Progress in Essential Oils

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Juniper Berry Oil

Juniper berry oil is produced from the steam distillation of the ripe bellies of *Juniperus communis* L. According to Farjon (2001, 2005), the following varieties are recognized:

J. communis var. *communis* (Northern Europe)

J. communis var. *depressa pursh* (North America)

J. communis var. *megistocarpa* Fernald et St. John (Eastern Canada)

J. communis var. *saxatilis* Pall. (Europe, Siberia, Central Asia, Far East, Greenland, Iceland and far Western North America)

Other varieties Farjon did not recognize are:

J. communis var. *hemispherica* (J. etc. Presli) Nyman (Sicily, Mediterranean)

J. communis var. *oblonga* (M. Bict) Pall (Caucuses Mountains)

J. communis var. *nipponiza* (Maxim.) E.lt. Wilson (Japan)

J. communis var. *charloltensis* R.P. Adams

J. communis var. *jackii* Rehder

Nevertheless, juniper berry oil ex *J. communis* irrespective of variety can occasionally be found as a source of the juniper berry oil of commerce.

Tasic et al. (1993) collected juniper berries from different areas (Brezovica, Gova, Besovo, Velika, Prijepolje and Prilep) in Croatia in September. The oils, which were produced in the laboratory, were subjected to analysis by GC-FID and GC/MS. The constituents characterized in these oils ranged as follows:

α-thujene (0.5–1.5%)
α-pinene (31.2–39.7%)
camphene (0.1–1.2%)
sabinene (9.3–19.4%)
β-pinene (1.1–3.2%)
myrcene (5.3–16.4%)
δ-3-carene (0–0.7%)
α-terpinene (0.1–0.4%)
p-cymene (0–1.4%)
limonene (3.0–7.9%)
γ-terpinene (0.2–0.9%)
sabinene hydrate* (0.1–0.2%)
terpinolene (0.5–1.9%)
linalool (t–0.1%)
terpinen-4-ol (0.5–1.9%)
α-terpined (0.1–0.6%)
bornyl acetate (0.1–0.4%)
citronellyl acetate (0–0.5%)
neoisothujyl acetate (t–0.2%)
neryl acetate (t–1.5%)
α-cubebene (0.1–0.8%)
α-copaene (0.4–1.0%)
β-elemene (0.4–2.1%)
epizonarene (0.1–0.5%)
γ-elemene (1.1–3.3%)
β-farnesene* (0.7–1.0%)
junipene‡ (0–0.1%)
α-humulene (0.1–3.7%)
β-cubebene† (3.2–6.4%)
α-muurolene (0–0.3%)
γ-cadinene (0–0.4%)
δ-cadinene (0.7–1.3%)

t = trace (<0.05%); * correct isomer not identified;
† incorrect identification based on GC elution order;
‡ also known as longifolene

Emami et al. (2007), using GC-FID and GC/MS, analyzed a particular oil collected from the Damloa and Sefaili regions (Golestan, Iran), which is produced from the berries of *J. communis* subsp. *hemisphaerica* (Fresl.) Nyman. The components characterized in this oil were:

α-thujene (0.9%)
α-pinene (13.6%)
sabinene (25.1%)
myrcene (3.6%)
α-terpinene (1.1%)
p-cymene (2.3%)
limonene (9.1%)
γ-terpinene (5.2%)
terpinolene (3.0%)
terpinen-4-ol (8.7%)
citronellol (0.95%)
α-terpinyl acetate (2.8%)
β-elemene (2.5%)
β-caryophyllene (2.9%)
α-humulene (0.7%)
germacrene D (5.3%)
α-bisabolene* (<0.1%)
δ-cadinene (0.5%)
caryophyllene oxide (6.5%)
α-bisabolol (0.4%)

* correct isomer not identified

Butkiene et al. (2007) collected berries from *J. communis* var. *communis* growing in Druskinkai district (Lithuania). Oils produced from both unripe and ripe berries were analyzed by GC-FID and GC/MS and the results can be seen in **T-1**. Hassanzadeh et al. (2008) repeated the results of the analysis described by Emami et al. (2007).

