Progress in Essential Oils

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Eucalyptus citriodora Oil

Tonzibo et al. (1998) compared the composition of oils produced from fresh and dried leaves of *Eucalyptus citriodora* Hook. from the Ivory Coast. The results of this study are shown in T-1. In a follow-up paper, Tonzibo et al. (2000) showed that the decrease in hydrocarbon content of the oil of *E. citriodora* produced from dried leaves with a corresponding increase in oxygenated constituents, including the conversion of citronellal to isopulegol, also was found in oils produced during different seasons of the year.

Chalchat et al. (2000) reported that leaf oils produced from *E. citriodora* trees grown in the vicinity of Fretomou (Mali) were found to possess the following constituents:

α-pinene (0.1 percent)
β-pinene (0.3 percent)
myrcene (0.1 percent)
limonene (0.1 percent)
1,8-cineole (0.2 percent)
citronellal (77.6-78.5 percent)
neoisopulegol (1.8-1.9 percent)
linalool (0.1-0.2 percent)
isopulegol (6.3-6.4 percent)
β-caryophyllene (0.5 percent)
iso(iso)pulegol (0.1 percent)
neoiso(iso)pulegol (0.2 percent)
citronellyl acetate (1.1 percent)
γ-elemene (0.2 percent)
geranyl acetate (0.3 percent)
citronellol (1.8 percent)
2-phenethyl acetate (0.1 percent)
methyl eugenol (2.2-2.3 percent)

The main constituents of an oil produced from *E. citriodora* leaves harvested in Morocco were determined by Lahlou et al. (2001). They were found to be as follows:

β-pinene (0.16 percent)
α-pinene (0.15 percent)
1,8-cineole (1.14 percent)
limonene (0.12 percent)
α-terpineol (0.16 percent)
citronellal (57.80 percent)
citronellol (7.62 percent)
citronellyl acetate (25.05 percent)
citronellic acid (1.07 percent)

Cimanga et al. (2002, 2002) reported that an oil of *E. citriodora* of the Democratic Republic of Congo origin was found to contain the following constituents:

α-pinene (2.3 percent)
camphene (0.3 percent)
β-pinene (1.7 percent)
myrcene (0.6 percent)
1,8-cineole (1.2 percent)
γ-terpinene (0.3 percent)
cis-linalool oxide* (1.3 percent)
citronellal (72.7 percent)
linalool (0.1 percent)
β-caryophyllene (2.6 percent)
α-terpineol (0.7 percent)
α-terpinyl acetate (1.5 percent)
citronellol (6.3 percent)
citronellyl acetate (2.3 percent)
eugenol (3.5 percent)
methyl eugenol (0.6 percent)

*correct isomer not identified

Using polydimethylsiloxane/divinylbenzene SPME fibers, the headspace of *E. citriodora* was examined by Zini et al. (2002). Although the authors did not present very useful quantitative data, they did characterize the presence in the headspace of isoprene, α-thujene, α-pinene, sabinene, β-pinene, myrcene, limonene, 1,8-cineole, (Z)-β-ocimene, (E)-β-ocimene, linalool, *cis*-rose oxide, *trans*-rose

Percentage composition of the oils of fresh and dried leaves of *Eucalyptus citriodora* **T-1**

Compound	Fresh leaf oil	Dried leaf oil[a]
α-pinene	1.1	0.3
β-pinene	0.8	0.1
myrcene	0.1	0.2
limonene	0.8	0.2
1,8-cineole	1.6	0.3
γ-terpinene	0.6	0.3
p-cymene	0.5	0.2
terpinolene	0.4	0.3
citronellal	68.9	70.0
linalool	4.0	4.2
isopulegol	9.0	10.4
β-caryophyllene	0.7	1.6
citronellyl acetate	0.7	0.8
citronellol	5.3	7.6

[a]leaves shade dried for 20 days

oxide, isopulegol, citronellal (major component), citronellol, 3,7-dimethyl-2,6-octadienal, citronellyl acetate, 3,7-dimethyl-2,6-octadienyl acetate, β-caryophyllene and α-humulene.

