# Progress in Essential Oils

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## New Caledonium Sandalwood Oil

An oil of sandalwood produced from the heartwood of *Santalum austrocaledonicum* Viell. var. *austrocaledonicum* has been available commercially for a number of years. According to Coppen (1995), small quantities of oil were being produced from New Caledonium sandalwood before 1995.

Alpha et al. (1996) determined that the main constituents of New Caledonium sandalwood oil were α-santalene, epi-β-santalene, β-santalene, α-santalol, epi-β-santalol and β-santalol. These same authors (Alpha et al. 1997a) identified 6,13-dihydroxybisabola-2,10-diene, 7,13-dihydroxybisabola-2,10-diene, (E)-lanceol and campherene-2,3-diol (Alpha et al. 1997b) in the same New Caledonium sandalwood oil. The main components of this oil were reported (Alpha et al. 1997c) to be as follows:

α-santalene (1.3%)
*trans*-β-bergamotene (0.2%)
epi-β-santalene (1.0%)
β-santalene (0.9%)
α-santalol (52.9%)
(Z)-*trans*-α-bergamotol (8.1%)
epi-β-santalol (3.3%)
β-santalol (20.9%)
(Z)-lanceol (4.5%)

Braun et al. (2005) analyzed a sample of New Caledonium sandalwood oil and determined that it possessed the following composition:

santene (0.1%)
α-santalene (1.1%)
*trans*-α-bergamotene (0.2%)
epi-β-santalene (0.9%)
β-santalene (0.9%)
β-bisabolene (0.3%)
β-curcumene (0.2%)
α-ekasantalal (0.1%)
ar-curcumene (0.3%)
dendrolasin (0.1%)
α-photosantalol (0.1%)
(E)-nerolidol (0.2%)
epi-β-photosantalol (0.1%)
nor-α-santalenone (0.1%)
β-photosantalol (0.1%)
nor-β-santalenone (0.1%)
β-bisabolol/epi-β-bisabolol (0.8%)
cyclosantalal (0.7%)
α-santalal* (0.9%)
(Z)-*trans*-α-bergamotal (0.2%)
epi-cyclosantalal (0.4%)
α-bisabolol* (0.7%)
*cis*-β-santalal (0.1%)
dihydro-α-santalol (0.4%)
*trans*-β-santalal (0.2%)
campherenol (0.5%)
(E,E)-farnesol (1.0%)
*cis*-α-santalol (38.2%)
(Z)-*trans*-α-bergamotol (9.9%)
*trans*-α-santalol (0.4%)
epi-β-santalol (3.8%)
*cis*-β-santalol (18.2%)
*trans*-γ-curcumen-12-ol (0.6%)
(Z)-γ-bisabolen-12-ol (0.6%)
*trans*-β-santalol (0.4%)
*cis*-β-curcumen-12-ol (1.1%)
(Z)-lanceol (9.1%)
(Z)-nuciferol (2.1%)
spirosantalol (0.8%)
bisabola-2,10-diene-6,13-ol (0.1%)

*correct isomer not identified

A number of constituents were found in amounts between 0.01–0.1%. They were limonene, epi-sesquithujene, santalenone, 1-(4-methyl-3-cyclohexenyl)-ethanone, *cis*-α-bergamotene, α-acoradiene, β-acoradiene, β-alaskene, (Z,E)-α-farnesene, (Z)-γ-bisabolene, sesquicineole, (E)-γ-bisabolene, N-furfurylpyrrole, geranyl acetone, a humuladienone isomer, two nor-helifolen-12-al isomers, tricycloekasantalol, acetyldihydroalbene and bisabola-2,10-diene-7,13-diol. Also, a further number of trace constituents (< 0.01%) such as α-pinene, p-cymene, dihydroarbene, furfural, teresantalal, linalool, sesquithujene, epi-α-cedrene, α-cedrene, terpinen-4-ol, a sesquisabinene isomer, γ-acoradiene, citronellol, sesquiphellandrene, (E)-α-bisabolene, β-ekasantalal, α-acorenol, epi-α-acorenol, β-acorenol, epi-β-acorenol, α-teresantalic acid, 11-epi-6,10-epoxy-bisabol-2-en-12-ol and *cis*-12-hydroxysesquicineole were found in this same oil. Furthermore, the authors determined that the ratio of bisabolol isomers found in this oil was (6R,7S)—(20%); (6R,7R)—(63%); (6S,7R)—(12%); and (6S,7S)—(5%). In conclusion, the authors noted that New Caledonium sandalwood oil was closer in composition and odor quality to East Indian sandalwood oil than the sandalwood oil of Western Australian origin.

J.J.W. Coppen, *Sandalwood oil.* In: *Non-wood Forest Products 1. Flavours and Fragrances of Plant Origin.* pp. 53–60, Food and Agricultural Organization of the United Nations, Rome (1995).

