Progress in Essential Oils

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Mandarin oil

The composition of a hydrodistilled peel oil of the ‘Santra’ cultivar of mandarin (ex *Citrus reticulata* Blanco) was analyzed by Mahalwal and Ali (2001). The composition of this oil was determined to be as follows:

α-pinene (0.9 percent)
β-pinene (3.2 percent)
limonene (59.6 percent)
myrcene† (4.1 percent)
terpinolene (3.5 percent)
trans-pinocarveol (0.5 percent)
terpinen-4-ol (0.5 percent)
α-terpineol (0.6 percent)
nonanol (0.2 percent)
cyclodecanol† (0.2 percent)
germacrene D-4-ol (0.1 percent)

†incorrect identification based on GC elution order

In addition, the author also identified an alkyl phthalate in the oil. This was a mistake because it obviously was a plasticizer contaminant.

The peel oil of Venezuelan mandarins produced by hydrodistillation was found by Gonzalez de et al. (2002) to contain the following major constituents:

α-pinene (0.92 percent)
myrcene (1.37 percent)
limonene (80.81 percent)
γ-terpinene (4.50 percent)
linalool (11.33 percent)
α-terpineol (1.06 percent)

A commercial sample of mandarin oil was the subject of analysis by Kubeczka and Formacek (2002). The oil, which was analyzed using a combination of capillary GC and ^{13}C-NMR spectroscopy, was determined to possess the following composition:

α-pinene (2.22 percent)
camphene (0.04 percent)
β-pinene (1.13 percent)
sabinene (0.23 percent)
δ-3-carene (0.04 percent)
myrcene (1.62 percent)
α-phellandrene (0.04 percent)
α-terpinene (0.13 percent)
limonene (77.02 percent)
β-phellandrene (0.21 percent)
γ-terpinene (11.94 percent)
p-cymene (2.32 percent)
terpinolene (0.49 percent)
octanal (0.02 percent)
cis-limonene oxide (0.04 percent)
trans-limonene oxide (0.12 percent)
decanal (0.03 percent)
linalool (0.25 percent)
linalyl acetate (0.07 percent)
β-caryophyllene (0.05 percent)
α-terpineol (0.14 percent)
α-farnesene* (0.09 percent)
methyl N-methyl anthranilate (0.35 percent)
α-sinensal† (0.11 percent)

*correct isomer not identified; †tentative identification

Mandarin oil produced in Sicily was analyzed by conventional (ca 46 min) and fast (9 min) GC by Mondello et al. (2003). A summary of the results of this study is shown in T-1.

The peel oil of the ‘Ciaculli Late’ cultivar of mandarin was the subject of analysis by Alonzo et al. (2003). In the oil the following constituents were characterized:

tricyclene (0.9 percent)
α-pinene (2.5 percent)

Comparative percentage composition of mandarin oil produced either by conventional or fast GC analysis

T-1

Compound	Conventional GC analysis	Fast GC analysis
α-thujene	0.74	0.72
α-pinene	2.21	2.01
camphene	0.02	0.02
sabinene	0.24	0.24
β-pinene	1.47	1.41
myrcene	1.79	1.72
octanal + α-phellandrene	0.13	0.14
δ-3-carene	t	t
α-terpinene	0.32	0.32
p-cymene + limonene†	73.84	75.25
(Z)-β-ocimene	t	t
(E)-β-ocimene	0.02	0.02
γ-terpinene	17.06	16.01
cis-sabinene hydrate	0.01	0.01
octanol	0.01	–
terpinolene	0.73	0.70
linalool	0.09	0.09
nonanal	0.03	0.02
(E)-myroxide	0.02	0.02
citronellal	0.02	0.03
terpinen-4-ol	0.02	0.02
α-terpineol	0.08	0.09
decanal	0.08	0.08
nerol	0.01	0.02
neral	t	t
geranial	0.04	0.06
undecanal	0.01	0.02
thymol	0.04	0.04
α-terpinyl acetate	0.03	0.04
citronellyl acetate	t	0.01
geranyl acetate	t	t
methyl N-methyl anthranilate	0.34	0.33
β-caryophyllene	0.07	0.07
α-humulene	0.01	0.01
α-selinene	0.03	0.04
α-farnesene*	0.15	0.15
(E,Z)-farnesol	t	0.01
α-sinensal	0.29	0.29
nootkatone	0.01	–

