Progress in Essential Oils

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Catnip Oil

Catnip oil is obtained from *Nepeta cataria* L. The genus *Nepeta* comprises annual or perennial herbs or shrubs which are mainly distributed in temperate Eurasia and North Africa. Although no members of this genus are native to North America, a few can be found as garden escapes. The three species of *Nepeta* that have been found in North America are *Nepeta cataria* L. (including var. *citriodora* Beck), *N. grandiflora* Bieb. and *N. racemosa* La. (syn. *N. mussini* Spreng.).

Nepeta cataria L., or catnip as it is more commonly known, is an herbaceous perennial plant which is native to Europe and Asia. Nevertheless, catnip is completely naturalized in North America where it can be found commonly occurring as a weed in waste land and along roadsides. In Canada, it ranges from British Columbia to Nova Scotia while in the United States it can be found southwards from Canada to Oregon, Georgia, Kansas and Utah (Gill, 1971), although it is found in abundance in the vicinity of the Great Lakes.

A number of years ago, McElvain et al. (1941/1942) examined the essential oil of catnip and identified nepetalactone and a number of its degradation products (see **F-1** for chemical structures of seven nepetalactones).

A summary of the early literature revealed that catnip oil was reported to contain β-caryophyllene, nepetalactone (ca. 42%), nepetalic acid and a so-called nepetalic anhydride (ca. 36%) (Guenther, 1949). Unfortunately, this author did not discuss the fact that nepetalic acid and nepetalic anhydride were degradation products of nepetalactone.

Bates et al. (1958) determined that catnip oil contained two stereoisomeric lactones. The predominant one possessed a *cis-trans*-configuration, while the smaller one possessed the *trans-cis*-configuration (later to be known as nepetalactone and epi-nepetalactone, respectively.

Bates and Sigel (1963) found that in the catnip oil that they examined the levels of nepetalactone and epi-nepetalactone were 70–75% and 20–25%, respectively.

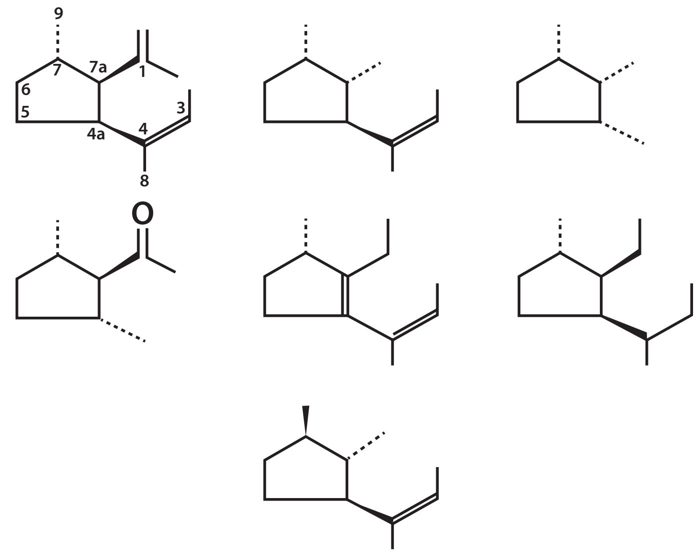
A number of oils of catnip that were produced from plants collected from their natural habitats in Wisconsin, Nebraska and Michigan were analyzed and compared with a commercially available catnip oil by Reigner (1966). Although he tentatively identified (Z)- and (E)-β-ocimene, myrcene and an allo-ocimene isomer, he did characterize β-caryophyllene, nepetalactone and epi-nepetalactone in the oils. He also found that the commercial sample of catnip oil contained nepetalactone (60%), whereas the oils from Wisconsin and Nebraska possessed nepetalactone and epi-nepetalactone in amounts of 29%:71% and 69%:31% ratios. The oil from Michigan was found to contain 99% nepetalactone and no epi-nepetalactone.

An oil of *N. cataria* produced from plants grown in Japan was found by Sakan et al. (1965) to contain dihydronepetalactone and isodihydronepetalactone along with nepetalactone.