Romeo et al. (2008) screened some commercial oils for their antimicrobial activity. One of two oils included in this study was juniper berry oil. Using GC-FID and GC/MS, the composition of this juniper berry oil was found to be as follows:

α-pinene (29.2%)
camphene (0.6%)
benzaldehyde (0.5%)
sabinene (0.1%)
β-pinene (8.7%)
myrcene (0.8%)
δ-3-carene (0.7%)
p-cymene (1.0%)
limonene (13.2%)
1,8-cineole (2.9%)
linalool (0.2%)
α-fenchol (0.7%)
alloocimene* (2.6%)
trans-pinocarveol (1.9%)
(E,E)-alloocimene (0.7%)
borneol (0.8%)
terpinen-4-ol (2.7%)
p-cymen-8-ol (2.2%)
α-terpineol (6.0%)
myrcenol (1.6%)
verbenone (2.5%)
trans-carveol (0.8%)
cis-carveol (0.5%)
carvone (0.3%)

T-1. Percentage composition of juniper berry oils produced from both unripe and ripe berries of Lithuanian origin

Compound	Unripe berry oil	Ripe berry oil
α-pinene	42.4–67.4	48.1–48.5
camphene	0.1–0.3	0.1–0.2
verbenene	0–0.6	0–0.3
sabinene	0.1–0.2	0.8–1.7
β-pinene	1.6–2.2	1.3–2.1
myrcene	0.1–3.9	12.2–13.8
δ-3-carene	t–0.1	t
α-terpinene	t–0.1	t–0.1
p-cymene	0.1	t
limonene	1.2–1.4	1.6–2.5
β-phellandrene	0.2–0.5	0.5–0.9
(+)-γ-pinene	0.1	0.1–0.2
terpinolene	0.5–0.6	0.5–1.4
linalool	0.1	0.2–0.6
α-campholenal	0.1–1.6	0.2–0.3
trans-pinocarveol	t–4.3	0.2–0.4
trans-verbenol	t–5.1	0.1–0.6
camphene hydrate	-	0–t
p-mentha-1(7), 2-dier-8-ol	0–0.8	-
borneol	0.1–0.4	0.6–0.9
p-mentha-1,5-dier-8-ol	0–2.9	-
terpinen-4-ol	0.4–0.6	0.9–1.5
p-cymen-8-ol	t–0.5	0.1–0.2
α-terpineol	0.4–0.6	0.8–1.2
verbenone	0.1–1.7	0.2
trans-carveol	t–0.8	0.1
citronellol	0–0.2	t–0.5
trans-chrysanthenyl acetate	-	0–t
carvone	0–0.1	-
piperitone	0–0.1	-
methyl citronnellate	0.1–0.4	0.1–0.9
trans-myrtanol	-	0–t
bornyl acetate	1.1–2.3	1.6–2.0
thymol	-	0–t
trans-pinocarvyl acetate	0–t	-
tridecane	0–t	-
myrtenyl acetate	0–0.1	-
δ-elemene	0–0.1	t–0.1
α-terpinyl acetate	0.1–0.3	0.1
thymyl acetate	0–0.2	0–t
citronellyl acetate	t–0.1	0.1
α-copaene	t	t
trans-myrtanyl acetate	t–0.1	t
β-bourbonene	-	0–t
β-elemene	0.2–0.5	0.3–0.5
longifolene	-	0–t
β-caryophyllene	t	t–0.2
β-ylangene	-	0–0.1
(E)-α-ionone	0–0.1	-
β-gurjunene	-	0–t
γ-elemene	t–0.2	0.1–0.2
(Z)-β-fasnesene	0–t	t–0.1