†major component of mixture; t = trace (< 0.01 percent); *correct isomer not identified

sabinene (0.3 percent)
β-pinene (1.4 percent)
myrcene (1.9 percent)
α-phellandrene (0.2 percent)
δ-3-carene (0.3 percent)
p-cymene (0.2 percent)
limonene (79.5 percent)
γ-terpinene (12.0 percent)
terpinolene (0.4 percent)

Trace amounts (< 0.1 percent) of (Z)-β-ocimene and (E)-β-ocimene also were found in this same oil.

A detailed analysis of the oil of the 'Honey Murcott' cultivar of mandarin was reported by Feger et al. (2003). The constituents characterized by the authors were as follows:

α-pinene (0.53 percent)
sabinene (0.29 percent)
β-pinene (0.03 percent)
octanal (0.36 percent)
myrcene (1.86 percent)
α-phellandrene (0.03 percent)
δ-3-carene (0.02 percent)
p-cymene (0.01 percent)
limonene (94.60 percent)
β-phellandrene (0.27 percent)
(E)-β-ocimene (0.04 percent)
octanol (0.04 percent)
terpinolene (0.01 percent)
nonanal (0.10 percent)
linalool (0.37 percent)
trans-p-mentha-2,8-dien-1-ol (0.01 percent)
cis-limonene oxide + *cis*-p-mentha-2,8-dien-1-ol (0.01 percent)
trans-limonene oxide (0.01 percent)
citronellal (0.12 percent)
α-terpineol (0.04 percent)
decanal (0.36 percent)
octyl acetate (0.01 percent)
γ-geraniol (0.01 percent)
trans-carveol (0.01 percent)
citronellol (0.06 percent)
nerol (0.01 percent)
neral (0.08 percent)
carvone (0.01 percent)
(E)-2-decenal (0.01 percent)
geranial (0.03 percent)
decanol + perillaldehyde (0.04 percent)
p-mentha-1(2),8-dien-10-ol (0.02 percent)
undecanal (0.03 percent)
(E,E)-2,4-decadienal (0.01 percent)
citronellyl acetate (0.02 percent)
neryl acetate (0.04 percent)
geranyl acetate (0.01 percent)
α-copaene (0.03 percent)
p-mentha-1(2),8-dien-10-yl acetate (0.01 percent)
dodecanal (0.07 percent)
β-cubebene + β-elemene (0.04 percent)
β-caryophyllene (0.01 percent)
β-copaene + 2-hexylcyclopropane acetic acid (0.01 percent)
(E)-β-farnesene (0.05 percent)
α-humulene (0.01 percent)
germacrene D (0.02 percent)
(E,E)-α-farnesene (0.07 percent)
germacrene A (0.01 percent)
valencene (0.01 percent)
bicyclogermacrene (0.01 percent)
δ-cadinene (0.04 percent)
elemol (0.01 percent)
tetradecanal (0.01 percent)

The authors also characterized a number of trace components (< 0.01 percent) in this same oil. These trace components were α-thujene, camphene, *trans*-sabinene hydrate, undecane, octanoic acid, nonanol, terpinen-4-ol, *cis*-p-mentha-1(7),8-dien-2-ol, *cis*-carveol, geraniol, isopiperitenone, tridecane, α-terpinyl acetate, decanoic acid, α-cubebene, tetradecane, α-guaiene, dodecanol, γ-muurolene, tridecanal, α-muurolene, α-bulnesene, cubebol, β-sesquiphellandrene, 7-epi-α-selinene, (E)-nerolidol, caryophyllene oxide, β-sinensal, α-sinensal, nootkatone and hexadecanal.

The oils of two mandarin cultivars ('Avana' and 'Tardivo di Ciaculli') grown in Italy were analyzed by Catalfamo et al. (2004). The constituents characterized in these oils are presented in T-2.