T. Alpha, P. Raharivelomanana, J-P. Bianchini, R. Faure, A. Cambon and L. Joncheray, *Santalenes from* Santalum austro-caledonicum. Phytochemistry, **41**, 829–832 (1996).

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T. Alpha, P. Raharivelomanana, J-P. Bianchini, R. Faure and A. Cambon, *Identification de deux derives dihydoxyles du bisabolane a partir de Santals oceaniens.* Rivista Ital. EPPOS, (Numero Speciale), 84–91 (1997).

N. Braun, M. Meier and F-J. Hammerschmidt, *New Caledonium sandalwood oil—a substitute for East Indian sandalwood oil?* J. Essent. Oil Res., **17**, 477–480 (2005).

## Chamomile Oil

The main components found in the oils of two cultivars ('Bona' a diploid and 'NL-90' a tetraploid) of *Chamomilla recutita* (L.) Rausch. produced during the different stages of anthodia development was the subject of study by Repcak et al. (1993). Although the highest oil yield was obtained when only bracts of involucres were differentiated, the highest content of chamazulene was found when 50% of the tubular flowers were blown over. The three major components found in the oils of 'Bona' and 'NL-90' over the anthodia development were determined to be as follows:

(E)-β-farnesene (15.8–31.9% and 11.3–34.2%)
α-bisabolol (39.3–46.8% and 38.3–45.6%)
chamazulene (16.8–25.3% and 16.9–34.2%)

Grgesina et al. (1995) analyzed oils produced from different plant parts of Croatian *C. recutita*. A summary of the results of this study are shown in **T-1**.

Chamomile oil produced from plants collected from various natural sites in the lowlands of the Slovak Republic was analyzed by Salamon and Danielovic (1997). The range in composition of the main components characterized in the 10 oils studied was found to be as follows:

(E)-β-farnesene (1.20–11.47%)
α-bisabolol oxide B (0.38–21.48%)
α-bisabolol (3.37–6.64%)
chamazulene (4.99–10.80%)
α-bisabolol oxide A (34.10–52.90%)
*trans*-en-yn-dicycloether (5.39–13.05%)
*cis*-en-yn-dicycloether (0–6.61%)

Oils produced from the flowerheads and disk florets of *C. recutita* collected in Attica (Greece) were analyzed by Papazoglou et al. (1998). The results obtained are presented in **T-2**.

The affect of drying on the main components of the oils of chamomile flowers produced from plants on alkaline soils (pH 8.2–8.7) was studied by Mishra et al. (1999). The conditions examined were fresh flowers versus shade or sun drying. The main components of the oil produced from fresh flowers were:

(E)-β-farnesene (10.7%)
α-bisabolol (16.5%)
chamazulene (21.6%)
α-bisabolol oxide A (10.4%)

Oils produced from shade-dried flowers contained:

(E)-β-farnesene (15.2%)
α-bisabolol (22.1%)
chamazulene (19.6%)
α-bisabolol oxide A (8.4%)

**T-1** Percentage composition of the main components of oils of different plant parts of *Chamomilla recutita*

| Compound | Flowerhead oil | Steam/leaf oil | Petal oil | Yellow floret oil |
|---|---|---|---|---|
| (E)-β-farnesene | 7.8 | 8.4 | 12.9 | 9.5 |
| α-bisabolol | 2.1 | 1.9 | 1.8 | 2.2 |
| chamazulene | 6.9 | 4.8 | 5.1 | 10.4 |
| bisabolol oxide A | 26.5 | 25.5 | 19.7 | 28.5 |
| bisabolol oxide B | 19.1 | 18.8 | 14.9 | 19.5 |
| en-yn-dicycloethers | 8.0 | 9.4 | 11.3 | 2.9 |

**T-2** Comparative percentage composition of oils produced from the flowerheads and disk florets of *Chamomilla recutita* of Greek origin

| Compound | Flowerhead oil | Disk floret oil |
|---|---|---|
| α-pinene | 4.7 | 2.3 |
| camphene | 2.0 | 3.0 |
| β-pinene | 3.7 | 3.8 |
| 6-methyl-5-hepten-2-one | 2.4 | 4.4 |
| myrcene | 1.3 | 3.2 |
| p-cymene | 1.9 | 3.8 |
| γ-terpinene | 2.4 | 3.6 |
| nonanal | 3.0 | 1.9 |
| camphor | 4.4 | 5.6 |
| β-elemene | 2.3 | 1.5 |
| (E)-β-farnesene | 21.2 | 16.0 |
| salicylic acid | 3.0 | 2.8 |
| γ-cadinene | 1.5 | 1.5 |
| δ-cadinene | 1.5 | 1.3 |
| germacrene B | 2.3 | 1.5 |
| α-bisabolol oxide B | 1.6 | 1.7 |
| β-bisabolol | 1.1 | 1.4 |
| bisabolone oxide A | 5.6 | 9.0 |
| α-bisabolol | 1.6 | 1.0 |
| chamazulene | 1.1 | 1.2 |
| α-bisabolol oxide A | 1.7 | 0.6 |

