Progress in Essential Oils

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Summer Savory Oil

Summer savory oil, which is produced from *Satureja hortensis* L., is an annual aromatic, herbaceous small plant endemic to the eastern Mediterranean region, including Turkey and Greece. It can be found growing throughout Europe and other countries as a garden escape. Savory oil is known for its richness in carvacrol, which accounts for its use as an antimicrobial oil.

Hawthorne et al. (1993) characterized five components in savory oil and compared the composition of it to that of supercritical fluid CO_2 extracts of the same batch of air-dried and coarsely ground *S. hortensis*. The comparative results are shown in **T-1**.

Oils produced from two samples of *S. hortensis* plants collected in the Crimean region of Ukraine were the subject of analysis by Misharina et al. (1999). The results of these analyses can be seen in **T-2**. A trace amount of α-phellandrene was also characterized in this oil.

Ozcan and Chalchat (2004) analyzed oils produced from *S. hortensis* collected over two seasons from Mersin (Turkey). The components identified in these oils were found to range as follows:

α-thujene (1.1–1.3%)
α-pinene (1.0–1.5%)
camphene (0.4–0.7%)
β-pinene (0.5–0.8%)
1-octen-3-ol (0.3–0.4%)
myrcene (1.4%)
α-phellandrene (0.2–0.3%)
δ-3-carene (0.1%)
α-terpinene (2.3–2.7%)
p-cymene (14.6–21.8%)
limonene (t–0.7%)
(Z)-β-ocimene (0.1–0.2%)
(E)-β-ocimene (0.1–0.2%)
γ-terpinene (18.9–23.1%)
cis-sabinene hydrate (0.1–0.2%)
terpinolene (0.2–0.3%)
linalool (1.9–2.5%)
cis-p-menth-2-en-1-ol (t–0.1%)
borneol (1.0–1.8%)
terpinen-4-ol (1.1–1.2%)
α-terpineol (t–0.1%)
methyl chavicol (0.1–0.3%)
methyl carvacrol (t–0.2%)
carvone (t–0.1%)
cuminyl alcohol (0.1–0.3%)
carvacrol (t–0.1%)
carvacryl acetate (0.1%)
β-caryophyllene (3.8–4.6%)
aromadendrene (0.2%)
α-humulene (0.2%)
allo-aromadendrene (t–0.2%)
viridiflorene (0.1–0.2%)
spathulenol (0.2–0.3%)
caryophyllene oxide (1.0–1.2%)
caryophylla-4(12),8(13)-dien-5β-ol (t–0.1%)

t=trace (<0.05%)

2-Methylbutyrate, tricyclene, thuja-2,4-(10)-diene, sabinene, 3-octanol, 1,8-cineole, *cis*-linalool oxide (furanoid form), 1-nonen-3-ol, *trans*-sabinene hydrate, *trans*-pinocarveol, methyl salicylate, p-menthane-1,8-diol, a dihydrocarvone isomer, piperitenone, eugenol, isocaryophyllene, 7-epi-α-selinene, γ-cadinene and δ-cadinene were also found in this same oil. It is of interest to note that the oils were rich in p-cymene and γ-terpinene and were almost devoid of carvacrol. This scenario is not that unexpected as all three compounds are biosynthetically related.

Seeds of *S. hortensis* of Hungarian and German origins were sown in an experimental garden owned by Zaraband Co. North of Tehran (Iran). Oils produced from the herbage of each selection that were air-dried in the laboratory by water distillation were analyzed by GC-FID and GC/MS by Omidbaigi and Hejazi (2004). The oil compositions, which were found to be similar, can be seen summarized as follows:

α-thujene (0.8–0.9%)
α-pinene (0.5–0.9%)
camphene (t–0.1%)
sabinene (0.1%)
β-pinene (0.3–0.8%)
myrcene (1.2–1.4%)
α-phellandrene (0.2%)
δ-3-carene (t–0.1%)
α-terpinene (2.3–2.9%)
p-cymene (28.3–29.8%)
limonene (0.4%)
(E)-β-ocimene (0.1%)
γ-terpinene (21.5–22.9%)
cis-sabinene hydrate (0.1%)
terpinolene (t–0.1%)
linalool (0.3–0.4%)
borneol (0.1%)
terpinen-4-ol (0.1–0.2%)
α-terpineol (0.1%)
thymol (0.1%)
carvacrol (35.8–40.4%)
thymyl acetate (0.2–0.3%)
β-caryophyllene (0.5–1.5%)
α-humulene (0–0.1%)
β-bisabolene (0.3–0.4%)

T-1. Comparative percentage composition of five components of *Satureja hortensis* oil and supercritical fluid CO_2 extracts

Compound	Oil	SF CO_2 extracts
α-pinene	1.1	0.9–1.0
β-pinene	0.5	0.4–0.5
p-cymene	7.0	5.9–6.6
γ-terpinene	24.6	20.3–22.9
carvacrol	59.5	55.9–59.3

elemicin (0–1.1%)
caryophyllene oxide (0.3–0.7%)

t=trace (<0.05%)

Furthermore, the authors reported that the oil contents of the plants grown from the German and Hungarian origin seeds were 4.5% and 3.5%, respectively.