Compound	Unripe berry oil	Ripe berry oil
cis-muurola-3,5-diene	-	0–t
trans-muurola-3,5-diene	-	t–0.1
α-humulene	-	0.2–0.3
cis-muurola-4(14),5-diene	t	t
trans-cadina-1(6),4-diene	t–0.1	t
γ-muurolene	t–0.6	0.1
germacrene D	0.4–0.6	0.7–0.4
(E)-β-ionone	0–0.1	t–0.3
β-selinene	0–0.2	0.1
δ-selinene	0–0.1	-
trans-muurola-4(14), 5-diene	0–0.3	0.1–0.4
α-muurolene	0.2–0.6	0.5–0.9
γ-cadinene	0.1–0.3	0.4
endo-1-tourbanalol	t	t–0.2
δ-cadinene	0.5–1.5	2.0–2.1
zonarene	0–0.1	-
citronellyl butyrate	0.2–0.4	t–0.5
trans-cadina-1(2),4-diene	t–0.1	t–0.2
α-cadinene	t–0.1	0.1–0.2
elemol	0.2–0.4	0.4–0.5
germacrene B	0–0.3	0–0.2
germacrene D-4-ol	1.4–5.6	1.3–3.1
caryophyllene oxide	0.1–0.9	0.2–0.4
viridiflorol	0–2.0	-
salvia1-4(14)-en-1-one	t–0.2	0.1
β-oplopenone	0–0.4	0–0.3
humulene epoxide II	0.1–1.3	0–0.4
1,10-di-epi-cubenol	t–0.1	0.1–0.2
1-epi-cubenol	0.1–0.2	0.2–0.3
γ-eudesmol	t	0.1–0.2
T-cadinol	0.3–0.7	1.1–1.2
T-muurolol	0.3	0.9
α-muurolol	0.2–0.3	0.3–1.0
α-cadinol	1.1–1.5	3.4–5.1
selin-11-en-4α-ol	0.4–0.9	0–0.1
14-hydroxy-9-epi-β-caryophyllene	0.3–1.5	0.3–0.7
selina-4(15),7-dien-1β-01	0–0.6	0–0.5
(Z,Z)-farnesol	0–t	0–t
selin-7(11)-en-4-01	0.1–0.4	0.3
14-hydroxy-α-humulene	0–0.2	0.2–0.5
nootkatol	0.2–1.0	0.2–0.4
oplopanone	0.2–0.6	0.1–0.3
cyclocolorenone	-	0–0.2
14-oxy-α-muurolene	-	0–t
14-hydroxy-α-muurolene	t–0.1	0.2
hydroxyl-δ-cadinene*	-	0–0.1
nootkatone	-	0-0.1
cyclopentadecanolide	t	t–0.1
manoyl oxide	-	0–t
abietatriene	t–0.1	t–0.1
octadecanol	-	0–t
abietadiene	t–0.1	t

bornyl acetate (0.5%)
longifolene (1.2%)
isocaryophyllene (0.5%)
α-humulene (0.4%)
α-muurolene (0.3%)
γ-cadinene (0.3%)
germacrene D-4-ol (0.6%)

Lohani et al. (2010) analyzed an oil produced by hydrodistillation of juniper berries that was collected from Shibok (Chamoli District, Uttarakhand, India) using GC/MS as their only method of analysis. The oil was determined to possess the following composition:

α-thujene (0.3%)
α-pinene (10.8%)
camphene (0.2%)
verbenene (0.2%)
sabinene (5.4%)
β-pinene (1.3%)
myrcene (3.6%)
δ-2-carene (0.1%)
δ-3-carene (0.5%)
α-terpinene (0.2%)
p-cymene (0.1%)
limonene (15.1%)
1,8-cineole (0.2%)
γ-terpinene (0.4%)
cis-sabinene hydrate (0.2%)
terpinolene (0.2%)
trans-sabinene hydrate (0.3%)
linalool (0.5%)
α-thujone (0.3%)
β-thujone(0.3%)
p-menth-2-en-1-ol* (0.6%)
α-campholenal(1.8%)
trans-pinocarveol (0.2%)
cis-verbenol (3.3%)
trans-verbenol (2.2%)
citronellal (0.7%)
borneol (0.5%)
terpinen-4-ol (8.8%)
p-cymen-8-ol (1.2%)
α-terpineol (1.1%)
myrtenol (1.5%)
verbenone (0.6%)
trans-carveol (1.7%)
citronellol (1.3%)
cis-carveol (0.4%)
myrtenyl acetate (5.0%)
carvone (0.8%)
methyl citronellate (3.6%)
bornyl acetate (1.4%)
thymol (0.1%)
α-terpinyl acelate (0.2%)
α-cubebene (0.2%)
α-copaenal (0.1%)
β-cubebene (0.5%)
β-elemene (0.5%)
β-bisabolene (2.0%)
γ-cadinene (0.3%)
elemol (1.0%)
germacrene B (0.5%)
caryophyllene oxide (0.3%)
T-muurolol (1.8%)
cubenol (0.1%)
α-muurolol (0.3%)
α-cudesmol (0.1%)
α-cadinol (0.9%)
α-bisabolol (1.6%)

* correct isomer not identified

Trace amounts (<0.05%) of tricyclene, α-phellandrene and β-eudesmol were also found in this oil. Loziene et al. (2010) collected juniper berries from shrubs cultivated at the Institute of Botany (Natural Research Center, Vilnius, Lithuania) and determined that two morphotypes could be distinguished by their berry color. One type had light-green berries when mature, while the other type had the typical bluish-green berries. Oils produced from both berry types were analyzed by GC-FID and GC/MS. The results of this comparative study are shown in **T-2**. As can be seen, the oils can be readily differentiated based on their myrcene, β-caryophyllene and caryophyllene oxide contents.