Xiong et al. (2003) developed a method of microwave-assisted SPME to examine the volatiles emitted from the leaves of *E. citriodora*. Using microwave heating, the shielded SPME fibers were able to absorb the volatiles faster than previously used ambient techniques.

Narayanan (2003) compared samples of commercial oils of *E. citriodora* of Chinese and Indian origin. A comparison of the main components of these two oils can be seen in T-2.

Using a field distillation unit, 350 kg of leaves of *E. citriodora* were distilled in the vicinity of Hyderabad (India), and ca. 3 kg (3000 mL) of oil were collected. All of the distillation water was collected, and it was extracted (shaken) with hexane for 30 min in 10-L batches. Once all of the distillation water was collected, a total of 4,180 mL of hexane was recovered, while 70 mL of hexane were lost. Upon removal of the hexane, 21 mL of water solubles were recovered. The oil and water solubles were analyzed separately (Rajeswara Rao et al. 2003) by GC, both retention indices and previously published data; the results obtained can be seen summarized in T-3. As expected, the oil was found to be rich in citronellal, whereas the major constituent of the water solubles was isopulegol. The authors inferred that the water solubles were a rich source of isopulegol, a compound of use in the flavor and fragrance industries. However, they failed to point out the impracticality of using the water solubles as an economic source of isopulegol.

Comparative percentage composition of the main components of *Eucalyptus citriodora* oils of Chinese and Indian origin **T-2**

Compound	Chinese oil	Indian oil
α-pinene	0.30	0.71
β-pinene	0.64	0.46
limonene + 1,8-cineole	1.16	1.50
citronellal	82.68	76.31
isopulegol	2.22	2.40
citronellol	4.66	7.78
β-caryophyllene	0.99	0.65

Comparative percentage composition of the oil and water-soluble oil obtained from *Eucalyptus citriodora* **T-3**

Compound	Oil	Water-soluble oil
α-thujene	0.2	t
sabinene	0.4	0.2
myrcene	0.2	-
α-phellandrene	t	-
α-terpinene	0.1	-
p-cymene	0.5	-
limonene	0.2	0.1
1,8-cineole	0.2	-
(Z)-β-ocimene	t	0.1
(E)-β-ocimene	0.2	0.1
cis-linalool oxide[†]	-	0.1
trans-linalool oxide[†]	0.1	0.1
linalool	0.6	1.0
citronellal	70.3	-
isopulegol	6.7	53.0
borneol	0.8	10.0
menthol	0.3	5.3
terpinen-4-ol	0.1	0.6
α-terpineol	-	0.8
citronellol	8.8	0.1
neral	0.1	6.9
geraniol	0.1	1.4
geranial	t	0.1
citronellyl acetate	1.3	t
eugenol	0.1	4.6
geranyl acetate	0.1	0.2
β-elemene	-	0.9
β-caryophyllene	2.6	0.1
aromadendrene	0.1	-
α-humulene	0.1	-
γ-cadinene	t	-
δ-cadinene	0.1	-
caryophyllene oxide	t	-

[†]furanoid form; t = trace (< 0.1 percent)

Vernin et al. (2004) analyzed an oil of *E. citriodora* (syn. *Corymbia citriodora* Hook.) produced from leaves obtained in Reunion. The components characterized in this analysis were as follows:

ethanol (0.1 percent)
cis-1-methyl-3-isopropylcyclopentane (0.1 percent)
trans-1-methyl-3-isopropylcyclapentane (0.1 percent)
isobutyl isobutyrate (0.1 percent)
α-pinene (2.2 percent)
camphene (0.1 percent)
sabinene (0.1 percent)
β-pinene (0.8 percent)
cis-1,2-dihydrolimonene (0.1 percent)
myrcene (0.1 percent)
trans-1,2-dihydrolimonene (0.1 percent)
α-terpinene (0.2 percent)
p-cymene (2.5 percent)
8,9-dihydrolimonene + p-cymenene (0.1 percent)
1,8-cineole (0.6 percent)
limonene (0.4 percent)
1-methyl-4-isopropylidene cyclohexane (0.2 percent)
(Z)-β-ocimene (0.1 percent)
(E)-β-ocimene (0.9 percent)
γ-terpinene (0.5 percent)
isolimonene (0.1 percent)
isoterpinolene (0.3 percent)
terpinolene (0.3 percent)
linalool (0.2 percent)
cis-rose oxide (0.1 percent)
menthone (0.2 percent)
isomenthone (0.2 percent)
citronellal (63.6 percent)
isopulegol (4.5 percent)
borneol (0.1 percent)
neoisopulegol (0.1 percent)
neoiso(iso)pulegol (0.1 percent)
iso(iso)pulegol (0.7 percent)
terpinen-4-ol (0.3 percent)
isocitronellal (0.1 percent)
α-terpineol (0.2 percent)
linalool oxide[†*] (0.2 percent)
citronellol (7.3 percent)
linalool oxide[†*] + 2-phenethyl acetate (0.4 percent)
geraniol (0.2 percent)
citronellic acid (0.7 percent)
cis-p-menthane-3,4-diol (0.9 percent)
4-hydroxy-α,p-dimethylcyclohexanemethanol[‡] (0.4 percent)
eugenol (0.1 percent)
citronellyl acetate (2.6 percent)
α-longipinene (0.1 percent)
geranyl acetate (0.2 percent)
(Z)-jasmone (0.2 percent)
longicyclene (0.2 percent)
linalyl propionate (0.1 percent)
β-elemene (0.1 percent)
longifolene (0.7 percent)
β-caryophyllene + β-cedrene (1.2 percent)
nerol (0.1 percent)
α-humulene (0.1 percent)
germacrene D (0.1 percent)
bicyclogermacrene (0.1 percent)
caryophyllene oxide (0.1 percent)
citronellal dimer* (1.8 percent)
citronellal dimer* (0.4 percent)

N-butylsulphonamide‡ (0.3 percent)
tetradecanoic acid (0.1 percent)
hexadecanoic acid (1.1 percent)

*correct isomer not identified; †pyranoid form; ‡natural origin requires corroboration

Trace amounts (< 0.1 percent) of 2-methyl-2-butene, acetaldehyde, 3-methylcyclopentene, methylcyclopentane, (E,E)-2,4-heptadiene, α-thujene, α-fenchene, isoamyl isobutyrate, 1,4-cineole, melonal (2,5-dimethyl-5-heptenal), α-pinene oxide, geranial, isopulegyl acetate, citronellyl formate, benzyl isobutyrate, 2-methoxy-4-vinylphenol, 1,8-terpinen, α-cubebene, neryl acetate, cyclosativene, sativene, α-santalene, 2-phenethyl isobutyrate, aromadendrene, γ-elemene, δ-cadinene, spathulenol, isocaryophyllene oxide, a couple of farnesol isomers and citronellyl citronellate also were characterized in the oil. This reviewer questions the characterization of 1,8-terpinen as a naturally occurring constituent.

Zaman et al. (2004) showed that the flower oil of *E. citriodora* was rich in α-thujene (13.1 percent), sabinene (23.4 percent), citronellal (16.2 percent) and epi-globulol (11.8 percent), thereby revealing that it is very dissimilar to a typical *E. citriodora* leaf oil.

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K. Zaman, M. Ali, R. Kapoor, A.W. Siddiqui and S.R. Mir, *Essential oil composition of flowers of* Eucalyptus citriodora *Hook.* J. Essent. Oil Bear. Plants, **7**(2), 160-164 (2004).

Ajowan Oil

The oil of ajowan, which is used as a source of natural thymol, is obtained from the fruit (seeds) of *Trachyspermum ammi* (L.) (syn. *Carum copticum* L.; *Ptychotis ammoides* Koch).

Seeds of *T. ammi* that were purchased at a local market in Oran (Algeria) were water distilled to produce an oil that was analyzed by Kambouche and El-Abed (2003). Using a combination of GC (for retention indices and quantitation) and GC/MS (for component identity confirmation), the oil was determined to contain the following constituents:

α-thujene (0.08 percent)
α-pinene (0.62 percent)
sabinene (0.13 percent)
β-pinene (0.16 percent)
myrcene (0.40 percent)
p-cymene (14.08 percent)
limonene (11.89 percent)
γ-terpinene (6.79 percent)
terpinolene (0.09 percent)
terpinen-4-ol (0.79 percent)
α-terpineol (0.08 percent)
methyl thymol (0.30 percent)
methyl carvacrol (0.06 percent)
isothymol (51.20 percent)
thymol (12.96 percent)
carvacrol (0.25 percent)

Trace amounts (< 0.01 percent) of m-cymene, linalool, an isomer of p-menth-2-en-1-ol and citronellal, also were characterized in this oil. It is worth noting that this oil is the richest source of isothymol that has, to the best of this reviewer's knowledge, been found to be naturally occurring.

