
neryl acetate (t-0.2 percent)
β-bourbonene (t-0.2 percent)
α-cedrene (0.1-0.4 percent)
β-caryophyllene (0.5-2.7 percent)
allo-aromadendrene (0.3-1.1 percent)
ar-curcumene (1.6-11.6 percent)

Percentage composition of lemon verbena oil produced over two different seasons **T-13**

Compound	1st season oil	2nd season oil	Compound	1st season oil	2nd season oil
methyl 2-methylbutyrate	0.35	0.10	epi-bicyclosesquiphell-andrene	0.10	-
α-pinene	1.42	0.87	6-methyl-3,5-heptadien-2-one	0.08	0.04
α-thujene	0.20	0.14	β-caryophyllene	3.49	4.25
2-methyl-3-buten-2-ol	0.10	0.08	terpinen-4-ol	0.31	0.45
β-pinene	0.19	0.10	rosefuran epoxide	0.31	0.45
sabinene	2.83	2.49	*cis*-p-mentha-2,8-dien-1-ol	0.41	0.20
myrcene	0.40	0.32	aromadendrene	0.54	0.55
α-terpinene	0.08	-	(E)-β-farnesene	0.11	0.07
1,3,3-trimethylbicyclo [2.2.2]oct-5-ene	0.05	-	α-humulene	0.51	0.42
limonene	18.59	14.80	neral	5.99	8.05
1,8-cineole	10.07	6.79	α-terpineol	2.00	2.01
(E)-2-hexenal	0.17	-	germacrene D	1.50	1.39
(Z)-β-ocimene	0.11	0.15	zingiberene	0.27	0.13
γ-terpinene	0.08	-	β-bisabolene	0.15	0.26
(E)-β-ocimene	1.41	1.95	geranial	11.93	19.05
p-cymene	0.11	0.04	carvone	0.50	0.20
6-methyl-5-hepten-2-one	1.40	1.87	neryl acetate	0.72	1.25
(Z)-3-hexenol	0.04	0.03	δ-cadinene	0.24	0.16
6-methyl-3-heptanol	t	0.15	γ-cadinene	0.26	0.19
perillene	0.06	0.10	ar-curcumene	4.93	5.72
photocitral B	0.14	0.11	nerol	0.12	0.31
cis-linalool oxide (furanoid)	0.04	-	geranyl propionate	0.21	0.42
cis-limonene oxide* + 1-octen-3-ol	0.47	0.41	*trans*-carveol	0.36	0.12
trans-limonene oxide	0.22	0.08	geraniol	0.04	0.08
trans-sabinene hydrate	0.80	0.75	*cis*-carveol	0.12	0.06
citronellal	0.17	0.18	piperitenone	0.07	0.04
cis,cis-photocitral	0.22	0.38	caryophyllene oxide	4.87	3.14
α-copaene	0.58	0.60	methyl eugenol	0.08	0.05
α-campholenal	0.05	-	nerolidol*	0.73	1.25
trans,trans-photocitral	0.40	0.80	viridiflorol	0.08	0.06
β-bourbonene	0.56	0.45	spathulenol	4.30	3.88
linalool	0.38	0.54	T-cadinol	0.97	1.14
cis-sabinene hydrate	0.20	0.12	eugenol	-	0.15
α-cedrene	0.43	0.40	T-muurolol	0.19	0.19

t = trace (<0.01 percent); *correct isomer not identified

δ-cadinene (0.1-0.4 percent)
(E)-nerolidol (0.2-0.5 percent)
spathulenol (1.8-3.9 percent)
caryophyllene oxide (1.2-4.4 percent)

t = trace (<0.05 percent); *incorrect identity based on elution order

Nonanal, which was isolated as a constituent of *A. triphylla* oils was determined to possess antidiarrhoeal activity (I bet you wanted to know that).

Lemon verbena can be found growing spontaneously all over South America even though it is cultivated in Morocco and southern Europe. In all of these areas, the leaves of *A. triphylla* are used as an herbal tea. Carnat et al. (1999) decided to compare the composition of the volatiles found in an infusion (tea) made from boiling distilled water (2 L) and lemon verbena leaves (10 g), which was left to draw for 15 min. GC analysis of an oil produced from the leaves and the volatiles produced by the infusion revealed that the infusion was richer in neral and geranial (the major constituents of the oil) than the oil. A summary of the analytical data can be seen in T-14.

