Progress in Essential Oils

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Clary Sage Oil

The oils of the inflorescences of a Sicilian spontaneous biotype of clary sage that was grown in the vicinity of Sparacia (Sicily, Italy) were analyzed using GC-FID and GC/MS by Carrubba et al. (2002). As expected, the inflorescence oils that were obtained by hydrodistillation were found to be rich in linalool and linalyl acetate as shown in **T-1**. The authors also showed that the leaf oils produced from flowering plants were determined to possess the following range in composition:

δ-elemene (0.39–0.40%)
α-cubebene (< 0.01%)
α-copaene (5.3–5.8%)
β-bourbonene (< 0.01–0.07%)
β-cubebene (0.33–0.45%)
β-elemene (2.00–2.14%)
β-caryophyllene (5.65–5.90%)
β-gurjunene (0.20–0.22%)
aromadendrene (0.03–0.07%)
allo-aromadendrene (0.23–0.76%)
γ-gurjunene (0.05%)
γ-muurolene (0.31–0.87%)
germacrene D (67.72–68.85%)
viridiflorene (< 0.01–0.10%)
bicyclogermacrene (6.41–7.95%)
α-muurolene (< 0.01–0.10%)
β-bisabolene (0.10–0.17%)
δ-cadinene (1.50–1.56%)
cadina-1,4-diene (< 0.01–0.06%)
α-cadinene (< 0.01–0.05%)
spathulenol (0.76–0.93%)
α-muurolol (< 0.01–0.04%)
α-eudesmol (0.07–0.08%)
α-cadinol (0.39–0.45%)
valeranone (0.54–0.60%)
sclareol (0.31–0.57%)

An oil of clary sage was compared with a volatile concentrate of the same batch of plant material using co-distillation with superheated pentane vapor (Mastelic and Jerkovic 2003). The results of this comparison are presented in **T-2**. As can be seen, the hydrolysis and rearrangement of linalyl acetate during water distillation did not occur during the volatile concentrate isolation, thereby making this a useful method for isolating oils that are susceptible to rearrangement during isolation.

Pesic and Bankovic (2003) studied *S. sclarea* grown experimentally in a garden near Leskovac (Serbia). Although the authors did not analyze the oils produced from plants harvested at different stages of inflorescence formation till seed production, they did show that the oil yield at the phase of full seed maturity was the highest and the linalool and linalyl acetate contents were 9.39% and 79.05%, respectively.

Salvia sclarea grown in Canelones Province (Uruguay) from seed of European origin was evaluated for its potential as a commercial crop for Uruguay. Oils produced from plants harvested either at full flowering or the commencement of seed ripening were analyzed by Lorenzo et al. (2004) over three seasons. The range in composition of the oils produced can be seen as follows:

α-pinene (0.1%)
camphene (0.1%)
sabinene (0.1–0.2%)
β-pinene (0.1–0.2%)
myrcene (1.4–1.8%)
limonene (0.3–0.4%)
(Z)-β-ocimene (0.5–0.6%)
(E)-β-ocimene (1.0–1.3%)
terpinolene (0.2–0.3%)
linalool (7.9–22.5%)
α-terpineol (0.9–2.2%)
nerol (0.4–0.5%)
linalyl acetate (38.6–48.1%)
α-ylangene (0.2–1.2%)
neryl acetate (1.0–1.3%)
α-copaene (1.1–2.6%)
β-bourbonene (0.3–2.5%)
geranyl acetate (0.7–3.6%)
β-caryophyllene (2.9–4.9%)
α-humulene (0.2–0.4%)
germacrene D (8.2–19.8%)
bicyclogermacrene (1.0–2.0%)
germacrene A (0.2%)
δ-cadinene (0.2–0.7%)
salvial-4(14)-en-1-ene (0.1–0.2%)
β-eudesmol (0.1–0.5%)
sclareol (1.1–2.7%)

The high level of germacrene D in this oil indicates that a percentage of leaves were mixed with the flowering tops used to produce the oil by steam distillation.

Clary sage that was grown in the clay soils of the Nitra region (Slovak Republic) was explored as a potential crop for the selected mild climate zone. An oil produced from the flowers by hydrodistillation for four hours was found by Farkas et al. (2005) to possess the following composition:

myrcene (1.5%)
limonene (0.4%)
(Z)-β-ocimene (0.7%)
(E)-β-ocimene (1.3%)
terpinolene (0.4%)
linalool (18.9%)
α-terpineol (6.5%)
nerol (1.2%)
linalyl acetate (13.7%)
neryl acetate (2.2%)
α-copaene (1.1%)
geranyl acetate (4.3%)

Comparative percentage composition of oils produced from inflorescences of Italian *Salvia sclarea* **T-1**

Compound	1	2
α-pinene	0.1	0.2
camphene	0.1	0.2
sabinene	t	0.1
β-pinene	0.2	0.3
myrcene	1.7	1.2
limonene	0.4	0.2
(Z)-β-ocimene	0.9	0.6
(E)-β-ocimene	1.5	1.0
terpinolene	0.4	0.2
linalool	28.9	25.7
terpinen-4-ol	0.1	0.1
α-terpineol	5.1	3.5
linalyl acetate	34.9	52.7
δ-elemene	0.1	0.1
neryl acetate	0.9	0.6
α-copaene	0.5	0.2
geranyl acetate	1.8	1.1
β-bourbonene	t	t
β-cubebene	0.1	0.1
β-elemene	0.2	0.1
β-caryophyllene	1.8	1.4
β-gurjunene	0.1	t
aromadendrene	0.3	0.3
allo-aromadendrene	0.1	0.1
γ-gurjunene	t	t
γ-muurolene	0.1	0.1
germacrene D	10.6	3.9
viridiflorene	1.6	1.3
bicyclogermacrene	0.5	0.3
α-muurolene	0.1	t
β-bisabolene	0.6	t
δ-cadinene	0.2	0.2
valeranone	0.8	0.2
sclareol	0.1	0.1

1. oil produced from full flowering inflorescences; 2. oil produced from inflorescences at the commencement of seed ripeness; t = trace (< 0.1%)

β-cubebene (0.2%)
β-elemene (0.2%)
dimethylbenzenebutanal† (0.9%)
β-caryophyllene (2.1%)
α-humulene (0.1%)
germacrene D (5.0%)
valencene (0.4%)
bicyclogermacrene (0.7%)
δ-cadinene (0.4%)
1,5-epoxy-salvial-4(14)-ene (0.1%)
spathulenol (0.6%)
caryophyllene oxide (0.8%)
salvia-4(14)-en-1-one (0.1%)
isospathulenol (0.1%)
β-eudesmol (0.7%)
α-eudesmol (0.4%)
eudesma-4(15),7-dien-1b-ol (0.1%)
sclareol oxide (2.5%)
manoyl oxide (2.4%)
13-epi-manoyl oxide (1.1%)
13-epi-manool (2.3%)
sclareol (15.7%)

† = incorrect identification based on GC elution order

Yaseen et al. (2006) analyzed an oil of clary sage grown under a sub-tropical climate (Lucknow, India). The components characterized in this oil were:

(Z)-3-hexenol (0.1%)
β-pinene (0.3%)
myrcene (0.6%)
limonene (0.2%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (0.2%)
linalool (23.2%)
α-terpineol (4.5%)
nerol (1.0%)
neral (0.1%)
linalyl acetate (49.3%)
geraniol (0.2%)
neryl acetate (1.6%)
geranyl acetate (3.0%)
α-copaene (0.5%)
β-caryophyllene (2.6%)
germacrene D (1.5%)
spathulenol (1.5%)
caryophyllene oxide (0.2%)
β-eudesmol (0.4%)
sclareol oxide (0.6%)
manoyl oxide (0.6%)
sclareol (5.3%)

The oil was obtained by hydro-distillation, consequently there was a reduced level of linalyl acetate and an increased level of linalool because linalyl acetate was partially hydro-lyzed during water distillation.