Using chiral GC, Loziene et al. determined that the enantiomeric ratio of α-pinene in the oil of light-green berries was as follows: (1S,5S)-(-)-α-pinene(11.1–11.4%):(1R,5R)-(+)- α-pinene (88.6–88.9%) while is the oil produced from bluish-green berries it was: (1S,5S)-(-)-α-pinene (31.4–31.6%):(1R,5R)-(+)-α-pinene (68.4–68.6%)

Rezvani (2010) determined that an oil produced from the powdered dried berries of *J. communis* collected in Chahar Bagh, Golestan (Iran) possessed the following composition:

α-pinene (46.6%)
α-ferchene (0.3%)
sabinene (0.6%)
β-pinene (1.4%)
myrcene (1.5%)
δ-3-carene (9.9%)
limonene (1.9%)
terpinolene (2.5%)
terpinen-4-ol (2.9%)
α-terpineol (0.9%)
carvone (0.7%)
carvacrol (0.8%)
γ-terpinene† (0.5%)
terpinolene† (4.6%)
α-amorphene† (1.0%)
β-caryophyllene† (1.1%)
α-humulene (1.0%)
germacrene D (1.8%)
α-muurolene (0.9%)
β-cadinene† (1.4%)

T-2. Percentage composition of oils produced from the berries of two morphotypes of *Juniperus communis*

Compound	Light-green berry oil	Bluish-green berry oil
α-pinene	33.5–37.2	32.3–35.6
β-pinene	0–0.3	0.5–0.6
myrcene	16.0–16.6	24.2–24.4
p-cymene	4.6–5.0	1.4–1.7
trans-carvyl acetate	0.2	0.9
α-cubebene	0.2	0.2
β-bourbonene	3.8–4.2	0.4
β-caryophyllene	1.6–1.7	9.8–11.3
β-gurjunene	0.5–0.6	0.8–1.1
(E)-isoeugenol	0.1	0.4
α-humulene	2.2–2.7	7.0–7.6
allo-aromadendrene	0.3	0.1–0.2
germacrene D	1.6–2.0	2.7–3.4
δ-muurolene	0.4	0.1
β-bisabolene	1.1	0.2
γ-cadinene	0.7–1.0	0–0.6
δ-cadinene	1.9	0.1–0.5
caryophyllene oxide	5.6–10.0	0.1–0.5
1,10-di-epi-cubenol	0.3	0–0.1
T-cadinol	0.5	0–0.1
α-cadinol	2.7–3.7	0–0.1

β-elemene† (0.9%)
junipene† (0.7%)
α-cedrol (12.4%)
γ-cadinene (1.3%)
δ-cadinene (0.9%)
α-cadinene (1.1%)
α-cadinol (0.5%)

[a] also known as longifolene
† incorrect identification based on GC elution order

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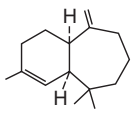
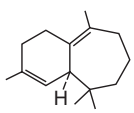
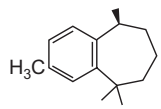
F-1. Uncommon sesquiterpenoids found in *Homalomena aromatica* rhizomes



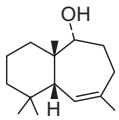
α-Himachalene



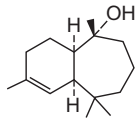
β-Himachalene



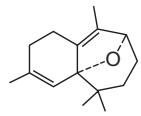
ar-Himachalene



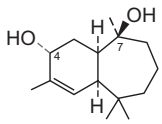
Himachalol
(2-himachalen-7-ol)



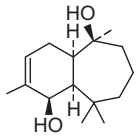
allo-Himachalol



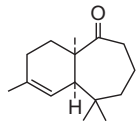
Isohimachalone
(7-oxo-2-himachalene)



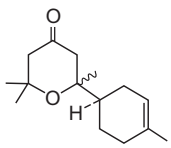
Centdarol
(3-himachaene-2,7-diol)



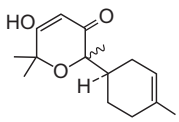
Isocentdarol
(2-himachalene-4,7-diol)



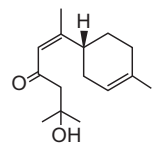
Oxidohimachalene
(1,8-epoxy-2,6-himachaladiene)



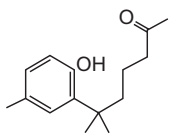
Deodarone



Deodardione



α-Atlantolone
(Z- and E-)



Himasecolone

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S. Rezvani, *Analysis of essential oil of* Juniperus communis *and terpenoids dried fruits from Codestan of Iran.* Asian J. Chem, **22**(2), 1–3 (2010).