Crabas et al. (2003) analyzed the composition of a volatile concentrate produced by supercritical CO_2 extraction of dried *A. triphylla* leaves of Italian origin, and compared it with the composition of a hydrodistilled oil of the same batch of leaves. The results of this study have been summarized in T-15. The fact

that the neral and geranial levels were so low would indicate that the leaves used to isolate the oil and volatiles were either very old or were an example of a chemotypic difference. This reviewer favors the former of these two possibilities.

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S. Zrira and B. Benjilali, *L'huile essentielle de verveine (Lippia citriodora) du Maroc*. Rivista Ital. EPPOS (Numero Speciale), 668-675 (1998).

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N. Crabas, B. Marongiu, A. Piras, T. Pivetta and S. Porcedda, *Extraction, separation and isolation of volatiles and dyes from Calendula officinalis L. and Aloysia triphylla (L'Her.) Britton by Supercritical CO_2*. J. Essent. Oil Res., **15**, 272-277 (2003).

Tolu Balsam Oil

Tolu balsam is a balsam resin that exudes from incisions made in the trunk of a large tree (>20 m height) that can be found growing in the northern part of South America. Steam distillation of this balsam, which dries to become a brown, easily fractured plastic solid, produces an oil in 1.5-10 percent yield. The taxonomic origin of tolu balsam is *Myroxylon balsamum* (L.) Harms var. *genuinim* Baill.

Akisue (1972) used thin-layer chromatographic characterization of isolated fractions of tolu balsam oil to identify vanillin, benzyl benzoate, benzyl cinnamate, benzyl alcohol, nerolidol, benzoic acid and cinnamic acid in it.

El-Mastry (1979) developed a direct spectrophotometric method to determine the amounts of benzoic and cinnamic acids in tolu balsam. Using his newly developed method, El-Mastry found that in the four samples analyzed the benzoic acid content was 11.5-16.6 percent; the cinnamic acid content was 15.5-25.1 percent.

Habib and Saleh (1980) developed a difference UV spectrophotometric method for the quantitative determination of cinnamic and benzoic acids in the presence of resin acids.

Saleh et al. (1980) modified their original method by incorporating a cleaner sample preparation. As a result, the new method could be used to accurately assay tolu balsam for benzoic and cinnamic acids. The authors found that for the two samples analyzed, the benzoic and cinnamic acids varied from 9.39-10.98 percent and 20.54-24.42 percent, respectively.

A year earlier, Harkiss and Linley (1979) examined a number of commercial samples of tolu balsam oil of various date origins using gas chromatography. The oils possessed the following range of acids and esters:

benzoic acid (4.4-13.3 percent)
cinnamic acid (6.1-18.4 percent)
benzyl benzoate (2.5-12.8 percent)
benzyl cinnamate (0-3.2 percent)

Comparative percentage composition of lemon verbena oil and lemon verbena tea volatiles **T-14**

Compound	Leaf oil	Tea volatiles
α-pinene	0.76	-
sabinene	1.10	-
limonene	12.82	1.34
1,8-cineole	5.73	3.44
linalool	0.60	0.89
β-caryophyllene	0.94	0.73
neral	17.64	31.33
α-terpinyl acetate	1.03	1.98
geranial	23.48	45.59
citronellol	5.29	-
nerol	0.37	0.73
geraniol	0.31	0.40
caryophyllene oxide	6.27	2.52
(Z)-nerolidol	1.13	0.27
spathulenol	5.12	3.95

Using a silver perchlorate impregnated silica gel column of a pentane extract of an ethanolic solution of tolu balsam, Friedel and Matusch (1987) were able to separate the non-polar sesquiterpene hydrocarbons. They separated the two epimers of guaia-1(5),6-diene. However, the authors failed to adequately describe the results of their analysis of the sesquiterpene hydrocarbons in tolu balsam; thus, a reader of this paper is not sure of the results obtained. The authors did show that separation of three aromadendrenes and two guaienes could be achieved using a silver loaded Li Chrosorb Si 60 HPLC (250 mm x 25 m) column with a pentane/diethyl (80:20) eluant and a flow rate of 11 mL/min. It could not be readily determined that the above aromadendrenes and guaienes were of tolu balsam origin. To clarify this situation, Friedel and Matusch (1987) isolated and structurally elucidated the two epimeric guaia-1(5),6-dienes, which were epimeric around C_4.

