Progress in Essential Oils

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Cinnamon Leaf Oil

Jazet-Dongmo et al. (2007) screened an oil of cinnamon leaves that was produced in 1.4% yield from cinnamon trees growing in the Botanic Garden of Limbe (S.W. Cameroon) for its antioxidant and antifungal activities. Using both GC-FID and GC/MS, the oil was found to contain the following components:

α-pinene (0.1%)
limonene (0.5%)
linalool (4.3%)
(E)-cinnnamaldehyde (1.5%)
eugenol (89.1%)
α-copaene (0.1%)
α-cedrene (0.3%)
β-caryophyllene (0.5%)
α-humulene (0.2%)
caryophyllene oxide (0.2%)
benzyl benzoate (3.1%)

Singh et al. (2007) compared the composition of the oil and oleoresin of cinnamon leaf produced from leaves purchased at a local market in Gorakhpur (U.P., India). The oil was produced by hydrodistillation in 3.1% yield, while the oleoresin was extracted using a Soxhlet extraction system with acetone as the solvent. Using a combination of GC-FID and GC/MS, the authors found that the oil contained the following components:

α-thujene (0.1%)
α-pinene (0.5%)
α-phellandrene (1.9%)
p-cymene (0.7%)
1,8-cineole (0.7%)
eugenol (87.3%)
β-caryophyllene (1.9%)
aromadendrene (1.1%)
germacrene D (0.6%)
bicyclogermacrene (3.6%)
δ-cadinene (0.4%)
spathulenol (0.5%)

Trace amounts (<0.01%) of β-pinene, myrcene, p-mentha-1(7),8-diene, terpinolene, α-terpineol, α-cubebene and α-amorphene were also found in this oil. In contrast, the volatiles in the oleoresin were determined to be as follows:

α-phellandrene (0.3%)
eugenol (87.2%)
β-caryophyllene (1.4%)
aromadendrene (0.8%)
α-amorphene (0.4%)
germacrene D (0.2%)
bicyclogermacrene (1.7%)
δ-cadinene (0.6%)
spathulenol (1.7%)
δ-elemene† (1.0%)
viridiflorol (0.3%)
methoxy-eugenol† (0.1%)
isospathulenol (0.3%)
neophytadiene (0.3%)
docosane (0.1%)
nonacosane (0.1%)
α-tocopherol (0.2%)

†incorrect identification

Trace amounts (<0.01%) of sabinene, p-cymene, γ-terpinene, terpinen-4-ol and α-terpineol were also characterized in the volatiles of this oleoresin.

Tira-Picos et al. (2009) examined the composition of the leaf oil of *C. zeylanicum* produced by hydrodistillation from fresh leaves harvested from the medicinal plant garden of the University of Uyo (Akwa Ibom State, Nigeria). Using GC/MS as their only method of analysis, the authors determined that the oil contained:

α-thujene (0.1%)
α-pinene (2.6%)
camphene (1.3%)
β-pinene (1.4%)
myrcene (0.3%)
α-phellandrene (1.2%)
limonene (1.3%)
terpinolene (0.1%)
linalool (2.4%)
camphor (0.1%)
borneol (0.3%)
α-terpineol (0.4%)
(E)-cinnamaldehyde (1.4%)
α-copaene (0.3%)
β-elemene (0.1%)
β-caryophyllene (3.2%)
(E)-cinnamyl acetate (4.1%)
α-humulene (0.9%)
germacrene D (1.1%)
bicyclogermacrene (0.9%)
δ-cadinene (0.1%)
spathulenol (0.1%)
caryophyllene oxide (0.4%)
viridiflorol (0.1%)
α-cadinol (0.1%)
benzyl benzoate (74.8%)

In addition, trace amounts (<0.05%) of γ-terpinene, terpinen-4-ol, β-cubebene, γ-cadinene and mint sulfide were found in this oil. It should be noted that benzyl benzoate-rich oils of *C. zeylanicum* are not common, but are known (Nath et al. (1996).

Wang et al. (2009) determined that a leaf oil of *C. zeylanicum* contained the following constituents:

benzyl alcohol (0.2%)
linalool (0.1%)
2-phenethanol (0.1%)
borneol (0.9%)
α-terpineol (0.2%)
3-phenpropanol (0.1%)
chavicol† (0.3%)
(E)-cinnamyl alcohol (0.1%)
eugenol (79.8%)
(Z)-isoeugenol (0.1%)
hydrocinnamaldehyde (<0.1%)
benzaldehyde (0.1%)
(E)-cinnamaldehyde (16.3%)
vanillin (0.1%)
coumarin (0.1%)

†doubtful identification

The authors also reported characterizing some other constituents whose identifications, according to this reviewer, are in question. As a consequence, they are not included in this report.

