Progress in Essential Oils

Brian M. Lawrence, Consultant

Lemon-scented Tea Tree Oil

Lemon–scented tea tree oil is obtained by steam distillation of the leaves of *Leptospermum petersonii* F.M. Bailey (syn. *L.citratum* R.W. Challinor, Cheel et A.R. Penfold) a fast-growing tall shrub that is popular as an ornamental throughout Australia. Fergus (2000) reported that lemon-scented tea tree oil was a potentially next important oil of Australian origin. With data obtained from Fergus (2008), Lawrence (2009) reported that ca. 1 tonne of lemon scented tea tree oil was produced annually in Australia.

Lassak and Southwell (1977) reported that an oil of *L.petersonii* contained citral (neral +geranial) (50%) and citronellal (40%) as the major components.

Brophy et al. (1989) reported the existence of more than one chemotype of *L.petersonii*. They noted that in addition to the oil, which was lemon-scented containing large amounts of neral + geranial and citronellal, they found a chemotype that was rich in sesquiterpenes. The composition of oils of this chemotype was as follows:

β-ylangene (1%)
α-bergamotene° (1–4%)
β-elemene (2–4%)
α-amorphene (4–6%)
viridiflorene (3%)
bicyclogermacrene (3%)
germacrene D (15%)
δ-cadinene (16%)
cadina-1,4-diene (1%)
cubenol (0.7%)
globulol (1.5%)
viridiflorol (0.7%)
spathulenol (1.5%)
T-cadinol (1.7%)
T-muurolol (1.7%)
α-muurolol (0.7%)
α-cadinol (3.6%)
methyl eugenol (0.3%)
eugenol (0.4%)

° correct isomer not identified

Lawrence (1993) determined that the major components of a commercial oil of lemon-scented tea tree oil were:

α-pinene (0.6%)
β-pinene (0.2%)
myrcene (2.0%)
limonene (0.2%)
terpinolene (0.5%)
6-methyl-5-hepten-2-one (0.6%)
citronellal (29.4%)
linalool (2.4%)
isopulegol (5.1%)
citronellyl acetate (0.2%)
neral (20.6%)
neryl acetate (0.3%)
geranial (26.3%)
citronellol (0.7%)
geranyl acetate (0.1%)
nerol (0.3%)
geraniol (2.5%)
spathulenol (1.6%)

Lis-Balchin et al. (1996) screened oils produced in New Zealand for their bioactivity. They noted that the main components of an oil of *L. petersonii* were:

limonene (23.6%)
neral (28.5%)
geranial (41.0%)

Brophy et al. (2000) examined oils of *L. petersonii* obtained from five different provenances in Australia. The two oils that contained neral, geranial and citronellal were found to be quantitatively dissimilar, and this is evident from the following data:

α-pinene (0.1–12.3%)
myrcene (0.1–0.3%)
limonene (t–0.1%)
(E)-β-ocimene (t–0.6%)
6-methyl-5-hepten-2-one (0.1–0.3%)
3-hexenol ° (0.1–0.2%)
citronellal (6.8–46.2%)
linalool (1.2–1.8%)
isopulegol (0.5–1.3%)
isopulegol ° (t–0.3%)
pinocarvone (1.3–2.7%)
β-caryophyllene (0.1%)
allo-aromadendrene (0.1%)
methyl benzoate (0.1–0.2%)
citronellyl acetate (0.1%)
neral (13.5–31.3%)
neryl acetate (0.2–0.4%)
piperitone (0.1%)
geranial (22.8–45.4%)
citronellol (0.7–1.9%)
geranyl acetate (0.2–0.7%)
nerol (0.2–0.3%)
geraniol (2.4–2.7%)
(E)-nerolidol (0.1%)
cubeb-11-ol (0.1%)
globulol (0.2–0.3%)
viridiflorol (0.1–0.2%)
spathulenol (0.5–1.0%)
eugenol (0.4–0.6%)
T-cadinol (0–0.1%)
α-muurolol (0–0.1%)
α-cadinol (0.1–0.2%)
citronellic acid (0.6–1.3%)

° correct isomer not identified
t = trace (< 0.05%)