**Percentage composition of the flower oils of three chamomile accessions** **T-3**

| Compound | 1 | 2 | 3 |
|---|---|---|---|
| 6-methyl-5-hepten-2-one | 0.5 | 0.7 | 0.7 |
| myrcene | 0.1 | – | 0.1 |
| (Z)-3-hexenyl acetate | 0.6 | 0.3 | 0.2 |
| p-cymene | 0.1 | 0.1 | 0.2 |
| limonene + 1,8-cineole | 0.3 | 0.1 | 0.2 |
| (Z)-β-ocimene | 0.1 | 0.1 | – |
| (E)-β-ocimene | 0.5 | 0.3 | 0.2 |
| artemisia ketone | 3.4 | 2.2 | 0.4 |
| γ-terpinene | 0.4 | 0.3 | 0.5 |
| artemisia alcohol | 1.5 | 0.5 | 0.2 |
| linalool | 0.1 | 0.1 | 0.1 |
| camphor | 0.5 | 0.7 | 0.2 |
| isoborneol | 0.1 | 0.5 | – |
| borneol | 0.8 | 0.5 | 0.2 |
| terpinen-4-ol | 0.1 | 0.1 | 0.1 |
| α-terpineol | 0.3 | 0.1 | 0.1 |
| pulegone | 0.1 | 0.5 | 0.5 |
| geraniol | 0.1 | 0.1 | 0.1 |
| β-bourbonene | 0.4 | 0.1 | 0.1 |
| β-caryophyllene | 0.2 | 0.1 | 0.1 |
| (E)-β-farnesene | 12.6 | 8.8 | 10.1 |
| γ-muurolene | 0.1 | 0.1 | 0.1 |
| germacrene D | 1.3 | 1.6 | 2.9 |
| α-patchoulene | 0.2 | 0.1 | 0.2 |
| (E,E)-α-farnesene | 0.4 | 0.7 | 0.6 |
| δ-cadinene | 0.2 | 0.2 | 0.2 |
| (E)-nerolidol | 0.2 | 0.2 | 0.5 |
| spathulenol | 0.1 | 0.1 | 0.2 |
| caryophyllene oxide | 0.2 | 0.2 | 0.2 |
| T-cadinol | 0.8 | 2.4 | 1.3 |
| α-bisabolol oxide B | 6.4 | 6.3 | 16.1 |
| α-bisabolone oxide | 0.2 | 0.4 | 1.1 |
| α-bisabolol | 14.8 | 15.5 | 2.2 |
| chamazulene | 2.4 | 3.5 | 18.2 |
| α-bisabolol oxide A | 38.0 | 37.4 | 13.7 |
| *cis*-en-yn-dicycloether | 4.4 | 4.2 | 7.7 |
| *trans*-en-yn-dicycloether | 0.2 | 0.6 | 0.6 |

1 = 'Vallary' cultivar; 2 = CR-SPL—a selection from 'Vallary'; 3 = CR-3A—a second selection from 'Vallary'

**Comparative main component composition (%) of an oil and a supercritical fluid $CO_2$ extract of chamomile flowers of Italian origin** **T-4**

| Compound | Oil | Extract |
|---|---|---|
| (E)-β-farnesene | 12.8 | 9.6 |
| spathulenol | 2.6 | 1.0 |
| α-bisabolol oxide B | 7.8 | 4.6 |
| α-bisabolone oxide | 9.2 | 2.5 |
| α-bisabolol | 3.6 | 2.3 |
| chamazulene | < 0.5 | 7.3 |
| α-bisabolol oxide A | 36.6 | 28.5 |
| *cis*-en-yn-dicycloether | 2.7 | 25.9 |
| *trans*-en-yn-dicycloether | – | 3.9 |
| waxes | – | 13.2 |

This revealed an increase in the (E)-β-farnesene and α-bisabolol contents and a decrease in the chamazulene and α-bisabolol oxide A contents. Similar and more drastic changes were found in oils were produced from sun-dried flowers. The oil content varied from 0.11% for fresh flowers, 0.44% for shade-dried flowers and 0.42% for sun-dried flowers.

Repcak et al. (1999) determined the main constituents of dried Chamomile flowers (diploid cultivar 'Novbona') using reversed phase high performance liquid chromatography. The results obtained were:

(E)-β-farnesene (12.1%)
chamazulene (13.7%)
α-bisabolol (21.1%)
α-bisabolol oxide A (7.3%)
α-bisabolol oxide B (5.4%)
*cis*- and *trans*-en-yn-dicycloethers (31.9%)

Das et al. (1999) compared the oils produced by water distillation of three accessions of chamomile flowers produced from plants grown in Lucknow (India). The results of this study are presented in **T-3**.

