Progress in Essential Oils

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Juniper Berry Oil and Extract

Maurer and Thomas (1994) reported on the occurrence of nitrogen bases in juniper berry oil (*Juniperus communis* L.). Starting with 10 kg of the oil, a basic fraction (10 mg) was obtained, which had a rich aroma. Although the two main components were found to be *cis*- and *trans*-p-menth-3-ene-1,2-diol, two pyrazines (3,6-dimethyl-2-ethylpyrazine and 2,3,5,6-tetramethylpyrazine) and 11 pyridines [3-methoxypyridine, 3-isopropylpyridine, 5-isopropyl-2-methylpyridine, 6-isopropyl-3-methylpyridine, 3-isopropenyl-6-methylpyridine, 3-pentylpyridine, (E)-3-pentenylpyridine, (Z)-3-pentenylpyridine, isopropyl nicotinate, 2-isopropylpyridinyl methyl ketone and sec.butyl nicotinate] were found as trace constituents of the oil.

Analysis of Polish juniper berry oil by Gosa et al. (1997) revealed that the major constituents were:

α-pinene (44.1 percent)
sabinene (6.6 percent)
limonene (4.2 percent)
p-cymene (11.9 percent)
borneol (5.2 percent)
farnesene* (5.0 percent)

*correct isomer not identified

The composition of juniper berry oil produced in different seasons from different locations in Greece was analyzed by Koukos and Papadopoulou (1997). A summary of the results of these analyses can be seen in T-1. The results of the study revealed that both the maturity of the juniper berry and the area from which it was harvested had a pronounced effect on the composition of the oil.

Oils produced from juniper berries harvested in the former Yugoslavia (now Serbia and Montenegro) were analyzed by Matovic and Lavadinovic (1999). The oil composition was found to range as follows:

α-thujene (1.17-1.39 percent)
α-pinene (16.65-27.82 percent)
camphene (0.21-0.23 percent)
sabinene (10.80-14.54 percent)
β-pinene (1.65-1.94 percent)
myrcene (11.18-14.17 percent)
limonene (3.50-4.51 percent)
γ-terpinene (0.89-1.03 percent)
terpinolene (0.86-0.98 percent)
terpinen-4-ol (3.74-8.17 percent)
α-terpineol (0.29-0.80 percent)
α-humulene (1.69-2.66 percent)
germacrene D (1.71-2.67 percent)
γ-cadinene (0.22-0.33 percent)
δ-cadinene (6.42-8.65 percent)

Chatzopoulou et al. (2002) compared the composition of a hydrodistilled oil of juniper berries and a supercritical fluid CO_2 extract of the same batch of berries produced under different processing conditions. A summary of their results is presented in T-2. As can be seen, there were similarities between the oil and the CO_2 extract produced from the comminuted berries, while the CO_2 extract produced from the whole berries was different. It should be noted that the CO_2 extracts were produced using the following conditions: 90 bar, 40°C and degree of comminution 2 mm, for 1 h.

Kubeczka and Formacek (2002) compared the composition of a commercial oil of juniper berry with one prepared in the laboratory. The comparative analysis can be seen in T-3.

The volatiles of a hexane extract, a supercritical fluid CO_2 extract and a hydrodistilled oil of juniper berries collected on Mount Jelovice (Pljevlja, Serbia and Montenegro) were the subject of analysis by Damjanovic et al. (2003). The results of these analyses are shown in T-4.

The composition of juniper berry oil from berries collected in the Gorgan province (Iran) was analyzed

Comparative percentage composition of juniper berry oil produced from berries harvested in different seasons and different locations in Greece **T-1**