Lattoo et al. (2006) reported that the composition of an oil of *S. sclarea* grown in Jammu (India) and produced by hydrodistillation of the inflorescences was found to contain:

linalool (41.9%)
trans-β-terpineol (1.3%)
α-terpineol (7.0%)
nerol (5.0%)
linalyl acetate (19.8%)
neral (1.3%)
geraniol (9.0%)
geranial (0.6%)
β-caryophyllene (1.4%)
β-humulene (6.9%)
α-cadinene (1.5%)
β-caryophyllene (1.6%)
sclareol (1.8%)

This is another example of a hydro-lyzed oil of clary sage being produced.

A. Carrubba, R. la Torre, R. Piccaglia and M. Marotti, *Characterization of an Italian biotype of clary sage (*Salvia sclarea *L.) grown in a semi-arid Mediterranean environment*. Flav. Fragr. J., **17**, 191–194 (2002).

J. Mastelic and I. Jerkovic, *Application of co-distillation with superheated pentane vapour to the isolation of unstable essential oils.* Flav. Fragr. J., **18**, 521–526 (2003).

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D. Lorenzo, D. Paz, P. Davies, J. Villamil, R. Vila, S. Canigueral and E. Dellacassa, *Characterization and enantiomeric distribution of some terpenes in the essential oil of a Uruguayan biotype of* Salvia sclarea *L.* Flav. Fragr. J., **19**, 303–307 (2004).

P. Farkas, M. Itolla, J. Tekel, S. Mellen and S. Vaverkova, *Composition of the essential oils from the flowers and leaves of* Salvia sclarea *L. (Lamiaceae) cultivated in Slovak Republic.* J. Essent. Oil Res., **17**, 141–144 (2005).

M. Yaseen, A. Sattar, A.A. Naqvi and S.P.S. Khanuja, *Clary sage (*Salvia sclarea*): high value essential oil crop in north Indian plains.* Indian Perfum., **50**, 35–38 (2006).

S.K. Lattoo, R.S. Dhar, A.K. Dhar, P.R. Sharma and S.G. Agarwal, *Dynamics of essential oil biosynthesis in relation to inflorescence and glandular ontogeny in* Salvia sclarea. Flav. Fragr. J., **21**, 817–821 (2006).

Lavender Oil

Mallavarapu et al. (2000) analyzed oils produced from lavender grown in Kodaikanal and Kashmir (India). The oils were found to be quite similar as can be seen from the following range data:

α-pinene (0–0.1%)
camphene (0.2–0.3%)
sabinene + 1-octen-3-ol (1.3–1.6%)
myrcene (0.1–0.3%)
α-phellandrene (0.1–0.2%)
δ-3-carene (0.1%)
p-cymene (0.2%)
limonene + 1,8-cineole (1.2–1.9%)
(Z)-β-ocimene (0–0.9%)
(E)-β-ocimene (0–1.3%)
cis-linalool oxide[f] (0.2–0.5%)
trans-linalool oxide[f] (0.1–0.4%)
linalool (28.2–28.7%)
1-octen-3-yl acetate (0.9–1.4%)
p-menth-2-en-1-ol* (0.1–0.2%)
camphor (0.2%)
borneol (0.3–0.6%)
cis-linalool oxide[‡] (0.1–0.2%)
lavandulol (0.4–0.5%)
terpinen-4-ol (0.5–0.7%)
(Z)-3-hexenyl butyrate (0–0.3%)
α-terpineol (2.0–4.9%)
hexyl butyrate (0–0.1%)
nerol (0.3–1.2%)
geraniol (0–1.7%)
linalyl acetate (43.1–50.6%)
bornyl acetate (0.2%)
lavandulyl acetate (0.9–1.6%)
α-terpinyl acetate (0.1%)
neryl acetate (0.5–1.3%)
geranyl acetate (1.0–2.0%)
β-caryophyllene (1.0–1.8%)
trans-α-bergamotene (0.1–1.0%)
(E)-β-farnesene (0–0.1%)
α-humulene (0.2–0.4%)
germacrene D (0.1–0.2%)
γ-muurolene (0–0.4%)
γ-cadinene (0.2–0.3%)
α-calacorene (0.1–0.2%)
ledol (0–0.2%)
caryophyllene oxide (0.5–2.2%)
T-cadinol (0–0.1%)
α-muurolol (0.3–0.7%)

[f] = furanoid form; * correct isomer not identified; [‡] = pyranoid form

Comparative percentage composition of an oil and volatile concentrate of *Salvia sclarea* **T-2**

Compound	Oil	Volatile concentrate
α-pinene	t	t
β-pinene	t	t
sabinene	t	–
myrcene	8.4	10.2
limonene	2.1	2.7
(Z)-β-ocimene	1.9	2.8
(E)-β-ocimene	4.4	6.4
terpinolene	0.9	t
allo-ocimene*	0.8	0.8
α-copaene	1.0	2.3
linalool	16.6	6.0
linalyl acetate	21.2	33.4
linalyl butyrate	–	0.5
calarene	1.0	1.3
β-caryophyllene	1.7	2.1
aromadendrene	0.1	0.1
(E)-β-farnesene	0.3	t
epi-bicyclosesquiphellandrene	0.4	1.9
α-terpineol	7.6	–
geranyl formate	0.2	0.4
β-cubebene	4.5	6.4
zingiberene	0.3	t
neryl acetate	4.1	3.4
geranyl acetate	7.3	6.7
nerol	1.7	–
geraniol	3.8	–
hedycaryol[a]	0.1	0.3
farnesol*	0.4	0.4
β-eudesmol	1.0	0.9
manoyl oxide	0.6	0.6
tetradecanoic acid	–	2.7

* correct isomer not identified; t = trace (< 0.1%); [a] = tentative identification

Kim and Lee (2002) compared the data obtained when 'Hidcote' lavender was examined by solid-phase trapping solvent extraction (SPTE), headspace solid phase microextraction (SPME), reduced pressure steam distillation (RPSD) and simultaneous distillation-solvent extraction (SDE) followed by analysis by GC/MS.