Scalia et al. (1999) compared the main component composition of an oil and a supercritical fluid $CO_2$ extract (SFE) of chamomile flowers obtained from plants grown in Verona (Italy). The results are summarized in **T-4**. It was of interest to note that the authors felt that large scale SFE of chamomile flowers was technically feasible using pure $CO_2$; however, they found that the use of modified $CO_2$ with organic solvents was not effective on the pilot scale.

Pekic et al. (1999) compared the compositions of chamomile oil produced from diploid and tetraploid plants grown in Novi Sad (Serbia). The results showed that oils produced from diploid plants were richer in α-bisabolol than oils produced from tetraploid plants, as can be seen in **T-5**.

Schulz et al. (2004) examined the oil compositions of a number of chamomile oils. They found that the main constituents varied as follows:

(E)-β-farnesene (3.1–47.3%)
chamazulene (0–21.2%)
α-bisabolol (0–55.5%)
α-bisabolol oxide A (0–54.3%)

**Comparative percentage composition of the oils of tubular flowers and ligulate flowers of diploid and tetraploid chamomile** **T-5**

| Compound | Diploid | | Tetraploid | |
|---|---|---|---|---|
| | Tubular flower oil | Ligulate flower oil | Tubular flower oil | Ligulate flower oil |
| menthone | – | 4.4 | – | 3.4 |
| (E)-anethol | 4.5 | – | 3.3 | – |
| (E)-β-farnesene | 1.0 | 0.6 | 1.2 | 1.2 |
| α-bisabolol oxide B | 17.8 | 13.2 | 5.9 | 5.6 |
| α-bisabolol | 34.2 | 21.3 | 9.6 | 9.4 |
| chamazulene | 4.4 | 1.9 | 12.2 | 5.5 |
| α-bisabolol oxide A | 24.4 | 18.3 | 54.3 | 45.6 |
| *cis*-en-yn-dicycloether | 0.1 | 0.8 | 3.6 | 1.0 |
| *trans*-en-yn-dicycloether | 3.3 | 5.7 | 2.2 | 6.7 |



α-bisabolone oxide A (0–15.7%)
α-bisabolol oxide B (0–49.2%)

Rubiolo et al. (2006) compared the results of standard capillary GC analysis with that of fast GC analysis. These results are shown in **T-6**.

An oil produced by hydro-distillation from freshly harvested chamomile flowers in India was analyzed using GC-FID and GC/MS by Sashidhara et al. (2006). The compounds characterized in this oil were as follows:

α-pinene (0.1%)
6-methyl-5-hepten-2-one (0.2%)
myrcene (0.1%)
(Z)-3-hexenyl acetate (0.1%)
p-cymene (0.1%)
limonene (0.3%)
(Z)-β-ocimene (0.1%)
1,8-cineole (0.1%)
(E)-β-ocimene (0.4%)
artemisia ketone (3.1%)
decanoic acid (0.8%)
γ-terpinene (0.3%)
artemisia alcohol (0.6%)
linalool (0.1%)
borneol (0.7%)
terpinen-4-ol (0.1%)
α-terpineol (0.3%)
pulegone (0.4%)
geraniol (0.1%)
geranyl acetate (0.1%)
β-bourbonene (0.2%)
β-elemene (0.1%)
β-caryophyllene (0.2%)
(E)-β-farnesene (14.0%)
δ-muurolene[†] (1.0%)
germacrene D (1.6%)
α-patchoulene[†] (0.3%)
α-farnesene[*] (0.6%)
γ-cadinene (0.2%)
(E)-nerolidol (0.2%)
spathulenol (0.1%)
caryophyllene oxide (0.3%)

**T-6 Comparative main component composition (%) of chamomile oil analyzed by standard and fast GC**

| Compound | 1 | 2 |
|---|---|---|
| (E)-b-farnesene | 2.0 | 1.9 |
| α-bisabolol oxide B | 15.0 | 15.0 |
| α-bisabolol | 35.6 | 35.3 |
| α-bisabolone oxide A | 2.8 | 3.0 |
| chamazulene | 6.9 | 6.6 |
| α-bisabolol oxide A | 29.4 | 29.7 |
| *cis*- and *trans*-en-yn-dicycloethers | 8.3 | 8.6 |

1 = standard GC (27.5 min); 2 = fast GC (7.2 min)

T-cadinol (0.8%)
β-eudesmol (0.4%)
α-bisabolol oxide B (8.6%)
α-bisabolone oxide (0.4%)
α-bisabolol (16.0%)
chamazulene (5.6%)
α-bisabolol oxide A (36.5%)
*cis*-en-yn-dicycloether (2.8%)
*trans*-en-yn-dicycloether (0.4%)

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

The components isolated from the oils of tubular and ligulate florets and receptacle of dried chamomile flowers were analyzed by Tirillini et al. (2006). The results of the analyses are summarized in **T-7**.