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An oil produced from cinnamon leaves that were harvested from a 12-year-old tree growing in the Pathshala area (Assam, India) was analyzed by Baruah et al. (2010). Using GC-FID and GC/MS as their methods of analysis, the oil was determined to contain:

p-cymene (0.1%)
1,8-cineole (0.4%)
linalool (0.9%)
(E)-cinnamaldehyde (2.2%)
eugenol (92.7%)
methyl (E)-cinnamate (0.2%)
β-caryophyllene (1.0%)
ethyl (E)-cinnamate (0.3%)
eugenyl acetate (0.7%)
caryophyllene oxide (1.4%)

Paranagama and Gunasekara (2011) reported that the fruit oil of *C. zeylanicum* of Sri Lanakan origin, which was devoid of eugenol and cinnamaldehyde, contained the following major constituents:

α-pinene (1.9%)
camphene (0.4%)
β-pinene (2.7%)
myrcene (2.6%)
limonene (1.9%)
1,8-cineole (1.9%)
β-phellandrene (1.3%)
(E)-β-ocimene (1.3%)
p-cymene (2.0%)
α-cubebene (0.6%)
α-ylangene (13.9%)
α-fenchyl alcohol (0.6%)
β-caryophyllene (1.3%)
terpinen-4-ol (1.1%)
β-gurjunene (0.8%)
γ-cadinene (9.0%)
α-cadinene (7.0%)
calamenene* (0.5%)
bisabolol* (0.4%)
elemol (0.5%)
(E)-cinnamyl acetate (1.8%)
T-cadinol (7.1%)
α-cadinol (2.3%)
eugenyl acetate (2.0%)

*correct isomer not identified

A commercial oil of cinnamon leaf was screened for its activity against *Aspergillus flavus* by Nogueira Trajano et al. (2012). The oil used in this study was found by GC/MS only to possess the following composition:

linalool (3.1%)
α-terpineol (0.3%)
cinnamaldehyde (1.1%)
safrole (2.0%)
eugenol (75.5%)
α-copaene (1.2%)
β-caryophyllene (5.5%)
cinnamyl acetate[a] (1.7%)
aromadendrene (0.1%)
α-humulene (1.0%)
ledene (1.0%)
α-muurolene (0.1%)
eugenol acetate (3.7%)
δ-cadinene (0.2%)
caryophyllene oxide (0.4%)
benzyl benzoate (3.9%)

[a]the (E)- form

S.C. Nath, M.G. Pathak and A. Baruah, *Benzyl benzoate, the major component of the leaf and stem bark oil of* Cinnamomum zeylanicum *Blume*. J. Essent. Oil Res., **8**, 327–328 (1996).

P.M. Jazet-Dongmo, L.T. Tatsadjieu, F. Tchoumougnang, M.L. Sameza, B. Ndongson, P.H. Amvam Zollo and C. Menut, *Chemical composition, antiradical and antifungal activities of essential oil of the leaves of* Cinnamomum zeylanicum *Blume from Cameroon.* Nat. Prod. Commun., **2**, 1–4 (2007).

G. Singh, S. Maurya, M.P. de Lampasona and C.A.N. Catalan, *A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents.* Food Chem. Toxicol., **45**, 1650–1661 (2007).

V. Tira-Picos, A.A. Gbolade, J.M.F. Nogueria and K.K. Ajibesin, *Analysis of leaf essential oil constituents of* Cinnamomum zeylanicum *grown in Nigeria*. J. Essent. Oil Bear. Plants, **12**, 76–80 (2009).

R. Wang, R-J. Wang and B. Yang, *Extraction of essential oils from five cinnamon leaves and identification of their volatile composition*. Innov. Food Sci. Emerging Technol., **10**, 289–292 (2009).

A. Baruah, S.C. Nath and A.K. Hazarika, *Investigation of the essential oils of* Cinnamomum verum *Presl. grown at lower Brahmaputra valley of Assam.* Indian Perfum., **54**(3), 21–23 (2010).

P.A. Paranagama and J.J. Gunasekera, *The efficacy of the essential oils of Sri Lankan* Cinnamomum zeylanicum *fruit and* Micromelum minutum *leaf against* Callosobruchus maculatus *(F.) (Coleoptera: Bruchidae)*. J. Essent. Oil Res., **23**, 75–82 (2011).

V. Nogueira Trajano, E. de Oliveira Lima and F. Santos de Souza, *Antifungal activity of the essential oil of* Cinnamomum zeylanicum *Blume and eugenol on* Aspergillus flavus. J. Essent. Oil Bear. Plants, **15**, 785–793 (2012).