Trace amounts of fenchone and T-muurolol were found in one or both oils. Three oils of *L. petersonii,* which were not lemon-scented, were characterized by Brophy et al. (2000). One of these oils contained the following major components:

α-pinene (9.6%)
γ-terpinene (26.5%)
(E)-β-ocimene (7.9%)
p-cymene (8.4%)
terpinolene (17.6%)

The major components of the second oil were:

γ-terpinene (11.5%)
terpinolene (7.3%)
geranyl acetate (38.3%)
geraniol (21.2%)

Finally, the major components of the third oil were:

germacrene D (8.2%)
bicyclogermacrene (11.2%)
globulol (6.9%)
spathulenol (12.0%)

An oil of *L. petersonii* of commercial origin was screened for its effect on phytopathogenic fungi by Lee et al. (2008). Using a combination of GC-FID and GC/MS, the following components were characterized in this oil:

α-pinene (0.5%)
6-methyl-5-hepten-2-one (0.8%)
β-pinene (0.2%)
myrcene (1.3%)
p-cymene (0.1%)
1,8-cineole (0.1%)
limonene (0.1%)
linalool (3.3%)
isopulegol (5.2%)
citronellal (16.7%)
citronellol (6.0%)
neral (22.8%)
geraniol (3.6%)
geranial (29.9%)
β-caryophyllene (0.1%)
aromadendrene (0.1%)

E.V. Lassak and I.A. Southwell, *Essential oil isolates from the Australian flora*. Internat. Flav. Food Addit., (3), 126–132 (1977).

J.J. Brophy, D.J. Boland and E.V. Lassak, *Leaf essential oils of* Melaleuca *and* Leptospermum *species from Tropical Australia*. In: *Trees for the Tropics*. pp 193–203 ACIAR, Canberra, Australia (1989).

B.M. Lawrence unpublished data (1993).

M. Lis-Balchin, S. Deans and S. Hart, *Bioactivity of New Zealand Medicinal Plant Essential Oils*. In: *Proceedings Int. Symp. Medicinal Aromatic Plants*. Edits., L.E. Craker, L. Nolan and K. Shetty, Acta Hort., 426, 13–30 (1996).

J. Fergus, *What will be the next big oil from Australia?* Perfum. Flavor., 25(6), 8–19 (2000).

J.J. Brophy, R.J. Goldsack, A. Punruckvong, A.R. Bean, P.I. Forster, B.J. Lepschi, J.C. Doran and A.C. Rozefelds, *Leaf essential oils of the genus* Leptospermum *(Myrtaceae) in eastern Australia. Part 7.* Leptospermum petersonii, L. liversidgei *and allies.* Flav. Frag. J., **15**, 342–351 (2000).

Y–S. Lee, J–H. Kim, S–C. Shin, S–G. Lee and I–K. Park, *Anti-fungal activity of Myrtaceae essential oils and their components against three phytopathogenic fungi.* Flav. Frag. J., **23**, 23–28 (2008).

J. Fergus, personal communication (2008).

B.M. Lawrence, *A preliminary report on the world production of some selected essential oils and countries.* Perfum. Flavor., 34(1) 38–44 (2009).

Cypress Oil

Using chiral GC as his method of analysis Casabianca (1996) determined that the enantiomeric ratio of α-thujene in cypress oil was as follows:

(1R)- (+)-α-thujene (45%): (1S)-(-)-α-thujene (55%)

Chanegriha et al. (1997) analyzed the leaf oil of cypress (*Cupressus sempervirens* L.) produced in two separate years in Algeria. The components characterized in these oils were as follows:

α-pinene (2.8–44.9%)
α-fenchene (0–0.5%)
β-pinene (0.4–1.6%)
sabinene (t–0.6%)
δ-3-carene (3.1–10.6%)
myrcene (0.4–1.4%)
limonene (2.2–4.5%)
β-phellandrene (0.2–0.4%)
γ-terpinene (0–0.5%)
terpinolene (0.9–2.7%)
bornyl acetate (0.8–2.0%)
terpinen-4-ol (1.9%)
α-terpinyl acetate (5.5–12.0%)
germacrene D (1.6–2.7%)
δ-cadinene (0.5–1.2%)
α-cadinol (0.3–0.8%)
sandaracopimaradiene (0.5–1.2%)
manoyl oxide (1.5–6.7%)
dehydroabietane (1.6–4.2%)

t = trace (< 0.1%)

