Progress in Essential Oils

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Erigeron, or Fleabane, Oil

At one time commercial quantities of Erigeron oil were produced in the United States. Occasionally oils are still produced in extremely limited quantities primarily aimed at the aromatherapy industry. As a result, it is perhaps of interest to examine what is known about its oil composition.

This oil is produced from *Conyza canadensis* (L.) Cronq. (syn. *Erigeron canadensis* L.), a plant that is known as horseweed in the United States and railwayweed in Japan. Ogg et al. (1975) noted that the weed could occasionally be found in mint fields. When distilled by mint oil producers that did not keep their mint fields free of weeds, Erigeron could contaminate the resultant oil. Ogg et al. further determined that the oil contaminants were α-thujene, β-pinene, myrcene, limonene, an ocimene isomer, a hexenyl acetate isomer, menthol, a menthone isomer, carvone, menthyl acetate, an α-farnesene isomer, a farnesol isomer, ar-curcumene, α-muurolol and a matricaria methyl ester.

Hrutifiord et al. (1988) analyzed an oil of *C. canadensis* produced from plants harvested in Washington State (United States) and found that it contained the following constituents:

α-thujene (0.4%)
β-pinene (4.1%)
myrcene (2.9%)
limonene (67.3%)
(E)-β-ocimene (1.0%)
cosmene[†*] (0.9%)
β-caryophyllene (0.2%)
cis-α-bergamotene (4.3%)
(E)-β-farnesene (0.8%)
(Z)-β-farnesene (0.3%)
β-himachalene (0.8%)
β-cubebene (0.9%)
trans-β-bergamotene (0.5%)
β-bisabolene (0.1%)
δ-cadinene (0.1%)
ar-curcumene (0.6%)
(Z,Z)-matricaria methyl ester (9.2%)
(Z,E)-matricaria methyl ester (0.8%)
(Z)-lacnophyllum methyl ester (1.0%)

[†]also known as 2,6-dimethyl-1,3,5,7-octatetraene
[*]correct isomer not identified

In addition, trace amounts of (Z)-β-ocimene, a cosmene isomer, (E,E)-matricaria methyl ester, an isomer of matricaria ethyl ester, matricaria lactone and (Z)-lacnophyllum were found in the same oil. Furthermore, the authors also showed that there was some seasonal variation in the sesquiterpene hydrocarbons found in the oil.

An oil of *C. canadensis* produced in the lab from plants harvested at their flowering stage in Japan was the subject of analysis by Miyazawa et al. (1992). This oil was found to comprise the following constituents:

α-pinene (1.1%)
camphene (14.2%)
β-pinene (7.2%)
limonene (31.2%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (7.6%)
γ-terpinene (0.3%)
p-cymene (0.6%)
terpinolene (0.3%)
perillene (2.7%)
α-copaene (0.3%)
cis-α-bergamotene (9.9%)
β-cubebene (0.2%)
β-caryophyllene (0.4%)
(E)-β-farnesene (1.6%)
(Z)-β-farnesene (1.6%)
α-cedrene (0.3%)
germacrene D (11.3%)
β-sesquiphellandrene (0.2%)
δ-cadinene (0.2%)
ar-curcumene (0.7%)
nerol (0.2%)
geraniol (0.2%)
β-ionone[*] (0.1%)
cubenol (0.1%)
(Z)-nerolidol (0.7%)
spathulenol (0.1%)
α-muurolol (0.1%)
β-eudesmol (0.1%)
α-cadinol (0.1%)
(E)-2-lacnophyllum methyl ester (0.2%)
(E,Z)-2,8-matricaria methyl ester (0.3%)
(Z)-2-lacnophyllum methyl ester (1.3%)
(Z,Z)-2,8-matricaria methyl ester (4.0%)

[*]correct isomer not identified

Trace amounts (<0.1%) of ethyl formate, valeraldehyde, 2-methyltetrahydrofuran-3-one, α-cubebene, β-bourbonene, α-humulene, α-terpineol, α-elemene, β-curcumene, *cis*-calamenene, *trans*-calamenene and lacnophyllum γ-lactone were also found in this oil.