Sugandh Mantri Gandhi Roots Oil

Sugandh mantri, also known as Gandhi root, is a member of the Aracea family. It can be found growing in northern India in Assam, the Sikkim region of the Himalayas, the Khasi Hills, Cooch Behar, Tripura, southern Manipur and the Sylhet and Chittagong districts of Bangladesh. It is found throughout Southeast Asia from Vietnam to Malaysia, the Philippines, Indonesia, New Guinea and adjacent islands. Its botanical origin is *Homalomena aromatica* (Roxb.) Schott. It is a large herbaceous, slow-growing pericardial plant that possesses large rhizomes which are used in snuff manufacture. It is also a component of hina attar in India and is used in traditional medicine throughout Southeast Asia. The oil of sugandh mantri is available in India in limited quantities.

Sharma et al. (1966) reported that the oil was rich in linalool (50.5%). Other minor components Sharma et al. reported were tentatively identified including α-pinene, β-pinene, limonene, terpinolene, linalyl acetate and dihydrocuminaldehyde.

Bahadur and Gupta (1966) used retention times only for characterization of the components of an oil produced in the laboratory from powdered dried rhizomes. The constituents tentatively identified were:

α-pinene (1.1%)
camphene (3.8%)
limonene (4.3%)
terpinolene (4.5%)
dehydrocuminaldehyde (4.2%)
linalyl acetate (2.2%)
linalool (49.9%)
cadinene* (23.2%)

* correct isomer not identified

Todorova et al. (1988) analyzed an oil produced in the laboratory from the rhizomes collected in Thanh Hoa Province (Vietnam). The components characterized in this oil were:

β-pinene (0.6%)
sabinene (1.0%)
δ-3-carene (1.3%)
limonene (0.5%)
β-phellandrene (0.3%)
γ-terpinene (0.6%)
linalool (71.2%)
linalyl acetate (3.3%)
β-elemene (0.8%)
β-caryophyllene (1.0%)
terpinen-4-ol (4.6%)
aromadendrene (0.4%)
α-muurolene + β-copaenet (0.6%)
α-terpineol + carvomentyl acetatet (1.2%)
γ-muurolene (0.3%)
geraniol, nerolt + geranyl acetate (0.3%)
p-cymen-8-ol (0.2%)
piperitone (0.2%)
ledolt (0.2%)
3-phenylpropanal (0.4%)
α-muurolol (0.2%)
cedrenolt (0.8%)

t tentative identification

Trace amounts (<0.1%) of α-phellandrene, α-cubebene, α-copaene, a linalool oxide isomer, β-bisabolene, α-terpinyl acetate, methyl geranate and δ-cadinene were also found in this oil.

Sung et al. (1992a) examined a flash chromatographic fraction of a chloroform extract of *H. aromatica* rhizomes of Vietnamese origin. In this fraction they characterized α-cadinol, T-muurolol and two new sesquiterpene alcohols, which they named homalomenol C and homalomenol D (see **F-1**). Further studies on the same fraction (Sung et al. 1992b) resulted in the structural elucidation of three new sesquiterpenoid alcohols: homalomenol A, homalomena B and 1b,4b,7a-trihydroxyeudesmane. Other known constituents found in this fraction were oplopanone, oplodiol and ballatantriol (see **F-1**).