Compound	Mount Pageon			Mount Vermion			Mount Hortiatis		
	GOS	GOA	BOA	GOS	GOA	BOA	GOS	GOA	BOA
α-pinene	42.51	27.22	38.88	40.09	62.08	57.06	39.51	54.43	45.59
camphene	0.24	0.18	0.20	0.19	0.32	0.31	0.20	0.29	0.26
β-pinene	2.52	2.08	2.00	1.89	3.47	3.41	2.08	3.42	2.76
sabinene	0.35	7.80	0.78	14.60	5.06	6.08	0.27	10.86	16.47
δ-3-carene	-	-	0.03	-	-	0.02	-	0.03	0.02
myrcene	20.23	14.67	19.90	19.38	7.23	10.74	14.21	5.41	9.14
α-phellandrene	-	-	0.02	-	0.04	0.40	0.09	0.04	0.02
α-terpinene	0.03	0.14	0.03	0.02	0.06	0.12	-	0.13	0.25
limonene	12.53	30.96	7.18	1.83	1.44	1.73	1.31	2.01	2.17
1,8-cineole	0.41	0.38	0.37	0.34	0.61	0.59	0.59	0.63	0.49
γ-terpinene	0.05	-	0.11	0.06	0.14	0.34	0.03	0.34	0.62
p-cymene	-	-	0.02	0.50	0.02	0.08	-	0.03	0.22
terpinolene	0.62	1.21	0.49	0.33	0.80	0.62	0.55	1.05	0.91
3-octanol	0.20	0.19	0.25	0.81	0.42	0.51	0.96	0.64	0.54
p-cymenene	0.13	0.18	0.04	0.04	0.02	0.15	0.02	0.05	0.06
decanal	-	0.04	-	-	0.08	0.06	0.02	0.13	0.11
linalool	0.32	0.23	0.23	0.34	0.31	0.26	0.28	0.31	0.22
terpinen-4-ol	0.16	-	0.15	-	0.04	0.05	-	0.05	0.06
bornyl acetate	0.64	0.25	0.97	0.69	1.19	1.08	0.65	1.51	1.02
β-caryophyllene	2.65	2.16	3.43	2.02	0.79	1.86	6.61	1.11	1.81
furfuryl alcohol	0.19	0.07	0.15	0.17	0.28	0.22	0.33	0.62	0.34
α-terpineol	0.50	1.24	0.86	1.03	0.64	0.85	2.64	0.88	0.98
carvone	0.14	0.15	0.33	0.18	0.15	0.19	0.35	0.27	0.22
geranyl acetate	-	-	-	-	0.09	0.01	-	0.26	0.02
citronellol	8.35	6.76	12.75	6.75	7.11	5.06	15.57	7.12	7.60
nerol	0.17	0.11	0.14	0.19	0.16	0.24	0.36	0.21	0.26
myrtenol	0.62	0.24	0.70	0.28	0.98	0.63	0.73	0.96	0.60
cedrol	0.60	0.56	1.24	1.16	0.88	1.15	1.84	1.20	0.99
geraniol	0.52	0.14	-	0.54	0.54	0.41	0.91	1.15	0.67
eugenol	0.76	0.45	1.30	1.73	1.97	0.96	2.33	1.45	0.99
thymol	-	-	0.04	-	0.21	0.27	-	-	0.03
borneol	1.87	1.43	2.54	1.61	0.86	1.47	4.51	1.01	1.30
carvacrol	0.16	0.10	0.14	0.22	0.05	0.03	0.29	0.24	0.20

GOS = spring green berry oil; GOA = autumn green berry oil; BOA = autumn blackberry oil

by Shamir et al. (2003). The oil composition was found to be as follows:

α-thujene (2.9 percent)
α-pinene (19.9 percent)
sabinene (36.8 percent)
β-pinene (0.8 percent)
myrcene (4.8 percent)
α-terpinene (1.1 percent)
p-cymene (0.9 percent)
limonene (10.6 percent)
γ-terpinene (1.8 percent)
trans-sabinene hydrate (0.5 percent)
terpinolene (1.9 percent)
cis-sabinene hydrate (0.3 percent)
α-thujone (0.1 percent)
cis-p-menth-2-en-1-ol (0.2 percent)
trans-p-menth-2-en-1-ol (0.2 percent)
terpinen-4-ol (3.6 percent)
α-terpineol (0.1 percent)
bornyl acetate (0.2 percent)
α-ylangene (0.1 percent)
β-elemene (0.1 percent)
cyperene (0.1 percent)
β-caryophyllene (1.5 percent)
β-cedrene (0.2 percent)
α-humulene (1.1 percent)
germacrene D (8.1 percent)
α-selinene (0.6 percent)
δ-cadinene (0.7 percent)
germacrene B (0.5 percent)