Lis and Gora (2000) produced an oil in the lab from flowering plants found growing wild near Lodz (Poland). The composition of this oil was determined to be as follows:

α-pinene (0.2%)
β-pinene (0.8%)
myrcene (1.2%)
limonene (70.0%)
(E)-β-ocimene (1.3%)
linalool (0.1%)
trans-p-mentha-2,8-dien-1-ol (0.6%)
cis-p-mentha-2,8-dien-1-ol (0.7%)
trans-limonene oxide (0.3%)

nonanol (0.1%)
trans-p-mentha-1(7),8-dien-2-ol (0.2%)
dihydrocarveol (0.2%)
cis-piperitol (0.4%)
trans-carveol (0.8%)
cis-p-mentha-1(7),8-dien-2-ol (0.1%)
cis-carveol (0.3%)
carvone (1.1%)
perillaldehyde (0.1%)
α-copaene (0.1%)
β-cubebene (0.1%)
β-caryophyllene (0.2%)
trans-α-bergamotene (7.0%)
(Z)-β-farnesene (0.6%)
α-humulene (0.1%)
ar-curcumene (2.2%)
(Z)-lachrophyllum methyl ester (0.3%)
germacrene D (0.7%)
(E)-β-farnesene (0.9%)
(Z,Z)-matricaria methyl ester (2.4%)
zingiberene (0.2%)
α-muurolene (0.1%)
α-farnesene* (0.2%)
β-bisabolene (0.2%)
δ-cadinene (0.1%)
(E)-nerolidol (0.3%)
1,5-epoxysalvial-4(14)-en-1-one (0.2%)
spathulenol (0.2%)
caryophyllene oxide (0.7%)
salvia-4(14)-en-1-one† (0.4%)
trans-α-bergamotol (0.3%)
α-bisabolol (0.4%)
octadecanal (0.2%)

*correct isomer not identified
†also known as mint ketone

In addition, trace amounts (<0.1%) of camphene, sabinene, nonanal, p-methylacetophenone, *trans*-dihydrocarvone, α-terpineol, decanal, *trans*-carvyl acetate, *cis*-α-bergamotene, geranyl acetone, (E)-β-ionone, gossonorol, benzyl benzoate and anthracene were also characterized in the oil.

Gora et al. (2002) examined the composition of oils of *C. canadensis* produced from the herbage and flowers harvested at different stages of maturity in Poland. The results of this study are shown in **T-1**.

In addition to repeating some of their earlier results, Lis et al. (2003) compared the composition of oils of *C. canadensis* produced from plants of French, Italian, Spanish, Belgian, Bulgarian, Lithuanian and Israeli origin. The oils were all found to possess similarities. A summary of their compositions can be seen as follows:

α-pinene (0.1–0.4%)
β-pinene (0.1–4.9%)
myrcene (0.4–2.5%)
limonene (51.4–87.9%)
(E)-β-ocimene (0.1–13.4%)
trans-p-mentha-2,8-dien-1-ol (t–0.7%)
cis-p-mentha-2,8-dien-1-ol (t–0.8%)
trans-limonene oxide (0.0–0.6%)
cis-piperitol (0.0–0.5%)
trans-carveol (0.0–0.6%)
cis-carveol (0.0–1.2%)
carvone (0.0–2.5%)
β-caryophyllene (t–4.6%)
trans-α-bergamotene (1.5–11.9%)
(Z)-β-farnesene (0.1–6.3%)
ar-curcumene (0.3–2.9%)
(Z)-lachnophyllum methyl ester (t–2.5%)
germacrene D (0.0–4.7%)
(E)-β-farnesene (0.1–3.1%)
(Z,Z)-matricaria methyl ester (0.0–7.7%)
(E)-nerolidol (t–0.3%)
caryophyllene oxide (0.1–1.0%)
trans-α-bergamotol (0.0–0.6%)
α-bisabolol (0.0–0.2%)

Curini et al. (2003) determined that the composition of *C. canadensis* oil of French origin was as follows:

α-pinene (<0.1%)
β-pinene (1.57 ± 0.06%)
myrcene (3.62 ± 0.04%)
cosmene (0.32 ± 0.04%)
limonene (76.03 ± 0.07%)
δ-3-carene† (3.87 ± 0.03%)
thujone* (1.70 ± 0.04%)
camphor (0.39 ± 0.06%)
isoborneol (<0.1%)
menthol (0.23 ± 0.05%)
isobornyl acetate (0.17 ± 0.05%)
β-caryophyllene (2.13 ± 0.05%)
epi-bicyclosesquiphellandrene (0.34 ± 0.06%)
α-santalene† (5.84 ± 0.04%)
germacrene D (0.16 ± 0.04%)
α-humulene (1.50 ± 0.05%)
β-sesquiphellandrene (0.35 ± 0.02%)
germacrene B (1.78 ± 0.07%)

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

Stoyanova et al. (2003) determined that the oil composition of *C. candensis* plants grown in Bulgaria that were harvested at different growth stages varied as expected. The oil produced from plants harvested in full flower was reported to be as follows:

α-pinene (0.3%)
β-pinene (2.0%)
myrcene (1.0%)
β-phellandrene (0.1%)
limonene (87.9%)
(E)-β-ocimene (0.3%)
trans-p-mentha-2,8-dien-1-ol (0.6%)
cis-p-mentha-2,8-dien-1-ol (0.8%)
cis-limonene oxide (0.5%)
dihydrocarveol (0.2%)
cis-piperitol (0.4%)
trans-carveol (0.6%)
carvone (1.4%)
trans-α-bergamotene (3.8%)
(Z)-β-farnesene (0.1%)
ar-curcumene (0.3%)
(Z,E)-α-farnesene & lachnophyllum methyl ester (0.2%)
caryophyllene oxide (0.2%)

Trace amounts (<0.1%) of sabinene, perillaldehyde, β-caryophyllene (Z,Z)-matricaria methyl ester, (E,E)-α-farnesene, (E)-nerolidol and salvia-4(14)-en-1-one were also found in this oil.

Tzakou et al. (2004) analyzed oils produced from three *Conyza* species

Percentage composition of the main components of both herbage and flower oils produced from *Erigeron canadensis* harvested at different times **T-1**

Compound	H-1	H-2	F-2
limonene	57.9–80.9	64.2–81.1	62.9–73.2
(E)-β-ocimene	2.1–9.1	0.2–2.1	0.3–2.0
carvone	t–0.2	0.2–1.8	nd
trans-α-bergamotene	5.6–8.5	6.8–8.9	6.3–14.1
(Z)-β-farnesene	0.7–11.1	t-0.9	0.1–0.3
ar-curcumene	0.9–1.5	1.3–2.5	1.2–3.5
(E)-β-farnesene	0.3–3.0	0.6–1.1	nd
(Z,Z)-matricaria ester	nd	nd	2.1–3.2

H-1 = Herbage seedling to inflorescence commencement stage
H-2 = Herbage flowering to senescence stage
F-2 = Flowers from buds to end of flowering stage
t = trace (<0.1%)
nd = not detected

growing in Greece. They found that oils produced from *C. canadensis* varied as shown in **T-2**.

A.G. Ogg, D.J. Stern, R.J. Molyneux and R. Teranishi, *Chemical constituents of horseweed oil.* Internat. Flav. Food Addit., **6**(3), 195, 198 (1975).

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A. Lis and J. Gora, *Essential oil of* Conyza canadensis *(L.) Cronq.* J. Essent. Oil Res., **12**, 781–783 (2000).

J. Gora, A. Lis, J. Kula, M. Staniszewska and A. Woloszyn, *Chemical composition variability of essential oils in the ontogenesis of some plants.* Flav. Fragr. J., **17**, 445–451 (2002).

