Progress in Essential Oils

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Chamomile Oil

Chamomile oil is produced by steam distillation of the flower heads of *Chamomilla recutita* (L.) Rausch. (syn. *Matricaria recutita* L., *Matricaria chamomilla* L.).

The main components of a lab-distilled chamomile oil that was produced by hydrodistillation from the flower heads of chamomile grown in Brazil were determined by Maia et al. (2004) to be:

β-farnesene* (4.9%)
bisabolol oxide B (9.4%)
bisabolol oxide A (56.5%)

*correct isomer not identified

Orav et al. (2010) examined the composition of lab-distilled oils of *C. recutita* of various European origin using GC-FID and retention indices only. The origins of the various flower samples were either purchased from a pharmacy in Europe or from cultivation in Estonia in an experimental garden. The only cultivated samples were Estonian cultivar 1 and the English cultivar. A summary of the analytical results can be seen in **T-1**. Examination off the results reveals that the chamomile oils can be subdivided according to their main constituents as follows:

1. Estonian cultivar 1: α-bisabolol oxide A > bisabolone oxide A > α-bisabolol oxide B > *cis*-bicyclo ether
2. Estonian cultivar 1: α-bisabolol oxide A > α-bisabolol > *cis*-bicyclo ether > α-bisabolol oxide B
3. Estonian 3, Greek, Scottish, German, English and Latvian cultivars: α-bisabolol oxide A > *cis*-bicyclo ether
4. Armenian cultivar: α-bisabolol oxide B > chamazulene > α-bisabolol oxide A = *cis*-bicyclo ether > bisabolone oxide A
5. Czech cultivar: α-bisabolol > *cis*-bicyclo ether

T-1. Comparative percentage composition of the dried flower oils of *Chamomilla recutita* of various origins

Compound	1	2	3	4	5	6	7	8
α-pinene	0.1	t	0–0.1	-	-	-	-	-
p-cymene	0.2	0.1	0.1–0.3	0.1	t	-	-	t
limonene	0.1	t	0–0.4	0.1	t	-	-	t
1,8-cineole	0.1	0.1	t–0.3	0.5	0.1	t	t	0.1
artemisia ketone	1.2	0.4	0.5–0.8	0.9	0.1	t	t	0.3
γ-terpinene	0.1	0.1	0–0.1	-	-	-	-	t
artemisia alcohol	-	0.1	0.1–0.5	-	t	-	-	0.1
linalool	0.1	-	t–0.3	0.1	-	0.1	-	0.2
cis-p-menth-2-en-1-ol	-	-	-	-	-	1.7	-	-
α-terpineol	0.2	0.5	0–0.7	-	-	0.1	0.4	-
carvone	0.2	0.1	0.1–0.9	-	0.1	0.1	-	0.2
bornyl acetate	-	-	0–1.3	-	0.4	-	-	t
decanol	-	-	0–0.4	0.1	0.2	0.3	0.2	0.1
decanoic acid	0.2	0.4	0.4–5.1	t	2.9	0.1	t	2.0
β-caryophyllene	0.6	0.1	0–0.6	-	-	0.1	0.6	-
(E)-β-farnesene	6.6	6.5	2.3–5.3	3.8	4.5	3.4	4.5	3.9
allo-aromadendrene	-	0.1	t–0.4	0.2	0.6	0.3	-	0.3
γ-muurolene	-	0.4	t–0.8	-	0.5	-	-	0.3
germacrene D	1.9	0.3	0–0.3	0.5	-	t	1.8	-
dodecanol	-	-	0–0.8	-	0.2	-	-	0.5
α-muurolene	0.5	0.5	0–0.2	-	0.2	t	0.4	-
α-farnesene*	-	-	0–1.3	0.3	0.1	0.4	-	0.1
β-bisabolene	0.3	0.2	0–0.4	-	-	0.1	0.2	-
δ-cadinene	0.5	0.3	0–0.5	t	-	t	0.2	-
germacrene B	0.2	0.4	0–0.3	0.3	-	0.1	0.1	-
(E)-nerolidol	2.8	0.1	0.1–0.4	t	0.4	t	7.4	0.4
spathulenol	2.5	2.5	1.7–2.2	4.8	2.6	4.5	3.8	4.4
cedrol	0.2	0.2	0.2–1.1	0.5	0.4	0.1	0.4	0.4
γ-eudesmol	0.2	0.2	0.1–0.7	0.1	0.3	-	-	0.4
β-bisabolol	0.2	0.2	0–1.1	0.3	-	0.1	0.4	-
α-bisabolol oxide B	12.3	11.9	6.4–9.9	27.2	3.9	6.6	10.5	11.0
α-farnesol*	0.2	0.5	0–0.3	-	0.4	-	-	0.4
bisabolone oxide A	17.1	1.6	4.3–7.6	11.2	0.5	12.4	5.3	24.8
α-bisabolol	0.1	15.3	0.1–2.5	4.9	37.0	44.2	23.9	17.1
chamazulene	4.5	5.4	1.0–3.0	15.3	9.8	1.0	2.9	3.8
α-bisabolol oxide A	27.5	31.4	41.9–56.0	12.6	3.1	9.3	16.4	12.3
cis-dicycloether[a]	11.7	14.9	11.4–14.1	12.6	26.1	13.2	14.4	8.8
trans-bicycloether[a]	1.2	1.0	0–0.9	0.7	0.4	0.8	1.6	0.5
cis-bicycloether[a]	0.4	0.4	0–0.6	0.3	1.3	0.5	0.7	0.4