Baser et al. (2004) examined the compositions of oils produced from both wild and cultivated *S. hortensis* in Turkey. The eight cultivated forms, which were obtained from Kayseri, Konya, Eskisehir, Bursa, Balikesir, Izmir, Denizli and Edirne possessed oil yields of 1.30–2.67%. In contrast, the 12 wild forms possessed oil yields of 1.71–4.75%. The oils were analyzed by a combination of GC techniques can be grouped into three: oils rich in carvacrol, oils rich in thymol and oils with comparable amounts of both phenols. The results of this study can be seen in **T-3**. From these results it can be determined that, as expected, all cultivated forms possessed carvacrol-rich oils.

An oil of *S. hortensis* that was produced in the laboratory by water distillation from wild plants collected from Sinop and Antalya provinces (Turkey) was analyzed using GC-FID and GC/MS by Baocy et al. (2005). The composition of this oil was determined to be as follows:

α-thujene (1.2%)
α-pinene (1.0%)
camphene (0.4%)
1-octen-3-ol (0.4%)
myrcene (0.4%)
α-phellandrene (1.4%)
α-terpinene (1.8%)
p-cymene (1.81%)
limonene (0.6%)
γ-terpinene[a] (20.1%)
linalool (3.0%)
borneol (1.0%)
terpinen-4-ol (1.1%)
thymol (11.4%)
carvacrol (21.9%)
β-caryophyllene (4.5%)
aromadendrene (6.4%)
α-humulene (4.2%)
viridiflorene (1.0%)

[a]incorrectly reported as terpinolene by authors

Satureja hortensis L. var. *laxiflora* (syn. *S. hortensis* L.) C. Koch, which is widely cultivated in Iran where it is used in culinary preparations, was collected from Teherabad (Kerman, Iran) and subjected to water distillation to yield an oil in 2.13%. The composition of this oil was determined by GC-FID and GC/MS by Foroumadi et al. (2005). The results of this analysis were as follows:

α-thujene (1.2%)
α-pinene (0.8%)
camphene (0.1%)
sabinene (0.1%)
β-pinene (0.3%)
myrcene (1.4%)
α-phellandrene (0.3%)
α-terpinene (3.8%)
p-cymene (2.7%)
β-phellandrene (0.6%)
(Z)-β-ocimene (0.1%)
γ-terpinene (26.9%)
(E)-β-ocimene (0.2%)
thymol (0.2%)
carvacrol (57.9%)
β-caryophyllene (0.6%)
bicyclogermacrene (0.3%)
β-bisabolene (1.9%)

Novak et al. (2006) planted seeds of *S. hortensis* purchased in the market of Aleppo (Syria) and raised 72 plants in pots in the greenhouse under 14-hr day-length conditions. The plants were harvested in full flower and were divided up into different parts (organs) such as corolla, calyx, young upper stalk leaves, middle stalk leaves and lower stalk leaves. Each plant part (5 g amounts)

T-2. Comparative percentage composition of oils produced from two samples of Crimean savory

Compound	Sample 1	Sample 2
α-pinene	0.9	1.4
camphene	0.1	0.2
sabinene	0.2	0.4
β-pinene	0.1	0.3
myrcene	0.2	0.3
p-cymene	14.1	20.6
1,8-cineole	3.9	5.2
γ-terpinene	0.2	0.3
terpinolene	-	0.4
linalool	0.5	0.7
menthone†	0.1	0.2
borneol	2.0	4.0
terpinen-4-ol	t	0.1
α-terpineol	t	0.2
dihydrocarveol	-	0.1
methyl chavicol	-	0.1
trans-carveol	0.3	1.1
cis-carveol	0.1	0.3
linalyl acetate	-	0.1
geranial†	-	0.3
(E)-anethole	0.2	0.6
carvacrol	73.1	58.0
thymol	1.4	1.0
carvyl acetate*	-	0.1
α-terpinyl acetate†	-	0.2
eugenol	0.2	0.5
neryl acetate†	t	0.3
α-humulene	t	0.1
β-copaene	t	0.1
β-selinene	t	0.2
α-farnesene*	t	0.1
elemol†	t	0.1

t = trace (<0.05%)
*correct isomer not identified
†incorrect identification

T-3. Comparative percentage composition of *Satureja hortensis* oils of Turkish origin