Effect of growth stage on oil composition of *Conyza canadensis* grown in Greece **T-2**

Compound	Vegetative stage oil	Flowering stage oil	Flowering/fruiting stage oil
α-pinene	0.7	0.8	t
sabinene	t	-	-
β-pinene	4.7	9.5	7.5
myrcene	5.3	4.7	2.4
limonene	50.0	57.3	70.3
(E)-β-ocimene	7.5	4.0	6.9
terpinolene	-	t	-
linalool	-	t	-
p-mentha-1,3,8-triene	0.8	0.4	t
p-mentha-1,5,8-triene	4.7	3.5	4.1
terpinen-4-ol	-	t	-
naphthalene	t	t	-
α-terpineol	-	t	-
β-maaliene	-	t	-
β-cubebene	t	-	-
β-elemene	t	t	-
(Z)-jasmone	t	t	-
β-caryophyllene	t	0.1	-
trans-α-bergamotene	3.3	0.7	t
geranyl acetone	-	0.2	-
α-humulene	t	-	-
(E)-β-farnesene	3.9	0.3	-
γ-muurolene	4.1	-	-
germacrene D	-	1.7	3.6
zingiberene	0.9	0.2	-
bicyclogermacrene	-	t	-
germacrene A	-	t	-
(E,E)-α-farnesene	t	t	-
β-bisabolene	-	t	-
matricaria methyl ester*	0.7	-	-
(Z)-lachnophyllum methyl ester	-	-	t
matricaria methyl ester*	7.9	0.6	5.1
cis-sesquisabinene hydrate	t	-	-
matricaria methyl ester*	-	14.4	-
(E)-nerolidol	1.7	0.3	-
germacrene-D-4-ol	t	0.2	-
α-cadinol	t	0.1	-
α-bisabolol	t	-	-
phytol*	1.9	0.3	-

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

A. Lis, J.R. Piggot and J. Gora, *Chemical composition variability of the essential oil of* Conyza canadensis *Cronq.* Flav. Fragr. J., **18**, 364–367 (2003).

M. Curini, A. Bianchi, F. Epifano, R. Bruni, L. Torta and A. Zambonelli, *Composition and in vitro antifungal activity of essential oils of* Erigeron canadensis *and* Myrtus communis *from France.* Chem. Nat. Comp., **39**, 191–194 (2003).

A. Stoyanova, E. Georgiev, D. Kermedchieva, A. Lis and J. Gora, *Changes in the essential oil of* Conyza canadensis *(L.) Cronquist during its vegetation.* J. Essent. Oil Res., **15**, 44–45 (2003).

O. Tzakou, C. Vagias, A. Gani and A. Yannitsaros, *Volatile constituents of essential oils isolated at different growing stages from three* Conyza *species growing in Greece*. Flav. Fragr. J., **19**, 425–428 (2004).

Java Citronella Oil

There are two commercially available citronella oils that are obtained from the steam distillation of different *Cymbopogon* species (tropical grasses—Poaceae, or Gramineae, family). Java citronella is obtained from *Cymbopogon winterianus* Jowitt.

Naqvi et al. (2002) examined the effect of salts (sodium chloride, sodium carbonate, calcium chloride and calcium carbonate) added to the water prior to hydrodistillation of the homogenized sample of *C. winterianus* plant material. Analyses of the oils revealed that they contained the following range of main components:

limonene (1.9–3.2%)
citronellal (27.8–30.8%)
linalool (0.5–0.9%)
linalyl acetate (0.3–0.4%)
β-caryophyllene (0.9–1.4%)
citronellyl acetate (3.2–4.5%)
geranyl formate (1.1–1.6%)
geranyl acetate (4,5–6.9%)
citronellol (8.9–9.8%)
nerol (0.3–0.4%)
geraniol (17.2–20.4%)
elemol (7.9–14.1%)

This reviewer is not sure of the value of this study as Java citronella oil is rarely if ever produced commercially by direct water distillation.

The main aroma components of a commercial sample of citronella oil (ex *C. winterianus*) were found by Jirovetz et al. (2006) to be as follows:

citronellal (37.4%)
citronellol (10.8%)
nerol (0.5%)

neral (0.4%)
geraniol (23.6%)
geranial (0.6%)
citronellyl formate (0.1%)
citronellyl acetate (2.2%)
neryl acetate (0.1%)
geranyl acetate (2.9%)
citronellyl propionate (0.1%)

Trace amounts (<0.1%) of citronellyl butyrate and geranyl butyrate were also found in this oil. The authors also reported the characterization of hydroxycitronellal (which does not occur naturally) in the oil. This could indicate either that the oil had been adulterated or at best contaminated with synthetic components.