Filipowicz et al. (2003) analyzed three oils of juniper berry — two produced in Poland from different batches of berries of Polish origin and one obtained commercially in

Comparative percentage composition of juniper berry oil and two supercritical fluid CO_2 extracts produced from whole and comminuted berries **T-2**

Compound	Supercritical fluid CO_2 extracts from whole berries	comminuted berries	Oil from comminuted berries
α-pinene	15.43	35.28	40.29
sabinene	4.21	3.54	3.84
β-pinene	1.14	2.33	2.76
myrcene	5.13	9.88	10.63
limonene	2.30	3.00	1.90
terpinen-4-ol	0.52	0.26	0.30
α-terpineol	0.57	0.17	0.29
β-caryophyllene	4.62	2.20	2.59
α-humulene	3.19	1.72	2.13
germacrene D	11.67	12.32	10.36
δ-cadinene	1.08	1.12	1.92
caryophyllene oxide	2.56	3.12	0.44
T-cadinol	0.49	0.50	0.97
α-cadinol	0.93	0.14	0.81

Poland. The composition of these three oils is presented in T-5. As can be seen, the oil composition varied to a large extent.

Using chiral GC, the authors also examined the enantiomeric distribution of four monoterpene hydrocarbons found in the three oils. As can be seen from the results shown in T-6, the two Polish oils appear similar, while the commercial oil appears to have been adulterated with (+)-limonene.

Using plant material collected in its natural habitat in Sardinia, Angioni et al. (2003) compared the composition of lab-distilled juniper berry oil produced from both ripe and unripe berries. The components found in these oils are shown in T-7.

Barjaktarovic et al. (2005) extracted juniper berries with supercritical fluid CO_2 (SFC). They ground the dry berries to a particle size of 0.25-0.40 mm so that the extractor had a 20 g bed. The extraction parameters examined were 80, 90 and 100 bar; 40°C; and various extraction times from 0.6 to 3.9 h. They found that the monoterpene hydrocarbons were almost completely extracted in 0.6 h at all pressures used. Furthermore, it was found that the percentage yield of oxygenated monoterpenes, sesquiterpene hydrocarbons and oxygenated sesquiterpenes varied according to extraction time and pressure. An example of the composition of the SFC extract obtained at 0.6 h and 80 bar can be seen as follows:

α-thujene (0.69 percent)
α-pinene (21.45 percent)
α-fenchene (0.24 percent)
camphene (0.09 percent)
sabinene (11.75 percent)
β-pinene (1.96 percent)
myrcene (4.97 percent)
δ-3-carene (0.15 percent)
α-terpinene (0.09 percent)
p-cymene (0.70 percent)
limonene (2.82 percent)
γ-terpinene (1.12 percent)
terpinolene (1.14 percent)
α-cubebene (1.98 percent)
α-copaene (0.87 percent)
β-elemene (2.64 percent)
β-caryophyllene (4.22 percent)
γ-elemene (0.64 percent)
α-humulene (3.09 percent)
(Z,Z)-α-farnesene (1.14 percent)
γ-cadinene (12.12 percent)
β-selinene (0.72 percent)
valencene (0.81 percent)
guaia-3,7-diene (0.25 percent)
viridiflorene (0.56 percent)
α-muurolene (0.61 percent)
δ-cadinene (0.76 percent)
germacrene D (3.85 percent)
germacrene B (1.08 percent)
terpinen-1-ol (1.13 percent)
β-terpineol* (0.89 percent)
cis- & *trans*-verbenol (0.92 percent)
pinocarveol* (1.52 percent)
borneol (0.20 percent)
terpinen-4-ol (4.60 percent)
α-terpineol (1.50 percent)
γ-terpineol† (0.76 percent)
bornyl acetate (0.92 percent)
geranyl acetate (0.12 percent)
caryophyllenol* (0.07 percent)
nerolidol* (0.65 percent)
spathulenol (0.43 percent)
humulene oxide I (0.11 percent)