Compound	1	2	3
α-pinene	1.1–4.5	1.9–4.4	3.5
camphene	0.1–0.2	0.1	0.1
β-pinene	0.3–2.4	1.0–3.9	1.6
sabinene	0.1	0.1	0.1
myrcene	0–2.5	0–2.8	-
α-phellandrene	t–2.6	t–2.9	2.6
α-terpinene	0–4.3	2.5–3.8	3.9
limonene	0.3–0.4	0.4–0.5	0.4
β-phellandrene	0.2–2.3	0.3	0.2
γ-terpinene	21.3–41.5	25.2–37.4	41.4
(E)-β-ocimene	0–0.2	0.1–0.2	0.1
p-cymene	2.6–9.8	4.8–13.8	9.0
terpinolene	0–0.1	0.1	0.1
6-methyl-3-heptanol	0–0.1	t–0.1	t
1-octen-3-ol	0.1–0.4	0.1–0.3	0.2
trans-sabinene hydrate	0.1–0.4	0.1–0.3	0.1
linalool	0–t	t	t
cis-sabinene hydrate	0.1–0.2	0.1–0.2	0.1
β-caryophyllene	0.1–1.1	0.1–1.4	1.0
terpinen-4-yl acetate	0.2–0.6	0–0.5	0.3
α-terpineol	0–0.1	0.1–0.2	0.1
borneol	0.1–0.3	0.2–0.5	0.5
β-bisabolene	0.5–1.2	0.3–0.9	0.3
p-cymen-8-ol	t	t–0.1	t
thymyl acetate	t	0.1–0.9	t
caryophyllene oxide	t–0.1	0–0.1	t
spathulenol	0–0.3	t–0.4	0.1
thymol	0.1–0.5	28.8–43.0	16.7
carvacrol	41.7–60.6	3.1–12.2	15.9

1 = All the oils from cultivated plants plus four from wild plants that were rich in carvacrol.
2 = Oils from wild plants that were rich in thymol.
3 = A single oil from a wild plant collection from Artvin in the Coruh Valley that contained equal amounts of carvacrol and thymol.

T-4. Percentage composition of the main constituents of oils produced from different plant parts of *Satureja hortensis*

Compound	1	2	3	4	5
myrcene	1.3	1.4	2.3	2.3	2.2
α-terpinene	1.1	1.9	3.2	3.4	3.4
p-cymene	1.7	2.1	1.9	2.4	1.9
γ-terpinene	9.2	16.1	30.7	31.5	30.3
carvacrol	84.8	74.0	58.9	57.3	59.1
β-bisabolene	1.1	2.2	2.2	2.1	2.3

1 = Corolla (interior flower including petals) oil
2 = Calyx (the outermost floral envelope) oil
3 = Upper stalk young leaf oil
4 = Middle stalk mature leaf oil
5 = Lower stalk old leaf oil

was separately water-distilled to yield an oil. The main constituents of each oil are shown in **T-4**.

Omidbaigi et al. (2007) determined that a lab-distilled oil (yield 3.0%) of *S. hortensis* grown in Iran contained:

α-thujene (0.8%)
α-pinene (0.8%)
β-pinene (0.8%)
myrcene (1.5%)
α-phellandrene (0.2%)
α-terpinene (2.2%)
p-cymene (32.2%)
(E)-β-ocimene (0.5%)
γ-terpinene (21.7%)
terpinolene (0.1%)
linalool (0.1%)
carvacrol (38.0%)
β-bisabolene (0.2%)

Trace amounts (<0.05%) of carvacryl acetate and β-caryophyllene were also characterized in this oil.

Savory cultivated in Quedlinburg (Germany) by Pfefferkorn et al. (2005) was harvested at separate times from the commencement of flowering during the summer (first harvest, commencing July 15) and autumn (second harvest, commencing September 14). Oils were produced from the various harvests. Oil yields obtained during the summer harvest ranged from 3.84% at commencement of flowering to 4.64% at full flowering, while in the autumn harvest the oil yield ranged from 2.97–3.8%, respectively. The composition of selected constituents of oils produced over 28 days from the commencement of flowering (with full flowering after 21 days) can be seen in **T-5**.