In addition, the authors also found trace (< 0.1%) amounts of tricyclene, undecane, α-phellandrene, dodecane, 1,8-cineole, (E)-β-ocimene, tridecane, p-cymenene, α-cubebene, α-copaene, camphor, linalool, p-isopropyl anisole, α-cedrene, β-cedrene, isobornyl acetate, umbellulone, α-terpineol, α-humulene, α-muurolene, *cis*-piperitol, γ-cadinene, myrtenol, cuparene, *cis*-calamenene, p-cymen-8-ol, undecanol, α-calacorene, dodecanol, caryophyllene oxide, cubenol, cedrol and cedrenol in one or both of the oils.

Tapondjou et al. (2005) determined that a lab-distilled oil of *C. sempervirens* needles possessed the following composition:

α-pinene (9.9%)
sabinene (14.8%)
δ-3-carene (4.2%)
myrcene (2.3%)
α-terpinene (4.2%)
limonene (3.9%)
β-phellandrene (1.5%)
γ-terpinene (5.7%)
p-cymene (3.8%)
terpinolene (2.4%)
terpinen-4-ol (11.4%)
bicyclosesquiphellandrene (2.3%)
α-terpineol (2.7%)
α-terpinyl acetate (3.3%)
eucumene[†] (1.4%)
cis-calamenene (1.7%)
δ-cadinene (1.9%)
cedrol (3.3%)

[†] This reviewer does not know what the structure of this compound is.

Cheraif et al. (2005) examined the effect of distillation time on the composition of oils produced by water distillation of *C. sempervirens* branches grown in Tunisia. They compared the compositions of oils produced after 15 min of distillation time to those produced after 240 min distillation time. The composition of oils produced after 30, 60, 120,180 and 240 min of distillation can be seen in **T-1**. These results show that the oil composition of *C. sempervirens* (like all other plants) varies according to the length of the distillation time (particularly hydrodistillation).

Emami et al. (2006) screened the leaf and fruit oils of *C. sempervirens* produced from plants grown in Iran for their antimicrobial activity. The comparative oil composition of the two oils is reported in **T-2.**

A number of commercially available oils in Italy were screened for

Comparative percentage composition of oils of *Cupressus sempervirens* produced over five different hydrodistillation times					T-1
Compound	30 min oil	60 min oil	120 min oil	180 min oil	240 min oil
tricyclene	0.1	0.1	0.2	0.2	0.2
α-thujene	0.2	0.1	0.2	0.2	0.2
α-pinene	33.8	39.5	52.4	64.6	52.9
α-fenchene	0.3	0.4	0.5	0.5	0.4
camphene	0.3	0.3	0.3	0.3	0.2
sabinene	1.2	0.9	0.6	0.4	0.3
β-pinene	2.1	2.2	2.1	2.0	1.7
myrcene	3.0	2.9	2.8	2.8	2.3
δ-3-carene	7.7	8.7	9.2	10.3	10.6
limonene	4.4	4.5	3.7	3.1	3.2
terpinolene	3.8	3.8	3.4	2.8	3.5
linalool	2.6	1.4	0.7	0.1	-
terpinen-4-ol	2.3	1.6	0.8	0.3	0.3
methyl carvacrol	0.8	0.2	0.2	0.1	0.1
bornyl acetate	0.7	0.7	0.6	0.2	0.2
carvacrol	0.6	0.8	0.7	0.2	0.3
terpinen-4-yl acetate	0.7	0.9	0.7	0.3	0.4
α-terpinyl acetate	6.1	7.1	5.2	2.5	3.5
α-cubebene	0.2	0.1	0.1	-	-
α-copaene	0.2	0.4	0.4	-	0.1
β-elemene	0.2	0.1	0.1	-	-
longifolene	0.6	0.4	0.2	0.1	0.1
β-cubebene	0.4	0.2	0.3	0.2	0.4
α-gurjunene	0.2	0.1	0.3	0.1	0.1
aromadendrene	0.4	0.3	0.4	0.3	0.6
α-humulene	0.4	0.4	0.4	0.2	0.3
γ-muurolene	0.3	0.2	0.2	0.1	0.1
germacrene D	1.8	1.0	1.0	0.7	1.7
β-selinene	0.4	0.4	0.4	0.2	0.4
α-muurolene	0.2	0.1	0.1	-	0.1
cis-calamenene	0.3	0.2	0.2	0.1	0.1
δ-cadinene	0.5	0.4	0.4	0.2	0.5
germacrene B	0.3	0.2	0.2	0.1	0.1
cedrol	5.3	6.5	5.5	3.5	9.5
sandaracopimaradiene	0.5	0.4	0.1	0.1	0.1
manoyl oxide	3.9	3.4	1.0	0.5	0.9
isopimaradiene	2.0	1.1	0.3	0.2	0.3
13-epi-manoyl oxide	1.3	1.3	0.4	0.2	0.5
abietatriene	1.7	1.7	0.6	0.4	0.7
abietadiene	0.2	0.1	0.1	-	-
13(16),14-1abdadien-8-ol	1.3	0.2	-	-	0.1
(E,Z)-11,13-1abdadien-8-ol	-	0.1	-	-	-
totarol	4.8	1.9	0.8	0.5	1.1
ferruginol *	0.2	0.6	0.2	-	-