In SPTE, 20 g of dried lavender was charged into the clean dry barrel of a 50 mL hyperdermic syringe that had the plunger and needle removed. A second barrel of a 50 mL syringe was fitted to the first with a Teflon gasket and a joint clip. A Pasteur pipette (15 cm x 0.565 cm) was used as a trap-housing packed with Porapak Q (500 mg) and plugged with glass wool. Purified N2 gas was passed through the two barrels and out through the plugged pipette at a rate of 400 mL/min for 3 h at ambient temperature. After 3 h the adsorbed volatiles were removed by 2 x mL extraction of the Porapak Q with pet ether and subjected to GC/MS. The other volatile isolation techniques used were standard with 1 g of lavender being used for SPME, 300 g for RPSD and 10 g for SDE. The highest amount of volatiles was obtained from SPTE. The amounts were as follows:

ethylbenzene[‡] (0.34%)
m- or p-xylene[‡] (0.85%)
o-xylene[‡] (0.40%)
α-thujene (0.36%)
α-pinene (0.97%)
camphene (1.57%)
β-pinene (0.63%)

myrcene (0.91%)
p-cymene (0.11%)
limonene (1.23%)
1,8-cineole (5.94%)
linalool oxide* (0.21%)

† = contaminants from the pet ether; * correct isomer not identified

Konakchiev and Tsankova (2003) compared the compositions of Bulgarian lavender oil produced from the 'Druzhba' and 'Hemus' cultivars. The results of this study can be found in **T-3**.

Shawl et al. (2005) analyzed an oil of lavender produced in the Kashmir region (India). Its composition was determined to be as follows:

methyl hexyl ether‡ (0.02%)
ethyl 2-methylbutyrate (0.02%)
(Z)-3-hexenol (0.06%)
(Z)-3-hexenyl formate (0.04%)
tricyclene (0.02%)
α-pinene (0.22%)
camphene (0.34%)
sabinene (0.07%)
1-octen-3-ol (0.18%)
3-octanone (0.90%)
myrcene (0.22%)
isobutyl butyrate (0.05%)
3-octanol (0.11%)
hexyl acetate (0.28%)
p-cymene (0.24%)
limonene (0.33%)
1,8-cineole (2.10%)
(Z)-β-ocimene (0.06%)
(E)-β-ocimene (0.03%)
thujyl alcohol (0.02%)
cis-linalool oxide[f] (0.49%)
trans-linalool oxide[f] (0.48%)
linalool (25.27%)
1-octen-3-yl acetate (0.66%)
bicycloheptan-3-ol‡ (0.10%)
camphor (1.07%)
octadienediol‡ (0.05%)
borneol (2.70%)
terpinen-4-ol (0.72%)
hexyl butyrate (0.29%)
α-terpineol (1.49%)
verbenone (0.07%)
isobornyl formate (0.10%)
geraniol (0.16%)
cuminaldehyde (0.14%)
carvone (0.06%)
linalyl acetate (44.9%)
geranial (0.06%)
borneol acetate (0.51%)
lavandulyl acetate (3.44%)
neryl acetate (0.44%)
geranyl acetate (0.81%)
β-caryophyllene (1.85%)
α-bergamotene* (0.12%)
α-humulene (0.05%)
(Z)-b-farnesene (0.67%)
dimethyloctatriene‡ (0.51%)
δ-cadinene (0.14%)
caryophyllene oxide (2.08%)

[f] = furanoid form; * correct isomer not identified; ‡ = misidentification, not a component of lavender oil

Comparative percentage composition of Bulgarian lavender oils obtained from two different cultivars **T-3**

Compound	'Druzhba' oil	'Hemus' oil
valeraldehyde	t	t–0.1
α-pinene	0.2–0.3	0.2
α-thujene	0.1–0.2	0.1
camphene	0.2–0.3	0.2–0.3
β-pinene	t–0.1	t–0.1
sabinene	t–0.1	t–0.1
δ-3-carene	0.1–0.2	0.1–0.2
myrcene	0.6–0.7	0.7–0.8
α-terpinene	t–0.1	t–0.1
limonene	0.3–0.5	0.3–0.7
1,8-cineole + β-phellandrene	1.0–1.4	0.5–2.5
(Z)-β-ocimene	5.8–8.1	4.4–5.7
γ-terpinene	0.1–0.2	0.1–0.2
(E)-β-ocimene + 3-octanone	2.7–5.1	3.0–3.6
p-cymene	0.4–0.5	0.4–0.6
terpinolene	0.1	0.1
hexanol	t–0.1	t–0.1
1-octen-3-yl acetate	0.8–1.0	0.8–1.0
octanol + galbanolene*[a]	0.1–0.2	0.1–0.2
hexyl butyrate	0.1–0.2	0.2
cis-linalool oxide*	0.1	0.1
1-octen-3-ol	0.2–0.3	0.1–0.3
trans-sabinene hydrate	t–0.1	t–0.1
trans-linalool oxide*	t–0.1	0.1
camphor	0.2–0.4	0.3–0.4
linalool	21.8–26.8	18.5–27.3
linalyl acetate	32.2–37.5	38.8–50.8
α-santalene	0.4–0.7	0.5
bornyl acetate	0.2–0.3	0.2–0.4
α-bergamotene*	0.1–0.2	0.1
β-caryophyllene	3.6–4.3	3.0–3.7
terpinen-4-ol	4.0–6.3	2.3–3.6
lavandulyl acetate	3.5–4.3	3.3–3.6
cryptone	0.1	0.1
(E)-β-farnesene	2.7–3.1	2.4–3.0
lavandulol	1.0–1.2	0.5–0.8
α-terpineol	0.9–1.1	1.0–1.3
borneol	0.7–1.1	0.7–1.2
germacrene D	0.3–0.4	0.2–0.5
neryl acetate	0.2–0.5	0.4
geranyl acetate	0.5–0.9	0.7–0.8
cuminaldehyde	0.1	0.1–0.2
nerol	0.2	0.2–0.3
geraniol	0.5–0.7	0.2
caryophyllene oxide	0.2	0.2
δ-cadinene	t–0.1	0.1

* correct isomer not identified; t = trace (< 0.05%); [a] = also known as 1,3,5-undecatriene

Ranade (2003) reported that the composition of lavender oil produced in the Kashmir Valley (India) was as follows:

α-pinene (0.20%)
camphene (0.42%)
β-pinene (1.29%)
cumene† (1.02%)
myrcene (0.47%)
limonene (11.00%)
1,8-cineole (1.82%)
p-cymene (0.27%)
limonene oxide* (0.57%)
linalool (10.00%)
linalyl acetate (45.30%)
citronellol (10.00%)
terpinen-4-ol (2.29%)
α-terpineol (7.58%)
borneol (0.23%)
bornyl acetate (0.45%)
lavandulyl acetate (0.13%)
β-caryophyllene (2.12%)
farnesene* (0.07%)

† = doubtful identification; * correct isomer not identified

An oil produced from lavender plants collected in Crete (Greece) was determined by Daferera et al. (2003) to possess the following composition:

camphene (0.5%)
myrcene (1.6%)
p-cymene (0.5%)
1,8-cineole (2.4%)
ocimene* (1.1%)
γ-terpinene (0.1%)
trans-linalool oxide[f] (3.0%)
cis-linalool oxide[f] (2.1%)
terpinolene (0.1%)
linalool (25.5%)
3,7-dimethyl-1,5,7-octatrien-3-ol[t] (2.1%)
1-octenyl acetate[t] (1.6%)
camphor (0.6%)
borneol (3.2%)
terpinen-4-ol (1.7%)
cryptone[t] (1.4%)
α-terpineol (5.0%)
verbenone[t] (0.2%)
nerol (1.0%)
linalyl acetate (17.7%)
bornyl acetate (1.0%)
lavandulyl acetate (3.9%)
thymol (3.2%)
carvacrol (3.2%)
neryl acetate (1.3%)
geranyl acetate (2.6%)
β-caryophyllene (1.7%)
caryophyllene oxide (0.2%)