Reigner et al. (1967a) reported the results of the ratios found between nepetalactone and epi-nepetalactone that was reported in his thesis. Reigner (1967b) analyzed an oil of catnip and determined that it contained camphor, β-caryophyllene, nepetalactone (major), epi-nepetalactone and a trace of dihydronepetalactone. Using preparative TLC on the oil of a large-leaf type *N. cataria*, Sastry et al. (1972) isolated a new nepetalactone derivative from the lactone fraction by preparative GC. It was structurally elucidated with the aid of ^{1}H-NMR and IR to be 5,9-dehydro-nepetalactone. This is the same as 4a,7a-dehydro-4aα,7α,7aα-nepetalactone.

Bellesia et al. (1984) determined that catnip oil produced from plants collected in Lombardia (Italy) contained nepetalactone and epi-nepetalactone in a ratio of 49:1.

F-1. Nepetalactones



Catnip oil produced from flowering plants collected in the vicinity of Toledo (Spain) was subjected to analysis by Velasco-Negueruela et al. (1988). It was found to possess the following composition:

1,8-cineole (0.1%)
linalool (0.1%)
myrtenal (0.1%)
terpinen-4-ol (0.5%)
trans-pinocarveol (0.1%)
longifolene (5.2%)
β-caryophyllene (0.3%)
α-humulene (0.5%)
4aα,7α,7aα-nepetalactone (90.6%)
4aα,7α,7aβ-nepetalactone (0.5%)
thymol[t] (0.2%)
caryophyllene oxide (0.2%)
δ-cadinene (0.1%)

[t]tentative identification

DePooter et al. (1988) collected flowering plants of *N. cataria* from the Botanic Gardens of Bokrijk (Belgium) and produced two oils using steam distillation. Analysis of this oil was performed using GC-FID (retention indices and quantitation) and GC/MS and the structures of certain components were elucidated using ‘H-NMR. The range in composition of the two oils was determined to be as follows:

(Z)-β-ocimene (t–0.2%)
(E)-β-ocimene (0–0.7%)
4aβ,7α,7aα-nepetalactone (0–0.1%)
4aα,7α,7aα-nepetalactone (70.1–91.9%)
4aα,7α,7aβ-nepetalactone (0.1–20.0%)
4aβ,7α,7aβ-nepetalactone (1.0%)
β-caryophyllene (4.2–4.6%)
β-farnesene* (0.2%)
α-humulene (0.5–1.0%)
dehydronepetalactone (0–0.1%)
germacrene D (0–0.1%)
caryophyllene oxide (0.4–0.8%)

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

A trace amount (<0.1%) of 1,8-cineole was also found in one of the oils.

The flowering aerial parts of *N. cataria* that were grown in the Baku region of Zerbaijan were hydrodistilled by Mishurova and Mamedova (1989) to produce an oil that was subjected to analysis. The components that were characterized in this oil were:

monoterpene hydrocarbons (2.8%)
α-thujone (1.8%)
linalool (0.9%)
α-terpinyl acetate (2.7%)
neral (4.8%)
citronellol (11.7%)
geranial (3.1%)
geranyl acetate (15.8%)
geraniol (8.2%)
2-phenethyl alcohol (9.5%)
nepetalactone* (38.0%)

*noted as an unidentified lactone

Lawrence (1992) analyzed a number of samples of catnip oil that were produced in the laboratory from plants collected in southern Ontario (Canada). The oils were found to range in composition as follows:

myrcene (t–1.5%)
limonene (t–0.4%)
(Z)-β-ocimene (t–0.2%)
(E)-β-ocimene (t–0.5%)
β-caryophyllene (1.1–6.8%)
α-humulene (t–4.3%)
cis,trans-nepetalactone (10.6–94.1%)
nepetalactone* (0.1–0.2%)
trans,cis-nepetalactone (0.4–65.2%)
dihydronepetalactone (0.2–2.7%)

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

An oil produced from the leaves of *N. cataria* found throughout China was analyzed by Zhu et al. (1993) and found to contain the following constituents:

α-pinene (0.2%)
sabinene (0.1%)
7-octen-4-ol† (1.2%)
3-octanone (0.1%)
myrcene (0.4%)
limonene (16.0%)
β-ocimene* (0.7%)
α-ocimene† (3.6%)
acetophenone (0.5%)
linalool (0.8%)
camphor (0.1%)
α-terpineol (0.3%)
carvomenthone† (0.7%)
trans-carveol (1.4%)
citronellol (0.1%)
cis-carveol (0.1%)
carvone (52.2%)
neral (1.3%)
carvyl acetate* (0.1%)
citronellyl acetate (0.2%)
geranyl acetate (0.1%)
α-copaene (0.1%)
β-bourbonene (0.3%)
β-caryophyllene (1.5%)
α-humulene (9.5%)
β-cubebene† (0.6%)
β-farnesene* (0.1%)
α-farnesene* (0.4%)
β-cadinene (0.2%)
nerolidol* (0.8%)
β-eudesmol (0.2%)

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

As this oil was devoid of nepetalactones, it was not produced from *N. cataria,* but a misidentified plant.

Bourrel et al. (1993) produced an oil of catnip that was collected from central France during its full flowering stage. Analysis of this oil revealed that it contained the following components:

3,7-dimethyl-1-oxa-bicyclo[3.3.0.]oct-2-ene (0.7%)
piperitone (0.8%)
4aα,7α,7aα-nepetalactone (2.8%)
4aα,7α,7aβ-nepetalactone (56.9%)
β-elemene (0.2%)
(Z)-3-hexenyl ester* (0.9%)
3,4β-dihydro-4α,7α,7αa-nepetalactone (1.7%)
β-caryophyllene (6.2%)
α-humulene (0.9%)
(E)-β-farnesene (0.8%)
methyl thymol (0.4%)
(Z)-3-hexenyl benzoate (0.2%)
caryophyllene oxide (18.2%)
humulene epoxide*

*correct isomer not identified

These same results were also reported by Perineau et al. (1993).

Nepeta cataria plants that were collected from a commercial cultivar (‘Rio Primero’) in full flower grown in the Cordoba Province of Argentina were subjected to steam distillation to produce an oil in 0.93% yield (Malizia et al., 1996). Analysis of this oil using GC and GC/MS showed that the oil possessed the following composition:

α-pinene (0.1%)
β-pinene (0.1%)
myrcene (0.1%)
δ-3-carene (0.8%)
limonene (0.1%)
1,8-cineole (0.1%)
linalool (0.1%)
piperitone (1.1%)
nepetalactone (57.3%)
dihydronepetalactone (3.4%)
β-caryophyllene (8.1%)
α-humulene (1.3%)
β-farnesene* (2.1%)
caryophyllene oxide (19.4%)
humulene epoxide* (1.6%)

*correct isomer not identified

Handjieva et al. (1996) collected two samples of catnip; one from Balchik and the other from Pirdop (Bulgaria). Oils produced from these plants that were collected when they were in full flower were produced in the laboratory by hydrodistillation. The composition of one of the oils was determined to be as follows:

2,6-dimethyl-2,5-heptadien-4-one (0.1%)
piperitone (0.3%)
nonanoinc acid (0.1%)
dihydroactinodiolide (0.2%)
4aα,7α,7aα-nepetalactone (11.0%)
4aα,7α,7aβ-nepetalactone (24.0%)
3,4α-dihydro-7aα,7α,7aβ-nepetalactone (10.0%)
iridomyrmecin or isoiridomyrmecin (0.5%)
3,4α-dihydro-4aα,7α,7aβ-nepetalactone (15.0%)
nepetalic acid (1.2%)
4α,7α-dehydronepetalactone (1.0%)
nepetalactone (0.2%)
hexadecanoic acid (0.2%)

The composition of the other oil was quite dissimilar as its main components were found to be as follows:

4aα,7α,7aα-nepetalactone (6.0%)
4aα,7α,7aβ-nepetalactone (78.0%)
nepetalic acid (1.6%)

Ibrahim and El-Din (1999) reported that an oil produced from catnip cultivated in Egypt contained monoterpene hydrocarbons (7.1%), sesquiterpene hydrocarbons (3.8%), the oxygenated fraction (77.8%) with neral, geranial and geraniol (54.7%), and nepetalactone (20.3%). It should be noted that, from the oil composition, it can be deduced this oil was actually obtained from *N. cataria* var. *citriodora*, not the pure species.