* correct isomer not identified

their antimicrobial activity by Romeo et al. (2008). Among the oils studied, an oil of *C. sempervirens* was shown to possess some bacteriostatic activity against *Listeria innocua*, no activity against *Staphylococcus aureus* and reasonable activity against *E. coli*. The composition of the screened oil was determined to be as follows:

tricyclene (0.3%)
α-thujene (1.3%)
α-pinene (31.1%)
camphene (2.4%)
sabinene (1.7%)
β-pinene (7.1%)
myrcene (2.1%)
δ-3-carene (18.6%)
α-terpinene (0.5%)
p-cymene (2.8%)
limonene (6.2%)

Comparative composition (%) of the leaf and fruit oils of *Cupressus sempervirens* grown in Iran **T-2**

Compound	Leaf oil	Fruit oil
α-pinene	21.4	46.0
sabinene	2.8	2.7
β-pinene	2.6	2.7
myrcene	5.0	5.4
δ-3-carene	16.0	27.0
limonene	3.3	2.2
terpinolene	5.9	6.4
α-terpinyl acetate	5.9	2.7
β-caryophyllene	4.2	t
α-humulene	4.2	t
germacrene D	13.0	2.1
δ-cadinene	1.6	t
cedrol	3.3	t

t = trace (< 0.05%)

Comparative percentage composition of French and Spanish Cypress oils **T-3**

Compound	French oil	Spanish oil
α-thujene	-	1.1
α-pinene	61.3	47.8
β-pinene	1.1	0.9
sabinene	0.4	1.2
myrcene	2.0	2.4
δ-3-carene	14.5	24.1
α-terpinene	t	0.6
p-cymene	t	0.3
limonene	5.0	2.8
γ-terpinene	0.4	0.9
terpinolene	1.9	2.8
linalool	t	0.8
karahanaenone	t	0.4
terpinen-4-ol	0.4	1.6
α-terpineol	t	0.4
α-terpinyl acetate	1.4	2.2
α-cedrene	0.5	0.6
β-caryophyllene	0.5	t
germacrene D	0.9	0.3
cedrol	1.2	0.7

γ-terpinene (1.0%)
terpinolene (4.6%)
linalool (0.7%)
α-fenchyl alcohol (0.2%)
camphor (0.8%)
borneol (1.3%)
terpinen-4-ol (2.0%)
p-cymen-8-ol (0.4%)
α-terpineol (0.7%)
myrtenol (0.1%)
bornyl acetate (1.8%)
p-menthan-8-yl acetate [a] (3.6%)
α-humulene (0.4%)
γ-muurolene (0.3%)
1-epi-bicyclosesquiphellandrene (0.8%)
α-muurolene (0.4%)
γ-cadinene (1.0%)
cedrol (1.7%)

[a] probable misidentification of α-terpinyl acetate.