Sung et al. (2000) examined a hydrodistilled oil of *H. aromatica* produced from rhizomes that were collected from Gopal Nagar (Assam, India) using GC-FID and GC/MS. The constituents characterized in this oil were:

sabinene (0.5%)
δ-3-carene (0.5%)
α-terpinene (1.0%)
p-cymene (0.9%)
β-phellandrene (0.3%)
limonene (0.3%)
γ-terpinene (1.9%)
cis-linalool oxide[f] (0.2%)
trans-linalool oxide[f] (0.3%)
terpinolene (0.5%)
linalool (62.5%)
terpinen-4-ol (17.2%)
α-terpineol (2.4%)
eucarvone (0.3%)
nerol (1.4%)
geraniol (1.8%)
phellandral (0.3%)
spathulenol (1.0%)
caryophyllene oxide (0.2%)
T-cadinol (1.0%)
α-cadinol (1.5%)
oplopanone (0.4%)
2-octanol-2-cyclohexen-3-ol[t] (0.4%)

[f] furanoid form; [t] tentative identification

In addition, trace amounts (<0.1%) of α-thujene, β-pinene, myrcene, α-phellandrene, (Z)-β-ocimene, (E)-β-ocimene, *cis*-p-menth-2-en-1-ol, *trans*-p-menth-2-en-1-ol, cryptone, cuminaldehyde, piperitone, cuminyl alcohol, neryl acetate, δ-cadinene, α-selinene and oplodiol were also characterized in this oil.

Chowdhury et al. (2008) performed an analysis on a lab distilled rhizome oil of *H. aromatica* that was collected from Chittagong, Bangladesh. The authors determined the main constituents of this oil were:

linalool (69.5%)
terpinen-4-ol (2.9%)
spathulenol (1.0%)
T-muurolol (1.0%)
α-cadinol (2.7%)

However, the authors misidentified another eight compounds that are not included in this review.

Rana et al. (2009), only using GC/MS, analyzed an oil produced by hydrodistillation from *H. aromatica* rhizomes collected from Jiribum (Imphal East district, Manipur, India). The oil was found to contain the following constituents:

cis-linalool oxide[f] (0.8%)
trans-linalool oxide[f] (0.8%)
linalool (58.3%)
cis-p-menth-2-en-1-ol (0.1%)
trans-p-menth-2-en-1-ol (0.3%)
p-mentha-1,5-dien-8-ol (0.3%)
terpinen-4-ol (16.7%)
cryptone (1.4%)
p-cymen-8-ol (0.1%)
α-terpineol (1.8%)
nerol (0.1%)
cuminaldehyde (0.2%)
car-3-en-2-one (0.2%)
piperitone (0.2%)
β-caryophyllene (0.1%)
α-humulene (0.1%)
alloaromadendrene (0.1%)
α-selinene (0.3%)
α-muurolene (0.1%)
γ-cadinene (0.1%)
δ-cadinene (0.4%)
spathulenol (1.5%)
ledol (0.3%)
humulene epoxide II (0.6%)
T-cadinol (1.0%)
α-cadinol (1.7%)
oplopanone (1.0%)
hexadecanoic acid (0.1%)

[f] furanoid form

In addition, a trace amount (0.05%) of carvone and α-calacorene was also found in this oil.

M.L. Sharma, M.C. Nigam, K.L. Handa and P.R. Rao, *Chemical and gas chromatographic investigation of linalool and linalyl acetate bearing plants in India.* India Oil Soap J., **31**, 303–307 (1966).

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T.V. Sung, B. Steffan, W. Steglich, G. Klebe and G. Adam, *Sesquiterpenes from the roots of* Homalomena aromatica. Phytochemistry, **31**, 3515–3520 (1992b).

J.U. Chowdhury, M. Yusuf and M.M. Hussain, *Aromatic plants of Bangladesh: constituents of rhizome oil of* Homalomena aromatica. Indian Perfum., **52**(1), 33–34 (2008).

V.S. Rana, M. Pukhrambam, H.B. Singh, M. Verdeguer and M.A. Blázquez, *Essential oil composition of* Homalomena aromatica *roots.* Indian Perfum., **53**(4), 43–44 (2009).

Himalayan Cedar Leaf Oil

Hirao and Izawa (1980) reported that an oil produced from the twigs and leaves of *Cedrus deodara* (Roxb.) Loud. Produced via steam distillation contained the following constituents:

α-pinene (16.8%)
β-pinene (21.4%)
myrcene (24.9%)
limonene (2.8%)
terpinolene (1.8%)
α-terpineol (16.9%)
β-caryophyllene (10.7%)
α-humulene (2.7%)

Trace amounts (<0.1%) of camphene, p-cymene, borneol, bornyl acetate, α-terpinyl acetate, α-muurolene and δ-cadinene were also found in this oil.