t=trace (<0.05%)
*correct isomer not identified; [a]isomers of spirocyclicpolyynes or en-yn-dicycloether
1=Estonian cultivar 1; 2=Estonian cultivar 2; 3=Estonian cultivar 3, Greek, Scottish, German, English and Latvian cultivars; 4=Armenian cultivar; 5=Czech cultivar; 6.Moldovan cultivar; 7=Russian cultivar; 8=Ukrainian cultivar

6. Moldovan cultivar> α-bisabolol > *cis*-bicyclo ether > bisabolone oxide A
7. Russian cultivar: α-bisabolol > α-bisabol oxide A > *cis*-bicyclo ether
8. Ukrainian cultivar: bisabolone oxide A > α-bisabolol > α-bisabolol oxide A > α-bisabolol oxide B

The flowers of *C. recutita* were collected during April-May from Fars Province (sub-central Iran) and were hydrodistilled for 4 hr to produce an oil in 0.26% yield by Tolouee et al. (2010). Analysis of this oil using GC/MS only revealed the following composition:

α-pinene (0.1%)
sabinene (0.1%)
β-pinene (0.1%)
α-phellandrene (0.1%)
α-terpinene (0.1%)
γ-terpinene (0.1%)
terpinen-4-ol (0.1%)
menthyl acetate[†] (0.2%)
α-cubebene (2.7%)
(Z)-β-farnesene (7.1%)
β-bisabolene (0.2%)
(E)-nerolidol (0.4%)
spathulenol (0.3%)
caryophyllene oxide (0.1%)
viridiflorol (0.2%)
β-bisabolol (0.1%)
α-bisabolol oxide A (2.2%)
α-bisabolol (56.9%)
chamazulene (2.2%)
(E,E)-farnesol (15.6%)
guaiazulene (4.2%)

[†]incorrect identification

The effect of the seasons' weather conditions over a three-year period on the oil content and composition of 28 wild populations and four registered Hungarian *C. recutita* cultivars ('Soroksari 40,' 'Lutea,' 'Goral' and 'Bona') grown in Soroksar (Hungary) was studied by Gosztola et al. (2010). They found that the oil content for the dry flowers of all of the chamomile populations varied in 2005, 2006 and 2007 from 0.20–0.93%, 0.39–0.88% and 0.11–0.80%, respectively. Furthermore, the authors determined that the four chamomile cultivars were richest in oil along with the populations originating from the Somogy region of Hungary. They found that the warmest and wettest of the three years studied revealed that the oil content and α-bisabolol contents were the highest found. Analysis of a single oil from one of the wild populations oil using GC/MS only resulted in characterizing the following constituents:

β-farnesene[*] (2.7%)
germacrene D (0.3%)
bicyclogermacrene (0.7%)
bisabolol oxide B (11.3%)
α-bisabolol (46.7%)
epi-α-bisabolol (0.4%)
chamazulene (9.4%)
α-bisabolol oxide A (20.6%)
cis-bicyclo ether (6.2%)
trans-bicyclo ether (0.3%)

[*]correct isomer not identified

Lal et al. (2010) have registered a new high-yielding cultivar known as 'CIMAP Sammohak' of chamomile for cultivation in India. A summary of the comparative findings of the new cultivar against existing Indian cultivars with respect to their oil content and major component amounts can be seen in **T-2**.