* correct isomer not identified; [f] = furanoid form; [t] = tentative identification (probably incorrect)

An oil of lavender of Russian origin has been the subject of analysis. The results of this analysis (Anon 2004) are shown as follows:

α-thujene (0.10%)
α-pinene (0.22%)
camphene (0.27%)
sabinene (0.03%)
1-octen-3-ol (0.32%)
β-pinene (0.08%)
3-octanone (0.10%)
myrcene (0.47%)
hexyl acetate (0.12%)
δ-3-carene (0.35%)
p-cymene (0.84%)
limonene (0.96%)
1,8-cineole (1.82%)
(Z)-β-ocimene (1.64%)
(E)-β-ocimene (0.75%)
cis-sabinene hydrate (0.10%)
cis-linalool oxide[f] (0.30%)
terpinolene (0.09%)
trans-linalool oxide[f] (0.30%)
rose furan (34.35%)
1-octen-3-yl acetate (0.70%)
(E,E)-allo-ocimene (0.18%)
nerol oxide (0.15%)
hexyl isovalerate (0.11%)
camphor (0.47%)
borneol (1.64%)
terpinen-4-ol (2.95%)
p-cymen-8-ol (0.14%)
cryptone (0.30%)
hexyl butyrate (0.29%)
α-terpineol (1.52%)
trans-carveol (0.02%)
nerol (0.22%)
cuminaldehyde (0.15%)
carvone (0.03%)
linalyl acetate (36.28%)
phellandrene† (0.02%)
lavandulyl acetate (1.87%)
cuminyl alcohol (0.04%)
hexyl tiglate (0.01%)
neryl acetate (0.46%)
geranyl acetate (0.73%)
β-bourbonene (0.03%)
7-epi-sesquithujene (0.03%)
trans-α-bergamotene (0.09%)
α-santalene (0.69%)
β-caryophyllene (2.88%)
cis-α-bergamotene (0.21%)
β-duprezianene (0.04%)
epi-β-santalene (0.02%)

Comparative percentage composition of a hydrodistilled oil of lavender with a solvent extraction-continuous hydrodistillation of the same batch of lavender flowers **T-4**

Compound	Oil	Extract
α-pinene	0.1	t
camphene	0.4	0.1
1-octen-3-ol	0.4	0.4
3-octanone	1.0	0.3
β-pinene	1.4	0.2
myrcene	0.2	t
hexyl acetate	t	0.1
α-phellandrene	0.2	0.9
α-terpinene	t	0.3
p-cymene	0.3	t
1,8-cineole	6.7	0.8
(Z)-β-ocimene	1.3	t
γ-terpinene	0.5	t
cis-linalool oxide*	0.4	0.7
linalool	35.3	32.8
camphor	1.6	1.9
lavandulol	3.0	4.3
α-terpineol	4.2	6.7
nerol	0.7	1.0
cuminaldehyde	1.6	2.5
carvone	0.3	–
piperitone	2.0	–
linalyl acetate	13.4	17.6
lavandulyl acetate	10.9	15.9
bornyl acetate	0.2	t
neryl acetate	1.2	2.4
geranyl acetate	2.5	5.0
β-caryophyllene	1.6	1.5
α-santalene	0.3	–
caryophyllene oxide	1.9	–

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

(Z)-β-farnesene (0.81%)
α-humulene (0.10%)
(E)-β-farnesene (0.04%)
ar-curcumene (0.01%)
germacrene D (0.13%)
β-bisabolene (0.03%)
γ-cadinene (0.15%)
cis-calamenene (0.03%)
caryophyllene oxide (1.25%)
1,10-di-epi-cubenol (0.01%)
α-cadinol (0.12%)
longifolenal (0.01%)
benzyl benzoate (0.01%)
hexahydrofarnesyl acetone (0.01%)

[f] = furanoid form; [†] = incorrect identification based on GC elution order

D'Auria et al. (2005) collected two samples of lavender plants from the Basilicata region of southern Italy and used SPME to determine that the headspace volatiles were as follows:

isovaleraldehyde (0.04–0.08%)
2-methylbutanol (0–0.05%)
toluene (0.04–0.05%)
hexanal (0–0.04%)
1-methoxyhexane[†] (0–0.67%)
(Z)-3-hexenol (0.04–0.06%)
hexanol (0.34–0.36%)
tricyclene (0–0.22%)
α-thujene (0.46–1.00%)
α-pinene (0.89–1.53%)
camphene (1.91–2.17%)
sabinene (0.81–2.57%)
1-octen-3-ol (0–0.85%)
3-octanone (0–2.17%)
myrcene (4.42–7.61%)
3-octanol (0–0.21%)
α-phellandrene (0.16–1.05%)
δ-3-carene (2.10–4.32%)
p-cymene (0–1.31%)
β-phellandrene (15.18–20.36%)
(E)-β-ocimene (0.64–0.85%)
γ-terpinene (0.09–0.51%)
linalool oxide*[f] (0–0.61%)
terpinolene (0–1.22%)
linalool (22.08–30.24%)
cis-limonene oxide (0–0.19%)
camphor (1.38–2.13%)
borneol (2.23–2.95%)
α-terpineol (0.12–1.06%)
cryptone (0.26–0.41%)
trans-piperitol (0–0.04%)
nerol (0.06–0.07%)
bornyl formate (0.30–0.64%)
linalyl acetate (18.66–21.38%)
lavandulyl acetate (0–1.23%)
neryl acetate (0.09–0.37%)
geranyl acetate (0.15–0.37%)
β-bourbonene (0–0.05%)
α-cubebene (0.02–0.09%)
α-gurjunene (0–0.08%)
α-cedrene (0.09–0.14%)
β-caryophyllene (1.63–2.91%)
α-humulene (0–0.03%)
bicyclosesquiphellandrene (0.54–1.33%)
γ-curcumene (0–0.04%)
germacrene D (0.16–0.38%)
zingiberene (0–0.03%)
bicyclogermacrene (0–0.01%)
β-selinene (0.05–0.12%)
γ-cadinene (0.21–0.41%)
cis-calamenene (0.07–0.10%)
α-cadinene (0–0.01%)
α-cadinol (0.02–0.04%)

* correct isomer not identified; [f] = furanoid form; [†] = incorrect identification

Percentage composition of lavender flower oils produced two separate ways **T-5**