M. Repcak, P. Cernaj and P. Martonfi, *The essential oil content and composition in diploid and tetraploid* Chamomilla recutita *during the ontogenesis of anthodia.* J. Essent. Oil Res., **5**, 297–300 (1993).

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M. Repcak, J. Imrich and J. Garcar, *Quantitative evaluation of the main sesquiterpenes and polyacetylenes of* Chamomilla recutita *essential oil*

| Percentage composition of receptacle, tubular and ligulate flower oils of *Chamomilla recutita* | | | T-7 |
|---|---|---|---|
| **Compound** | **Receptacle oil** | **Tubular flower oil** | **Ligulate flower oil** |
| p-xylene | – | – | 0.1 |
| α-pinene | 0.1 | – | 0.1 |
| 6-methyl-3-heptanone | – | 0.1 | 0.1 |
| (Z)-2-heptenal | 0.2 | – | 0.1 |
| benzaldehyde | 0.1 | 0.2 | 0.1 |
| sabinene | – | 0.1 | 0.1 |
| 1-decene | – | – | 0.1 |
| 6-methyl-5-hepten-2-one | 0.3 | 0.2 | 0.3 |
| fufuryl methyl sulphide | – | 0.1 | 0.1 |
| yomogi alcohol | 1.0 | 1.3 | 0.7 |
| octanal | – | 0.1 | 0.1 |
| decane | – | – | 0.1 |
| p-cymene | 0.1 | 0.1 | 0.1 |
| limonene | – | 0.1 | 0.1 |
| 1,8-cineole | 1.1 | 1.2 | 0.4 |
| butyl 2-methylbutyrate | – | 0.1 | 0.1 |
| (E)-β-ocimene | 0.2 | 0.1 | 0.1 |
| artemisia ketone | 1.4 | 2.1 | 1.3 |
| artemisia alcohol | 1.1 | 1.6 | 1.0 |
| linalool | 0.2 | 0.3 | 0.3 |
| *trans*-sabinene hydrate | 0.1 | – | – |
| nonanal | 0.1 | 0.1 | 0.2 |
| α-thujone | 0.1 | 0.2 | 0.1 |
| dehydrosabina ketone | 0.8 | 0.1 | 0.5 |
| camphor | 0.1 | 0.1 | 0.2 |
| *cis*-chrysanthenol | 0.2 | 0.3 | 0.2 |
| borneol | 0.1 | 0.2 | 0.1 |
| artemisyl acetate | 0.7 | 1.2 | 0.6 |
| terpinen-4-ol | 0.2 | 0.2 | 0.2 |
| α-terpineol | 0.3 | 0.4 | 0.2 |
| methyl salicylate | 0.1 | 0.1 | – |
| dodecane | 0.2 | 0.2 | 0.2 |
| decanal | 0.1 | – | 0.1 |
| isobornyl formate | 0.1 | 0.2 | 0.2 |
| carvone | 0.2 | 0.3 | 0.3 |
| (Z)-3-hexenyl isovalerate | 0.2 | 0.1 | – |
| benzyl propionate | 0.1 | – | – |
| (E)-2-decenal | 0.1 | – | – |
| (E)-anethole | – | – | 0.1 |
| neoiso(iso)pulegyl acetate | 0.1 | 0.2 | 0.1 |
| methyl decanoate | 0.1 | 0.1 | 0.2 |
| δ-elemene | 0.6 | 2.1 | 0.9 |
| α-longipinene | 0.1 | 0.1 | 0.1 |
| eugenol | 0.4 | 0.4 | 0.4 |
| α-copaene | 0.1 | 0.1 | 0.1 |
| decanoic acid | 0.1 | 0.1 | 0.1 |
| β-elemene | 0.2 | 0.3 | 0.2 |
| *cis*-α-bergamotene | 0.3 | 0.1 | 0.2 |
| b-caryophyllene | 0.3 | 1.6 | 0.5 |
| aromadendrene | 0.1 | 0.1 | 0.1 |
| (E)-β-farnesene | 15.9 | 17.1 | 14.4 |
| dehydro-sesquicineole | – | 0.3 | 0.3 |
| *trans*-cadina-1(6),4-diene | 0.1 | 0.1 | – |
| α-amorphene | 0.1 | 0.1 | – |
| germacrene D | 1.6 | 4.1 | 4.6 |