Lohani et al. (2011) evaluated the oil contents and compositions of chamomile grown on 10 separate village farms (Haridwar, Chakrata, Ranipokhari, Sahaspur, Kalsi, Pauri Garhwal, Ramnagar, Okhalkhanda, Almora and Champawat) in Uttarakhand (India). The authors found that the oil content the dried flowers varied from 0.2–0.6% with the maximum (0.60%) from the Kalsi farm and the minimum (0.20%) from the Pauri Garhwal farm. Separate analyses of the oils using GC-FID and GC/MS revealed that eight of the oils contained only low levels of chamazulene while the other two (from the Almora and Champawat farms) contained a chamazulene content greater than 10%. A summary of the results of analyses are presented in **T-3**.

The effect of nitrogen application (Urea) and plant density on the dry flower yield oil content and main constituent levels of the 'Bodegold' cultivar of chamomile grown in an experimental garden of the Ferdowsi University, a semi-tropical region with relatively dry winters in Mashad (Iran) was examined by Rahmati et al. (2011). The authors found that plant height and dry flowery yield increased with increasing plant densities from 20 plants/m^2 to 50 plants/m^2 of area further increased the dry flower yield and oil yield/m^2. Analysis of the major oil constituents produce from the various plant densities and area applications was determined by GC-FID and GC/MS and can be summarized as follows:

(Z)-β-farnesene (0.6–4.6%)
spathulenol (0.2–1.5%)
trans-calamenen-10-ol (0–0.9%)
α-bisabolol oxide B (3.7–13.4%)
α-bisabolone oxide A (2.2–7.4%)
α-bisabolol (1.3–6.9%)
chamazulene (1.1–5.7%)
α-bisabolol oxide A (42.6–63.0%)

Rafieiolhossaini et al. (2012) examined the composition of an oil produced by simultaneous steam distillation-solvent

T-2. Comparison of the percentage oil content and main component levels of a selection of Indian chamomile cultivars

Compound	1	2	3	4	5	6	7	8
α-bisabolol oxide B	11.0	9.3	9.3	9.3	10.3	12.0	10.5	9.3
α-bisabolol oxide A	11.3	8.1	-	10.9	7.5	11.3	7.6	8.1
α-bisabolol	9.2	9.2	6.1	6.1	6.9	5.1	7.5	9.2
chamazulene	13.0	0.6	7.2	1.2	0.4	0.4	0.7	0.5
α-bisabolol oxide A	20.1	18.4	19.7	19.7	31.5	12.0	32.4	19.7
oil content	1.01	0.63–0.64	0.50–0.52	0.59–0.63	0.42–0.57	-	-	-

1. 'Sammohak,' 2. 'Prashant,' 3. 'Vallary,' 4. M10-2-11,' 5. 'M70-1-22,' 6. 'M-20-22,' 7. 'M-20-25,' 8. 'M-20-15'

extraction and the headspace of the dried flowers of chamomile. A divinylbenzene/carboxen/polydimethylsiloxane fiber was used to trap the headspace. Both the oil and headspace were determined by GC/MS only, the results of which are shown in **T-4**.

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Hyssop Oil

Maheshwari et al. (1986) analyzed an oil produced from *Hyssopus officinalis* L. collected from Gulling and Chimeret in Himachal Pradesh (India). The constituents identified in this oil by GC/MS were as follows:

α-pinene (0.2%)
β-pinene (6.0%)
sabinene (0.9%)
myrcene (0.2%)
limonene (0.5%)
1,8-cineole (5.4%)
(Z)-β-ocimene (0.1%)
p-cymene (1.2%)
myrtenyl methyl ether (2.5%)
β-thujone (0.1%)
sabinene hydrate* (8.5%)
pinocamphone (38.4%)
isopinocamphone (5.3%)
linalool (1.7%)
pinocarvone (11.7%)
trans-p-menth-2-en-1-ol (0.2%)
terpinen-4-ol (3.4%)
myrtenal (0.9%)
trans-pinocarveol (0.8%)
myrtenyl formate (0.3%)
cryptone (0.1%)
δ-terpineol (0.5%)
p-mentha-1,8-dien-4-ol* (0.2%)
methyl myrtenate (0.1%)
α-terpineol (1.4%)
pinocampheol* (0.4%)
piperitone (0.2%)
γ-cadinene (0.2%)

myrtenol (2.9%)
methyl phenylpropionate (0.1%)
p-cymen-8-ol (0.3%)
piperitenone (0.2%)
2-hydroxy-isocamphone (0.3%)
ledol (0.3%)
viridiflorol (0.6%)
α-muurolol (0.4%)