Saika et al. (2006) compared the compositions of the leaf and inflorescence oils obtained from *C. winterianus* grown in an experimental garden in Jorhat (Assam, India). The authors were only able to characterize the main constituents of the oils as shown in **T-3**.

Rajeswara Rao et al. (2007) studied the effect of various proportions of weed biomass (0%, 5%, 10%, 15% and 30%) mixed with Java citronella biomass prior to hydrodistillation in the laboratory. They found that there were only minor changes in the oil compositions of the "Bio-13" and "Java 11" cultivars. The main constituents ranged as follows:

limonene (0.6–0.8%)
linalool (1.7–2.0%)
citronellal (23.8–26.3%)
citronellol (9.0–10.2%)
geraniol (19.9–23.6%)
citronellyl acetate (4.8–5.8%)
geranyl acetate (6.8–8.4%)
elemol (9.9–12.6%)

Not unexpectedly, the authors found that admixtures of weed biomass with crop biomass had a deleterious effect on the aromas of the oils produced.

Ranade (2008) reported that the typical composition of Java citronella oil was as follows:

limonene (2.3%)
p-cymene (0.1%)
6-methyl-5-hepten-2-one (0.1%)
citronellal (38.4%)
linalool (0.5%)
citronellyl acetate (3.4%)
citral* (1.4%)
geranyl acetate (6.2%)
citronellol (8.7%)
nerol (0.5%)
geraniol (26.5%)
methyl eugenol (0.1%)
eugenol (1.3%)
isopulegol (0.5%)
elemene* + elemol (0.5%)

*correct isomer not identified

Ram et al. (2008) performed a field experiment in Lucknow (Uttar Pradesh) on three clones ("M6-10," "Bio-13" and "Manjari") of Java citronella to examine the potential economic return on the cultivar biomass and major component oil compositions. The major effect on economic return was the mortality rate of plants in the field. The authors found that the oil content and mortality rates of the three cultivars were:

Percentage composition of the main constituents of *Cymbopogon winterianus* leaf and inflorescence oil **T-3**

Compound	Leaf oil	Inflorescence oil
limonene	4.6	2.2
linalool	0.8	0.7
citronellal	37.5	21.6
citronellol	19.2	12.0
geraniol	18.0	15.9
citronellyl acetate	4.8	8.6
geranyl acetate	2.4	6.8

The range of main component percentage in three Java citronella cultivar oils produced from two harvests **T-4**

Compound	"M6-10" oil	"Manjari" oil	"Bio-13" oil
citronellal	34.0[a] (24.7)[b]	32.7[a] (24.5)[b]	33.0[a] (23.4)[b]
citronellol	11.4 (12.5)	12.4 (13.1)	10.1 (11.9)
geraniol	18.8 (21.6)	19.1 (22.2)	20.8 (21.3)
geranyl acetate	3.9 (4.2)	4.6 (4.0)	5.3 (4.6)
elemol	11.0 (14.2)	10.2 (14.0)	11.1 (16.1)

[a]first harvest
[b]second harvest

Comparative percentage composition of the main components of five Java citronella cultivar oils **T-5**

Compound	1	2	3	4	5
limonene	2.2	2.5	2.3	2.8	2.6
citronellal	45.1	38.3	38.6	43.0	37.8
citronellol	13.0	15.3	13.9	14.1	14.1
geraniol	20.9	22.4	20.9	21.9	20.1
citronellyl acetate	4.8	6.4	5.3	6.3	6.5
geranyl acetate	6.8	6.9	7.1	8.3	8.1
elemol	0.6	2.1	6.8	1.3	1.9

1 = "CIM Jeeva" oil
2 = "Mandakini" oil
3 = "Manjusha" oil
4 = "Manjari" oil
5 = "Bio-13" oil

"M6-10": 1.5% oil, 9.0% mortality
"Manjari": 1.5% oil, 17.1% mortality
"Bio-13": 1.3% oil, 33.2% mortality

Based on the major components of the oils at two harvest times (April 25 and July 11) the cultivar oils were found to be as shown in **T-4**. The authors also noted that the "MG-10" cultivar has been renamed as "CIM Jeeva."