Eucalyptus staigeriana Oil

The oil of *Eucalyptus staigeriana* F. Muell. ex F.M. Bailey is obtained from the leaves of the lemon-scented iron bark member of the Myrtaceae family. The tree, which possesses black, hard, irregularly fissured bark, is a small-to-medium-sized crookedly growing eucalypt found growing in its natural habitat in grantic or sandstone hills in the far north of Queensland (Australia). No oil is produced from *E. staigeriana* in Australia. *Eucalyptus staigeriana* was introduced along with a number of other *Eucalyptus* species into the Kiva region of Belgian Congo (now Democratic Republic of Congo), Brazil, Guatemala and the Seychelles; however, only the cultivation in Brazil has been successfully sustained (Coppen, 2002). As a result, commercial production of *E. staigeriana* oil is limited to Brazil.

A summary of the literature from Porsch et al. (1965) examined the composition of *E. staigeriana* oil produced commercially in Brazil. They reported that it contained the following constituents:

α-pinene (2.1%)
β-pinene (1.3%)
myrcene (0.7%)
α-terpinene (0.6%)
α-phellandrene (0.6%)
limonene (24.1%)
p-cymene (3.0%)
γ-terpinene (0.7%)
terpinolene (3.5%)
linalool (1.0%)
terpinen-4-ol (1.0%)
neral (14.8%)
geranial (21.0%)
citronellol (1.3%)
methyl geranate (4.1%)
nerol (1.1%)
neryl acetate (1.7%)
geraniol (4.1%)
geranyl acetate (5.1%)

D'Andrea Pinto et al. (1976) collected leaf samples from a number of *E. staigeriana* trees. They found that the oil content varied from 0.85–2.53% with a composite citral content ranging from 40.5% to 63.0%. They recommended that *E. staigeriana* plantation development be selective for the genotype of trees planted.

Alencar et al. (1984) used retention indices to substantiate the characterization of α-pinene, sabinene, β-pinene, myrcene, limonene, γ-terpinene, terpinolene, methyl geranate, neryl acetate and geranyl acetate in an oil of *E. staigeriana* produced from leaves of trees collected in northeastern Brazil.

Bignell et al. (1997) used GC-FID and GC/MS to analyze an oil produced in 2.27% yield in the laboratory from powdered, dried leaves of *E. staigeriana*. The constituents characterized in this oil were as follows:

α-pinene (1.0%)
sabinene (0.1%)
myrcene (0.7%)
α-phellandrene (0.4%)
isobutyl isovalerate (0.1%)
limonene (24.1%)
1,8-cineole (0.8%)
(Z)-β-ocimene (0.1%)
γ-terpinene (1.7%)
p-cymene (0.4%)
terpinolene (10.0%)
trans-p-menth-2-en-1-ol (0.1%)
pinocarvone (0.1%)
β-caryophyllene (0.3%)
terpinen-4-ol (0.7%)
cis-p-menth-2-en-1-ol (0.1%)
allo-aromadendrene (0.1%)
trans-pinocarveol (0.1%)
α-humulene (0.1%)
δ-terpineol (11.9%)
methyl geranate (7.2%)
geranial (19.4%)
geranyl acetate (1.8%)
nerol (3.8%)
geraniol (7.4%)
p-cymen-8-ol (0.3%)
globulol (0.1%)
viridiflorol (0.1%)
spathulenol (0.3%)
eugenol (0.3%)
α-eudesmol (0.1%)
β-eudesmol (0.3%)
torquatone[a] (0.1%)

[a]also known as 3-methyl-(2,4,6-trimethoxy-3,5-dimethylphenyl-1-butanone

This oil is very unusual because it is rich in geranial and yet no neral was found. It is possible that the δ-terpineol characterized was actually neral, which would give a more normally encountered ratio of geranial to neral.