*correct isomer not identified

An oil of hyssop produced from plants obtained in Calabria (Italy) was determined by Gionfriddo et al. (2001) to contain the following major components:

β-pinene (11.8%)
sabinene (1.7%)
limonene (11.1%)
pinocamphone (13.0%)
isopinocamphone (42.0%)

A commercial sample of hyssop oil that was screened for its anti-platelet activity by Tognolini et al. (2006) was determined through the use of GC/MS and GC/FID to possess the following composition:

α-thujene (0.2%)
α-pinene (2.3%)
camphene (0.5%)
β-pinene (5.5%)
3-octanone (0.2%)
myrcene (1.2%)
p-cymene (0.4%)
1,8-cineole (6.1%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (0.4%)
γ-terpinene (0.1%)
cis-sabinene hydrate (0.4%)
fenchone (0.3%)
terpinolene (0.2%)
linalool (5.5%)
α-thujene (6.1%)
β-thujone (0.9%)
camphor (3.7%)
trans-pinocamphone (8.3%)
cis-pinocamphone (17.2%)
terpinen-4-ol (0.8%)
cryptone (0.3%)
α-terpineol (5.2%)
myrtenal (0.8%)
γ-terpineol[a] (0.4%)
nerol (0.3%)
carvone (0.2%)
linalyl acetate (5.9%)
myrtenyl acetate (0.2%)
δ-elemene (0.4%)
α-terpinyl acetae (1.4%)
α-copaene (0.3%)
β-bourbonene (1.4%)
α-cedrene (4.4%)
β-caryophyllene (2.8%)
β-copaene (1.0%)
α-humulene (0.7%)
allo-aromadendrene (1.9%)
germacrene D (1.0%)
bicyclogermacrene (0.5%)
elemol (1.2%)
spathulenol (2.0%)
humulene epoxide II (0.3%)
β-eudesmol (0.3%)

[a]does not occur naturally

Costa et al. (2007) reported the usefulness of linear retention indices to assist in the identification of essential oil components whose MS fragment patterns are identical. In this report the authors showed that hyssop oil contained the following components such as: isoamyl alcohol, (Z)-3-hexenol, α-thujene, α-pinene,

T-3. Comparative percentage composition of the chamomile oils produced on different farms in Uttarakhand

Compound	1	2
α-pinene	0–0.3	t–0.1
camphene	0–0.1	-
benzaldehyde	0–0.3	0.2
sabinene	0–0.1	-
6-methyl-5-hepten-2-one	0–0.5	-
myrcene	0–0.1	-
p-cymene	0–0.2	-
1,8-cineole	0–0.1	-
artemisia ketone	0.1–1.4	0.7–1.2
artemisia alcohol	0–0.3	0.2–0.3
linalool	0–0.9	0.1
camphor	0–0.4	-
borneol	0–0.2	t–0.1
aretemisyl acetate	0–0.1	-
α-terpineol	0–0.1	-
nerol	0–0.1	-
carvone	0–0.3	-
geraniol	0–0.3	-
α-ylangene	0–0.2	-
α-copaene	0–1.5	-
decanoic acid	0–0.4	-
β-elemene	0–0.8	-
β-caryophyllene	0–0.4	-
(E)-β-farnesene	4.7–13.5	7.1–7.7
germacrene D	0.3–0.9	0.6–0.7
β-selinene	0–0.5	0.6
bicyclogermacrene	0.1–0.4	0.2
α-muurolene	0–0.9	-
(E,E)-α-farnesene	0–0.4	t
δ-cadinene	0–0.1	0.2
(E)-nerolidol	0–0.5	0.1
spathulenol	0.5–2.0	1.7–2.0
caryophyllene oxide	t–0.7	0.1
α-bisabolol oxide B	12.5–21.4	11.3–12.0
α-bisabolol	18.4–39.4	7.2–8.1
chamazulene	1.6–4.9	15.8–16.6
α-bisabolol oxide A	9.9–14.9	31.1–31.2
hexahydrofarnesyl acetone	t–0.1	-
cis-bicyclo ether	4.0–8.3	10.4–13.2
trans-bicyclo ether	0–1.2	-
hexadecanoic acid	0.5–6.0	0.2–0.5