Lal et al. (2008) compared five elite clones of Java citronella grown in Lucknow for their growth habit, herbage yield oil content, oil yield per hectare and main components of the oil. The results of this comparative study on the main oil components are reported in **T-5**. Furthermore, the authors determined that the oil yield was 285, 232, 201, 193 and 191 kg/ha for "CIM Jeeva," "Mandakini," "Manjusha," "Manjari" and "Bio-13," respectively.

A.A. Naqvi, S. Mandal, A. Chattopadhyay and A. Prasad, *Salt effect on the quality and recovery of the essential oil of citronella (*Cymbopogon winterianus *Jowitt).* Flav. Fragr. J., **17**, 109–110 (2002).

L. Jirovetz, G. Eller, G. Buchbauer, E. Schmidt, Z. Denkova, A.S. Stoyanova, R.N. Nikdova and M. Geissler, *Chemical composition, antimicrobial activities and some odor descriptions of some essential oils with characteristic floral-rosy scent and of their principal aroma compounds.* Recent Res. Devel. Agron. Hort., **2**, 1–12 (2006).

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Melissa, or Lemon Balm, Oil

A German commercial sample of Melissa oil was analyzed by Reichling et al. (1999) using GC and GC/MS. The oil was found to contain:

ocimene* (1.7%)
citronellal (6.6%)
neral (26.2%)
geranial (37.3%)
neryl acetate (4.8%)
β-caryophyllene (11.2%)
α-humulene (0.6%)
caryophyllene oxide (0.7%)

*correct isomer not determined

An oil of *Melissa officinalis* produced in the laboratory from plants grown in Scotland was the subject of analysis by Dorman et al. (2000). The main components in this oil were determined to be as follows:

α-pinene (0.4%)
sabinene (0.5%)
myrcene (0.6%)
limonene (57.5%)
linalool (0.6%)
isopulegol (1.9%)
citronellal (24.9%)
nerol (4.3%)
geraniol (5.7%)

Oils produced from two collections of *M. officinalis* of Calabrian (Italy) origin were analyzed for their major constituents by Gionfriddo et al. (2001). The components characterized were:

limonene (22.0–23.0%)
linalool (2.0–2.5%)
geraniol (2.7–3.3%)
neral (8.2–10.0%)
geranial (11.2–13.3%)
nerol (3.7–4.7%)
thymol (2.0–3.7%)
β-caryophyllene (9.0–10.0%)

Leon-Fernandez et al. (2008) analyzed an oil of *M. officinalis* that was produced from plants grown at an experimental agricultural station near Havana (Cuba). The components characterized in this oil in amounts greater than trace (<0.1%) were:

2-butanone (0.1%)
1-octen-3-ol (0.2%)
6-methyl-5-hepten-2-one (3.8%)
phenylacetaldehyde (0.2%)
trans-linalool oxide[f](0.1%)
cis-linalool oxide[f] (0.1%)
linalool (1.6%)
trans-p-mentha-2,8-dien-1-ol (0.1%)
cis-p-mentha-2,8-dien-1-ol (0.1%)
citronellal (0.2%)
trans-p-mentha-1(7),8-dien-2-ol (1.2%)
α-terpineol (0.5%)
cis-carveol (0.3%)
neral (30.4%)
piperitone (0.8%)
geraniol (1.0%)
geranial (39.0%)
methyl geranate (0.2%)
geranyl acetate (5.3%)
β-caryophyllene (1.5%)
α-humulene (0.2%)
δ-cadinene (0.1%)
caryophyllene oxide (12.1%)
humulene epoxide II (0.4%)
α-cadinol (0.2%)