Chagas et al. (2002) screened some eucalyptus oils for their acaricidal (pesticide-specific for ticks and mites) effect. Among the oils screened was a Brazilian commercial oil of *E. staigeriana*. The oil, which was analyzed using GC/MS only, was determined to possess the following constituents:

α-thujene (0.4%)
α-pinene (3.4%)
β-pinene (2.3%)
myrcene (1.0%)
α-phellandrene (3.3%)
α-terpinene (0.2%)
p-cymene (1.1%)
limonene (24.8%)
(E)-β-ocimene (0.5%)
γ-terpinene (2.4%)
p-cymenene (0.2%)
terpinolene (10.8%)
citronellal (1.6%)
pulegone[†] (0.5%)
2-methylbutylcyclopropane[†] (0.9%)
terpinen-4-ol (1.2%)
α-terpineol (1.0%)
neral (11.4%)
p-menth-2-en-1-ol[*] (0.1%)
geranial (15.0%)
methyl geranate (5.5%)
citronellyl propionate (0.8%)
neryl acetate (3.2%)
geranyl acetate (7.6%)
nerolidol[*] (0.3%)
germacrene B (0.8%)

[*]correct isomer not identified; [†]incorrect identification

Coppen (2002) reported the results of the GC/MS analysis of a commercial sample of Brazilian *E. staigeriana* oil. The oil was found to contain the following constituents:

α-pinene (3.1%)
β-pinene (1.2%)
sabinene (0.1%)
myrcene (0.9%)

α-phellandrene (2.3%)
α-terpinene (0.2%)
limonene (26.8%)
1,8-cineole (3.3%)
(Z)-β-ocimene (0.2%)
γ-terpinene (2.6%)
(E)-β-ocimene (0.2%)
p-cymene (0.8%)
terpinolene (10.8%)
6-methyl-5-hepten-2-one (0.2%)
p-cymenene (0.3%)
citronellal (0.2%)
linalool (1.3%)
β-caryophyllene (0.2%)
terpinen-4-ol (0.8%)
citronellyl acetate (0.3%)
neral (9.6%)
methyl geranate (4.7%)
germacrene B (3.1%)
geranial (12.5%)
geranyl acetate (4.6%)
citronellol (0.5%)
nerol (1.4%)
geraniol (4.7%)
unidentified (3.1%)

A trace amount (<0.05%) of piperitone was also characterized in this oil.

Analysis of an oil of *E. staigeriana* produced in the laboratory from leaves and twigs harvested from their natural habitat in Australia was analyzed by Gilles (2006; and Gilles et al. 2010) using GC/MS only.

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

α-thujene (1.8%)
α-pinene (0.5%)
sabinene (0.7%)
myrcene (1.5%)
α-phellandrene (8.8%)
α-terpinene (0.9%)
p-cymene (1.1%)
1,8-cineole (34.8%)†
(E)-β-ocimene (0.5%)
γ-terpinene (1.3%)
terpinolene (1.5%)
linalool (0.9%)
cis-p-menth-2-en-1-ol (0.5%)
trans-p-menth-2-en-1-ol (0.3%)
(E)-tagetone† (0.2%)
lavandulol† (0.6%)
p-mentha-1,5-dien-8-ol (0.2%)
terpinen-4-ol (2.3%)
thuj-3-en-10-al† (1.0%)
α-terpineol (0.7%)
trans-piperitol (0.3%)
nerol (1.4%)
neral (10.8%)
geraniol (3.2%)
geranial (10.8%)
methyl geranate (5.2%)
neryl acetate (2.1%)
methyl (E)-cinnamate (2.0%)
geranyl acetate (3.1%)

†identification requires corroboration

It should be noted that this oil composition is somewhat peculiar because in all oils (including *E. staigeriana*) within which neral and geranial are constituents, they are always found in rations of geranial>neral ca. 1.3–1.6:1.0.

Maciel et al. (2010) screened some oils produced from *Eucalyptus* species against the sand fly *Lutzomyia longipalpis*, which is the main vector in Latin America and Brazil for the protozoa responsible for the serious chronic disease known as *Leishmaniasis*. One of the oils screened was a commercial sample of *E. staigeriana*. The oil, which was analyzed by GC-FID and GC/MS, was determined to contain the following composition:

α-pinene (3.3%)
o-cymene (1.8%)
limonene (28.8%)
1,8-cineole (5.4%)
terpinolene (9.4%)
citronellal (0.8%)
neral (10.8%)
geraniol (4.2%)
geranial (14.2%)
methyl geranate (3.7%)
geranyl acetate (3.9%)

The authors found that the oil of *E. staigeriana* was most effective against all developmental stages of *L. longipulpis*, particularly larvae.