Usai et al. (2004) examined the variation in volatile constituents of the 'Honey Murcott' cultivar of mandarin of Italian origin stored under different conditions. The conditions examined were (a) constant temperature at 6°C, (b) 6°C for 18 days and seven days at 14°C, (c) six days at 6°C and one day at 14°C, (d) 18 days at 2°C and seven days at 14°C, and (e) six days at 2°C and one day at 14°C all for repeating cycles over an eight-week period at 90 percent relative humidity, after which they were transferred to typical shelf-life conditions of 20°C at 70 percent relative humidity for two weeks. Oils from each of the conditions were analyzed at four weeks, eight weeks and at the end of the shelf-life study. The authors showed that all volatiles were even sensitive to low temperature conditions; however, they found that a repeating cycle of six days at 6°C and one day at 14°C allowed the storage of mandarin fruit up to 10 weeks from harvest. Oils produced from fruit stored under these conditions were found to vary as follows:

formaldehyde (0.74–1.39 percent)
acetaldehyde (0.01–0.06 percent)
hexanal (0.06–0.07 percent)
octanal (0.12–0.19 percent)
nonanal (0.78–0.89 percent)
decanal (0.50–0.89 percent)
pulegone (0.02–0.03 percent)
neral (0.09–0.15 percent)
geranial (0.06–0.08 percent)
undecanal (0.03–0.04 percent)
dodecanal (0.02–0.06 percent)
α-pinene (0.17–0.37 percent)
camphene (0.01 percent)
sabinene (0.11–0.24 percent)

Comparative percentage composition of mandarin oil produced from two cultivars **T-2**

Compound	'Avana' oil	'Tardivo di Ciaculli' oil
tricyclene	t	t
α-thujene	0.45–0.71	0.37–0.66
α-pinene	1.29–1.86	1.35–1.92
camphene	t–0.01	t–0.01
sabinene	0.19–0.22	0.19–0.24
β-pinene	1.06–1.41	0.99–1.37
myrcene	1.63–1.74	1.51–1.97
octanal	0.09–0.15	0.09–0.15
α-phellandrene	0.06–0.07	0.06–0.08
δ-3-carene	t	t
α-terpinene	0.29–0.39	0.27–0.38
p-cymene	0.34–0.55	0.43–0.47
limonene	69.42–71.87	72.17–74.75
(E)-β-ocimene	0.02–0.11	0.03–0.11
γ-terpinene	17.54–18.89	14.74–17.27
trans-sabinene hydrate	0.02–0.09	0.04–0.25
octanol	t–0.02	0.02–0.24
terpinolene	0.74–0.89	0.75–0.97
linalool	0.07–0.16	0.05–0.19
nonanal	0.03–0.05	0.02–0.04
camphor	t–0.01	t–0.01
citronellal	t–0.03	0.01–0.03
terpinen-4-ol	0.03–0.07	0.03–0.08
α-terpineol	0.11–0.16	0.07–0.20
decanal	0.25–0.32	0.10–0.16
octyl acetate	t	t
nerol	t–0.03	t–0.05
cis-sabinene hydrate acetate	t	t
neral	0.01–0.05	0.02–0.05
geraniol	t–0.03	0.01–0.05
geranial	0.01–0.04	0.02–0.04
undecanal	t–0.06	0.01–0.08
citronellyl acetate	t–0.01	t–0.01
neryl acetate	t–0.01	0.01–0.05
geranyl acetate	t–0.02	t–0.05
dodecanal	t–0.02	0.01–0.02
decyl acetate	t–0.01	t–0.01
methyl N-methyl anthranilate	0.42-0.53	0.19-0.65
β-caryophyllene	0.07–0.12	0.05–0.09
dodecenal*	0.01–0.04	0.01–0.04
α-selinene	t–0.06	0.01–0.06
α-farnesene*	0.10–0.37	0.11–0.31
(Z,E)-farnesol	0.01–0.03	0.01–0.03
α-sinensal	0.31–0.51	0.12–0.34

*correct isomer not identified; t = trace (< 0.01 percent)

Comparative percentage composition of 'Cai' and 'Montenegrina' mandarin oils produced either by hydrodistillation (HD) or cold-pressed (CP) over a four-month period in Brazil