An oil of ajowan produced in the laboratory from seed purchased from a market in Gorakhpur (India) was analyzed by Singh et al. (2004). It was found to possess the following constituents:

α-thujene (0.2 percent)
α-pinene (0.2 percent)
β-pinene (1.7 percent)

myrcene (0.4 percent)
α-terpinene (0.2 percent)
p-cymene (30.8 percent)
β-phellandrene (0.6 percent)
γ-terpinene (23.2 percent)
terpinolene (0.2 percent)
trans-sabinene hydrate (0.1 percent)
linalool (0.1 percent)
terpinen-4-ol (0.8 percent)
α-terpineol (0.1 percent)
thymol (39.1 percent)
carvacrol (0.3 percent)
β-selinene (0.1 percent)

Trace amounts (< 0.1 percent) of 2-methyl-3-buten-2-ol, methyl 2-methylbutyrate, camphene, sabinene, α-phellandrene, δ-3-carene, 1,8-cineole, α-selinene, caryophyllene oxide and δ-dodecalactone also were reported as constituents of the same oil.

Khajeh et al. (2004) compared the oil composition (major components only) with a supercritical fluid CO_2 (SFC) extract of the same batch of ajowan seed. They found that the main constituents of the oil were:

α-thujene (0.4 percent)
β-pinene (2.1 percent)
α-terpinene (0.5 percent)
myrcene (0.8 percent)
p-cymene (15.7 percent)
limonene (0.7 percent)
γ-terpinene (30.8 percent)
thymol (49.0 percent)

The authors found that the SFC extract with the highest thymol content (62.8 percent) was obtained using the following parameters: pressure, 20.3 MPa, 35°C, dynamic extraction time 20 min, 400 µL methanol modifier and an extraction yield of 3.90 percent w/w. However, using the conditions 30.4 MPa pressure, 35 C temperature, a dynamic extraction time of 30 min and no methanol modifier, the method was most selective for extraction of thymol.

An ajowan oil produced by hydrodistillation was compared with an oil produced from the same batch of seed by solvent-free microwave distillation by Lucchesi et al. (2004). The results of this study are shown in T-4.

Oils produced from three samples of ajowan seed oil — produced either at the CIMAP (Central Institute of Medicinal and Aromatic Plants) research farm or collected from markets in Lucknow (U.P.) or Chennai (T.N.) — were analyzed by GC and GC/MS by Raina et al. (2004). The composition of these three oils can be seen in T-5.

Comparative percentage composition of oils of ajowan produced by hydrodistillation and solvent-free microwave distillation **T-4**

Compound	Hydrodistilled oil	Microwave-distilled oil
α-pinene	1.3	-
β-pinene	4.8	1.5
myrcene	0.8	-
γ-terpinene	28.6	16.4
p-cymene	29.2	21.2
anethole*	-	0.7
thymol	35.4	60.3

*correct isomer not identified

Comparative percentage composition of three samples of ajowan oil **T-5**

Compound	Sample 1	Sample 2	Sample 3
α-pinene	0.4	0.4	0.6
camphene	0.2	0.2	0.3
β-pinene	3.1	2.7	4.6
myrcene	0.1	0.1	0.1
α-terpinene	0.1	< 0.1	0.5
p-cymene	21.8	20.9	27.2
limonene	0.1	0.1	0.1
1,8-cineole	0.3	0.3	0.3
γ-terpinene	35.7	32.3	25.9
linalool	0.1	0.1	0.6
α-terpineol	0.2	0.2	0.2
methyl chavicol	0.2	0.2	0.1
cuminaldehyde	0.1	0.2	0.2
citronellol	0.1	0.1	0.1
(E)-anethole	0.1	0.1	0.1
thymol	36.5	41.1	37.6
carvacrol	0.2	0.2	0.1