Williams (2008) reported the results on the analyses of French and Spanish cypress oils. These results can be seen summarized in **T-3.** In addition, a trace amount (< 0.1%) of β-phellandrene and bornyl acetate was also found in the Spanish oil. Trace amounts of α-fenchene, camphene, bornyl acetate, α-cubebene and α-copaene were also found in the French oil.

Manimaran et al. (2008) analyzed the cone oil of *C. sempervirens* grown in a botanic garden in Ootacamund (Tamil Nadu, India). Its composition was determined to be as follows:

α-pinene (1.9%)
β-pinene (14.3%)
sabinene (5.3%)
myrcene (0.8%)
terpinen-4-ol (12.1%)
cubebene° (0.8%)
β-caryophyllene (0.4%)
α-humulene (1.2%)
trans-muurola-3,5-diene (0.5%)
cis-muurola-3,5-diene (0.3%)
germacrene D (1.4%)
β-cadinene† (0.5%)
γ-cadinene (1.5%)
calamenene° (1.4%)
cedrol (25.1%)
T-cadinol (1.7%)
α-cadinol (3.2%)
muurol-5-en-4-ol (3.9%)
naloxone† (1.8%)
abietadiene (18.4%)
phyllocladene (1.4%)
rimuene (1.4%)

° correct isomer not identified
† incorrect identification based on GC elution order.

H. Casabianca, *Méthods analytiques axées sur l' enantiomer avantages – inconvenient – limites*. Rivista Ital EPPOS (Numerospeciale), 205–219 (1996).

N. Chanegriha, A. Baaliouamer, B-Y. Meklati, J.R. Chretien and G. Keravis, *GC and GC/MS leaf oil analysis of four Algerian Cypress species.* J. Essent. Oil Res., **9**, 555–559 (1997).

A.L. Tapondjou, C. Adler, D.A. Fontem, H. Bouda and C. Reichmuth, *Bioactivities of cymol and essential oils of* Cupressus sempervirens *and* Eucalyptus saligna *against* Sitophilus zeamais Motschulsky *and* Tribolium confusum *du Vale.* J. Stores Prod. Res., **41**, 91–102 (2005).

I. Cheriaf, H. Ben Jannet, M. Hammami and Z. Mighri, *Hydrodistillation kinetic investigation of essential oil from the Tunisian* Cupressus sempervirens *L.*. J. Essent. Oil Bear. Plants, **8**, 165–172 (2005).

S. A. Emami, J. Assili, M. Rahimizadeh, B.S. Fazly-Bazzaz and M. Hassanzadeh-Khayyat, *Chemical and antimicrobial studies of* Cupressus sempervirens *L. and* Cupressus horizontalis *Mill. essential oils.* Iran J. Pharm. Sci., **2,** 3–8 (2006).

Percentage composition of the phenol-rich oils of *Lippia graveolens* of Guatemalan origin **T-4**

Compound	Thymol-rich oils	Carvacrol-rich oil
α-thujene	0.2–0.4	0.3
α-pinene	t–0.2	t
camphene	0–0.1	t
1-octen-3-ol + sabinene	0.2–0.3	0.2
β-pinene	t–0.2	t
myrcene	1.3–2.4	1.9
α-phellandrene	0–0.2	0.2
δ-3-carene	t–0.3	0.1
α-terpinene	0.5–1.1	1.3
p-cymene	2.7–4.9	6.9
limonene	0.2–0.3	0.3
1,8-cineole	0.1–5.2	0.6
β-ocimene*	t–0.1	0.1
γ-terpinene	1.7–4.1	7.3
cis-p-menth-2-en-1-ol	0.6–1.1	0.6
terpinolene	0.3–0.5	0.2
linalool + *cis*-sabinene hydrate	0.7–2.7	1.4
trans-p-menth-2-en-1-ol	0.5–0.8	0.4
trans-sabinene hydrate	0–0.2	t
borneol	0–0.6	0.2
terpinen-4-ol	1.8–2.3	1.5
p-cymen-8-ol	0.1–0.2	t
α-terpineol	0–0.1	t
methyl thymol	0.4–0.7	0.4
thymol	56.6–80.6	19.9
carvacrol	1.1–4.4	45.2
eugenol	t	t
β-caryophyllene	2.8–4.6	3.5
trans-α-bergamotene	0.3–0.5	0.6
α-humulene	1.9–2.9	2.3
γ-muurolene	0–t	-
germacrene D	t-0.1	1.4
α-selinene	0–t	-
β-bisabolene	t–0.3	t
δ-cadinene	0–0.1	-
caryophyllene oxide	0.3–0.9	0.8
guaiol	0–0.2	-
β-eudesmol	0–0.5	-
α-eudesmol	0–0.3	-