T-3

Compound	'Cai'		'Montenegrina'	
	HD	CP	HD	CP
α-thujene	0.38–0.50	0.10–0.53	0.44–0.45	0.13–0.54
α-pinene	1.04–1.44	0.26–1.53	1.21–1.36	0.35–1.49
camphene	0.01	t–0.01	0.01	0–0.01
sabinene	0.17–0.19	0.11–0.17	0.17–0.19	0.12–0.19
β-pinene	1.01–1.11	0.50–1.17	1.02–1.12	0.55–-1.24
myrcene	1.53–1.71	1.33–1.78	1.47–1.70	1.42–1.72
octanal	0.25–0.38	0.06–0.19	0.14–0.29	0.07–0.12
α-terpinene	0.32–0.38	0.23–0.27	0.32–0.42	0.22–-0.31
limonene	70.54–76.41	69.29–75.04	67.14–75.80	70.35–73.64
(E)-β-ocimene	0.01–0.02	0.02–0.03	0.01–0.02	0.01–0.02
γ-terpinene	13.76–15.80	15.41–19.52	13.67–16.50	17.20–19.76
cis-sabinene hydrate	0.03–0.06	0.05–0.09	0.04–0.07	0.06–0.11
octanol	0.06–0.11	0–0.01	0.02–0.16	t–0.02
terpinolene	0.66–0.83	0.73–1.11	0.67–0.86	0.71–0.96
trans-sabinene hydrate	0.07–0.14	0.12–0.19	0.07–0.17	0.14–0.22
linalool	0.34–0.69	0.12–0.19	0.07–0.17	0.18–0.25
nonanal	0.04–0.06	0.04–0.08	0.03–0.04	0.03–0.06
cis-pinene hydrate	0.03–0.05	0–0.01	0.03–0.06	0–t
p-menth-2-en-1-ol*	0.01–0.04	–	0.01–0.04	–
camphor	0.01–0.03	0–t	0.01–-0.02	0–t
citronellal	0.04–0.07	0.04–0.10	0.03–0.04	0.02–0.11
borneol	0.01–0.02	0–t	0–0.02	0–0.01
terpinen-4-ol	0.32–0.75	0–t	0.32–0.88	0.07–0.14
α-terpineol	0.61–1.46	0.29–0.53	0.68–1.69	0.33–0.59
decanal	0.11–0.15	0.12–0.30	0.08–0.10	0.09–0.24
trans-carveol	0.02–0.03	0.01–0.09	0.02	0.01–0.03
octyl acetate	0.02–0.04	0–t	0.02–0.05	0–t
citronellol	0.10–0.20	0.04–0.12	0.12–0.21	0.07–0.15
methyl thymol	0.01–0.03	–	0.01–0.03	–
neral	0.03–0.06	0–0.02	0.03–0.06	0.01–0.03
piperitone	0.01–0.02	0–t	0.01–0.02	0–t
geraniol	0.02–0.04	0–t	0.01–-0.03	0–-t
perillaldehyde	0.16–0.27	0.08–-0.16	0.19–0.32	0.11–0.23
geranial	0.01–0.04	0–t	0.01–0.03	0–t
p-cymen-7-ol	0.03–0.06	t–-0.05	0.04–0.07	0.03–0.04
thymol	0.20–0.67	0.16–0.32	0.13–0.47	0.12–0.24
carvacrol	0–0.01	t–0.05	t–0.01	0.02–0.03
undecanal	0.01	0.01–0.04	0.01	0.02–0.03
(E,E)-2,4-decadienal	t–0.01	0–0.01	0–0.01	0–t
citronellyl acetate	0–0.01	0–t	0–0.01	0–t
neryl acetate	0–0.01	0–t	0–0.01	0–t
α-copaene	0–0.02	t–0.05	0.01	t–0.08
geranyl acetate	0.01	0.01–0.04	0.01	0.01–0.09
β-cubebene	0–0.01	0–0.01	0–t	0–0.02
methyl N-methyl anthranilate	0.59–1.45	0.41–1.05	0.93–3.36	0.67–1.27
dodecanal	0.02–0.04	0.03–0.16	0.02–0.03	0.02–0.15
β-caryophyllene	0.05–0.10	0.11–0.27	0.04–0.09	0.10–0.22
α-humulene	0.01	0.01–0.06	0.01	0.02–0.05
3-dodecenal*	0.01–0.02	0.02–0.12	0.01–0.02	0.02–0.12
germacrene D	0–0.01	t–0.03	0–0.01	t–0.07

continued				
T-3				

Compound	'Cai'		'Montenegrina'	
	HD	CP	HD	CP
α-selinene	0.03–0.05	t–0.18	0.04–0.07	0.07–-0.30
(E,E)-α-farnesene	0.14–0.22	0.31–0.84	0.15–0.25	0.30–0.71
δ-cadinene	0.01	0.01–0.05	0.01	0.01–0.10
tetradecanal	0–0.01	t–0.03	0–t	0–0.01
α-sinensal	0.05–0.28	0.55–1.05	0.19–0.45	0.26–0.82