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Kewda or Keora Oil

Misra and Rao (1997) analyzed an oil produced from the male flowers of *Pandanus fasiculatus* Lam. (syn. *P. odoratissimus* L.), known commercially as kewda oil. The constituents found in this oil were:

β-phellandrene (0.95 percent)
(E)-β-ocimene (0.60 percent)
myrcene (0.72 percent)
p-cymene (1.63 percent)
α-pinene (1.56 percent)
2-phenethyl methyl ether (65.32 percent)
2-phenethyl alcohol (0.98 percent)
terpinen-4-ol (15.53 percent)
myrcenol (2.1 percent)
piperitone (0.5 percent)

They also characterized (E)-α-ocimene and β-terpinene by MS; however, β-terpinene does not occur naturally, and the identity of (E)-α-ocimene is highly questionable.

Rao (2000) published a detailed description of the botany, history, cultivation, distillation and economics of kewda cultivation and oil production in the Ganjam district of the coastal region of Orissa, along the Bay of Bengal. Within this report, he noted that the oil composition ranged throughout the year as follows:

α-thujene (0.02-3.80 percent)
α-pinene (0.07-1.30 percent)
β-pinene (0.01-3.00 percent)
α-phellandrene (0.01-0.45 percent)
p-cymene (0.40-4.50 percent)
limonene (0.01-1.10 percent)
γ-terpinene (0.01-4.90 percent)
2-phenethyl methyl ether (63.0-84.0 percent)
linalool (< 0.01-0.30 percent)
2-phenethyl alcohol (0.04-0.30 percent)
terpinen-4-ol (6.3-21.3 percent)
α-terpineol (0.10-1.70 percent)
piperitone (0.02-0.25 percent)
carvenone (0.02-0.20 percent)

Furthermore, Rao reported that the range of oil composition of 13 market samples was as follows:

α-thujene (0.1-1.8 percent)
α-pinene (0.06-0.6 percent)
β-pinene (0.04-1.8 percent)
α-phellandrene (0.02-0.3 percent)
p-cymene (0.2-3.3 percent)
limonene (0.08-0.6 percent)
γ-terpinene (0.07-2.5 percent)
2-phenethyl methyl ether (66.0-86.0 percent)
linalool (< 0.01-0.1 percent)
2-phenethyl alcohol (0.1-0.7 percent)
terpinen-4-ol (8.2-23.9 percent)
α-terpineol (1.1-3.2 percent)
piperitone (0.04-0.5 percent)
carvenone (0.01-0.1 percent)

Misra et al. (2000) used a combination of GC and GC/MS to examine the composition of three commercial samples of kewda oil collected from the Tulu village (Ganjam district). The compounds that were characterized in amounts greater than 0.1 percent were as follows:

ethanol (t-0.3 percent)
α-thujene (t-1.0 percent)
α-pinene (t-0.6 percent)
benzaldehyde (t-0.1 percent)
β-pinene (t-1.2 percent)
myrcene (t-0.1 percent)
α-phellandrene (t-0.1 percent)
p-cymene (1.0-3.1 percent)
limonene (0.4-0.5 percent)
γ-terpinene (t-2.4 percent)
2-phenethyl methyl ether (65.6-75.4 percent)
linalool (t-0.2 percent)
α-thujone (t-0.1 percent)
2-phenethyl alcohol (t-0.4 percent)
terpinen-4-ol (11.7-19.5 percent)

α-terpineol (1.3-2.9 percent)
piperitone (0.2-0.5 percent)
carvenone (t-0.3 percent)
benzyl benzoate (t-0.1 percent)
2-phenethyl benzoate (t-0.5 percent)
methyl palmitate (t-0.1 percent)
2-phenethyl phenylacetate (t-0.1 percent)
palmitic acid (t-0.2 percent)
methyl linoleate (t-0.2 percent)
1-docosene (t-0.2 percent)

t = trace (< 0.1 percent)

In addition, trace amounts (< 0.1 percent) of acetic acid, isoamyl alcohol, toluene, hexanol, camphene, 1,8-cineole, *cis*-linalool oxide (furanoid), *cis*-p-menth-2-en-1-ol, camphor, dihydrocarveol, verbenone, *cis*-carveol, citronellol, benzyl methyl ketone, α-amorphene, an isomer of nerolidol, α-muurolol, 1-heptadecene, ethyl myristate, ethyl palmitate, phyllocladene, eicosane, ethyl oleate, docosane, (Z)-9-tricosene, tricosane, pentacosane and heptacosane also were found in the same oils.