A commercial oil of *E. staigeriana* of Brazilian origin was examined by Gusamo et al. (2013) for its screening against a weevil (*Callosobruchus maculatus*), which is a major storage pest of the cow-pea grain (an important crop for the rural Brazilians in the north and northeastern sections of the country). Analysis of this oil using GC-FID and GC/MS led to the characterization of the following constituents:

α-thujene (0.4%)
α-pinene (3.5%)
sabinene (0.1%)
β-pinene (2.5%)
6-methyl-5-hepten-2-one (0.2%)
myrcene (0.6%)
α-phellandrene (2.0%)
α-terpinene (0.1%)
o-cymene (1.4%)
limonene (28.7%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (0.3%)
γ-terpinene (1.8%)
terpinolene (8.5%)
linalool (1.4%)
(E)-myroxide (0.2%)
citronellal (0.4%)
p-mentha-1,5-dien-8-ol (0.1%)
terpinen-4-ol (1.1%)
exo-isocitral (0.1%)
p-cymen-8-ol (0.2%)
α-terpineol (0.6%)
neral (12.2%)
piperitone (0.1%)
methyl citronellate (0.1%)
geranial (15.2%)
neryl formate (0.1%)
trans-linalool oxide[p] (0.2%)
geranyl formate (0.4%)
methyl geranate (5.9%)
citronellyl acetate (0.5%)
neryl acetate (2.4%)
geranyl acetate (7.9%)
β-caryophyllene (0.2%)
aromadendrene (0.2%)
bicyclogermacrene (0.3%)

[p]pyranoid form

In addition, trace amounts (<0.05%) of the furanoid form of *cis*-linalool oxide, α-humulene and (E)-β-farnesene were found in this oil.

F. Porsch, H. Farnow and H. Winkler, *The most important constituents of the oil off* Eucalyptus staigeriana. Dragoco Rept. 8, 171–173 (1965).

A.J. D'Andrea Pinto, C.J. DeSouza and M.G.R. Donalisio, *Selecting* Eucalyptus f*or both high oil yield and citral content.* Bragantia, **35**, 115–118 (1976).

J.W. Alencar, A.A. Craveiro and F.J.A. Matos, K*ovats' Indices as a preselection routine in mass spectra library searches of volatiles.* J. Nat. Prod., **47**, 890–892 (1984).

C.M. Bignell, P.J. Dunlop, J.J. Brophy and J.F. Jackson, *Volatile leaf oils of some Queensland and Northern Australian species of the genus* Eucalyptus. *(Series II). Part I. Subgenus* Symphyomyrtus *section* Adnataria*: (a) Series* Oliganthae*, (b) Series* Ochrophloiae*, (c) Series* Moluccanae*, (d) Series* Polyanthemae*, (e) Series* Paniculatae*, (f) Series* Melliodorae *and (g) Series* Porantheroideae. Flav. Fragr. J., **12**, 19–27 (1997).

J.J.W. Coppen, *Appendix 4. Composition of some commercially distilled eucalyptus oils.* In: Eucalyptus *the genus* Eucalyptus. Edit., J.J.W. Coppen, p. 415, Taylor & Francis, London, UK (2002).

A.C. de Souza Chagas, W.M. Passos, H.T. Prates, R.C. Leite, J. Furlong and I.G.P. Fortes, *Efeito acaricida de oleos essenciais e concentrados emulsionaveis de* Eucalyptus *spp. em* Boophilus microplus. Braz. J. Vet. Res. Anim. Sci., **39**, 247–253 (2002).

M. Gilles, *Screening of the antimicrobial properties of four Australian native* Eucalyptus *species*. Diploma, 34 pp., Charles Stuart Univ., Wagga Wagga, Australia (2006).

M. Gilles, J. Zhao, M. An and S. Agboola, *Chemical composition and antimicrobial properties of essential oils of three Australian* Eucalyptus *species*. Food Chem., **119**, 731–737 (2010).

M.V. Maciel, S.M. Morais, C.M.L. Beviloqua, R.A. Silva, R.S. Barros, R.N. Sousa, L.C. Sousa, E.S. Brito and M.A. Sousa-Neto, *Chemical composition of* Eucalyptus *spp. essential oils and their insecticidal effects on* Lutzomyia longipalpis. Vet. Parasitol., **167**, 1–7 (2010).

N.M.S. Gusmao, J.V. de Oliveira, D.M. do A.F. Navarro, K.A. Dutra, W.A. da Silva and M.J.A. Wanderley, *Contact and fumigant toxicity and repellency of* Eucalyptus citriodora *Hook.*, Eucalyptus staigeriana *F.*, Cymbopogon winterianus. *Jowitt and* Foeniculum vulgare *Mill. Essential oils in the management of* Callosobruchus maculatus *(FRABR) (Coleoptera: Chrysomelidae, Bruchinae)*. J. Stored Prod. Res., **54**, 41–47 (2013).