Comparative percentage composition of juniper berry oils **T-3**

Compound	Commercial oil	Lab-distilled oil
tricyclene	0.08	0.08
α-pinene	70.82	41.13
camphene	0.81	0.27
β-pinene	13.67	2.76
sabinene	0.33	9.78
δ-3-carene	0.03	0.10
myrcene	2.67	15.20
α-terpinene	0.01	0.50
limonene	2.58	3.11
β-phellandrene	0.34	0.43
γ-terpinene	0.31	0.85
p-cymene	1.39	0.26
terpinolene	0.35	0.87
α-cubebene	0.11	0.57
trans-sabinene hydrate	-	0.10
α-copaene	0.10	0.56
linalool + unknown	-	0.45
bornyl acetate	0.08	0.20
β-elemene	0.09	1.02
β-caryophyllene + terpinen-4-ol	2.19	3.59
γ-elemene	-	0.18
(E)-β-farnesene	-	0.54
α-humulene	0.21	1.43
γ-muurolene & α-terpineol	0.57	0.84
borneol	0.08	0.10
germancrene D	0.19	6.27
bicyclosesquiphellandrene	-	0.16
β-selinene	0.09	0.37
α-selinene & α-muurolene	0.04	0.58
bicyclogermacrene	-	0.54
δ-cadinene	0.20	2.67
γ-cadinene	0.08	0.18
germacrene B	-	1.75
geraniol	0.12	0.08
cubebol	-	0.10
caryophyllene oxide	0.10	0.09
germacra-1(10)E,5E-dien-4-ol	-	0.32
epi-cubenol	-	0.18
spathulenol	-	0.25
T-cadinol	-	0.22
T-muurolol	-	0.29
α-muurolol	-	0.14
α-cadinol	-	0.65
citronellic acid	-	0.11

α-muurolol (0.12 percent)
α-cadinol (0.16 percent)

*correct isomer not identified; †the natural occurrence of this compound is questioned

In addition, at different extraction times minor amounts of caryophyllene oxide, T-cadinol and β-eudesmol also were characterized.

B. Maurer and A.F. Thomas, *Alkaloids, bases and essential oils*. Perfum. Flavor., **19**(2), 19-27 (1994).

J. Gosa, T. Majda, A. Lis, A. Tichek and A. Kurowska, *Chemical composition of some Polish commercial essential oils*. Rivista Ital EPPOS, (Numero Speciale) 761-766 (1997).

P. Koukos and K.I. Papadopoulou, *Essential oil of Juniperus communis L. grown in northern Greece: Variation of fruit oil yield and composition*. J. Essent. Oil Res., **9**, 35-39 (1997).

Percentage composition of the volatiles of juniper berry extracts and oil **T-4**

Compound	Oil	Hexane extract	Supercritical fluid extract
α-thujene	0.1	1.2	2.5
α-pinene	39.2	23.1	32.9
camphene	0.2	0.2	0.5
sabinene	17.8	2.8	3.9
β-pinene	-	1.7	3.2
myrcene	18.2	10.0	1.9
α-phellandrene	0.1	-	-
δ-3-carene	1.0	-	-
p-cymene	0.7	-	2.6
limonene	5.2	2.8	5.0
γ-terpinene	1.4	0.2	2.2
linalool	0.1	0.3	-
terpinen-4-ol	2.6	0.9	10.5
α-terpineol	0.2	-	0.4
bornyl acetate	0.2	-	0.9
azulene†	-	0.4	-
α-cubebene	0.4	-	-
β-elemene	0.6	1.3	-
longifolene	-	3.7	-
α-cedrene	-	-	0.5
β-caryophyllene	1.0	1.3	2.9
aromadendrene	-	3.4	1.6
γ-elemene	0.2	-	-
α-humulene	0.7	1.0	-
(E)-β-farnesene	0.2	0.5	2.9
α-amorphene	-	-	0.3
germacrene D	3.8	4.3	1.7
α-muurolene	0.2	-	1.2
γ-cadinene	0.2	-	-
δ-cadinene	0.7	0.3	-
germacrene B	1.4	0.9	4.9
caryophyllene oxide	-	0.6	-
α-cadinol	0.1	-	1.0
methyl *trans*-communate	-	13.7	3.2
hexadecanoic acid	-	8.7	-
10-nonadecenol*	-	1.2	-
tetracosanol	-	2.3	-

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

M. Matovic and V. Lavadinovic, *Essential oil of the fruit of Juniperus communis L. growing in Yugoslavia*. J. Essent. Oil Bear. Plants, **2**(3), 101-106 (1999).