An oil produced from the male flowers of *P. fasiculatus* var. *ketaki* also was analyzed by Misra et al. The composition of the oil was found to be as follows:

p-benzoquinone (1.3 percent)
phenylacetaldehyde (0.4 percent)
2-phenethyl methyl ether (66.2 percent)
2-methoxyphenol (0.3 percent)
linalool (0.3 percent)
2-phenethyl alcohol (4.5 percent)
4-hydroxyphenol[a] (6.1 percent)
3-acetylanisole (2.3 percent)
hexadecane (0.2 percent)
heptadecane (0.3 percent)
benzyl benzoate (0.2 percent)
octadecane (0.4 percent)
9-hexadecenoic acid[b] (1.9 percent)

[a]quinol; [b]oleic acid

Trace amounts (< 0.1 percent) of 2-furfuryl alcohol, nonanol, 2-methyloctadecane, palmitic acid, eicosane, octadecane and octacosane also were found in this ketaki oil. In addition, methoxy-methylbenzene (0.4 percent), 1,2-dimethoxy-ethylbenzene (5.5 percent) and 4-methoxyphenylacetic acid also were identified tentatively by MS only.

Ranade (2003) reported the results of an analysis of kewda oil. He found that the oil contained the following major constituents:

benzyl alcohol (1.4 percent)
benzyl acetate (1.6 percent)
benzyl benzoate (0.9 percent)
benzyl salicylate (0.1 percent)
geraniol (1.5 percent)
guaiacol (0.1 percent)
linalool (0.5 percent)
linalyl acetate (0.5 percent)
2-phenethyl alcohol (3.0 percent)
2-phenethyl methyl ether (70.0 percent)
terpinen-4-ol (9.0 percent)
phenylacetaldehyde (1.0 percent)

He also reported that the oil contained phenylacetaldehyde acetal (1.0 percent) and bromostyrene (0.1 percent). These two compounds were identified erroneously because neither is known to occur naturally.

Raina et al. (2004) collected kewda flowers (70 kg) from Behrampur village (Ganjam district) that, upon distillation, produced 85 L of distillation, which, upon redistillation, yielded 17 mL kewda oil (0.024 percent). Analysis of this oil by GC and GC/MS revealed that its composition was as follows:

(Z)-3-hexenol (0.1 percent)
α-thujene (0.5 percent)
sabinene (0.4 percent)
β-pinene (0.3 percent)
myrcene (0.5 percent)
δ-3-carene (0.3 percent)
α-terpinene (0.2 percent)
p-cymene (0.4 percent)
phenylacetaldehyde (0.6 percent)
1,8-cineole (0.1 percent)
benzyl alcohol (0.2 percent)
γ-terpinene (0.5 percent)
2-phenethyl methyl ether (37.7 percent)
trans-sabinene hydrate (0.6 percent)
trans-linalool oxide[†] (0.2 percent)
linalool (0.1 percent)
2-phenethyl alcohol (7.5 percent)
α-fenchyl alcohol (0.5 percent)
camphor (0.5 percent)
trans-β-terpineol (0.1 percent)
benzyl acetate (0.4 percent)
2-phenethyl formate (0.1 percent)
terpinen-4-ol (18.6 percent)
α-terpineol (8.3 percent)
cis-sabinol (0.1 percent)
verbenone (0.4 percent)
viridine[a] (0.2 percent)
trans-carveol (0.1 percent)
dodecane (0.1 percent)
citronellol + nerol (0.4 percent)
2-phenethyl acetate (0.4 percent)
piperitone (0.4 percent)
geraniol (1.2 percent)
geranial (0.4 percent)
citronellyl formate (0.1 percent)
neryl formate (0.2 percent)
geranyl formate (0.1 percent)
linalyl propionate (0.9 percent)
citronellyl acetate (0.1 percent)
eugenol (0.6 percent)
decanoic acid (0.6 percent)
geranyl acetate (0.8 percent)