Compound	Hydrodistilled oil	Microwave-assisted hydrodistilled oil
α-thujene	t	0.08
α-pinene	0.90	0.51
camphene	0.52	0.32
3-octanone	0.73	0.78
sabinene	0.18	0.14
β-pinene	0.82	0.59
myrcene	0.85	0.50
δ-3-carene	0.29	0.22
1,8-cineole	7.29	7.23
(Z)-β-ocimene	0.41	0.33
γ-terpinene	–	0.09
(E)-β-ocimene	0.53	0.37
terpinolene	0.40	0.37
3-octanol	0.37	0.26
cis-sabinene hydrate	–	0.66
linalool	46.85	47.82
camphor	10.23	11.82
terpinen-4-ol	5.54	5.94
borneol	4.07	4.15
α-terpineol	1.16	0.68
dihydromyocenol	–	0.34
linalyl acetate	11.90	10.74
geranyl acetate	0.26	0.08
cis-α-bergamotene	–	0.10
β-caryophyllene	1.72	1.28
α-santalene	–	0.15
(E)-β-farnesene	0.65	0.63

Baser et al. (2005) determined the enantiomeric ratio of linalool, linalyl acetate and camphor in three cultivar oils and one commercial sample of lavender oils. The ratios were measured to be as follows:

(3S)-(+)-linalool (3.4–5.0%):(3R)-(-)-linalool (95.0–96.6%)
(3S)-(+)-linalyl acetate (0%):(3R)-(-)-linalyl acetate (100%)
(1R)-(+)-camphor (27.4–52.2%):(1S)-(-)-camphor (47.8–78.6%)

Fakhari et al. (2005) used a solvent microextraction combined with continuous hydrodistillation to isolate the volatiles from lavender flowers and compared the isolate with the oil obtained by hydrodistillation. The results of this study are summarized in **T-4**.

In addition, trace amounts (< 0.1%) of tricyclene, *trans*-linalool oxide, terpinolene, chrysanthenone, cryptone, terpinen-4-ol and verbenone were found in both the oil and extract. α-Pinene, myrcene, p-cymene, (Z)-β-ocimene, γ-terpinene and bornyl acetate were found as trace components only in the extract, while the trace components found exclusively in the oil were hexyl acetate, α-terpinene and γ-cadinene. The lavender used was not a normal source of commercial oil production.

Chemat et al. (2005) compared the results of a lavender oil isolated either by microwave-accelerated hydro-

distillation with an oil isolated by the standard hydrodistillation methodology. **T-5** presents the results of this study.

In addition, Chemat et al. also characterized trace amounts of p-cymen-8-ol and limonene in both oils. It should be pointed out that the lavender flowers used to produce the oils are not obtained from a commercial planting of lavender for oil production.

Iriti et al. (2006) also presented the results of a study in which lavender oil was isolated by hydrodistillation (HD), microwave-assisted hydrodistillation (MAHD), microwave-assisted steam distillation (MASD) and microwave-assisted steam distillation under vacuum (MASDV). The study results can be found in **T-6**.

Pavela (2006) screened a few Lamiaceae oils against typical greenhouse pests such as the cabbage aphid. He found that French lavender oil was one of the more toxic oils for the aphid. The main components of the tested oil were:

camphene (0.33%)
α-terpinene (2.82%)
1,8-cineole (1.11%)
camphor (0.55%)
linalool (29.98%)
linalyl acetate (45.34%)
α-terpineol (15.33%)
geraniol (2.43%)

It should be noted that the level of α-terpineol reported is very unusual.

To reduce the microbiological contamination and insect infestation of dried plants it is not uncommon to use ionizing radiation. Haddad et al. (2007) showed that the use of γ-irradiation or e-beam ionization (using a double beam linear electron accelerator) did not affect the oils produced from treated or untreated lavender flowers either qualitatively or quantitatively.

Moon et al. (2007) screened a number of Australian-produced oils of *Lavandula* species for their antifungal activity. The range in composition of the two lavender oils screened was found to be as follows:

α-pinene (0.1–0.2%)
β-pinene (0.1%)
1,8-cineole (1.1–1.5%)
(Z)-β-ocimene (1.0–1.8%)
cis-linalool oxide[f] (0.1–0.3%)
trans-linalool oxide[f] (0–0.2%)
linalool (29.1–36.2%)
camphor (0.3–1.0%)
borneol (0.8–1.1%)
terpinen-4-ol (1.5–2.3%)
cryptone + p-cymen-8-ol (0–0.4%)
(Z)-3-hexenyl butyrate (0–0.2%)
α-terpineol (0.5%)
linalyl acetate (40.4–41.3%)
lavandulyl acetate (1.2–6.1%)
caryophyllene oxide (0.2–0.9%)

[f] = furanoid form

Comparative percentage composition of lavender oils produced from lavender flowers by four different distillation methods **T-6**

Compound	HD	MAHD	MASD	MASDV
α-thujene	t	t	0.1	t
α-pinene	0.6	0.3	0.6	0.2
camphene	0.4	0.2	0.4	0.2
sabinene	t	0.1	0.1	t
β-pinene	0.6	0.4	0.6	0.4
3-octanone	0.7	0.6	0.6	0.7
myrcene	1.1	0.5	0.6	0.4
δ-3-carene	0.2	0.2	0.2	0.1
limonene	t	0.4	t	t
1,8-cineole	7.4	5.3	6.3	7.2
(Z)-β-ocimene	0.5	0.3	0.4	0.2
γ-terpinene	0.2	0.1	0.1	t
terpinolene	0.5	0.3	0.5	0.3
cis-sabinene hydrate	t	0.4	0.4	0.6
linalool	49.7	48.3	43.8	50.1
camphor	10.8	11.0	10.1	12.5
borneol	4.4	4.6	4.2	4.9
terpinen-4-ol	6.1	5.9	5.4	6.2
p-cymen-8-ol	t	t	0.1	t
α-terpineol	2.4	1.0	1.0	0.8
dihydromyrcenol	0.6	0.3	0.4	0.4
linalyl acetate	7.6	12.5	13.8	9.5
neryl acetate	0.7	0.2	0.3	0.1
cis-α-bergamotene	t	0.1	0.2	t
β-caryophyllene	0.5	1.3	2.2	0.6
α-santalene	t	0.1	t	t
farnesene*	0.2	0.6	1.0	0.3
caryophyllene oxide	t	0.2	0.4	0.2
α-bisabolol	0.7	0.5	1.4	0.8

* correct isomer not identified; t = trace (< 0.1%); HD = hydrodistilled oil; MAHD = microwave-assisted hydrodistilled oil; MASD = microwave-assisted steam distilled oil; MASDV = microwave-assisted steam distilled oil under vacuum

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Comparative percentage composition of ginger oil produced from three cultivars **T-7**

Compound	'Desi' oil	'Pahari' oil	'Nepali' oil
camphene	0.33	–	–
myrcene	0.28	0.78	0.57
limonene	–	0.65	0.45
β-phellandrene	–	1.05	0.79
1,8-cineole	0.74	2.54	1.10
linalool	1.51	1.80	1.41
borneol	5.20	2.99	5.84
α-terpineol	1.70	1.36	1.52
neral	9.95	11.94	6.93
geraniol	3.63	4.55	0.58
geranial	14.33	16.37	9.53
isoamyl methyl ketone†	0.36	0.26	0.66
citronellyl acetate	0.60	0.63	0.38
α-copaene	0.60	0.50	0.50
geranyl acetate	2.00	2.20	0.50
cedrene*	0.70	0.59	0.58
bergamotene*	0.51	0.44	0.38
ar-curcumene	0.27	0.22	0.22
zingiberene	17.42	12.33	23.79
α-farnesene*	–	0.73	0.21
isocaryophyllene†	0.89	2.16	0.77
β-sesquiphellandrene	9.80	7.70	10.80
nerolidol*	2.59	5.99	5.30
caryophyllene oxide	0.39	0.31	0.53
cedrene epoxide	0.83	0.21	0.34
cedrol	1.66	1.08	1.73
cadinol*	3.04	2.41	1.47
eudesmol*	1.29	0.93	1.87
farnesol*	1.44	1.32	1.87