Lawrence (2000) examined the composition of an oil of *N. cataria* produced from plants collected from a natural stand in southern Ontario (Canada). Using a combination of analytical techniques the oil was found to contain the following constituents:

α-pinene (0.1%)
β-pinene (0.1%)
myrcene (0.3%)
limonene (0.4%)
(Z)-β-ocimene (0.1%)
(E)-β-ocimene (0.4%)
4aα,7α,7aα-nepetalactone (40.0%)
4aα,7α,7aαβ-nepetalactone (45.0%)
β-caryophyllene (2.1%)
α-humulene (0.7%)
caryophyllene oxide (1.0%)
3,4β-dihydro-4aα,7α,7aβ-nepetalactone (0.6%)

A commercial sample of catnip oil was also determined (Lawrence, 2000) to contain the following constituents:

α-pinene (0.1%)
β-pinene (0.1%)
limonene (0.1%)
4aα,7a,7aα-nepetalactone (88.3%)
4aα,7a,7aβ-nepetalactone (3.2%)
β-caryophyllene (3.9%)
(E)-β-farnesene (0.9%)
caryophyllene oxide (0.5%)

The dried flowering aerial parts of *N. cataria* collected in the vicinity of Larijan (Mazandaran Province, Iran) were hydrodistilled to produce an oil that was analyzed by Morteza-Semnani and Saeedi (2004). This oil was found to contain the following constituents:

α-pinene (0.7%)
sabinene (0.4%)
β-pinene (3.0%)
p-cymene (0.4%)
δ-3-carene[†] (0.4%)
1,8-cineole (13.5%)
(Z)-β-ocimene (3.1%)
(E)-β-ocimene (0.4%)
γ-terpinene (0.4%)
terpinolene (0.4%)
δ-terpineol (0.5%)
terpinen-4-ol (0.9%)
α-terpineol (1.2%)
myrtenal (0.3%)
citronellyl acetate (5.2%)
4aα,7α,7aα-nepetalactone (2.6%)
4aα,7α,7aβ-nepetalactone (28.8%)
β-bourbonene (0.6%)
4aα,7β,7aα-nepetalactone (11.9%)
isocaryophyllene (0.8%)
β-caryophyllene (5.7%)
(Z)-β-farnesene (3.6%)
α-humulene (0.4%)
allo-aromadendrene (0.3%)
ar-curcumene (1.0%)
germacrene D (1.3%)
β-bisabolene (2.6%)
β-sesquiphellandrene (1.6%)
spathulenol (2.6%)
caryophyllene oxide (3.6%)
T-cadinol (1.1%)

[†]incorrect identification based on GC elution order

Pavela (2006) determined that catnip oil produced from plants grown in Canada was quite toxic to the common greenhouse pest cabbage aphid. The composition of this oil of Canadian origin was found to be as follows:

α-pinene (0.2%)
sabinene (0.2%)
β-pinene (1.2%)
α-phellandrene (0.2%)
limonene (0.2%)
(Z)-β-ocimene (0.3%)
(E)-β-ocimene (0.9%)
carvone (0.2%)
nepetalactone 1[*] (29.7%)
nepetalactone 2[*] (45.3%)
nepetalactone 3[*] (1.8%)
isocaryophyllene (0.1%)
β-caryophyllene (10.8%)
α-humulene (1.4%)
valencene (0.1%)
nepetalactone 4[*] (0.7%)
nepetalactone 5[*] (3.4%)
caryophyllene oxide (1.0%)

[*]correct isomer not identified

Trace amounts (<0.10%) of α-thujene, α-terpinene, p-cymene, γ-terpinene and geraniol were also found in this same oil.

Flowering plants of *N. cataria* that were harvested from Bolar (Erzurum, Turkey) were subjected to hydrodistillation by Adiguzel et al. (2009), the oil yield of which was determined to be 0.74%. Analysis of this oil by GC/MS only revealed that it contained the following composition:

β-pinene (0.4%)
myrcene (0.1%)
limonene (0.3%)
1,8-cineole (0.7%)
camphor (0.4%)
pinocamphone (0.4%)
pinocarvone (1.2%)
isopinocamphone (0.1%)
terpinen-4-ol (0.1%)
α-terpineol (0.2%)
pulegone (1.8%)
piperitone (0.8%)
thymol (2.3%)
carvacrol (0.5%)
piperitenone (1.7%)
piperitenone oxide (1.7%)
4aα,7α,7aα-nepetalactone (6.0%)
4aα,7β,7aβ-nepetalactone (70.4%)
4aα,7β,7aα-nepetalactone (2.5%)
β-caryophyllene (0.9%)
spathulenol (0.1%)
caryophyllene oxide (0.4%)

Shirin and Saharkhiz et al. (2011) collected *N. cataria* plants at various developmental states (vegetative, bud formation, full flowering, fruit-setting) that were grown from seed at the Research Field Station, Shahid Beheshti University (Shiraz, Iran). Oils produced from these separate ontogenetic stages were analyzed by GC-FID and GC/MS. The analytical

T-1. Comparative percentage composition of *Nepeta cataria* oils produced from plants harvested at different developmental stages

Compound	1	2	3	4
α-pinene	2.7	3.1	4.6	3.3
sabinene	-	-	0.2	0.3
β-pinene	0.8	1.1	1.6	-
4-cyclohexenyl-methyl ketone†	0.5	0.6	0.7	0.5
triplal†	0.1	0.4	0.4	0.2
thymol	0.4	0.4	0.6	1.3
4aα,7α,7aβ-nepetalactone	55.0	58.0	55.0	59.0
4aα,7β,7aα-nepetalactone	30.1	31.1	31.2	30.0
β-caryophyllene	1.1	2.7	2.1	1.1
α-humulene	0.8	0.9	0.9	1.2
11-dodecenol†	0.8	0.7	1.1	1.5
spathulenol	0.6	0.4	0.3	-
caryophyllene oxide	0.5	0.2	0.1	-
6,10-dimethyl-2-undecanone†	0.2	-	0.3	0.2

1=vegetative stage oil
2=bud formation stage oil
3=full flowering stage oil
4=seed setting stage oil
†incorrect identification

results obtained from the oils can be seen in **T-1**.

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Pinus sylvestris, or Scots Pine Oil and Extract

The oil produced by steam distillation of the needles and small branches of *Pinus sylvestris* L. in Austria, Bulgaria, Bosnia Herzegovina, Lithuania and Russia is known as Scots pine oil.

An absolute produced from the needles of *P. sylvestris* that was grown in Bulgaria was the subject of analysis by Nicolov et al. (1972). They found that this absolute contained the following components:

α-pinene (25.4%)
camphene (1.9%)
β-pinene (21.7%)
sabinene (1.0%)
myrcene + δ-3-carene (3.5%)
α-phellandrene (1.0%)
limonene (15.3%)
β-phellandrene (2.4%)
1,8-cineole (0.8%)
p-cymene + γ-terpinene + terpinolene (0.3%)
camphor (2.4%)
bornyl acetate + terpinen-4-ol (4.3%)
borneol + α-terpineol (3.6%)

Gornostaeva et al. (1977) examined the monoterpene hydrocarbon fraction of *P. sylvestris* oil produced in Siberia. They found the following components in this oil:

tricyclene (0.8%)
α-pinene (52.7%)
camphene (6.0%)
β-pinene (7.6%)
myrcene (5.7%)
δ-3-carene (13.9%)
limonene (6.6%)
β-phellandrene (4.7%)
terpinolene (0.75)

Interestingly enough, the authors also found some bornyl acetate (0.9%) in this fraction.

T-2. Comparative percentage composition of *Pinus sylvestris* needle oils from two different regions

Compound	Caucuses oil	Siberia oil
α-pinene	20.3	28.0–31.0
camphene	9.4	6.0–8.5
β-pinene	2.0	8.3–10.3
myrcene	-	2.1–3.8
δ-3-carene	20.4	9.5–11.3
α-terpinene	3.2	-
β-phellandrene	4.0	8.6–10.9
limonene	3.1	-
γ-terpinene	0.2	0.2–0.4
borneol	-	0.1–0.3
α-terpineol	1.9	-
bornyl acetate	1.7	2.9–4.2
longifolene	3.5	0.5–1.2
β-caryophyllene	1.7	3.3–3.8
α-humulene	1.8	-
α-cadinene†	-	0.3–0.6
γ-muurolene	-	0.5–0.9
α-muurolene	2.6	7.8–11.6
β-bisabolene	0.2	-
γ-cadinene	5.4	-
δ-cadinene	9.5	-