Lavandin Oil

A number of years ago, Lawrence (1983) examined the chemical composition of oils produced from the 'Grosso' cultivar of lavandin over a season in eastern North Carolina. The oil was found to range in composition as follows:

α-pinene (0.7–1.1%)
α-thujene (t–0.2%)
camphene (0.3–0.5%)
β-pinene (0.6–1.1%)
sabinene (0.2–0.4%)
δ-3-carene (t–0.3%)
myrcene (0.7–1.0%)
α-phellandrene (t–0.1%)
α-terpinene (t–0.1%)
limonene (0.9–1.2%)
1,8-cineole (6.0–10.0%)
3-octanone (0.2–1.0%)
(Z)-β-ocimene (0.4–0.9%)
γ-terpinene (t–0.1%)
(E)-β-ocimene (0.2–0.8%)
p-cymene (0.1–0.4%)
terpinolene (0.1–0.4%)
hexyl acetate (t–0.1%)
hexyl isobutyrate (t–0.2%)
1-octen-3-yl acetate (0.1–0.3%)
hexyl butyrate (t–0.4%)
hexyl 2-methylbutyrate (t–0.3%)
trans-linalool oxide[f] (t–0.1%)
1-octen-3-ol (t–0.7%)
cis-linalool oxide[f] (t–0.1%)
camphor (7.6–9.2%)
linalool (21.5–33.0%)
linalyl acetate (21.7–29.0%)
terpinen-4-ol (1.2–2.8%)
β-caryophyllene (0.5–1.5%)
lavandulyl acetate (1.0–1.9%)
lavandulol (t–0.3%)
(Z)-β-farnesene (1.1–1.5%)
(E)-β-farnesene (0.7–0.8%)
α-terpineol (1.1–1.7%)
borneol (2.4–3.5%)
germacrene D (0.2–0.5%)
neryl acetate (0.3–1.3%)
β-bisabolene (0.1–0.2%)
(E)-α-bisabolene (0.1–0.3%)
geranyl acetate (0.8–1.3%)
γ-cadinene (0.3–0.7%)
β-sesquiphellandrene (0.2–0.3%)
nerol (0.2–0.3%)
geraniol (0.5–1.1%)
p-cymen-8-ol (t–0.1%)
caryophyllene oxide (t–0.4%)
T-cadinol (t–1.1%)
α-bisabolol (t–0.1%)
coumarin (t–0.2%)

t=trace (<0.05%); [f]furanoid form

Lane and Mahmoud (2008) compared the compositions of vie samples of lavandin oil produced in Kelowna (British Columbia, Canada) from different cultivars. Their results are summarized in **T-1**. As can be seen, these oils bear little resemblance to the lavandin oils encountered in commerce. Unfortunately, many scientists in the academic community fail to realize that the lavandin cultivars that are grown commercially are cultivated and distilled to produce an oil that is acceptable to the fragrance industry and meets the ISO standards for the oil.

Williams (2008) reported that the composition of a commercial sample of lavandin 'Grosso,' thought to be of French origin, was as follows:

α-pinene (0.3%)
β-pinene (0.3%)
myrcene (0.8%)
hexyl acetate (0.5%)
1,8-cineole (5.6%)
limonene (0.6%)
(Z)-β-ocimene (1.0%)
(E)-β-ocimene (0.5%)
terpinolene (0.3%)
linalool (32.2%)
1-octen-3-yl acetate (0.4%)
camphor (7.3%)
borneol (2.1%)
lavandulol (0.5%)
terpinen-4-ol (3.0%)
α-terpineol (1.2%)
hexyl butyrate (0.3%)
linalyl acetate (30.5%)
lavandulyl acetate (1.9%)
neryl acetate (0.3%)
geranyl acetate (0.6%)
nerol (0.3%)
geraniol (0.8%)
β-caryophyllene (1.5%)
(Z)-β-farnesene (1.1%)
germacrene D (0.6%)

Trace amounts (<0.1%) of (Z)-3-hexenol, hexanol, α-thujene, camphene, 1-octen-3-ol, sabinene, α-phellandrene, δ-3-carene, α-terpinene, p-cymene, γ-terpinene, the furanoid forms of *cis*- and *trans*-linalool oxide, hexyl isobutyrate, hexyl tiglate, coumarin, (E,E)-α-farnesene, β-bisabolene, (E)-α-bisabolene, caryophyllene oxide, hexyl 2-methylbutyrate and α-bisabolol were also characterized in this oil.