methyl eugenol (0.1 percent)
2-phenethyl isobutyrate (0.4 percent)
isoeugenol* (0.1 percent)
vanillin (0.4 percent)
β-caryophyllene (1.8 percent)
β-gurjunene (1.8 percent)
geranyl propionate (0.4 percent)
allo-aromadendrene (0.1 percent)
α-amorphene (0.1 percent)
γ-muurolene (2.0 percent)
eugenyl acetate (0.1 percent)
α-muurolene (0.1 percent)
ledene (1.2 percent)
pentadecane (0.1 percent)
citronellyl butyrate (0.2 percent)
γ-cadinene (0.3 percent)
germacrene B (0.3 percent)
2-phenethyl tiglate (0.3 percent)
caryophyllene oxide (0.2 percent)
globulol (0.1 percent)
viridiflorol (0.1 percent)
hexadecane (0.1 percent)
α-muurolol (0.1 percent)
T-muurolol (0.1 percent)
T-cadinol (0.2 percent)
α-cadinol (0.3 percent)
heptadecane (0.1 percent)
geranyl hexanoate (0.1 percent)
benzyl benzoate (0.1 percent)
geranyl heptanoate (0.4 percent)
2-phenethyl benzoate (0.5 percent)
methyl linoleate (0.1 percent)

[a]also known as 2,2-dimethoxy ethyl benzene; *correct isomer not identified; [†]furanoid form

Trace amounts of (E)-3-hexanol, α-phellandrene, *cis*-p-menth-2-en-1-ol, an isomer of sabinyl acetate, neryl acetate, tetradecane, humulene epoxide II, (Z,E)-farnesol, neryl heptanoate, geranyl heptanoate and eicosane also were found in this lab-distilled oil. It was surprising to this reviewer that the 2-phenethyl methyl ether content was so low compared with previously analyzed oils. It is possible that Raina et al. did not distill the flowers long enough, as 2-phenethyl methyl ether is quite high boiling, resulting in the possibility that the flowers still retained a portion of it when distillation was ended.

Raina et al. also analyzed a sample of kewda oil that they produced at a local Lucknow (U.P., India) market. The composition of this oil was determined to be:

α-thujene (0.1 percent)
myrcene (0.1 percent)
phenylacetaldehyde (0.3 percent)
2-phenethyl methyl ether (16.1 percent)
2-phenethyl alcohol (33.2 percent)
cis-p-menth-2-en-1-ol (0.3 percent)
2-phenethyl formate (0.5 percent)
viridine[a] (8.7 percent)
citronellol + nerol (2.7 percent)
piperitone (0.4 percent)
geranial (0.1 percent)
neryl formate (0.1 percent)
eugenol (0.1 percent)
2-phenethyl isobutyrate (4.6 percent)
β-caryophyllene (0.1 percent)
β-gurjunene (0.1 percent)
α-amorphene (0.1 percent)
γ-muurolene (0.5 percent)
ledene (0.1 percent)
pentadecane (0.5 percent)
γ-cadinene (1.1 percent)
(Z)-nerolidol (0.4 percent)
geranyl butyrate (0.1 percent)
germacrene B (8.3 percent)

2-phenethyl tiglate (0.5 percent)
globulol (0.2 percent)
viridiflorol (0.4 percent)
α-muurolol (0.3 percent)
T-muurolol (0.3 percent)
T-cadinol (0.1 percent)
α-cadinol (0.6 percent)

(Z,E)-farnesol (0.1 percent)
heptadecane (0.3 percent)
benzyl benzoate (11.0 percent)
tetradecanoic acid (1.8 percent)
butyl dodecanoate (0.2 percent)
ethyl tetradecanoate (0.3 percent)
octadecane (1.2 percent)

Comparative percentage composition of the concrete, absolute and waxes of *Pandanus fasiculatus* flowers **T-6**