These same authors (Friedel and Matusch, 1987) also isolated and structurally elucidated further five aromadendrene derivatives in tolu balsam. In addition to identifying aromadendrene, ledene and α-gurjunene in tolu balsam, they also structurally elucidated five new constituents: 1-epi-α-gurjunene, 1,didehydroaromadendrane, 9,10-didehydroaromadendrane,

Comparative percentage composition of the oil and volatile concentrate obtained from a supercritical CO_2 extract of the dried leaves of *Aloysia triphylla* **T-15**

Compound	Oil	Volatile concentrate
1-octen-3-ol	1.0	0.5
6-methyl-5-hepten-2-one	0.6	0.2
3-octanol	0.3	0.4
limonene	0.5	-
1,8-cineole	0.9	0.5
benzyl alcohol	-	0.3
cis-sabinene hydrate	0.3	-
linalool	0.5	-
6-methyl-3,5-heptadien-2-one	0.2	-
cis-limonene oxide	0.2	-
trans-p-menth-2-en-1-ol	0.2	-
cis-chrysanthenol	0.2	-
terpinen-4-ol	0.9	0.3
α-terpineol	1.6	1.0
trans-carveol	0.4	0.4
nerol	0.5	0.3
(E)-tagetenone	0.2	-
neral	2.2	1.4
carvone	0.5	0.5
geraniol	0.8	0.5
geranial	3.2	2.3
(E)-anethole	0.2	-
eugenol	0.1	0.6
geranic acid	-	2.8
α-copaene	0.5	0.6
geranyl acetate	1.6	t
β-bourbonene	t	0.9
methyl eugenol	0.3	1.2
α-cedrene	0.6	0.3
β-caryophyllene	0.4	t
β-gurjunene	0.2	-
aromadendrene	0.1	-
geranyl acetone	0.5	-
allo-aromadendrene	1.1	0.6
γ-muurolene	0.3	-
γ-curcumene	0.6	-
ar-curcumene	7.7	4.6
epi-cubebol	0.7	0.5
cis-β-guaiene	0.1	-
β-bisabolene	0.2	-
γ-cadinene	0.4	t
cubebol	1.0	0.5
δ-cadinene	0.4	1.6
α-cadinene	0.2	1.0
1-nor-bourbonanone	0.3	-
(E)-nerolidol	3.8	2.0
spathulenol	23.2	7.1
caryophyllene oxide	t	5.6
cedrol	0.7	-
β-oplopenone	0.9	-
1-epi-cubenol	0.4	-
cubenol	0.9	0.4
epi-bicyclosesquiphellandrene	2.3	1.1
ledol	0.8	-
α-bisabolol	0.4	0.6
(Z)-α-bisabolene oxide	0.3	-
allo-aromadendrene oxide	-	0.3
oplopanone	0.4	1.0
xanthorrhizol	-	0.6
calarene epoxide	-	0.4
6,10,14-trimethyl-2-pentadecanone	0.6	0.6
methyl eicosanoate	0.2	-
methyl hexadecanoate	1.3	1.2
hexadecanoic acid	0.4	2.7
methyl linoleate	1.5	1.8
methyl linolenate	4.4	5.6
phytol	4.2	11.6
squalene	-	1.5

t = trace (<0.1 percent)

aromadendra-1(5),3-diene and aromadendra-1(10), 4-diene in the same sample of tolu balsam.

Moyler and Clery (1997) subjected a sample of the volatile fraction of tolu balsam to analysis using retention indices (non-polar column) and GC/MS and determined that it contained the following constituents:

benzaldehyde (0.1 percent)
benzyl alcohol (43.4 percent)
methyl benzoate (t)
ethyl benzoate (t)
benzoic acid (0.11 percent)
(Z)-cinnamyl alcohol (t)
(E)-cinnamyl alcohol (t)
methyl cinnamate* (t)
vanillin (0.16 percent)
ethyl cinnamate* (1.0 percent)
cinnamic acid* (1.4 percent)
benzyl benzoate (50.7 percent)
(E)-cinnamyl benzoate (0.1 percent)
(E)-benzyl cinnamate (0.5 percent)
(Z,E)-cinnamyl cinnamate (1.5 percent)

*correct isomer not identified

The authors further stated that this fraction contained an additional 44 components (0.84 percent of the fraction), but they did not identify them.