Akimov (1986) examined the volatile emission from *C. deodara* trees growing along the Crimean coast in the former Soviet Union. He also analyzed oils isolated from leaves and twigs harvested at different times in a year. The constituents characterized were:

α-pinene (20.2–29.9%)
camphene (0.5–2.0%)
sabinene (17.3–23.0%)
myrcene (23.5–33.3%)
δ-3-carene (0.2–0.8%)
limonene (4.4–9.0%)
β-phellandrene (0.3–3.7%)
terpinolene (0.6–1.2%)
sesquiterpenes (9.6–17.5%)

In 1988, Yatagai and Takahashi analyzed the needle oil composition of

Himalayan cedar (*C. deodara*) grown in Japan. The components identified in this oil were as follows:

α-pinene (34.1%)
α-fenchene (0.1%)
camphene (0.8%)
β-pinene (28.0%)
sabinene (0.2%)
δ-3-carene (12.1%)
α-terpinene (0.2%)
limonene (4.7%)
β-phellandrene (1.8%)
γ-terpinene (0.2%)
p-cymene (0.1%)
terpinolene (2.1%)
(Z)-3-hexenyl acetate (0.1%)
α-copaene (0.2%)
α-fenchol (0.5%)
bornyl acetate (0.2%)
terpinen-4-ol (0.4%)
β-caryophyllene (4.0%)
α-humulene (0.7%)
α-terpineol (8.1%)
α-muurolene (0.1%)
δ-cadinene (0.3%)
germacrene D (0.7%)

Zhu et al. (1993) reported the results of an analysis of the oil produced from the leaves and twigs of *C. deodara* growing in southwestern Xizang (Tibet Autonomous Region, China). The constituents identified in the oil were:

α-pinene (19.9%)
camphene (0.6%)
β-pinene (25.5%)
myrcene (24.3%)
α-phellandrene (0.1%)
δ-3-carene (0.1%)
limonene (4.5%)
γ-terpinene (0.1%)
δ-2-carene[*] (1.3%)
fenchene[*] (0.4%)
camphor (0.4%)
borneol (0.5%)
terpinen-4-ol (0.3%)
azulene[*] (0.3%)
α-terpineol (13.1%)
bornyl acetate (0.5%)
α-copaene (0.1%)
β-caryophyllene (2.6%)
α-humulene (0.6%)
β-cubebene[*] (1.1%)
α-muurolene (0.1%)
δ-cadinene (0.2%)
α-muurolol (0.2%)
T-cadinol (0.2%)

[*] incorrect identification based on GC elution order

Ramachandraiah et al. (2000) analyzed an oil produced from the seeds of *C. deodara* and found that it possessed the following composition:

tricyclene (0.1%)
α-pinene (47.9%)
camphene (1.2%)
β-pinene (33.4%)
myrcene (<0.1%)
α-phellandrene (0.3%)
p-cymene (0.4%)
limonene (1.3%)
cis-linalool oxide[f] (0.1%)
trans-linalool oxide[f] (0.2%)
p-cymenene (0.1%)
terpinolene (0.1%)
linalool (0.2%)
camphor (3.0%)
citronellal (0.1%)
isopulegol (0.4%)
borneol (0.4%)
terpinen-4-ol (0.4%)
α-terpineol (1.6%)
decanal (0.4%)
trans-carveol (0.6%)
cis-carveol (0.1%)
citronellol (0.1%)
nerol (0.1%)
carvone (0.3%)
geraniol (0.5%)

bornyl acetate (0.2%)
terpinen-4-yl acetate (0.1%)
citronellyl acetate (0.1%)
neryl acetate (0.3%)
α-copaene (0.1%)
β-caryophyllene (0.1%)
α-guaiene (0.1%)

[f] furanoid form

N. Hirao and I. Izawa, *On the constituent of the essential oil of Himaray-sugi* (Cedrus deodara *Loud.) planted in Higashiosaka-shi.* Kinki Daigaku Rikogakubu Kenkyu Hokoku, (15), 61–64 (1986).

V.A. Akimov, *Comparative analysis of volatile organic compounds from plants by gas-liquid chromatography.* J. Chromatogr., **365**, 155–160 (1986).

M. Yatagai and T. Takahashi, *Evaluation of essential oil producing conifers.* Baiomasu Henkan Keikaku Kenkyu Hokoku, (9), 3–30 (1988).

L.-F. Zhu, Y.-H. Li, B.-L. Li, B.-Y. Lu and N.-H. Xia, *Aromatic Plants and Essential Oil Constituents.* P. 233, Peace Book Co. Ltd., Hong Kong, China (1993).