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

F.V. Romeo, S. De Luca, A. Piscopo and M. Poiana, *Antimicrobial effect of some essential oils*. J. Essent. Oil Res., **20**, 373–379 (2008).

D.G. Williams, *The chemistry of essential oils*. 2nd Edn., pp 179–181, Micelle Press. Port Washington, NY (2008).

S. Manimaran, L. Ramanathan, S.P. Dhanabal, M.J. Nanjan and B. Suresh, *Volatile constituents and antimicrobial activity of cone essential oil and its cream formulation of* Cupressus sempervirens Linn. Indian Perfum., **52**, 23–27 (2008).

Mexican Oregano Oil

The herb known as Mexican oregano is obtained from *Lippia graveolens* Humb. Borpl. et Kunth. It is mainly harvested from its natural environment in the wild although some cultivation does occur. On occasion, an oil of Mexican oregano is an item of commerce. Martinez et al. (1992) determined that oils produced from *L. graveolens* harvested in different regions of the state of Jalisco were found to vary in major components as listed here:

thymol (0.2–56.9%)
carvacrol (0.4–20.4%)
p-cymene (4.1–17.1%)

Fischer et al. (1997) examined the variability of oils produced from *L. graveolens* harvested from different regions of Guatemala. Three of the oils were found to be rich in thymol, one rich in carvacrol and one in which no constituent was found to exceed 10%. A summary of the phenol-rich oil compositions is shown in **T-4.**

Senatore and Rigano et al. (2001) analyzed a lab-distilled oil produced from *L. graveolens* harvested in Chimaltenango (Guatemala) using GC-FID and GC/MS. The composition of this oil was found to be as follows:

α-thujene (0.2%)
α-pinene (0.2%)
camphene (0.1%)
myrcene (1.1%)
α-phellandrene (0.3%)
δ-3-carene (1.2%)
p-cymene (5.5%)
1,8-cineole (2.1%)
limonene (0.8%)
γ-terpinene (0.3%)
p-cymenene (0.2%)
terpinolene (1.2%)
linalool (0.3%)
borneol (0.2%)
terpinen-4-ol (1.7%)
p-cymen-8-ol (0.7%)
α-terpineol (0.7%)
methyl thymol (1.0%)
thymol (31.6%)
carvacrol (0.8%)
eugenol (0.7%)
α-ylangene (0.3%)
α-copaene (0.8%)
methyl eugenol (0.4%)
β-caryophyllene (4.6%)
aromadendrene (3.2%)
α-humulene (3.0%)
trans-α-bergamotene (0.9%)
allo-aromadendrene (0.5%)
γ-muurolene (0.2%)
β-selinene (1.2%)
valencene (0.2%)
α-selinene (1.1%)
α-muurolene (0.5%)
γ-cadinene (1.3%)
cis-calamenene (0.8%)
δ-cadinene (1.1%)

(Z)-nerolidol (0.2%)
(E)-nerolidol (0.5%)
caryophyllene oxide (4.8%)
globulol (0.5%)
viridiflorol (0.6%)
guaiol (1.2%)
epi-globulol (0.4%)
humulene expoxide II (2.0%)
α-muurolol (0.2%)
α-eudesmol (3.1%)
T-cadinol (1.1%)
β-eudesmol (2.1%)
α-cadinol (1.2%)
β-bisabolol (1.6%)
phytol (0.9%)
hexadecanoic acid (1.1%)
heptacosane (0.1%)
nonacosane (0.3%)
hentriacontane (0.2%)
tritriacontane (0.1%)