1. Oils from all farms, except Almora and Champawat
2. Oils from Almora and Champawat farms

camphene, thuja-2,4-(10)-diene, benzaldehyde, sabinene, β-pinene, 3-octanone, myrcene, 3-octanol, α-phellandrene, α-terpinene, p-cymene, limonene, 1,8-cineole, (Z)-β-ocimene, (E)-β-ocimene, γ-terpinene, *cis*-sabinene hydrate, terpinolene, linalool, nonanal, α-thujone, β-thujone, *trans*-pinocarveol, pinocamphone, isopinocamphone, terpinen-4-ol, cryptone, myrtenol, carvotanacetone, 2-hydroxypinocamphone, phellandral, α-cubebene, eugenol, cyclosativene, α-copaene, β-bourbonene, β-cubebene, methyl eugenol, α-gurjunene, β-maaliene, isocaryophyllene, *trans*-α-bergamotene, aromadendrene, α-humulene, 9-epi-β-caryophyllene, 10β-cadina-1(6),4-diene, γ-muurolene, germacrene D, bicyclogermacrene, α-muurolene, (E,E)-α-farnesene, β-bisabolene, γ-cadinene, δ-cadinene, zonarene, cadina-1,4-diene, elemol, spathulenol and caryophyllene oxide. Based on the GC profile shown in the report, the major components of the oil were sabinene + β-pinene, 3-octanol, limonene, pinocamphone, isopinocamphone and α-copaene.

A supercritical fluid CO_2 extract of hyssop grown in Iran was compared with a hydrodistilled oil produced from the same hyssop batch by Kazazi et al. (2007). Analysis of 25 extracts and one oil was performed by GC-FID and GC/MS. These comparative analyses can be seen in **T-5**. Hyssop plants were collected from Malari (3255 m; Uttarakhand, India) and subjected to hydrodistillation by Sah et al. (2008). The composition of the oil that was produced in 1.3% yield was determined by GC-FID and GC/MS to be as follows:

α-thujene (0.2%)
α-pinene (0.8%)
sabinene (2.3%)
β-pinene (12.8%)
myrcene (1.4%)
β-phellandrene (3.6%)
1,8-cineole (13.0%)
(Z)-β-ocimene (0.3%)
γ-terpinene (0.1%)
cis-sabinene hydrate (0.1%)
terpinolene (0.1%)
rose furan† (0.2%)
linalool (0.3%)
α-thujone (0.2%)
bicycloheptanol† (0.7%)
carveol* (3.4%)
pinocarvone (11.0%)
linalyl propionate (0.4%)
isopinocamphone (43.8%)
p-menthanol† (0.9%)
myrtenol (1.1%)
benzaldehyde (0.1%)
β-bourbonene (0.1%)
germacrene D (0.4%)
bicyclogermacrene (0.1%)
dehydroaromadendrene† (0.1%)
endotrimethylamine† (0.1%)
phenandrene† (0.1%)
succinic acid† (0.2%)
pentacosadienoic acid† (0.1%)
hexahydronaphthalene† (0.1%)

*correct isomer not identified; †incorrect identification

In addition, trace amounts of more than 25 other components were listed; however, as most were misidentified, they will not be included in this review.

Kizil et al. (2008) examined the effect of ontogeny (different developmental stages) on the oil composition of a local ecotype of hyssop that is found naturally occurring in the northeastern Turkish Black Sea region and southern Anatolia (Turkey) over three seasons. Using GC/MS as their only method of analysis, the oil compositions found from pre-blooming, full-blooming and post-blooming plants can be seen in **T-6**.