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**T-7**

| Compound | Receptacle oil | Tubular flower oil | Ligulate flower oil |
|---|---|---|---|
| β-selinene | 0.4 | 0.4 | 0.7 |
| bicyclogermacrene | < 0.1 | 3.0 | 4.4 |
| α-muurolene | – | 0.2 | – |
| *trans*-b-guaiene | 0.2 | 0.1 | 0.3 |
| (E,E)-a-farnesene | 0.7 | 1.9 | 3.0 |
| γ-cadinene | 0.3 | 0.1 | 0.1 |
| δ-cadinene | – | 0.2 | 0.6 |
| epi-longipinanol | 0.1 | 0.1 | – |
| α-cedrene oxide | 0.1 | 0.2 | 0.2 |
| spathulenol | 12.6 | 11.3 | 4.4 |
| *trans*-sesquisabinene hydrate | – | 1.5 | – |
| caryophyllene oxide | – | 0.3 | 0.1 |
| salvial-4(14)-en-1-one | 0.8 | – | 0.6 |
| β-atlanol | 0.1 | 0.1 | 0.2 |
| α-eudesmol | 0.2 | 0.1 | 0.5 |
| α-bisabolol oxide B | 5.6 | 9.9 | – |
| 14-hydroxy-9-epi-β-caryophyllene | – | 0.4 | – |
| (Z)-α-santalol | 0.4 | 0.1 | – |
| guaia-3,10(14)-dien-11-ol | 0.6 | – | – |
| α-bisabolone oxide A | 9.2 | 11.2 | 10.5 |
| α-bisabolol | 3.6 | 1.6 | 1.4 |
| chamazulene | 13.7 | 8.4 | 10.5 |
| α-bisabolol oxide A | 11.6 | 4.9 | 10.1 |
| *cis*-en-yn-dicycloether | 6.4 | 2.7 | 13.4 |
| hexadexanoic acid | 0.2 | 0.2 | 0.4 |
| *trans*-en-yn-dicycloether | 0.1 | 0.1 | 0.3 |
| methyl linoleate | 0.1 | 0.1 | 0.3 |
| phytol acetate | 0.2 | 0.2 | 1.1 |
| tricosane | 0.2 | 0.2 | 0.9 |
| tetracosane | 0.1 | 0.1 | 0.4 |
| pentacosane | 0.7 | 0.8 | 2.1 |
| hexacosane | – | – | 0.2 |
| heptacosane | 0.2 | 0.2 | 1.2 |
| octacosane | – | 0.1 | 0.2 |


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**Comparative major component composition (%) of lavandin oil and a supercritical fluid $CO_2$ extract (SFE)** **T-8**

| Compound | Oil | SFE |
|---|---|---|
| limonene | 1.4 | 0.6 |
| linalool | 46.0 | 31.0 |
| borneol + camphor | 9.2 | 8.4 |
| α-terpineol | 3.6 | – |
| linalyl acetate | 20.4 | 37.5 |
| bornyl acetate + lavandulyl acetate | 5.6 | 5.0 |
| β-caryophyllene | 1.0 | 1.2 |
| geranyl acetate | 4.3 | 7.2 |


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**T-9** Comparative percentage composition of lavandin oil obtained from four cultivars

| Compound | 'Abrialii' | 'Grosso' | 'Super' | 'Provence' |
|---|---|---|---|---|
| 1,8-cineole | 8.8 | 10.7 | 6.8 | 21.1 |
| linalool | 31.1 | 27.9 | 38.5 | 29.1 |
| camphor | 7.5 | 8.1 | 3.5 | 3.8 |
| linalyl acetate | 17.2 | 17.8 | 17.7 | 1.5 |
| lavandulyl acetate | 2.9 | 3.1 | 2.2 | 0.5 |
| β-caryophyllene | 1.9 | 1.9 | 1.1 | 0.8 |

**T-10** Comparative percentage composition of lavandin oil and lavandin water from the 'Grosso' cultivar

| Compound | Lavandin oil | Lavandin water |
|---|---|---|
| camphene | 0.49 | 0.09 |
| β-pinene | 0.89 | 0.10 |
| myrcene | 0.94 | 0.09 |
| limonene | 1.10 | 0.57 |
| 1,8-cineole | 7.43 | 1.57 |
| γ-terpinene | 1.61 | 0.05 |
| 3-octanone | 0.50 | 0.08 |
| terpinolene | 0.38 | – |
| hexanol | – | 0.10 |
| 3-octanol | – | 0.06 |
| *cis*-linalool oxide[f] | – | 0.80 |
| *trans*-linalool oxide[f] | – | 0.64 |
| camphor | 8.08 | 0.81 |
| linalool | 29.58 | 68.49 |
| linalyl acetate | 29.15 | 0.12 |
| α-santalene | – | 0.07 |
| bornyl acetate | – | 0.09 |
| β-caryophyllene | 1.76 | 0.10 |
| terpinen-4-ol | 1.90 | 4.39 |
| cryptone | 1.33 | 0.10 |
| (E)-β-farnesene | – | 0.17 |
| lavandulol | 0.50 | 1.36 |
| α-terpineol | 1.55 | 8.98 |
| borneol | 2.50 | 1.35 |
| neryl acetate | 0.62 | 0.06 |
| geranyl acetate | 1.53 | 0.10 |
| nerol | – | 1.69 |
| geraniol | 0.71 | 5.25 |
| coumarin | – | 0.08 |

f = furanoid form

## Lavandin Oil

Simandi et al. (1993) compared the major components of a steam distilled lavandin oil with that of a supercritical fluid $CO_2$ extract of lavandin plants grown in Hungary. As can be seen from the data presented in **T-8** the extract was found to be richer in linalyl acetate presumably because no hydrolysis of linalyl acetate occurred during preparation unlike that which happened during steam distillation.