Moyler (1998) examined an oil produced from the gum resin extract of tolu balsam using GC and GC/MS. The composition of this oil was as follows:

benzaldehyde (0.08 percent)
benzyl alcohol (41.80 percent)
methyl benzoate (0.08 percent)
ethyl benzoate (0.04 percent)
benzoic acid (2.50 percent)
(Z)-cinnamyl alcohol (0.01 percent)
(E)-cinnamyl alcohol (0.05 percent)
methyl (E)-cinnamate (0.05 percent)
vanillin (1.40 percent)
ethyl (E)-cinnamate (0.80 percent)
(E)-cinnamic acid (2.70 percent)
(Z)-nerolidol (0.01 percent)
(E)-nerolidol (0.40 percent)
benzyl benzoate (46.60 percent)
(E)-cinnamyl benzoate (0.10 percent)
benzyl (E)-cinnamate (0.90 percent)
(Z)-cinnamyl (E)-cinnamate (1.50 percent)

Moyler noted that there were another 108 constituents whose composite total was 1.08 percent.

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Ajowan Oil

The oil of ajowan is obtained from the seeds (fruit) of *Trachyspermum copticum* (L.) Link [syn. *Carum copticum* (L.) Bernh. Et J.D. Hook.; *Ammi copticum* L.; *Trachyspermum ammi* (L.) Sprague]. The oil is known to be a rich source of thymol and was at one time fractionally distilled to obtain it for use in flavors and as a starting point for chemical syntheses.

As part of a study on essential oil isolation procedures, Koedam et al. (1979) identified α-pinene, β-pinene, γ-terpinene, p-cymene and thymol in a lab-prepared sample of ajowan oil.

An oil of ajowan derived from the seeds of *T. copticum* that was grown in Ethiopia was reported by Demissew (1993) to contain the following components:

α-pinene (6.3 percent)
β-pinene (0.5 percent)
myrcene (1.0 percent)
α-terpinene (10.0 percent)
α-phellandrene (11.0 percent)
1,8-cineole (t)
thujyl alcohol (t)
pulegone (0.5 percent)
terpinen-4-ol (0.1 percent)

α-terpineol (0.1 percent)
carvacrol (69.0 percent)

t = trace (<0.1 percent)

This is the first time that carvacrol was been found as a major constituent of ajowan oil. As a result, this should be corroborated before it can be accepted as an example of an infraspecific chemical difference.

Choudhury et al. (1998) isolated an oil of *T. copticum* collected from Barpeta district (Assam, India) and found that it was a new chemotype of ajowan. The main constituents of this unusual oil, which possessed similarities to the oil of *Anethum sowa* Roxb., were as follows:

myrcene (0.1 percent)
α-phellandrene (0.5 percent)
limonene (38.1 percent)
cis-dihydrocarvone (1.1 percent)
trans-dihydrocarvone (2.5 percent)
carvone (46.2 percent)
myristicin (2.4 percent)
dillapiole (8.9 percent)

Nagalakshmi et al. (2000) examined a number of oils produced by different methods of ajowan seed of Mysore and Mumbai (India) origin. The results of these analyses can be seen as follows:

α-pinene (0.38-0.90 percent)
β-pinene + myrcene (2.90-3.93 percent)
p-cymene (18.49-22.82 percent)
γ-terpinene (22.44-33.50 percent)
p-menth-2-en-1-ol* (0.03-0.22 percent)
terpinen-4-ol (0.10-0.76 percent)
thymol (37.42-48.42 percent)
cuminyl alcohol (0.07-0.39 percent)
carvacrol (0.09-1.55 percent)

*correct isomer not identified

A single sample of ajowan oil produced by hydrodistillation by the same authors was found to contain the following components:

α-pinene (1.48 percent)
β-pinene (5.45 percent)
myrcene (1.40 percent)
α-terpinene (0.09 percent)
p-cymene (19.47 percent)
limonene (0.48 percent)
γ-terpinene (30.97 percent)
α-p-dimethylstyrene (0.06 percent)
terpinolene (t)
p-menth-2-en-1-ol* (0.13 percent)
linalool (0.07 percent)
terpinen-4-ol (0.12 percent)
α-terpineol (0.12 percent)
cuminaldehyde (t)
thymol (39.36 percent)
cuminyl alcohol (t)
carvacrol (t)

t = trace (<0.01 percent)
*incorrect identification based on elution order

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