An oil of hyssop of Iranian origin, which was analyzed by GC-FID and GC/MS by Mahboubi and Kazempour (2009), was found to contain the following components:

2,3-dimethyl-1,3-pentadiene† (0.1%)
4-methyl-3-penten-2-one† (0.5%)
α-pinene (0.2%)
sabinene (0.8%)
β-pinene (2.9%)
p-cymene (1.2%)

T-4. Comparative percentage composition of the headspace and oil of chamomile flowers

Compound	Headspace	Oil
methyl 2-methylbutyrate	0.3	-
ethyl 2-methylbutyrate	1.6	-
2-acetylfuran	0.4	-
α-pinene	0.5	-
propyl 2-methylbutyrate	0.5	-
benzaldehyde	0.5	0.1
sabinene	7.7	0.2
6-methyl-5-hepten-2-one	0.3	-
myrcene	0.4	-
p-cymene	3.8	0.1
limonene	0.5	-
1,8-cineole	2.2	0.2
(Z)-β-ocimene	0.7	-
(E)-β-ocimene	2.8	-
artemisia ketone	10.1	0.6
artemisia alcohol	2.8	0.1
α-terpineol	0.4	-
α-isocomene	1.1	-
β-caryophyllene	1.0	-
(E)-β-farnesene	42.2	6.7
germacrene D	9.1	1.4
β-selinene	0.3	-
bicyclogermacrene	2.3	0.5
(E,E)-α-farnesene	0.6	-
spathulenol	0.5	0.7
α-bisabolol oxide B	1.4	6.8
α-bisabolene oxide A	1.7	7.3
chamazulene	-	20.4
α-bisabolol oxide A	3.8	48.0
cis-bicyclo ether	0.5	6.7
trans-bicyclo ether	t	0.2

t=trace (<0.1%)

limonene (0.2%)
1,8-cineole (0.2%)
trans-sabinene hydrate (0.9%)
cis-linalool oxide[f] (0.3%)
trans-linalool oxide[f] (0.2%)
linalool (0.7%)
β-thujone (0.2%)
trans-pinocarveol (0.3%)
pinocamphone (22.1%)
isopinocamphone (39.3%)
β-fenchyl alcohol[†] (0.5%)
myrtenal (2.0%)
carvotanacetone[†] (0.4%)
trimethyl norpinen-3-one[†] (5.4%)
4-methyl-3-pentenal[†] (0.4%)
thymol (0.2%)
carvacrol (0.5%)
p-cymen-9-ol[†] (0.2%)
methyl p-anisate[†] (0.3%)
β-bourbonene (1.7%)
methyl eugenol (0.4%)
5-(1-hydroxy-1-methylethyl)-2-cyclohexan-1-one[†] (0.8%)
germacrene D (0.2%)
cis-pinonic acid (1.8%)
aromadendrene[†] (0.5%)
γ-cadinene (0.2%)
croweacin[†] (0.2%)
elemol (1.7%)
spathulenol (2.8%)
caryophyllene oxide (1.2%)
viridiflorol (0.2%)
α-selinene[†] (0.1%)
ledol[†] (0.2%)
γ-eudesmol (0.3%)
α-cadinol (0.3%)
β-eudesmol (0.9%)
hexahydrofarnesyl acetone (0.2%)

[†]incorrect identification
[f]furanoid form

An oil produced in 0.25% yield from the aerial parts of *H. officinalis* collected from Malari (Chamoli district, Uttar Pradesh, India) was subjected to analysis using GC-FID and GC/MS by Pal et al. (2010). The constituents characterized in amounts greater than 0.1% were as follows:

α-thujene (0.2%)
α-pinene (0.9%)
formic acid (0.1%)
sabinene (2.2%)
β-pinene (11.8%)
myrcene (1.5%)
β-phellandrene (3.6%)
1,8-cineole (10.8%)
β-ocimene[*] (0.3%)
γ-terpinene (0.1%)
sabinene hydrate[a] (0.1%)
terpinolene (0.1%)
rosefuran[†] (0.3%)
linalool (0.3%)
α-thujone (0.2%)
bicycloheptanol[†] (0.7%)
carveol[*] (3.4%)
pinocarvone (10.9%)
linalyl propionate (0.4%)
isopinocamphone (42.7%)
menthanol[†] (0.9%)
myrtenol (1.1%)
bicycloheptene carboxaldehyde[†] (0.6%)
benzaldehyde[†] (0.1%)
tetrahydropyran[†] (0.3%)
β-bourbonene (0.1%)
nitrobicyclononane[†] (0.1%)
germacrene D (0.4%)
bicyclogermacrene (0.1%)
dehydroaromadendrene[†] (0.1%)
β-copaene (0.1%)
heptacosane (0.1%)