Kizil (2009) collected seeds of S. hortensis from Diyarbakir and Kahramanmaras in Turkey and planted them in the experimental garden of Dicle University (Diyarbakir). Plants from each seed origin were harvested at full flowering and shade-dried at room temperature before being subjected to water distillation. The oil yields were 3.25% (Diyarbakir) and 2.40% (Kahramanmaras). GC analysis of the oils using only retention times of authentic compounds for component characterization yielded the results reported in **T-6**.

Oils produced from *S. hortensis* that were harvested over two seasons at pre-, full- and post-full-flowering stages were analyzed by Kizil et al. (2009) using GC/MS only. Their results are summarized in **T-7**.

An oil of *S. hortensis* that was screened against the Colorado potato beetle was analyzed by Pavela et al. (2009) using GC-FID and GC/MS. It was found to contain the following constituents:

α-thujene (0.9%)
α-pinene (0.9%)
β-pinene (0.4%)
myrcene (1.6%)
α-phellandrene (0.2%)
α-terpinene (3.5%)
p-cymene (4.7%)
limonene (0.5%)
β-phellandrene (0.1%)
γ-terpinene (36.7%)
terpinen-4-ol (0.1%)
carvacrol (48.1%)
β-caryophyllene (0.7%)
β-bisabolene (1.7%)

Supercritical fluid CO_2 extracts were produced using varying conditions; the compositions of these extracts can be seen in **T-8**.

T-5. Percentage composition of selected constituents of *Satureja hortensis* oils produced from plants harvested during two different seasons

Compound	Summer oils	Autumn oils
α-thujene	0.8–1.2	0.9–1.1
α-pinene	0.5–0.7	0.5–0.6
myrcene	1.5–1.7	1.6–1.8
β-pinene	0.2–0.4	0.2–0.3
α-phellandrene	0.2–0.3	0.3
α-terpinene	3.0–3.3	3.1–3.3
p-cymene	2.4–3.8	2.3–3.3
limonene	0.2–0.3	0.3
β-phellandrene	0.2–0.3	0.3
γ-terpinene	30.1–33.8	32.1–33.5
carvacrol	55.3–59.5	555.5–57.9
β-bisabolene	0.3–0.4	0.3

T-6. Comparative percentage composition of *Satureja hortensis* oils from two seed sources in Turkey

Compound	Dyarbakir oil	Kahramanmaras oil
α-pinene	8.8	2.9
camphene	-	2.9
myrcene	8.4	1.6
limonene	-	0.3
γ-terpinene	0.6	-
1,8-cineole[a]	1.7	1.2
p-cymene	1.0	0.4
α-terpineol	9.3	29.1
linalool	2.0	0.2
β-caryophyllene	-	0.1
camphor[†]	0.9	0.1
borneol	0.3	0.2
geranyl acetate[†]	0.4	0.1
carvone	0.4	0.1
thymol	26.1	1.6
carvacrol	39.8	58.5

[†]incorrect identifications
[a]mixed with β-phellandrene

T-7. Comparative percentage composition of the oils of *Satureja hortensis* harvested at different stages of development

Compound	Pre-flowering stage oil	Full-flowering stage oil	Post-flowering stage oil
α-thujene	1.5	1.5	0.8
α-pinene	0.9	0.8	0.4
octenol[a]	0.3	t	t
myrcene	2.1	1.6	1.1
α-terpinene	1.6	0.9	1.0
p-cymene	11.5	10.5	7.1
limonene	0.2	t	t
γ-terpinene	21.0	22.1	15.7
terpinen-4-ol	0.7	0.2	0.2
thymol	43.2	49.3	51.2
carvacrol	11.8	11.2	21.0
β-bisabolene	1.2	0.2	t
oil yield	2.2	2.3–2.8	1.7–1.8

t = trace (<0.1%)
[a]should be 1-octen-3-ol

T-8. Comparative percentage composition of three supercritical fluid CO_2 extracts of *Satureja hortensis*

Compound	1	2	3
α-thujene	0.4	0.5	-
α-pinene	0.4	0.4	-
β-pinene	0.2	0.2	-
myrcene	1.1	1.2	0.1
α-phellandrene	0.1	0.2	-
α-terpinene	1.2	2.1	0.1
p-cymene	3.5	4.3	1.3
limonene	0.1	-	-
γ-terpinene	27.5	29.2	9.9
thymoquinone	2.0	1.0	3.6
thymol	0.1	-	0.4
carvacrol	60.6	57.9	80.5
β-caryophyllene	0.8	0.8	0.9
thymohydroquinone	0.1	-	4.4

1. Conditions: 50°C pure CO_2 at 28 MPa
2. Conditions: 50°C pure CO_2 at 15 MPa
3. Conditions: 50°C CO_2 modified with 4.3% acetone entrainer at 28 MPa

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