The flowering spikes of *L.* x *intermedia* (cultivar unknown) that were harvested from a farm in Bonera Kashmir (India) were steam distilled for 2 hr to produce

T-1. Comparative percentage composition of lavandin oils produced from different cultivars

Compound	1	2	3	4	5
β-pinene	0.6	-	-	-	-
myrcene	4.0	8.5	9.5	13.8	16.8
limonene	1.4	2.0	2.7	2.4	2.5
1,8-cineole	17.1	10.7	13.1	4.8	5.2
(Z)-β-ocimene	7.8	3.4	3.5	3.1	4.0
(E)-β-ocimene	12.2	4.4	6.2	8.0	9.8
camphor	13.3	10.8	5.5	2.1	4.8
linalool	23.8	30.6	28.3	35.2	25.2
linalyl acetate	0.3	8.3	10.0	11.6	12.2
terpinen-4-ol	4.1	3.3	-	-	0.5
lavandulyl acetate	-	3.7	3.4	1.8	2.7
lavandulol	1.6	-	-	-	-
α-terpineol	0.4	3.3	1.6	-	-
borneol	6.4	4.1	8.7	9.2	4.6

Cultivar oils: 1 = 'Hidcote Giant'; 2 = 'Grosso'; 3 = 'Super'; 4 = 'OK Farm Super'; 5 = 'French Super'

an oil in 2.0% yield. Shawl et al. (2008) analyzed this oil using GC-FID and GC/MS. The constituents characterized in this oil were:

(E)-3-hexanol[a] (0.3%)
α-thujene (0.1%)
α-pinene (0.6%)
camphene (0.3%)
sabinene (0.2%)
β-pinene (0.7%)
myrcene (0.7%)
α-phellandrene (0.2%)
α-terpinene (0.2%)
p-cymene (0.3%)
1,8-cineole (11.4%)
(Z)-β-ocimene (3.2%)
(E)-β-ocimene (0.8%)
γ-terpinene (0.1%)
cis-linalool oxide[f] (0.2%)
cis-sabinene hydrate (0.2%)
linalool (49.2%)
camphor (7.9%)
borneol (3.2%)
terpinen-4-ol (4.5%)
α-terpineol (1.0%)
carvone (0.2%)
hexyl butyrate (0.5%)
hexyl 2-methylbutyrate (0.1%)
linalyl acetate (6.1%)
geranial (0.6%)
isobornyl acetate (0.1%)
geranyl acetate (0.1%)
cis-α-bergamotene (0.1%)
α-copaene (0.1%)
β-cubebene (0.1%)
β-caryophyllene (2.2%)
trans-α-bergamotene (0.1%)
germacrene D (0.5%)
γ-cadinene (0.2%)
α-bisabolol (0.1%)

[f]furanoid form

In addition, trace amounts (<0.05%) of 3-octanone, geraniol and neryl acetate were found in this oil.

Bombarda et al. (2008) studied the differentiation of lavandin 'Grosso' oils produced from controlled areas of the south of France. They examined 25 samples from the Simiane region, 40 samples from Puimoisson region and 18 samples from the Recherenches region. They found that there were enough differences between the samples using 13 component levels that the regional samples could be differentiated. A summary of the component levels in the samples can be seen in **T-2**. The authors also developed a methodology combining FTIR with chemometric treatment to show that they could show the origin

T-2. Comparative percentage composition of selected constituents of lavandin 'Grosso' oils from different regions

Compound	1	2	3	4
1,8-cineole	4.0–7.6	5.6–8.7	5.2–8.6	5.1–6.1
limonene	0.4–0.6	0.4–0.5	0.4–0.6	0.5–0.6
(Z)-β-ocimene	0.7–1.4	0.6–1.4	0.8–1.3	0.7–0.9
(E)-β-ocimene	0.2–0.7	0.2–0.4	0.3	0.4–0.5
linalool	29.4–35.5	28.1–33.9	27.1–28.6	31.1–35.1
camphor	6.3–7.3	7.0–8.8	7.4–8.3	6.9–7.8
borneol	2.1–2.9	1.6–2.4	1.8–2.5	2.2–2.6
lavandulol	0.3–0.7	0.3–0.6	0.2–0.4	0.5–0.7
terpinen-4-ol	1.5–3.4	1.6–2.6	1.8–2.8	2.0–3.2
α-terpineol	0.9–1.4	1.0–1.3	0.8–1.5	1.3–1.7
linalyl acetate	28.8–34.4	31.0–32.6	29.4–35.4	28.3–30.6
lavandulyl acetate	1.6–2.6	2.1–2.8	2.3–2.9	2.5–2.9
β-caryophyllene	1.6–2.0	1.4–1.9	1.8–2.3	1.6–1.9

1. 25 samples from Simiane region; 2. 30 samples from Puimoisson region; 3. 10 samples from Puimoisson region; 4. 18 samples from Richerenches origin

T-3. Comparative percentage composition of the products of lavandin 'Super' grown in Turkey