T-5. Comparative percentage of the main constituents of the supercritical fluid CO_2 extracts and oil of Iranian-grown hyssop

Compound	SFE	Oil
α-pinene	0.2–1.0	0.6
β-pinene	0.2–1.4	0.5
cumene	0.1–2.1	0.1
p-cymene	0.6–2.5	1.6
sabinene	4.2–16.3	11.0
pinocamphone	1.2–13.6	8.7
pinocarvone	0.1–0.9	0.4
isopinocarvone	1.4–16.5	10.9
germacrene D	0.1–2.6	1.5

T-6. Comparative percentage composition of hyssop oils produced from plants harvested at different developmental stages

Compound	Pre-blooming oil	Full-blooming oil	Post-blooming oil
α-pinene	0–0.7	0.2–1.1	0.2–0.5
camphene	0–0.1	0–0.2	0–0.1
sabinene	0–1.1	0.2–1.5	0.2–1.0
β-pinene	0.4–13.1	4.0–15.4	1.1–9.4
myrcene	0–1.2	1.1–1.7	0.1–1.1
α-phellandrene	0.5–0.6	0.5–0.6	0.4
α-terpinene	0.2–1.5	1.6–1.9	0.5–1.2
p-cymene	0.8–0.9	0.9–3.0	1.3–1.9
β-phellandrene	0–1.0	0.8–1.3	0.4–0.9
1,8-cineole	0–0.8	1.0–1.1	0–0.7
γ-terpinene	2.0–4.6	3.8	2.9–3.8
terpinolene	0–0.6	0.6–0.7	0–0.5
cis-sabinene hydrate	0–1.5	0–2.4	0–3.1
linalool	1.7–1.8	1.0–1.1	1.2–1.9
α-thujone	0–0.3	0.3–0.4	0.3–0.4
pinocarvone	2.1–5.3	3.5–6.8	2.7–3.9
isopinocamphone	44.9–55.9	40.9–56.7	45.6–55.2
myrtenol	1.1–5.0	0.9–2.1	1.0–2.0
trans-pinocarveol	0–0.8	0–0.5	0–0.5
α-terpineol	0.5–1.7	0–0.8	0.6–1.2
4-carvomenthenol	5.0–14.0	4.5–10.5	5.4–13.1
methyl chavicol	0–0.2	0–0.2	0–0.2
neryl acetate	0.1–0.4	0–0.4	0.3–0.6
thymol	0.5–2.0	0.3–1.3	0.3–2.3
carvacrol	2.4–7.0	0.9–5.1	1.2–8.7
elemol	0.6–5.6	0.3–1.3	0.5–1.1
caryophyllene oxide	0.1–0.5	0.1–0.3	0–0.1

methyl arachidonate† (0.1%)
endo-trimethylamine† (0.1%)
phenanthrene† (0.1%)
succinic acid† (0.2%)
tricosadienoic acid (0.1%)
caryophyllene oxide (0.1%)
pentacosadienoic acid† (0.2%)
hexahydronaphthalene (0.1%)

†incorrect identification
*correct isomer not identified
a*cis*-form

Hyssop plants grown in Srinigar (Indian Kashmir), which were harvested monthly from March to October, were subjected to hydrodistillation to produce oil in 0.02–0.41% yield. The maximum oil content was produced in June, July and August, the minimum oil content March–May (the post-blooming stage) with an intermediate amount in September–October (the post-blooming stage). The separate oils were analyzed using GC-FID and GC/MS. A summarized version of Khan et al. (2010) can be seen in **T-7**.