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

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Ginger Oil

An oil of ginger produced from cultivated rhizomes in Reduit (Mauritius) was analyzed using GC and GC/MS by Gurib-Fakim et al. (2002). This oil, which was particularly rich in neral and geranial, was found to possess the following composition:

β-phellandrene (1.7%)
1,8-cineole (2.0%)
linalool (1.2%)
borneol (4.7%)
α-terpineol (3.3%)
citronellol (1.3%)
neral (10.3%)
geraniol (3.1%)
geranial (16.3%)
2-undecanone (1.3%)
geranyl acetate (2.2%)
ar-curcumene (5.1%)
(E,E)-α-farnesene (2.4%)
zingiberene (9.5%)
β-bisabolene (3.0%)
γ-cadinene (1.8%)
β-sesquiphellandrene (6.3%)
trans-β-sesquiphellandrol (2.0%)
cis-β-sesquiphellandrol (0.6%)
elemol (2.7%)
trans-sesquisabinene hydrate (1.4%)
zingiberenol (2.7%)
(E,E)-α-farnesol (4.1%)

An Indian oil of ginger was reported by Ranade (2002) to contain the following components, which are listed in alphabetical order and not in GC elution order:

bornyl acetate (0.1%)
borneol (2.2%)
β-bisabolene (0.2%)
camphene (1.1%)
cumene (0.1%)
δ-3-carene (0.1%)
ar-curcumene (17.7%)
p-cymene (0.1%)
1,8-cineole (1.3%)
decanal (0.2%)
β-elemene (1.0%)
β-farnesene* (9.8%)
geranial (1.4%)
geraniol (0.1%)
2-heptanol (0.1%)
linalool (1.3%)
limonene (1.2%)
myrcene (0.1%)
6-methyl-5-hepten-2-one (0.1%)
neral (0.8%)
nonanal (0.1%)
2-nonanol (0.2%)
α-pinene (0.4%)
β-pinene (0.2%)
β-phellandrene (1.3%)
sabinene (0.1%)
α-selinene (1.4%)
α-terpineol (0.1%)
zingiberene (35.6%)

* correct isomer not identified

Ranade also stated that a series of gingerols, dihydrogingerols, shogaols, gingerones, etc. (21.7%) were also found in the oil. This is ludicrous as these components are not found in

the oil but in the oleoresin or extracts.

In India a number of cultivars of ginger are grown commercially. Three cultivars ('Desi,' 'Pahari,' and 'Nepali') are widely grown in Northern India. Ahmad et al. (2002) produced oils from these three cultivars and subjected them to GC/MS analysis, the results of which can be seen in **T-7**.

The headspace of chopped, fresh Australian ginger rhizomes that have had the skin removed was analyzed by Shao et al. (2003) using solid-phase microextraction-comprehensive two dimensional gas chromatography. The components identified in this headspace were as follows:

α-pinene (3.03%)
camphene (6.45%)
β-pinene (0.42%)
myrcene (2.39%)
α-terpinene (0.73%)
β-phellandrene (16.07%)
(Z)-β-ocimene (0.16%)
(E)-β-ocimene (0.01%)
γ-terpinene (0.05%)
terpinolene (0.03%)
2-nonanone (0.45%)
p-mentha-1,3,8-triene (0.38%)
camphor (0.02%)
isopulegol (0.04%)
citronellol (0.06%)
iso(iso)pulegol (0.04%)
borneol (0.08%)
terpinen-4-ol (0.08%)
α-terpineol (0.23%)
neral (0.45%)
geranial (4.20%)
bornyl acetate (1.04%)
2-undecanone (0.07%)
cyclosativene (1.23%)
α-copaene (0.39%)
trans-α-bergamotene (0.20%)
allo-aromadendrene (0.21%)
epi-bicyclosesquiphellandrene (0.62%)
γ-curcumene (2.09%)
ar-curcumene (0.03%)
α-muurolene (11.57%)
zingiberene (4.15%)
(Z)-α-bisabolene (4.46%)
α-farnesene* (14.26%)
β-sesquiphellandrene (5.68%)

* correct isomer not identified

Gong et al. (2004) determined the volatiles found in oils produced from fresh and dried ginger rhizomes purchased from Hong Kong. Although a number of the constituents were correctly characterized, a large number of constituents were not correctly identified. Consequently, the results of this study are not included in this review.

The composition of an oil of ginger produced from rhizomes purchased at a local market in Gorakhpur (India) was analyzed by Singh et al. (2004). They found that the oil contained the following components:

2-methyl-3-buten-2-ol (0.01%)
hexanal (0.11%)
2-heptanone (0.03%)
tricyclene (0.14%)
α-pinene (2.57%)
camphene (9.32%)
sabinene (0.11%)
β-pinene (0.14%)
6-methyl-5-hepten-2-one (0.21%)
myrcene (0.75%)
octanal (0.12%)
α-phellandrene (0.41%)
δ-3-carene (0.03%)
p-cymene (0.08%)
β-phellandrene (7.97%)
1,8-cineole (1.20%)
terpinolene (0.15%)
linalool (0.47%)
camphor (0.15%)
camphene hydrate (0.08%)
citronellal (0.10%)
borneol (2.04%)
terpinen-4-ol (0.13%)
α-terpineol (0.35%)
decanal (0.06%)
nerol (0.22%)
citronellol (0.39%)
neral (1.72%)
geraniol (0.50%)
geranial (2.08%)
bornyl acetate (0.35%)
2-undecanone (0.01%)
δ-elemene (0.07%)
cyclosativene (0.13%)
α-copaene (0.26%)
β-elemene (0.48%)
γ-elemene (0.07%)
trans-α-bergamotene (0.07%)

Comparative percentage composition of some oils of ginger produced from different Indian locations **T-8**

Compound	1	2	3	4
hexanal	0.2	0.4	0.3	0.2
2-heptanone	0.1	0.1	0.1	0.1
α-pinene	1.5	1.9	2.2	1.7
camphene	6.1	6.6	7.6	4.9
sabinene	1.0	0.5	1.4	1.3
myrcene	1.0	1.3	1.7	1.7
p-cymene	0.1	0.1	1.4	1.4
β-ocimene*	0.9	1.4	6.5	5.0
limonene	1.3	6.4	1.9	2.9
β-phellandrene	3.4	4.2	–	–
linalool	1.7	0.6	1.3	0.7
borneol	2.6	0.1	2.0	0.8
terpinen-4-ol	0.2	1.9	0.1	0.1
α-terpineol	0.8	1.0	0.2	0.2
citronellol	0.9	0.6	1.1	1.4
neral	7.0	5.3	8.8	6.9
geraniol	1.7	1.2	2.0	2.4
geranial	10.5	7.4	12.0	10.2
geranyl acetate	0.6	0.1	0.4	0.6
β-caryophyllene	0.1	2.2	0.1	0.1
α-farnesene*	0.3	0.2	0.3	0.3
ar-curcumene	9.8	5.4	2.9	4.3
zingiberene	10.5	15.2	16.6	16.6
β-farnesene*	5.1	5.6	6.0	8.4
farnesol*	5.8	4.9	3.9	4.5
germacrene D	1.6	2.7	0.8	2.2
β-sesquiphellandrene	7.1	7.2	5.8	6.8
nerolidol*	2.1	1.2	0.8	0.5
cedrol	1.3	0.9	0.6	0.6