P. Chatzopoulou, A. de Haan and S.T. Katsiotis, *Investigation on the supercritical CO_2 extraction of the volatile constituents from Juniperus communis obtained under different treatments of the berries (cones)*. Planta Med., **68**, 827-831 (2002).

K-H. Kubeczka and V. Formacek, *Essential oils analysis by capillary gas chromatography and carbon -13 NMR spectroscopy*. 2nd Ed., 145-154, J. Wiley & Sons, NY (2002).

B.M. Damjanovic, D. Skala, D. Petrovic-Djakov and J. Baras, *A comparison between the oil, hexane extract and supercritical carbon dioxide extract of Juniperus communis L.* J. Essent. Oil Res., **15**, 90-92 (2003).

F. Shamir, L. Ahmadi, M. Mizra and S.A.A. Korori, *Secretory elements of needles and berries of Juniperus communis L. ssp. communis and its volatile constituents*. Flav. Fragr. J., **18**, 425-428 (2003).

N. Filipowicz, M. Kaminski, J. Kurlenda, M. Asztemborska and J.R. Ochocka, *Antibacterial and antifungal activity of juniper berry oil and its selected components*. Phytotherap. Res., **17**, 227-231 (2003).

A. Angioni, A. Barra, M.T. Russo, V. Coroneo, S. Dessi and P. Cabras, *Chemical composition of the essential oils of Juniperus from ripe and unripe berries and leaves and their antimicrobial activity*. J. Agric. Food Chem., **51**, 3073-3078 (2003).

B. Barjaktarovic, M. Sovilj and Z. Knez, *Chemical composition of Juniperus communis L. fruits supercritical CO_2 extracts: dependence on pressure and extraction time*. J. Agric. Food Chem., **53**, 2630-2636 (2005).

Percentage composition of Polish juniper berry oil **T-5**

Compound	Oil 1	Oil 2	Oil 3*
α-pinene	22.93	60.07	39.88
camphor	0.89	-	0.30
β-pinene	5.60	1.50	2.85
sabinene	2.12	1.53	3.43
δ-3-carene	-	0.06	-
myrcene	0.68	5.54	15.72
limonene	6.52	1.93	4.48
β-phellandrene	2.13	-	0.50
γ-terpinene	0.16	-	0.35
p-cymene	9.96	1.35	0.68
bornyl acetate	3.21	1.41	0.34
β-caryophyllene	-	2.54	-
linalool	0.27	-	0.30
terpinen-4-ol	1.45	2.88	5.52
α-humulene	2.10	1.46	2.84
borneol	0.46	1.44	-
nerol	2.21	0.61	0.18
α-terpineol	-	0.24	3.86
geraniol	1.58	0.62	1.37
carvacrol	0.45	-	0.25

*commercial oil

Enantiomeric distribution percentage of four monoterpene hydrocarbons found in three different juniper berry oils **T-6**

Compound	Oil 1	Oil 2	Oil 3*
(1R,5R)-(+)-α-pinene	14.6	26.4	28.4
(1S,5S)-(-)-α-pinene	85.4	73.6	71.6
(1R,5R)-(+)-β-pinene	7.4	27.6	-
(1S,5S)-(-)-β-pinene	92.6	72.4	100
(1R,5R)-(+)-sabinene	100	100	100
(4R)-(+)-limonene	47.8	47.5	83.6
(4S)-(-)-limonene	52.2	52.5	16.4

*commercial oil

Santolina Oil

An oil of santolina (ex *Santolina chamaecyparissus* L.), also known as cotton lavender, that was produced from plant material collected in Turkey was the subject of analysis by Demirci et al. (2000). The components found in this oil were as follows:

α-pinene (0.2 percent)
santolinatriene (0.5 percent)
camphene (1.2 percent)
β-pinene (2.1 percent)
sabinene (2.2 percent)
myrcene (4.3 percent)
α-terpinene (0.1 percent)
limonene (0.8 percent)

Comparative percentage composition of juniper berry oil produced from fruit of different maturity **T-7**