O.S. Ramachandraiah, G.Azemoddin, G.R. Mallavarapu and S. Ramesh, *Oils and aroma chemicals from Deodar* (Cedrus deodara) *seeds.* FAFAI, (Oct/Nov), 19–22 (2000).

Boldo Leaf Oil

Boldo (*Peumus boldus* Mol.), a shrub-tree known to possess medicinal properties, is found growing in central Chile. Vogel et al. (1999) determined that a few of the constituents of the oils produced from different regions of Chile varied slightly in their quantitative amounts. These were:

ascaridole (26.0–34.6%)
p-cymene (1.8–3.9%)
1,8-cineole (0.1–0.5%)
limonene (trace–0.1%)
γ-terpinene (trace–0.1%)

Villa et al. (1999) used GC-FID and GC/MS to analyze a lab-distilled oil of *P. boldus* leaves that were collected from the VIII region of Bio-Bio (Chile). The oil was found to possess the following composition:

α-thujene (0.6%)
α-pinene (5.3%)
camphene (0.3%)
β-pinene (2.3%)
sabinene (6.3%)
δ-3-carene (0.2%)
α-phellandrene (1.4%)
α-terpinene (0.6%)
limonene (17.0%)
β-phellandrene (8.4%)
γ-terpinene (1.4%)
p-cymene (13.6%)
terpinolene (0.4%)
1,8-cineole (11.8%)
trans-sabinene hydrate (0.8%)
campholenaldehyde (0.9%)
camphor (0.2%)
linalool + *cis*-sabinene hydrate (3.2%)
pinocarvone (0.4%)
bornyl acetate (0.5%)
terpinen-4-ol (5.3%)
trans-pinocarveol (0.5%)
neral (0.1%)
cryptone (0.3%)
α-terpineol (5.2%)
ascaridole (1.0%)
geranial (0.4%)
carvone (0.4%)
cuminaldehyde (0.1%)
trans-carveol (0.3%)
carvacrol (0.3%)
β-caryophyllene (0.1%)
α-humulene (0.1%)
bicyclogermacrene (0.1%)
caryophyllene oxide (0.1%)
(E)-nerolidol (0.4%)
farnesol* (0.4%)
2-nonanone (0.1%)

* correct isomer not identified

Trace amounts (<0.05%) of a linalool oxide isomer, myrtenal, myrtenol, thymol and 2-undecanone were also found in this oil. It is of interest to note that this analysis reveals that oils of *P. boldus* are not all rich in ascaridole. This may be an example of the occurrence of chemotype forms of boldo.

α-pinene (0.3%)
camphene (0.1%)
sabinene (1.2%)
β-pinene (0.2%)
α-terpinene (0.3%)
p-cymene (16.3%)
β-phellandrene (0.3%)
γ-terpinene (0.4%)
p-mentha-1,3,8-triene (0.6%)
2-cyclohexen-1,4-dione (0.1%)
2-nonanone (0.1%)
2-undecanone (0.2%)
dehydro-1,8-cineole (0.1%)
1,8-cineole (14.5%)
cis-sabinene hydrate (0.6%)
trans-sabinene hydrate (0.5%)
dehydrosabina ketone (0.8%)
trans-pinocarveol (1.5%)
camphor (0.1%)
pinocarvone (0.3%)
δ-terpineol (0.6%)
terpinen-4-ol (2.2%)
α-terpineol (0.1%)
myrtenal (0.1%)
myrtenol (1.1%)
ascaridole (51.2%)
cis-piperitone oxide (0.8%)
bornyl acetate (0.1%)
thymol (0.1%)
cumin alcohol (0.1%)
carvacrol (0.2%)
spathulenol (0.1%)
β-oplopenone (0.2%)
methyl eugenol (1.2%)

Trace amounts (<0.05%) of α-phellandrene, δ-3-carene, p-cymene, fenchone, linalool, sabina ketone, thuj-3-en-10-al, cryptone and *trans*-piperitone oxide were also found in this oil. The authors determined that the oil possessed strong phytotoxic activity against the commonly encountered weeds *Amaranthus hybridus* and *Portulaca oleracea.*

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M. Verdeguer, D. Garcia-Rellan, H. Boira, E. Perez, S. Gandolfo and M. Amparo Blazquez, *Herbicidal activity of* Peumus boldus *and* Drimys winteri *essential oils form Chile.* Molecules, **16**, 403–411 (2011).