[f]furanoid form

The trace constituents characterized were (Z)-3-hexenol, hexanol, α-pinene, camphene, benzaldehyde, myrcene, dehydro-1,8-cineole, 6-methyl-5-hepten-2-ol, 3-octanol, octanal, p-cymene, limonene, 1,8-cineole, (Z)-β-ocimene, (E)-β-ocimene, γ-terpinene, p-cymenene, 6-methyl-3,5-heptadien-2-one, *cis*-rose oxide, β-thujone, *trans*-rose oxide, camphor, nerol oxide, *trans*-linalool oxide (pyranoid), rose furan epoxide, terpinen-4-ol, p-cymen-8-ol, decanal, citronellol, geranyl formate, carvacrol, citronellyl acetate, eugenol, neric acid, neryl acetate, α-copaene, β-elemene, geranic acid, coumarin, allo-aromadendrene, ar-curcumene, (E)-β-ionone, α-muurolene, γ-cadinene, *trans*-calmenene, (Z)-nerolidol, humulene epoxide I and α-muurolol.

Khalid et al. (2008) examined the effect of melissa herbage drying on oil yield and composition of plants grown in plastic pots in Shanghai (China). The oil yield ranged from 0.35% for fresh herbage to 0.30% for shade-dried herbage to 0.20% for oven-dried (40°C) herbage to 0.15% for sun-dried herbage at first harvest. The range in oil composition for oils produced from fresh herbage and herbage dried under differing conditions for the first and second harvests (each harvest performed when plants were in full flower) was as follows:

α-pinene (0.1–0.9%)
camphene (0.2–1.9%)
sabinene (0.1–0.9%)
β-pinene (0.2–2.0%)
myrcene (0.1–2.3%)
α-phellandrene (0.4–3.9%)
α-terpinene (0.1–8.2%)
linalool (0.7–6.9%)
α-thujone (0.1–1.2%)
β-thujone (0.1–1.0%)
α-fenchyl acetate (0.1–9.6%)
trans-rose oxide (0.1–1.7%)
limonene (1.1–11.6%)
(Z)-β-ocimene (0.1–2.2%)
camphor (0.2–0.8%)
citronellal (22.2–37.8%)
isomenthone (0.1–1.2%)
borneol (0.1–0.4%)
menthol (0.1–1.3%)
methyl chavicol (0.1–1.2%)
carveol[*] (0.1–2.2%)
nerol (0.1–5.6%)
citronellol (11.9–18.3%)
neral (0.3–3.4%)
geraniol (0.2–1.9%)
geranial (0.2–1.4%)
limonene oxide[*†] (0.1–0.7%)
α-cubebene (0.1–0.7%)
carvyl acetate[*] (t–1.6%)
α-copaene (0.1–0.5%)
geranyl acetate (10.3–15.5%)
(Z)-β-damascenone (0.1–0.8%)
β-cubebene (0.1–0.6%)
dodecanal (0.1–2.1%)
β-caryophyllene (0.1–6.8%)
α-humulene (0.1–1.9%)
β-selinene (0.1–0.4%)
germacrene D (0.1–0.7%)
γ-cadinene (0.1–0.4%)
α-cadinene (0.1–0.8%)
(Z)-β-farnesene[†] (0.1–0.4%)
ledol (0.2–1.5%)
caryophyllene oxide (0.2–7.3%)

t = trace (<0.1%); [*]correct isomer not identified; [†]incorrect identification based on GC elution order

Lemon balm (Melissa) oil that was obtained commercially in Italy was screened for its antimicrobial activity by Romeo et al. (2008). Dilutions of the oil below 10% were not found to exhibit antimicrobial activity against *Staphylococcus aureus*, *Listeria innocua* or *E. coli*. Romeo et al. reported that the oil that was screened possessed the following composition:

α-pinene (0.3%)
sabinene (0.1%)
β-pinene (1.6%)
2-octanone (0.1%)
p-cymene (0.6%)
limonene (5.8%)
γ-terpinene (0.3%)
trans-linalool oxide[f] (0.1%)
terpinolene (0.1%)
linalool (4.5%)
isopulegol (3.5%)
citronellal (23.8%)
terpinen-4-ol (0.1%)
citronellol (6.2%)
neral (8.8%)
piperitone (0.1%)
geraniol (5.1%)
geranial (11.6%)
geranyl formate (1.5%)
hexyl tiglate (0.2%)
citronellyl acetate (1.8%)
eugenol (0.8%)
neryl acetate (0.4%)
α-copaene (0.4%)
geranyl acetate (7.7%)
longifolene (0.6%)
cis-α-bergamoene (0.1%)
β-caryophyllene (8.3%)
trans-α-bergamotene (0.1%)
α-humulene (1.4%)
γ-muurolene (0.1%)
α-muurolene (0.3%)
β-bisabolene (0.1%)
γ-cadinene (0.2%)
δ-cadinene (1.0%)
elemol (1.1%)