Compound	Unripe berry oil	Ripe berry oil
α-thujene	0.56	0.53
α-pinene	52.91	52.26
camphene	0.22	0.22
sabinene	13.73	5.58
β-pinene	2.98	2.86
myrcene	8.13	15.32
α-terpinene	0.21	-
p-cymene	-	0.25
limonene	3.81	3.11
γ-terpinene	0.59	0.52
terpinolene	1.06	0.49
terpinen-4-ol	1.13	1.51
bornyl acetate	0.66	-
α-cubebene	-	1.25
α-copaene	0.65	-
β-caryophyllene	0.78	-
α-humulene	0.86	0.81
germacrene D	6.57	6.69
α-muurolene	1.16	-

β-phellandrene (9.2 percent)
γ-terpinene (0.2 percent)
p-cymene (0.3 percent)
terpinolene (1.6 percent)
artemisia ketone (38.1 percent)
yomogi alcohol (1.5 percent)
cis-2,7-dimethyl-4-octene-2,7-diol (0.1 percent)
trans-sabinene hydrate (0.2 percent)
4,8-epoxyterpinolene (0.1 percent)
artemisia alcohol (1.5 percent)
camphor (11.7 percent)
linalool (0.1 percent)
1-methyl-4-acetyl-1-cyclohexene (0.1 percent)
trans-p-menth-2-en-1-ol (0.1 percent)
pinocarvone (0.4 percent)
methyl thymol (0.2 percent)
terpinen-4-ol (1.1 percent)
cis-p-menth-2-en-1-ol (0.1 percent)
myrtenal (0.2 percent)
trans-pinocarveol (0.2 percent)
lavandulol (0.3 percent)
cryptone (0.5 percent)
γ-curcumene (0.1 percent)
α-terpineol (0.1 percent)
borneol (0.9 percent)
germacrene D (0.4 percent)
phellandral (0.1 percent)
cis-chrysanthenol (0.1 percent)
ar-curcumene (0.2 percent)
myrtenol (0.4 percent)
p-cymen-8-ol (0.2 percent)
benzyl 2-methylbutyrate (0.2 percent)
benzyl isovalerate (0.1 percent)
caryophyllene oxide (0.4 percent)
(E)-nerolidol (0.5 percent)
cuminyl alcohol (0.1 percent)
spathulenol (0.2 percent)
α-bisabolol oxide B (0.3 percent)
α-bisabolol oxide A (0.2 percent)
α-cadinol (0.1 percent)
T-muurolol (0.1 percent)
α-bisabolol (6.6 percent)
caryophylla-2(12),6(13)-dien-5β-ol (0.1 percent)
(6S,7R)-bisabolone (0.1 percent)

In addition, trace amounts (< 0.1 percent) of 1,3-octadiene, tricyclene, α-thujene, 2-methylbutyl 2-methylbutyrate, 6-methyl-5-hepten-2-one, perillene, p-cymenene, (Z)-3-hexenyl isovalerate, α-campholenal, 2-methyl-6-methylene-3,7-octadien-2-ol, piperitone, *trans*-piperitol, neryl propionate, *trans*-p-menth-1(7),8-dien-2-ol, p-mentha-1,3-dien-7-al, (Z)-jasmone, humulene epoxide III, (2R,5S)-caryophyll-5-en-12-al and eugenol also were found in this same oil.

Garg et al. (2001) determined that the composition of an oil of *S. chamaecyparissus* produced from plants cultivated in India was as follows:

α-pinene (0.7 percent)
camphene (0.7 percent)
sabinene (4.5 percent)
β-pinene (4.7 percent)
myrcene (14.2 percent)
α-terpinene (0.4 percent)
p-cymene (0.2 percent)
limonene (1.6 percent)
1,8-cineole (15.6 percent)
(Z)-β-ocimene (0.2 percent)
γ-terpinene (0.5 percent)
artemisia ketone (31.8 percent)
artemisia alcohol (0.8 percent)
terpinolene (2.3 percent)
linalool (0.3 percent)
camphor (1.9 percent)
isopulegol (0.6 percent)
isoborneol (0.9 percent)
terpinen-4-ol (2.9 percent)
α-terpineol (1.2 percent)
β-caryophyllene (0.1 percent)
γ-gurjunene (0.9 percent)
germacrene D (8.8 percent)
spathulenol (0.8 percent)