George (1996) used a stable isotope dilution assay and mass fragmentography to determine that the coumarin contents of lavandin 'Grosso', 'Abrialis' ('Abrialii') and 'Super' were 315 ppm, 433 ppm and 530 ppm, respectively.

Canaud and Martineau (1996) determined that a lab-distilled lavandin oil contained the following components:

α-pinene (0.63%)
camphene (0.37%)
β-pinene (0.37%)
sabinene (0.14%)
myrcene (0.44%)
limonene (0.79%)
1,8-cineole (4.30%)
(Z)-β-ocimene (0.73%)
(E)-β-ocimene (0.29%)
3-octanone (trace)
p-cymene (0.14%)
camphor (6.45%)
linalool (31.57%)
linalyl acetate (30.76%)
lavandulyl acetate (1.10%)
terpinen-4-ol (3.10%)
β-caryophyllene (2.28%)
lavandulol (0.55%)
α-terpineol (0.22%)
borneol (2.34%)
neryl acetate (0.43%)
geranyl acetate (0.36%)
nerol (0.30%)
geraniol (0.08%)

Renaud et al. (2001) identified the main components of the oils of four lavandin cultivars ('Abrialii', 'Grosso', 'Super' and 'Provence') grown organically in Iowa. The findings of this study are shown in **T-9**. Also the authors determined that the enantiomeric ratios of linalool and linalyl acetate were as follows:

(3R)-(-)-linalool (87.2–97.3%):(3S)-(+)-linalool (2.7–12.2%)
(3R)-(-)-linalyl acetate (99–100%):(3S)-(+)-linalyl acetate (0–1%)

Plotto and Roberts (2001) compared the composition of lavandin 'Grosso' oil with that of a sample of lavandin water obtained from the same cultivar. A summary of the results of this study can be seen in **T-10**. The components identified in the lavandin water were characterized by use of SPME and GC/MS.

A sample of lavandin oil was the subject of analysis by Kubeczka and Formacek (2002) using GC and $^{13}$C-NMR. The composition of the oil was found to be as follows:

α-pinene (0.39%)
α-thujene (0.13%)
camphene (0.57%)
β-pinene (0.21%)
sabinene (0.14%)
limonene (1.68%)
1,8-cineole + β-phellandrene (12.25%)
(E)-β-ocimene + 3-octanone (0.31%)
p-cymene (0.57%)
1-octen-3-yl acetate (0.51%)
hexyl butyrate (0.40%)
*trans*-linalool oxide[f] (2.59%)
1-octen-3-ol (0.21%)
*cis*-linalool oxide[f] (2.28%)
camphor (13.25%)
linalool (28.00%)
linalyl acetate (23.51%)
terpinen-4-ol (0.15%)
β-caryophyllene + lavandulyl acetate (1.40%)
lavandulol (0.41%)
α-terpineol (0.29%)
borneol + α-terpinyl acetate (3.58%)
geranyl acetate (0.05%)

[f] = furanoid form

A commercial lavandin oil sample that was screened for its antifungal activity by Giamperi et al. (2002) was found to possess the following composition:

α-pinene (0.8%)
camphene (0.3%)
β-pinene (0.4%)
myrcene (0.7%)
α-phellandrene (0.2%)
1,8-cineole (3.2%)
limonene (0.1%)
(Z)-β-ocimene (1.8%)
(E)-β-ocimene (0.4%)
linalool (54.0%)
camphor (7.5%)
borneol (0.1%)
terpinen-4-ol (1.9%)
linalyl acetate (23.5%)
lavandulyl acetate (2.0%)
neryl acetate (0.2%)
geranyl acetate (0.1%)
β-caryophyllene (1.4%)
germacrene D (0.4%)

The camphor, linalool and linalyl acetate contents of a commercial sample of lavandin oil were found by Mori et al. (2002) to be 6.5%, 32.5% and 29.5%, respectively.