†incorrect identification based on GC elution order

T-3. Comparative percentage composition of *Pinus sylvestris* oils

Compound	1	2
tricyclene + α-thujene	0.3–1.4	t–0.8
α-pinene	19.8–35.0	18.0–28.0
camphene	0.8–2.2	1.5–4.7
sabinene + β-pinene	0.2–1.4	1.3–2.7
myrcene	0.8–1.1	0.9–3.3
δ-3-carene	22.7–33.7	19.9–25.9
p-cymene	0.2–0.5	t–0.3
limonene + β-phellandrene	0.7–1.4	0.9–2.7
(Z)-β-ocimene	t–0.5	0–0.3
(E)-β-ocimene	0.4–2.0	0.2–1.5
γ-terpinene	0.3–0.9	0.5–1.3
terpinolene	0.6–2.9	0.5–2.7
undecane	t–0.2	0–0.3
borneol	0.4–1.1	0.3–1.2
p-menth-1,5-dien-8-ol	t–0.2	0.3–1.2
terpinen-4-ol	0.6–2.4	0.6–1.2
m-cymen-8-ol	0–0.3	0–0.2
p-cymen-8-ol	t–0.4	0–0.4
α-terpineol	0.3–1.2	0.6–3.3
2-decanone	0–0.3	0–0.2
methyl thymol	0–0.7	0–0.6
bornyl acetate	1.0–3.4	0.5–2.4
2-undecanone	0–0.8	0.1–0.8
(E,E)-2,4-decadienal	0–0.3	-
δ-elemene	0.4–2.0	t–1.4
α-terpinyl acetate	t–1.4	0.4–1.2

T-3. Comparative percentage composition of *Pinus sylvestris* oils (Cont.)

Compound	1	2
α-cubebene	t–0.5	t–0.5
α-copaene	0.2–0.6	0.1–0.6
β-bourbonene	0.1–0.5	t–0.4
β-cubebene	0.2–0.4	t
β-elemene	0.7–2.3	0.7–1.8
β-caryophyllene	2.6–7.0	2.7–6.5
β-copaene	0.1–0.8	t–0.4
β-gurjunene	t–0.5	t
aromadendrene	0.1–1.2	0.2–0.8
trans-muurola-3,5-diene	t–0.5	0.1–0.3
α-humulene	0.8–1.8	0.6–1.4
cis-muurola-4(14),5-diene	0.1–0.4	t–0.3
γ-muurolene	0.8–7.3	0.8–1.9
germacrene D	0.8–6.9	0.6–7.0
β-selinene	0.5–1.4	t
trans-muurola-4(14),5-diene	0–0.4	0–0.5
bicyclogermacrene	0.2–2.0	0.5–3.6
α-muurolene	1.5–5.0	0.6–4.1
γ-cadinene	1.2–9.3	1.7–11.1
δ-cadinene	2.9–9.0	1.3–10.6
trans-cadina-1(2),4-diene	0.1–0.7	0.1–0.4
α-cadinene	0.2–0.5	0.2–0.4
α-calacorene	t–0.4	0–0.2
β-calacorene	0–0.2	0–0.1
(Z)-3-hexenyl benzoate	0–0.2	0–0.2
germacrene D-4-ol	0.5–5.2	2.1–6.7
spathulenol	0.5–1.5	0.7–2.3
caryophyllene oxide	0.6–1.7	0.4–4.4
gleenol	0–0.4	t–2.5
β-oplopenone	0–0.5	0–0.5
1,10-di-epi-cubenol	0.4–1.1	0.3–2.5
1-epi-cubenol	0.7–2.0	0.8–4.2
T-cadinol + α-muurolol + T-muurolol	4.3–6.7	3.5–8.7
α-cadinol	4.9–7.8	2.5–9.6
eudesma-4(15),7-dien-1β-ol	t–0.6	0–0.5
manoyl oxide	0–0.4	t–0.4
abietadiene	0–0.3	t–0.6
abieta-8(14),13(15)-diene	0–0.4	0–0.2

1=current year growth oil
2=one year growth oil
t=trace (<0.05%)

Gornostaeva et al. (1978) determined that the phenol content of *P. sylvestris* oil of Siberian origin was 0.21%.