Ahuja et al. (2005) analyzed an oil of *S. chamaecyparissus* produced from plants grown in Srinagar (India) and found that the main constituents of this oil were as follows:

santolinatriene (0.5 percent)
α-pinene (0.2 percent)
β-pinene (0.1 percent)
myrcene (7.0 percent)
δ-3-carene (0.3 percent)
p-cymene (0.3 percent)
limonene (11.7 percent)
1,8-cineole (0.5 percent)
(Z)-β-ocimene (13.5 percent)

(E)-β-ocimene (5.4 percent)
γ-terpinene (8.8 percent)
artemisia alcohol (0.2 percent)
linalool (1.9 percent)
α-thujone (0.7 percent)
cryptone (1.7 percent)
borneol (1.6 percent)
terpinen-4-ol (2.6 percent)
α-terpineol (2.1 percent)
β-elemene (0.3 percent)
β-caryophyllene (2.0 percent)
β-gurjunene (0.9 percent)
α-humulene (0.6 percent)
caryophyllene oxide (2.0 percent)
globulol (1.6 percent)
β-oplopenone (1.0 percent)

B. Demirci, T. Özek and K.H.C. Baser, *Chemical composition of Santolina chamaecyparissus L. essential oil.* J. Essent. Oil Res., **12**, 625-627 (2000).

S.N. Garg, D. Gupta, V.K. Mehta and S. Kumar, *Volatile constituents of the essential oil of Santolina chamaecyparissus Linn. from the southern hills of India.* J. Essent. Oil Res., **13**, 234-235 (2001).

A. Ahuja, S.K. Bakshi, S.K. Sharma, R.K. Thappa, S.G. Agarwal, S.K. Kichlu, R. Pau and M.K. Paul, *Production of volatile terpenes by proliferating shoots and micropropagated plants of Santolina chamaecyparissus L. (cotton lavender).* Flav. Fragr. J., **20**, 403-406 (2005).

Angelica Seed Oil

Using chiral GC, Takeoka et al. (1990) determined that the enantiomeric ratio of α-copaene in angelica seed oil was: (+)-α-copaene (> 99 percent): (-)-α-copaene (< 1 percent). This interest in α-copaene was because the (+)-enantiomer is reputed to be highly attractive to the Mediterranean fruit fly.

Bernard (2001) analyzed lab-distilled fruit oils of *A. archangelica* subsp. *archangelica* var. *sativa* and *A. archangelica* subsp. *litoralis* produced from plants collected from their natural habitat in France. The oil of var. *sativa* (the normally cultivated form) was found to possess the following composition:

α-pinene (2.3-6.6 percent)
camphene (t-0.1 percent)
β-pinene (0.3-0.6 percent)
sabinene (t-0.2 percent)
δ-3-carene (t-0.1 percent)
myrcene (2.4-3.2 percent)
α-phellandrene (t-1.9 percent)
limonene (t-1.8 percent)
psi-limonene (0-2.6 percent)
β-phellandrene (64.9-65.8 percent)
(Z)-β-ocimene (0-0.6 percent)
(E)-β-ocimene (1.3-1.8 percent)
p-cymene (0.5-0.8 percent)
2-methylbutyl 2-methylbutyrate (0-0.1 percent)
isoamyl isovalerate (t-0.3 percent)
longicyclene (t-0.6 percent)
α-humulene (t-0.6 percent)
cryptone (0.6-1.1 percent)
germacrene D (t-0.3 percent)
δ-cadinene (0-0.6 percent)
γ-cadinene (0-0.5 percent)

cuminaldehyde (t-0.1 percent)
bicyclogermacrene (0.7-1.5 percent)
(E)-anethole (0-0.7 percent)
benzyl isovalerate (t-0.1 percent)
spathulenol (0-2.5 percent)
15-cyclopentadecanolide (t-0.6 percent)

Trace amounts (< 0.1 percent) of isovaleraldehyde, α-thujene, heptanal, γ-terpinene, terpinolene, methyl thymol, methyl carvacrol, β-bourbonene, linalool, hexyl isovalerate, bornyl acetate, β-caryophyllene, an isomer of p-menth-2-en-1-ol and an isomer of farnesol were found in at least one of the oils.