Trace amounts (< 0.05%) of (Z)-β-ocimene, (E)-β-ocimene, decane, hexadecane and triacontane were also found in this oil. Two oils of Mexican oregano obtained from *L. graveolens* detected in El Salvador were analyzed by Vernin et al. (2001). The oils were rich in phenols such as carvacrol (71.0% and 34.6%) and thymol (5% and 7%). Other constituents characterized in the oils were α-pinene, camphene, β-pinene, sabinene, myrcene, limonene, α-terpinene, 1,8-cineole, p-cymene, (Z)-3-hexenol, 3-octanol, p-cymenene, *cis*-linalool oxide (furanol form), 1-octen-3-ol, linalool, β-caryophyllene, terpinen-4-ol, methyl carvacrol, umbellulone, *cis*-myrtenal, aromadendrene, γ-elemene, α-humulene, α-terpineol, borneol, γ-muurolene, carvenone, eremophilene, piperitone, carvone, β-bisabolene, β-farnesene isomer, p-methylacetophenone, cuminaldehyde, δ-cadinene, γ-cadinene, *cis*-calamenene, 1-hydroxymethyl-2-methyl-5-isopropenylcyclopentane, *cis*-sabinol, p-cymen-8-ol, geraniol, benzyl alcohol, carvacryl acetate, caryophyllene oxide, humulene epoxide II, elemen-9β-ol, cumin alcohol, eugenol, 2-isopropyl-4-methylphenol, thymol, 2-methyl-4-isopropylphenol, carvacrol, caryophylla-2(12),6(13)-dien-5-ol and 2-methoxycarvacrol.

This reviewer has not included a few components that were either tentatively identified or their identities are highly questionable. Finally, although the authors did not include much quantitative data, they did note that for the oil containing carvacrol (71.0%) this oil also contained p-cymene (21%), thymol (7.0%), 2-methyl-4-isopropylphenol (0.2%), 2-isopropyl-4-methylphenol (0.3%), β-caryophyllene (4.7%), α-humulene (2.6%) and γ-cadinene (0.9%).

A lab-distilled oil of the so-called Mexican oregano oil obtained from *L. graveolens* collected in Aldeia Rio de la Virgen (Jutiapa, Guatemala) was analyzed by Salgueiro et al. (2003). The components characterized in this oil were:

α-thujene (0.6%)
α-pinene (0.4%)
camphene (0.1%)
1-octen-3-ol (0.2%)
myrcene (2.1%)

δ-3-carene (0.2%)
α-terpinene (1.7%)
p-cymene (21.8%)
1,8-cineole (1.0%)
(Z)-β-ocimene (0.1%)
γ-terpinene (4.4%)
trans-sabinene hydrate (0.1%)
linalool (0.9%)
borneol (0.1%)
p-cymen-8-ol (0.2%)
terpinen-4-ol (1.1%)
α-terpineol (0.2%)
thymol (7.4%)
carvacrol (44.8%)
eugenol (0.1%)
α-copaene (0.1%)
β-caryophyllene (3.4%)
trans-α-bergamotene (1.3%)
α-humulene (1.9%)
γ-muurolene (0.1%)
β-selinene (0.2%)
γ-cadinene (0.4%)
cis-calamenene (0.1%)
δ-cadinene (0.2%)
spathulenol (0.2%)
caryophyllene oxide (0.9%)
globulol (0.1%)
guaiol (0.2%)
T-cadinol (0.1%)
β-eudesmol (0.4%)

Trace amounts (< 0.05%) of terpinolene and limonene were also found in this oil. A second oil of *L. graveolens* produced from plants collected in Antigua (Guatemala) was also analyzed by Salgueiro et al. It was determined to possess the following composition:

α-thujene (1.0%)
α-pinene (0.7%)
camphene (0.4%)
sabinene (1.2%)
β-pinene (0.3%)
myrcene (3.9%)
α-phellandrene (0.3%)
δ-3-carene (4.7%)
α-terpinene (1.7%)
p-cymene (6.8%)
1,8-cineole (4.5%)
limonene (1.1%)
(E)-β-ocimene (0.9%)
γ-terpinene (11.2%)
terpinolene (2.5%)
linalool (4.7%)
cis-p-menth-2-en-1-ol (0.3%)
trans-p-menth-2-en-1-ol (0.2%)
p-cymen-8-ol (0.2%)
terpinen-4-ol (2.9%)
α-terpineol (1.2%)
cis-piperitol (0.1%)
trans-piperitol (0.1%)
methyl thymol (0.5%)
thymol (18.1%)
carvacrol (0.2%)
eugenol (0.1%)

methyl eugenol (0.3%)
β-bourbonene (0.1%)
β-cubebene (0.2%)
β-elemene (1.0%)
β-caryophyllene (6.5%)
trans-α-bergamotene (0.6%)
α-humulene (3.5%)
γ-muurolene (0.5%)
germacrene D (0.9%)
β-selinene (0.8%)
valencene (1.1%)
α-muurolene (0.2%)
γ-cadinene (0.7%)
δ-cadinene (0.4%)
elemol (0.3%)
(E)-nerolidol (0.2%)
spathulenol (0.2%)
caryophyllene oxide (1.3%)
guaiol (1.3%)
T-cadinol (0.3%)
β-eudesmol (2.2%)

In addition trace amounts (< 0.05%) of 1-octen-2-ol, (Z)-β-ocimene, *cis*-sabinene hydrate and α-copaene were found in this oil.

Mexican oregano oils produced from plants collected in the vicinity of Jimenez city, Ejido Heros de la Revolucion, Tomes Uriona and Chihauha were found by Vazquez and Dunford (2005) to contain the following range of major components:

p-cymene (12.3–19.7%)
1,8-cineole (1.7–13.2%)
γ-terpinene (4.7–10.0%)
thymol (18.4–42.2%)
carvacrol (1.9–11.6%)

Hernandez et al. (2008) produced oils from plants collected in Zapotitlan Salinas Puebla (Central Mexico), and found that their main components ranged as follows:

p-cymene (17.9–20.3%)
1,8-cineole (0–0.7%)
α-terpinyl acetate (9.2–10.8%)
carvacrol (0–4.2%)
thymol (61.6–70.5%)
β-caryophyllene (1.8–2.1%)
α-humulene (0–0.9%)

M.A. Martinez, C.J. Uribe and J.B. Hurtado, *Evaluation physique et chimique de l' huile essentielle d' organ provenent d' endroits naturels localizes sans la zone Nord de l' etat du Jalisco.* Rivista Ital. EPPOS,(Numero special), 620–630 (1992).

U. Fischer, Ch. Franz, R. Lopez and E. Poll, *Variability of the essential oils of* Lippia graveolens *HBK from Guatemala*. In: *Proceedings 27th International Symposium on Essential Oils.,* Edits. Ch. Franz, A. Mathé and G. Buchbauer, pp. 266–269, Allured Publishing Corp., Carol Stream, IL (1997).

G. Vernin, C. Lageot, E.M. Gaydou and C. Parkanyi, *Analysis of the essential oil of* Lippia graveolens *HBK from El-Salvador.* Flav. Fragr. J. , **16**, 219–226 (2001).

F. Senatore and D. Rigano, *Essential oil of two* Lippia *spp. (Verbenaceae) growing wild in Guatemala.* Flav. Fragr. J. **16**, 169–171 (2001).

L.R. Salgueiro, C. Cavaleiro, M.J. Gonçalves and A. Proença da Cunha, *Antimicrobial activity and chemical composition of the essential oil of* Lippia graveolens *from Guatemala.* Planta Med., **69**, 80–83 (2003).

R. Silva Vazquez and N.T. Dunford, *Bioactive components of Mexican Oregano oil as affected by moisture and plant maturity.* J. Essent. Oil Res., **17**, 668–671 (2005).

T. Hernandez, M. Canales, M. Alvarado, A. Duran and S. Meraz, *Variation in the antimicrobial activity and chemical composition of the essential oil of* Lippia graveolens *in two zones of Zapotitlan Salinas, Mexico*. Biopestic. Internat., **4**, 22–27 (2008).