Using chiral GC, Wilbe et al. (1998) determined that the enantiomeric ratios of some monoterpene hydrocarbons of Norwegian Scots pine oil were as follows:

(1R,5R)-(+)-α-pinene (62.2%):(1S,5S)-(-)-α-pinene (37.8%)
(3R)-(+)-camphene (38.5%):(3S)-(-)-camphene (61.5%)
(1R,4R,5R)-(+)-β-pinene (15.4%):(1S,4S,5S)-(-)-β-pinene (84.6%)
(4R)-(+)-limonene (27.3%):(4S)-(-)-limonene (72.7%)
(1R,4R,5R)-(+)-δ-3-carene (100%):(1S,4S,5S)-(-)-δ-3-carene (0%)
(4S)-(+)-sabinene (3.2%):(4R)-(-)-sabinene (96.8%)
(4R)-(+)-β-phellandrene (5.9%):(4S)-(-)-β-phellandrene (94.1%)

Gora and Lis (2000) compared the composition of Scots pine needle oils produced in the Caucasus and Siberia. The results of this study are presented in **T-2.** Trace amounts of tricyclene, p-cymene and terpinolene were also found in the Caucasian oil.

A commercial sample of Scots pine oil that was screened for its antiplatelet activity by Tognolini et al. (2006) was analyzed by GC-FID and GC/MS. The constituents characterized in this oil were as follows:

tricyclene (1.0%)
α-pinene (22.3%)
camphene (4.2%)
thuja-2,4(10)-diene (0.6%)
β-pinene (13.9%)
myrcene (2.6%)
p-cymene (2.0%)
limonene (9.4%)
δ-2-carene (0.3%)
(Z)-β-ocimene (0.3%)
(E)-β-ocimene (0.3%)
γ-terpinene (0.5%)
p-cymenene (0.8%)
trans-pinocarveol (1.3%)
camphor (0.3%)
menthone (0.3%)
menthol (0.9%)
terpinen-4-ol (1.6%)
isomenthol (1.3%)
p-cymen-8-ol (0.4%)
carvyl acetate* (0.4%)
α-copaene (0.5%)
β-bourbonene (1.4%)
β-elemene (0.5%)
β-caryophyllene (2.8%)
β-copaene (0.5%)
aromadendrene (0.4%)
2-pentadecanone† (0.6%)
α-humulene (0.8%)
(E)-β-farnesene (0.7%)
germacrene D (1.3%)
3-tridecanone (0.6%)
endo-1-bourbonanol (1.1%)
δ-cadinene (2.4%)
α-cadinene (0.7%)
dodecanoic acid (2.0%)
spathulenol (0.9%)
caryophyllene oxide (1.9%)

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

Kaminska (2007) reviewed the plant insect relations between the volatile emissions from *P. sylvestris* needles and the attractiveness to Scots pine insect predators.

Judzentiene et al. (2006 and 2007) examined the effect of the prevailing northeast wind direction from a nitrogen fertilizer factory (Jonava District, Lithuania) on the essential oils produced by young trees (current year growth) and one-year growth of *P. sylvestris*. The oils, which were produced by simultaneous hydrodistillation extraction in 0.25–0.47% (current-year growth) and 0.25–0.49% (one-year growth), were analyzed by GC-FID and GC/MS, the results of which can be seen in **T-3**.

Maciag et al. (2007) reviewed the composition of Scots pine needle oil, however, no new data was presented.