* correct isomer not identified; 1 = Mizoram; 2 = Chennai; 3 = Sikkim Majhauley; 4 = Sikkim Bhainsey

aromadendrene (0.11%)
(E)-β-farnesene (0.12%)
γ-gurjunene (0.11%)
germacrene D (1.03%)
ar-curcumene (9.09%)
valencene (1.42%)
zingiberene (28.62%)
β-bisabolene (5.40%)
(E,E)-α-farnesene (5.52%)
δ-cadinene (0.17%)
β-sesquiphellandrene (8.64%)
(E)-γ-bisabolene (0.38%)
elemol (0.49%)
germacrene B (0.43%)
(E)-nerolidol (0.47%)
trans-sesquisabinene hydrate (0.40%)
10-epi-γ-eudesmol (0.06%)
zingiberenol (0.92%)
agarospirol (0.11%)
β-eudesmol (0.25%)
α-eudesmol (0.11%)

Comparative percentage composition of water distilled and steam distilled oils of Vietnamese ginger **T-9**

Compound	Water distilled oil	Steam distilled oil
tricyclene	0.1	0.1
α-pinene	0.6	0.7
camphene	2.5	1.8
6-methyl-5-hepten-2-one	0.7	0.2
p-cymene	0.2	0.1
limonene	0.4	–
β-phellandrene	–	1.2
1,8-cineole	3.2	1.5
linalool	1.1	0.9
camphor	0.7	0.1
borneol	2.5	1.2
terpinen-4-ol	0.3	0.1
cryptone	0.6	0.1
α-terpineol	1.2	0.7
citronellol	0.4	0.4
2,3-epoxygeraniol†	0.2	–
neral	0.8	1.3
geraniol	0.9	1.2
geranial	1.2	2.0
bornyl acetate	0.6	0.4
2-undecanone	0.4	0.3
citronellyl acetate	0.4	0.1
α-copaene	0.8	0.7
geranyl acetate	3.0	3.1
β-elemene	0.5	1.1
cis-α-bergamotene	t	0.4
(E)-β-farnesene	0.2	0.7
allo-aromadendrene	0.3	1.1
γ-muurolene	0.5	t
ar-curcumene	11.7	12.6
α-selinene	1.5	–
zingiberene	t	10.3
α-amorphene	1.1	0.9
β-bisabolene	4.1	8.1
β-sesquiphellandrene	–	7.4
δ-cadinene	0.5	–
trans-calamenene	0.3	–
elemol	1.0	t
(E)-nerolidol	0.9	–
ar-turmerol	0.9	t
trans-sesquisabinene hydrate	1.4	t
zingiberenol	0.8	1.3
β-eudesmol	1.5	0.6
isoacorone†	t	1.1

† incorrect identification based on GC elution order

In addition, trace amounts (< 0.01%) of α-thujene, α-terpinene, (Z)-β-ocimene, (E)-β-ocimene, γ-terpinene, *cis*-sabinene hydrate, octanol, nonanal, *cis*-p-menth-2-en-1-ol and β-caryophyllene were also found in this oil.

The authors also analyzed a sample of ginger oleoresin produced in the laboratory from the same batch of India rhizomes using Soxhlet extraction with acetone as the solvent. The components characterized in this oleoresin were:

camphene (0.01%)
β-phellandrene (0.01%)
δ-elemene (0.03%)
cyclosativene (0.04%)
α-copaene (0.10%)
β-elemene (0.15%)
γ-elemene (0.04%)
trans-α-bergamotene (0.04%)
aromadendrene (0.04%)
germacrene D (0.14%)
ar-curcumene (2.76%)
valencene (0.51%)
zingiberene (9.66%)
β-bisabolene (1.98%)
(E,E)-α-farnesene (1.63%)
δ-cadinene (0.08%)
β-sesquiphellandrene (2.94%)
(E)-γ-bisabolene (0.08%)
germacrene B (0.06%)
zingerone (0.04%)
cis-6-shogaol (3.31%)
6-paradol (1.50%)
trans-6-shogaol (26.32%)
6-gingerol (1.87%)
cis-8-shogaol (1.21%)
trans-8-shogaol (7.72%)
6-gingerdiol diacetate (2.00%)
8-gingerdione (1.45%)
cis-10-shogaol (3.11%)
trans-10-shogaol (13.00%)
10-gingerdione (6.80%)

Trace amounts (< 0.01%) of β-caryophyllene, (E)-β-farnesene and elemol were also found in this oleoresin.

The water distilled oils of ginger rhizomes obtained from three different locations (Mizoram, Chennai and Sikkim where two cultivars were also collected) in India were analyzed by Raina et al. (2005). The analytical results obtained from this study are presented in **T-8**.

Comparative percentage changes in composition of the main components of fresh ginger oil stored over a two-month period **T-10**

Compound	Control oil	Month one oil	Month two oil
β-phellandrene	1.9	1.4	2.1
linalool + α-terpineol	7.4	6.1	7.3
neral	0.7	0.5	0.6
geranial	1.8	1.7	1.5
ar-curcumene	15.6	17.3	18.3
zingiberene + zingiberenol	29.3	29.0	25.3
β-sesquiphellandrene + β-bisabolene	15.4	14.7	13.2
nerolidol*	0.8	0.6	0.8

* correct isomer not identified

Comparative percentage composition of ginger oil and juice volatiles **T-11**

Compound	Fresh ginger oil	Drying ginger oil	Fresh ginger juice volatiles
heptane	–	–	0.2
3-methylpentan-2-ol	–	–	0.1
toluene	–	t–0.1	–
hexanal	0.1	t–0.1	0.1
2-hexanone	–	0–t	–
3-buten-2-ol	–	–	0.1
(E)-2-hexenal	–	–	0.1
hexanol	–	t–0.1	0.1
o-xylene	t	–	0.1
2-heptanone	–	0–0.1	–
amyl acetate	t	–	t
2-heptanol	–	0–0.1	–
tricyclene	–	0–t	–
α-pinene	0.1	0.3–0.5	0.2
camphene	4.0	1.0–1.5	t
heptanol	0.2	–	–
sabinene	3.0	0.8–1.2	0.6
octenal*	–	0–t	–
β-pinene	1.6	–	1.1
myrcene	–	2.1–2.8	0.3
6-methyl-5-hepten-2-one	0.9	–	0.5
α-phellandrene	–	0.7–1.8	–
1,4-cineole	–	–	0.3
β-phellandrene	–	0–1.8	–
1,8-cineole	2.4	1.7–2.3	3.1
limonene	1.9	1.0–1.5	1.6
(E)-β-ocimene	1.3	–	1.9
thujyl alcohol	–	0–0.1	–
γ-terpinene	0.8	0–t	–
cis-linalool oxide[f]	–	–	0.9
linalool	–	0–t	–
trans-linalool oxide[f]	–	–	0.7
terpinolene	–	0–0.2	–
undecane	0.4	–	0.2
myrcenol	–	–	0.5
α-fenchol	–	0–0.2	–
citronellol	–	0–0.1	–
limonene oxide*	–	–	0.5