An oil of hyssop was screened for its antimicrobial and antioxidant properties by Kizil et al. (2010). The composition of this oil as determined by GC/MS only was found to possess the following composition:

α-thujene (0.2%)
α-pinene (0.3%)
thuja-4,10-ene (0.1%)
β-pinene (7.2%)
1-octen-3-ol (0.5%)
myrcene (0.5%)
isoterpinolene† (0.1%)
p-cymene (2.8%)
limonene (0.6%)
1,8-cineole (0.3%)
linalool (0.8%)
β-thujone (0.1%)
4-carvomenthol† (0.1%)
nopinone† (0.8%)
pinocamphone (2.6%)
pinocarvone (6.5%)
isopinocamphone (57.3%)
terpinen-4-ol (7.1%)
p-cymen-8-ol (0.3%)
myrtenal (2.3%)
pinanediol† (0.4%)
thymol (0.6%)
carvacrol (3.0%)
myrtenyl acetate (1.0%)
neryl acetate (0.2%)
methyl eugenol (0.2%)
β-caryophyllene (0.4%)
cis-pinonic acid (0.6%)
β-bisabolene (0.6%)
elemol (0.6%)
spathulenol (0.6%)
caryophyllene oxide (0.2%)
isopropyl myristate† (0.1%)

†incorrect identification

The aerial parts of *H. officinalis* that were grown in Turkey were hydrodistilled for 4 hr to produce an oil in 2.29% yield. Analysis of this oil by GC-FID and GC/MS by Figueredo et al. (2012) revealed that it possessed the following composition:

α-thujene (0.2%)
α-pinene (0.8%)
camphene (0.1%)
sabinene (1.7%)
β-pinene (17.6%)
myrcene (2.9%)
p-cymene (0.1%)
limonene (0.7%)
β-phellandrene (0.6%)
1,8-cineole (3.0%)
(Z)-β-ocimene (1.3%)
(E)-β-ocimene (0.1%)

α-thujone (0.1%)
nopinone[†] (0.1%)
trans-pinocarveol (0.5%)
pinocamphone (27.2%)
pinocarvone (29.2%)
isopinocamphone (4.7%)
terpinen-4-ol (0.4%)
myrtenol (1.4%)
β-caryophyllene (0.2%)
germacrene D (0.2%)
bicyclogermacrene (0.3%)
spathulenol (0.3%)

T-7. Comparative percentage composition of oils of Kashmiri-grown hyssop harvested throughout the year

Compound	March–May oil	June–August oil	September–October oil
α-thujene	t–0.2	0.1–0.3	0.3–0.5
α-pinene	0.1–1.5	0.2–0.4	0.4–0.5
camphene	0–t	0–t	t–0.1
sabinene	0–1.0	0.8–1.6	1.6–2.3
β-pinene	7.1–32.3	6.2–9.9	7.9–9.1
myrcene	0.7–2.7	1.5–2.2	1.9–2.9
α-phellandrene	0–t	0–t	0–t
α-terpinene	0–0.3	0.2–0.5	0.3–0.7
p-cymene	t–1.8	t–0.1	0.1
limonene	t–9.0	5.9–7.1	5.4–7.6
1,8-cineole	0–11.8	0.3–0.4	0.3–0.4
β-ocimene*	0–0.8	0–0.3	0–0.4
γ-terpinene	0–0.7	0.8–1.1	0.8–1.3
sabinene hydrate[a]	0–1.0	2.0–3.7	2.1–5.4
terpinolene	0–0.2	0.1–0.2	0.2–0.3
linalool	0–1.5	0.6–1.0	0.4–0.5
α-thujone	t–0.2	0.3	0.3–0.4
pinocamphone	10.9–64.8	50.9–55.0	54.1–60.8
isopinocamphone	0–0.4	0–2.5	-
terpinen-4-ol	0.7–8.1	2.5–7.7	3.8–8.3
α-terpineol	0.1–1.1	0.2–0.3	0.2
myrtenol	0–1.3	2.4–3.0	1.6–2.4
methyl eugenol	0.1–0.5	0.3–0.5	0–0.2
β-caryophyllene	0.2–2.8	0.2–0.6	0–0.1
α-humulene	0.2–0.7	0–0.1	-
allo-aromadendrene	0–0.9	0.4–0.6	0.1–0.3
germacrene D	0–11.2	0.8–3.1	0.5–0.7
bicyclogermacrene	0–3.7	1.0–1.4	0.4–0.8
γ-cadinene	0–0.1	0–t	-
elemol	0–7.2	1.7–7.5	0.3–2.4
spathulenol	t–0.5	t–0.1	0–0.1
10-epi-γ-eudesmol	0–0.5	0.1–0.3	0–t
α-cadinol	0–0.6	0.1–0.8	-

*correct isomer not identified; [a]*cis*-form; t = trace (<0.05%)

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