[f]furanoid form

Khalid et al. (2009a) compared the effect of distillation conditions on an oil production from *M. officinalis*. They compared the effect of water distillation, steam and water

distillation, and steam distillation on the oil composition. Unfortunately, the authors failed to adequately describe their distillation conditions in sufficient detail so that the work could be replicated if so desired. As a result, the compositional data obtained did not make sense, so it is not included in this report.

Khalid et al. (2009b) examined the range in composition of oils of *M. officinalis* produced from pot-grown plants that were harvested at different times of the day (from two harvest times) when the plants were in full bloom. The range in composition was determined to be:

α-pinene (0.3–0.6%)
camphene (0.3–2.1%)
sabinene (0.4–0.9%)
β-pinene (0.2–0.6%)
myrcene (0.2–5.7%)
α-phellandrene (0.2–0.5%)
α-terpinene (0.4–4.6%)
linalool (0.7–2.7%)
α-thujone (0.2–1.2%)
β-thujone (0.2–0.5%)
α-fenchyl acetate (0.1–3.9%)
trans-rose oxide (0.1–2.7%)
limonene (1.2–6.6%)
(Z)-β-ocimene (0.1–0.5%)
camphor (2.0–4.3%)
citronellal (27.7–42.6%)
isomenthone (0.2–2.9%)
borneol (0.1–0.7%)
menthol (0.7–2.9%)
methyl chavicol (0.1–2.3%)
carveol* (0.1–0.9%)
nerol (0.2–2.7%)
citronellol (10.11–18.3%)
neral (0.1–2.2%)
geraniol (0.9–3.9%)
geranial (0.5–3.8%)
limonene oxide*† (0.3–1.5%)
α-cubebene (0.1–2.2%)
carvyl acetate* (0.1–2.3%)
α-copaene (t–1.8%)
geranyl acetate (7.7–17.4%)
(Z)-β-damascenone (0.1–1.2%)
β-cubebene (0.1–0.6%)
dodecanal (t–1.1%)
β-caryophyllene (0.1–1.8%)
α-humulene (t–1.2%)
β-selinene (t–1.1%)
germacrene D (0.3–2.1%)
γ-cadinene (0.2–1.4%)
δ-cadinene (0.1–1.2%)
(Z)-β-farnesene† (0.2–0.8%)
ledol (0.1–0.5%)
caryophyllene oxide (0.1–0.3%)

t = trace (<0.1%); *correct isomer not identified; †incorrect isomer identification based on GC elution order

A commercial sample of Melissa oil was screened for its preservative qualities on commercial grade carrots by Poiana et al. (2010). The main components of this oil were determined to be:

α-pinene (0.2%)
β-pinene (1.3%)
p-cymene (0.5%)
limonene (4.7%)
γ-terpinene (0.2%)
linalool (3.7%)
isopulegol (2.8%)
menthone (0.3%)
citronellol (19.5%)
α-terpineol (0.1%)
citronellol (5.0%)
neral (7.2%)
piperitone (0.1%)
geraniol (4.8%)
geranial (9.5%)
geranyl formate (0.2%)
α-cubebene (0.2%)
citronellyl acetate (1.4%)
eugenol (0.6%)
neryl acetate (0.3%)
α-copaene (0.3%)
geranyl acetate (6.3%)
β-caryophyllene (6.8%)
trans-α-bergamotene (0.1%)
α-humulene (1.1%)
γ-muurolene (0.1%)
α-muurolene (0.2%)
β-bisabolene (0.1%)
γ-cadinene (0.2%)
elemol (0.8%)

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