An oil of lavandin, which was produced in the laboratory in Turkey, was

**T-10** Comparative percentage composition of lavandin oil and lavandin water from the 'Grosso' cultivar

| Compound | Lavandin oil | Lavandin water |
|---|---|---|
| camphene | 0.49 | 0.09 |
| β-pinene | 0.89 | 0.10 |
| myrcene | 0.94 | 0.09 |
| limonene | 1.10 | 0.57 |
| 1,8-cineole | 7.43 | 1.57 |
| γ-terpinene | 1.61 | 0.05 |
| 3-octanone | 0.50 | 0.08 |
| terpinolene | 0.38 | – |
| hexanol | – | 0.10 |
| 3-octanol | – | 0.06 |
| *cis*-linalool oxide[f] | – | 0.80 |
| *trans*-linalool oxide[f] | – | 0.64 |
| camphor | 8.08 | 0.81 |
| linalool | 29.58 | 68.49 |
| linalyl acetate | 29.15 | 0.12 |
| α-santalene | – | 0.07 |
| bornyl acetate | – | 0.09 |
| β-caryophyllene | 1.76 | 0.10 |
| terpinen-4-ol | 1.90 | 4.39 |
| cryptone | 1.33 | 0.10 |
| (E)-β-farnesene | – | 0.17 |
| lavandulol | 0.50 | 1.36 |
| α-terpineol | 1.55 | 8.98 |
| borneol | 2.50 | 1.35 |
| neryl acetate | 0.62 | 0.06 |
| geranyl acetate | 1.53 | 0.10 |
| nerol | – | 1.69 |
| geraniol | 0.71 | 5.25 |
| coumarin | – | 0.08 |

f = furanoid form

**T-11** Comparative percentage composition of the main compounds found in French lavandin oils

| Compound | 'Abrialis' | 'Grosso' | 'Super' |
|---|---|---|---|
| 1,8-cineole | 9.2 | 5.2 | 3.6 |
| limonene | 2.5 | 0.4 | 0.5 |
| (Z)-β-ocimene | 1.8 | 0.9 | 1.5 |
| (E)-β-ocimene | 3.8 | 0.2 | 1.3 |
| linalool | 31.1 | 28.0 | 32.7 |
| camphor | 8.9 | 6.6 | 4.5 |
| borneol | 2.6 | 2.4 | 2.9 |
| linalyl acetate | 23.0 | 37.5 | 38.6 |
| lavandulyl acetate | 1.5 | 2.4 | 1.5 |
| β-caryophyllene | 3.1 | 1.9 | 1.4 |
| (Z)-β-farnesene | 0.8 | 1.6 | 0.9 |

found (Aridogan et al. 2002) to contain the following major constituents:

1,8-cineole (1.8%)
β-ocimene (2.5%)
linalool (32.8%)
linalyl acetate (29.9%)
camphor (5.3%)
borneol (1.6%)
α-terpineol (2.8%)
citronellol (6.7%)
geraniol (1.4%)
α-humulene (1.0%)
bisabolone[†] (1.9%)

[†] doubtful correct identification

Three commercial oils of lavandin produced from 'Abrialis' ('Abrialii'), 'Grosso' and 'Super' cultivars of French origin were analyzed by Milchard et al. (2004). The comparative results of this study are summarized in **T-11**.

The main components of a sample of 'Grosso' lavandin oil were reported by Ranade (2004) to be as follows:

limonene (1.0%)
1,8-cineole (5.5%)
(Z)-β-ocimene (1.0%)
(E)-β-ocimene (0.5%)
camphor (7.0%)
linalool (29.5%)
linalyl acetate (33.0%)
lavandulol (0.5%)
lavandulyl acetate (2.3%)
terpinen-4-ol (3.3%)
borneol (2.3%)

Moon et al. (2007) examined the antifungal activity of the oils of three lavandin cultivars ('Miss Donnington', 'Seal' and 'Grosso') grown in Australia. The composition of these oils is reported in **T-12**.

**Comparative percentage composition of lavandin oils of Australian origin** **T-12**

| Compound | 'Miss Donnington' oil | 'Seal' oil | 'Grosso' oil |
|---|---|---|---|
| α-pinene | – | – | 1.0 |
| β-pinene | – | – | 1.1 |
| 1,8-cineole | 11.6 | t | 10.9 |
| (Z)-β-ocimene | – | – | 1.9 |
| *cis*-linalool oxide[f] | 4.6 | t | 0.1 |
| *trans*-linalool oxide[f] | 4.2 | t | – |
| linalool | 12.1 | 19.0 | 34.3 |
| camphor | 20.3 | 2.4 | 7.3 |
| borneol | 6.0 | 5.2 | 1.6 |
| terpinen-4-ol | – | 14.0 | 2.3 |
| cryptone + p-cymen-8-ol | – | 7.1 | 0.6 |
| (Z)-3-hexenyl butyrate | 1.9 | – | – |
| α-terpineol | – | – | 0.9 |
| linalyl acetate | 9.3 | 24.0 | 23.6 |
| lavandulyl acetate | 0.2 | – | 2.2 |
| caryophyllene oxide | 1.1 | – | – |

t = trace (< 0.1%); [f] = furanoid form


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