For comparison purposes, the oil of var. *litoralis* was found to contain:

α-pinene (4.2 percent)
sabinene (0.5 percent)
α-phellandrene (3.4 percent)
limonene (0.6 percent)
β-phellandrene (76.0 percent)
cryptone (1.2 percent)

In addition, trace amounts (< 0.1 percent) of camphene, β-pinene, myrcene, (E)-β-ocimene, γ-cadinene and (E,Z)-α-farnesene also were found in this oil, which is of no commercial value.

Using a combination of GC and ^{13}C-NMR, Kubeczka and Formacek (2002) determined that an oil of angelica seed had the following composition:

α-pinene (8.80 percent)
camphene (0.38 percent)
β-pinene (0.74 percent)
sabinene (0.67 percent)
δ-3-carene (0.07 percent)
myrcene (2.87 percent)
α-phellandrene (2.72 percent)
p-mentha-1(7),8-diene (0.60 percent)
limonene (2.32 percent)
β-phellandrene (72.06 percent)
(Z)-β-ocimene (0.28 percent)
(E)-β-ocimene (0.54 percent)
p-cymene (0.49 percent)
terpinolene (0.09 percent)
2-methylbutyl valerate (0.09 percent)
butyl angelate (0.06 percent)
α-ylangene (0.12 percent)
α-copaene (0.78 percent)
β-bourbonene (0.10 percent)
β-cubebene (0.03 percent)
β-elemene (0.14 percent)
β-caryophyllene (0.07 percent)
γ-elemene (0.08 percent)
α-humulene (1.06 percent)
germacrene D (0.69 percent)
zingiberene (0.62 percent)
α-muurolene + β-bisabolene (0.31 percent)
bicyclogermacrene (0.42 percent)
δ-cadinene (0.15 percent)
β-sesquiphellandrene (0.15 percent)
ar-curcumene (0.10 percent)
germacrene B (0.67 percent)
cyclotridecanolide (0.18 percent)
cyclopentadecanolide (0.19 percent)

An oil that was produced from angelica seed (fruit) of Canadian origin in 1.13 percent yield was analyzed by Lopes et al. (2004). The composition of this oil was determined to be as follows:

α-thujene (0.18 percent)
α-pinene (6.58 percent)
camphene (0.26 percent)
sabinene (0.37 percent)
β-pinene (0.59 percent)
myrcene (2.91 percent)
α-phellandrene (3.65 percent)
δ-3-carene (0.20 percent)
p-cymene (0.62 percent)
limonene (2.67 percent)
β-phellandrene (74.66 percent)
(Z)-β-ocimene (0.16 percent)
(E)-β-ocimene (0.32 percent)
terpinolene (0.09 percent)
linalool (0.27 percent)
borneol (0.13 percent)
terpinen-4-ol (0.16 percent)
cryptone (0.12 percent)
linalyl acetate (0.19 percent)
bornyl acetate (0.06 percent)
α-copaene (0.24 percent)
β-caryophyllene (0.08 percent)
β-copaene (0.06 percent)
α-humulene (0.63 percent)
γ-muurolene (0.45 percent)
α-muurolene (0.07 percent)
germacrene B (0.28 percent)
13-tridecanolactone (0.32 percent)
15-pentadecanolactone (0.15 percent)

G. Takeoka, R.A. Flath, T.R. Mon, R.G. Bultery, R. Teranishi, M. Güntert, R. Lautamo and J. Szejtli, *Further applications of permethylated β-cyclodextrin capillary gas chromatographic columns.* J. High Resol. Chromatogr., **13**, 202-206 (1990).

C. Bernard, *Essential oils of three angelica species growing in France. Part II: fruit oils.* J. Essent. Oil Res., **13**, 260-263 (2001).

K-H. Kubeczka and V. Formacek, *Essential oils analysis by capillary gas chromatography and carbon -13NMR spectroscopy.* 2nd Ed., 3-9, J. Wiley & Sons, NY (2002).

D. Lopes, H. Strobl and P. Kolodziejczyk, *14-Methylpentadecano-15-lactone (Muscolide): A new macrocyclic lactone from the oil of Angelica archangelica L.* Chemistry Biodiversity, **1**, 1880-1887 (2004).

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