Oils produced from *P. sylvestris* grown in northern Lithuania were analyzed by Judzentiene and Kupcinskiene (2008) using GC-FID and GC/MS. The oils were found to range in composition as follows:

tricyclene + α-thujene (0.1–0.7%)
α-pinene (7.0–30.8%)
camphene (1.8–4.3%)
sabinene + β-pinene (0.6–2.0%)
myrcene (0.7–2.4%)
δ-3-carene (5.2–25.5%)
p-cymene (0.1–0.4%)
limonene + β-phellandrene (0.7–1.8%)
(Z)-β-ocimene (0–0.2%)
(E)-β-ocimene (0.7–1.8%)
γ-terpinene (0.3–0.7%)
terpinolene (1.2–3.9%)
undecane (t–1.3%)
borneol (t–0.3%)
p-mentha-1,5-dien-8-ol (t–0.2%)
terpinen-4-ol (0.2–0.8%)
m-cymen-8-ol (t–0.1%)
p-cymen-8-ol (t–0.2%)
α-terpineol (0.2–1.0%)
2-decanone (0–0.2%)
dodecane (t–0.6%)
methyl thymol (0.1–0.3%)
decanol (0–0.1%)
bornyl acetate (0.8–3.2%)
2-undecanone (0–1.1%)
(E,E)-2,4-decadienal (t–1.2%)
δ-elemene (0.4–1.2%)
α-terpinyl acetate (0.3–1.1%)
α-copaene (0–0.2%)
β-bourbonene (t–0.4%)
β-elemene (0.7–1.8%)
tetradecane (0.1–0.4%)
β-caryophyllene (2.6–5.8%)
β-copaene (0–0.3%)
β-gurjunene (0–0.2%)
aromadendrene (t–0.3%)
trans-muurola-3,5-diene (0–0.2%)
α-humulene (0.7–1.5%)
(E)-β-farnesene (0–0.3%)
cis-muurola-4(14),5-diene (t–0.4%)
γ-muurolene (1.0–1.5%)
germacrene D (0.8–1.9%)
β-selinene (0.2–0.8%)
trans-muurola-4(14),5-diene (t–0.2%)
bicyclogermacrene (1.1–2.4%)
α-muurolene (0.6–1.6%)
γ-cadinene (1.3–3.2%)
δ-cadinene (2.0–5.9%)
trans-cadina-1(2),4-diene (t–0.4%)
α-cadinene (t–0.3%)
α-calacorene (t–0.2%)
β-calacorene (t–0.1%)
(Z)-3-hexenyl benzoate (0–0.2%)
germacrene D-4-ol (0.2–3.4%)
spathulenol (0.1–2.0%)
caryophyllene oxide (t–0.6%)
gleenol (0–0.2%)
β-oplopenone (0–0.8%)
1,10-di-epi-cubenol (0.2–0.5%)
1-epi-cubenol (0.2–1.1%)
α-muurolol + T-cadinol +T-muurolol (3.8–9.1%)
α-cadinol (3.7–8.5%)
manoyl oxide (0–1.0%)
abietadiene (t–0.5%)
abieta-8(14),13(15)-diene (0.1–0.4%)

t=trace (<0.05%)

Kupcinskiene et al. (2008) studied the effect of a range of industrial emissions on the concentrations of constituents found in the needle oils of *P. sylvestris* growing in Lithuania. They found that the δ-3-carene and terpinolene levels decreased when the trees were grown near a cement factory, while there was an increase in the levels of camphene, sabinene and β-pinene bear an oil refinery.

Yang et al. (2010) collected pine cones of *P. sylvestris* from Heilongjang province (China) and subjected them to hydrodistillation for 3 hrs to yield 0.8% oil. Analysis of this pine cone oil using GC-FID and GC/MS revealed that it possessed the following composition:

α-pinene (18.5%)
camphene (0.5%)
β-pinene (0.9%)
myrcene (0.2%)
δ-3-carene (0.8%)
α-terpinene (1.0%)
limonene (3.3%)
p-cymene (0.1%)
β-phellandrene (1.0%)
γ-terpinene (2.5%)
terpinolene (0.9%)
trans-pinocarveol (3.0%)
camphor (1.4%)
borneol (2.0%)
p-cymen-8-ol (2.6%)
α-terpineol (5.5%)
carvone (1.5%)
isobornyl acetate (1.3%)
bornyl acetate (1.2%)
α-longipinene (10.5%)
longicyclene (1.0%)
α-ylangene (0.2%)
α-cubebene (0.7%)
aromadendrene (20.2%)
α-selinene (0.2%)
isolongifolan-8-ol (0.2%)
longicamphenylone (0.6%)
caryophyllene oxide (3.6%)

In addition, trace amounts (<0.1%) of α-copaene, β-caryophyllene and α-cadinene were characterized in this oil.

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