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T-11

Compound	Fresh ginger oil	Drying ginger oil	Fresh ginger juice volatiles
citronellal	0.1	–	–
camphor	0.2	0–0.3	0.3
menthone	–	–	0.1
borneol	–	0.2–0.5	0.3
β-terpineol*	–	–	0.2
cis-verbenol	–	0–t	–
terpinen-4-ol	0.2	–	0.6
menthol	t	–	0.1
a-terpineol	1.3	0.5–0.9	1.3
dihydrocarveol	–	–	0.1
decanal	0.3	–	t
myrtenol	–	0–0.2	–
myrtenal	–	0.2–0.6	–
nerol	0.4	0.2–1.3	0.1
neral	1.8	0–2.7	8.2
carveol*	–	0.1	–
cis-p-mentha-1,8-dien-6-ol	–	–	t
geraniol	1.8	0.1	1.5
linalyl acetate	–	0.2–0.4	–
(E)-cinnamaldehyde	–	–	t
geranial	8.5	3.6–4.4	24.2
trans-carvone oxide	0.6	–	0.4
bornyl acetate	0.2	t–0.4	0.9
2-undecanone	0.1	t–0.1	0.1
undecanal	0.2	–	–
neric acid	–	–	0.4
α-terpinyl acetate	–	0–t	–
neryl acetate	–	–	0.1
β-cubebene	–	2.3–2.4	–
geranyl acetate	0.1	0–0.3	0.5
α-copaene	–	1.5–1.6	–
δ-elemene	0.5	1.3	0.1
β-elemene	0.4	0.5–1.7	0.1
β-caryophyllene	–	1.4–1.9	–
α-bergamotene*	1.3	1.0–1.9	0.3
β-farnesene*	–	1.5–3.3	–
germacrene D	1.3	2.2–2.3	0.2
γ-muurolene	–	0–1.4	–
ar-curcumene	5.6	9.1–20.0	0.6
α-muurolene	–	1.2	–
zingiberene	28.6	25.7–29.3	5.6
α-farnesene*	–	2.2–3.5	–
β-bisabolene	–	5.2–6.8	–
β-sesquiphellandrene	2.5	5.6–6.6	0.6
δ-cadinene	2.2	–	0.4
(Z)-nerolidol	0.5	0.2–0.4	1.2
elemol	0.2	0.2–0.3	0.6
eudesma-3,7(11)-diene	–	0–0.2	–
(E)-nerolidol	–	0.1–0.2	–
cubenol	–	0.1–0.2	–
guaiacol	–	0–t	–
sesquisabinene hydrate*	–	0–0.2	–

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

Stoyanova et al. (2006) compared the compositions of water distilled and a steam distilled oil of ginger of Vietnamese origin. **T-9** shows the results of this study.

Wolhmuth et al. (2006) water distilled oils from 17 clones of Australian ginger, which included commercial cultivars (all tetraploids), some experimental tetraploids and five diploid clones, two of Australian origin and one each of Jamaican, Brazilian and Chinese origins. Analysis of these oils revealed that with the exception of the diploid of Jamaican origin all the other oils were found to be relatively similar in composition. The data range for these 16 oils can be seen as follows:

6-methyl-5-hepten-2-one + myrcene (0.10–0.61%)
β-phellandrene (0.12–1.67%)
1,8-cineole (0.39–2.83%)
linalool (0.97–1.55%)
borneol (1.84–2.94%)
α-terpineol (1.49–2.18%)
citronellol (1.49–2.49%)
neral (19.71–26.49%)
geraniol (2.73–7.30%)
geranial (31.29–44.31%)
2-undecanone (0.16–0.55%)
bornyl acetate (0–0.27%)
citronellyl acetate (0.52–3.45%)
ar-curcumene (2.43–5.31%)
(E,E)-α-farnesene (2.10–3.81%)
zingiberene (1.86–9.00%)
germacrene D (0–0.50%)
β-bisabolene (1.18–2.16%)
β-sesquiphellandrene (2.93–5.62%)
(E)-nerolidol (0–0.76%)
elemol (0–0.56%)

The composition of the oil from the Jamaican clone was found to be as follows:

6-methyl-5-hepten-2-one + myrcene (0.14%)
β-phellandrene (1.49%)
1,8-cineole (0.79%)
linalool (1.02%)
borneol (3.91%)
α-terpineol (1.13%)
citronellol (1.09%)
neral (10.80%)
geraniol (1.54%)
geranial (17.51%)
2-undecanone (0.93%)
bornyl acetate (0.29%)
citronellyl acetate (0.14%)
geranyl acetate (0.26%)
ar-curcumene (5.72%)
(E,E)-α-farnesene (4.36%)
zingiberene (11.24%)
germacrene D (0.73%)
β-bisabolene (4.05%)
β-sesquiphellandrene (9.40%)
(E)-nerolidol (1.14%)
elemol (0.73%)

Variyar et al. (2006) examined the changes that take place with γ-irradiated and non-irradiated ginger during a two month storage period. The changes in the main components of the oil can be seen in **T-10**. As shown in T-10, no significant qualitative or quantitative differences were observed between any of the fresh ginger oils. It would appear that γ-irradiation at a dose of 60 Gy was found to extend the life of fresh ginger rhizomes and prevent sprouting on storage over a two month period without affecting any of the essential oil components.

Mathew (2006) published a review of ginger oil. Although the author did not have a very thorough review, he reported that the export of ginger oil from India increased from 4.12 tonnes in 1996/1997 to 16.30 tonnes in 2004/2005.

Nirmala-Menon et al. (2007) analyzed the composition of fresh ginger oil, dry ginger oil and fresh ginger juice volatiles. The results of this study can be seen summarized in **T-11**. In addition to the data presented in T-11, the following constituents were also characterized in dry ginger oil:

epi-α-cedrenol (0–0.2%)
cedr-8-en-13-ol (0–0.1%)
zingerone (0–0.5%)
α-muurolol (t–0.1%)
β-bisabolol (0.3–0.4%)
eudesm-7(11)-en-4-ol (0–0.1%)
(Z)-α-bergamotol (0.1–0.3%)
(Z,Z)-farnesol (0.1–0.3%)
(Z,E)-farnesol (0–0.2%)
(E,E)-farnesol (0.1–0.3%)
(Z)-lanceol (0–0.1%)

t = trace (< 0.1%)

Finally, Nirmala-Menon et al. tentatively characterized *trans*-α-bisabolene oxide, a farnesene epoxide, α-bergamotol acetate, a cucumenol acetate and 2,5-dimethylbenzoic acid in the dry ginger oils analyzed.

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