Compound	Concrete	Absolute	Waxes
α-thujene	0.6 ± 0.2	0.8 ± 0.4	0.1
α-pinene	0.1	0.1	0.1
sabinene	0.2	0.4	t
β-pinene	0.4 ± 0.1	0.8	t
myrcene	0.1	0.1	0.1
α-terpinene	0.1	0.1	t
p-cymene	0.2	0.3	t
limonene	0.2	0.4	t
1,8-cineole	0.1	0.1	t
γ-terpinene	0.2	0.2	0.1
cis-sabinene hydrate	0.1	0.1	t
2-phenethyl methyl ether	30.6 ± 1.5	43.4 ± 1.3	4.0 ± 1.2
trans-sabinene hydrate	0.1 ± 0.1	0.1	t
2-phenethyl alcohol	0.4	0.6	t
terpinen-4-ol	0.7 ± 0.1	0.8 ± 0.1	0.1
α-terpineol	0.1	0.2	-
tridecane	0.1	0.1	t
α-cubebene	t	t	t
α-muurolene	t	t	t
δ-cadinene	0.1	0.1	t
hexadecene*	0.1	0.1	0.1
hexadecane	0.2 ± 0.1	0.2 ± 0.1	0.1
heptadecane	0.1	0.1	0.1
methyl tetradecanoate	t	t	-
ethyl tetradecanoate	0.1	0.1	t
2-phenethyl phenylacetate	0.3 ± 0.1	0.2	0.2 ± 0.2
methyl hexadecanoate	0.2	0.2	0.2 ± 0.1
ethyl hexadecanoate	0.3	0.7 ± 0.2	0.2
methyl linoleate	0.9 ± 0.2	0.5 ± 0.1	0.5 ± 0.1
methyl linolenate	1.4 ± 0.5	0.7 ± 0.1	0.3 ± 0.1
methyl oleate	0.2	0.2	0.1 ± 0.1
methyl octadecanoate	0.7 ± 0.1	0.6 ± 0.1	0.3
9,12,15-octadecatrienal[t]	1.3 ± 1.0	0.6 ± 0.4	0.3 ± 0.2
9,12-octadecadienal[t]	3.3 ± 1.1	3.3 ± 1.2	1.2 ± 0.8
9,12-octadecadienol[t]	7.4 ± 2.5	7.7 ± 2.5	2.9 ± 1.5
oleic acid[t]	0.3 ± 0.2	0.3 ± 0.1	0.9 ± 0.9
heneicosanol[t]	0.8	0.9 ± 0.1	0.1
4-methyltetracosane	5.4 ± 0.4	4.2	9.9 ± 0.1
heptacosane	0.7 ± 0.5	0.3 ± 0.1	3.0 ± 2.8
branched C_{28} hydrocarbon[t]	2.8 ± 1.1	1.0	5.3 ± 2.7
mixed hydrocarbons[t]	8.5 ± 0.5	2.2 ± 1.7	32.1 ± 2.6
mixed hydrocarbons[t]	7.4 ± 4.3	6.0 ± 3.9	2.8 ± 0.8
fatty acid*	9.0 ± 3.5	8.9 ± 2.5	9.1 ± 4.4

*unknown structure; [t]tentative identity

neryl heptanoate (0.8 percent)
hexadecanal (0.2 percent)
2-phenethyl octadecanoate (0.1 percent)
geranyl heptanoate (0.3 percent)
2-phenethyl benzoate (0.3 percent)
geranyl benzoate (0.1 percent)
eicosane (0.4 percent)

[a]also known as 2,2-dimethoxy-ethylbenzene

The authors noted that the compositions of the lab-distilled oil and the market oil were quite different from those of the other published reports (Lawrence 1998 and this report). They considered that this drastic variation in the composition of the major and minor constituents may be due to the existence of different chemotypes of *P. fasiculatus*.

Rout et al. (2005) compared the composition of the concrete produced by hexane extraction to an absolute produced from it using cold methanol, further cooling and filtration, and to the waxes isolated by filtration. The results of these analyses are presented in T-6. As can be seen, the 2-phenethyl methyl ether content is less than 45 percent, which lends credence to the hypothesis of Raina et al. that chemotypes of *P. fasiculatus* exist. It should be noted, however, that ontogeny also could affect the oil composition.

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