Compound	Oil	Hydrosol	Concrete	Absolute
1,8-cineole	2.6	9.8	2.2	1.0
linalool oxide*	0.4	6.0	t	t
camphor	4.8	13.4	5.0	4.3
linalool	34.0	55.6	17.7	17.2
linalyl acetate	47.7	t	46.6	45.0
neryl acetate	2.4	t	1.7	1.3
β-caryophyllene	1.0	t	1.4	1.2
farnesene*	0.5	t	1.1	0.9
geraniol	0.3	1.6	t	t
borneol	4.2	13.5	7.0	6.4
limonene dioxide†	0.2	t	2.6	2.8
caryophyllene oxide	0.3	t	3.5	2.4
α-bisabolol†	0.8	t	7.4	5.7
farnesyl acetone	t	t	3.8	3.6

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

differentiation between samples to the same extent as they found by running GC analyses on the 83 samples of oil.

Tiliacos et al. (2008) examined a cyclohexane extract of the spent plant material after hydrodistillation of lavandin 'Grosso' flower heads. Using GC-FID and GC/MS, the authors found that the extract contained the following constituents:

undecane (0.2%)
camphor (0.8%)
exo-2-hydroxy-1,8-cineole (0.5%)
exo-3-hydroxy-1,8-cineole (0.2%)
3,4-dimethyl-2-oxa-bicyclo[2.2.2]-methanol (0.2%)
1-hydroxy-2,4,4-trimethyl-pent-3-yl isobutyrate (0.2%)
2,7-dimethyl-oct-(Z)-4-ene-diol (0.3%)
dihydrocoumarin (1.0%)
β-caryophyllene (0.2%)
coumarin (16.9%)
(E)-β-farnesene (0.3%)
γ-muurolene (0.2%)
linalyl valerate (0.3%)
γ-cadinene (0.3%)

cis-calamenene (0.3%)
caryophyllene oxide (0.4%)
T-cadinol (5.0%)
α-cadinol (1.0%)
3-oxo-7,8-dihydro-α-ionone (0.4%)
α-bisabolol (9.6%)
heptadecane (0.1%)
herniarine (16.0%)
cadina-4,10(15)-dien-3-one (0.2%)
neophytadiene (0.2%)
hexahydrofarnesylacetone (0.3%)
10-hydroxycadin-4-en-3-one (1.2%)
hexadecanoic acid (0.4%)
4-methyldocosane (0.4%)
tricosane (0.2%)
4-methyltricosane (0.3%)
pentacosane (1.1%)
3-methylpentacosane (0.2%)
hexacosane (5.1%)
heptacosane (2.7%)

A number of batches of freshly harvested (25 kg) flower heads of the 'Super' lavandin cultivar that were grown in a research garden in Isparta (Turkey) were subjected to steam distillation, from which oils were produced in 1.1–1.3% yield. In addition, Soxhlet extraction of the same harvested flower heads was used to produce a concrete, which in turn was treated with alcohol to produce an absolute. Baydar and Kineci (2009) determined the compositions of the oil, the distillation water (hydrosol), the concrete and the absolute by GC/MS only. Their results are summarized in **T-3**.

B.M. Lawrence, *Lavandin in oil 'Grosso.'* Unpublished Data (1983).

D.G. Williams, *The chemistry of essential oils*. 2nd Edn., pp. 190–191, Micelle Press, Port Washington, NY (2008).

W.A. Lane and S.S. Mahmoud, *Composition of essential oil from* Lavandula angustifolia *and* L. intermedia *varieties grown in British Columbia, Canada*. Nat. Prod. Comm., **3**, 1361–1366 (2008).

A.S. Shawl, A. Rouf, T. Kumar and M.A. Qurieshi, *Chemical investigation of essential oil of* Lavandula *x* intermedia. Indian Perfum., **52**, 33–35 (2008).

I. Bombarda, N. Dupuy, J-P. Le Van Da and E.M. Gaydou, *Comparative chemometric analyses of geographic origins and compositions of lavandin var. 'Grosso' essential oils by mid infrared spectroscopy and gas chromatography.* Anal. Chim. Acta, **613**, 31–39 (2008).

C. Tiliacos, E.M. Gaydou, J-M. Bessiere and R. Agnel, *Distilled lavandin (*Lavandula intermedia *Emeric ex Loisel) wastes: a rich source of coumarin and herniarin*. J. Essent. Oil Res., **20**, 412–413 (2008).

H. Baydar and S. Kineci, *Scent composition of essential oil, concrete, absolute and hydrosol from lavandin (*Lavandula *x* intermedia *Emeric ex Loisel)*. J. Essent. Oil Bear. Plants, **12**, 131–136 (2009).

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