*correct isomer not identified; t = trace (< 0.01 percent)

β-pinene (0.73–1.26 percent)
myrcene (0.11–0.25 percent)
δ-3-carene (0.02–0.05 percent)
limonene (78.52–89.67 percent)
ocimene* (0.07–0.14 percent)
γ-terpinene (0.01–0.02 percent)
α-copaene (0.04–0.09 percent)
β-caryophyllene (0.03–0.10 percent)
α-humulene (0.01–0.05 percent)
formic acid (0.02–0.75 percent)
acetic acid (1.28–1.59 percent)
amyl alcohol (0.01 percent)
octanol (0.06–0.15 percent)
linalool (0.07–0.08 percent)
p-menth-1-en-9-ol (0.03 percent)
citronellol (0.18–0.21 percent)
nonanol (0.01 percent)
α-terpineol (1.08–2.20 percent)
nerol (0.02–0.04 percent)
geraniol (0.01–0.02 percent)

*correct isomer not identified

Frizzo et al. (2004) analyzed the oils produced from two cultivars of mandarin ('Cai' and 'Montenegrina') grown in southern Brazil. The results of this study can be seen in T-3.

Two mandarin cultivars ('Kara' and 'Sabine') that were grown in Kenya were subjected to cold-pressed oil isolation by Njoroge et al. (2005). These oils were analyzed, and the components identified can be seen in T-4. Trace amounts (< 0.1 percent) of the following compounds were found in one or both of the mandarin cultivar oils: α-thujene, camphene, α-phellandrene, β-phellandrene, nonanal, *cis*-linalool oxide (furanoid), δ-elemene, 3-cyclohexene-1-carboxaldehyde, citronellal, *cis*-verbenol, terpinen-4-ol, (Z,Z)-4,6-octadienol, *trans*-p-mentha-2,8-dien-1-ol, (Z)-2-decenal, isopropenyl 5-methylhex-4-enal, dodecanal, linalyl isobutyrate, nerol, methoxycitronellal, *trans*-pinocarvyl acetate, dodecyl acetate, perillyl acetate,

Comparative percentage composition of the oils of two Kenyan mandarin cultivars **T-4**

Compound	'Kara' oil	'Sabine' oil
α-pinene	1.0	0.4
β-pinene	0.3	0.2
sabinene	0.1	0.1
δ-3-carene	–	0.1
myrcene	1.8	1.5
α-terpinene	–	3.4
limonene	90.7	87.1
(Z)-β-ocimene	–	0.1
γ-terpinene	2.7	1.5
(E)-β-ocimene	–	0.1
m-cymene	–	0.1
terpinolene	1.4	2.2
p-cymene	0.1	0.1
octanal	0.2	0.3
heptyl acetate	–	0.1
cis-limonene oxide	0.1	t
trans-limonene oxide	t	0.1
decanal	0.2	0.3
α-cubebene	0.1	t
linalool	0.2	0.3
p-menth-8-en-1-ol	t	0.1
linalyl acetate	t	0.1
p-mentha-1(7),8(10)-dien-9-ol	t	0.1
β-caryophyllene	0.1	0.2
undecanal	t	0.1
neral	t	0.1
α-terpineol	0.1	0.1
geranial	0.1	0.1
carvone	0.1	t
(E,E)-α-farnesene	t	0.1
neryl acetate	0.1	t
perillaldehyde	t	0.1
geranyl propionate	–	0.1
cis-carveol	t	0.1
trans-carveol	t	0.1
tetradecenal*	t	0.1
thymol	–	0.1

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

5-methylene-9-decen-2-one, tetradecanal, (Z)-nerolidol, decanoic acid, elemol and viridiflorol.

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Chirality

König et al. (1994) determined that (+)-bicyclogermacrene was the predominant enantiomer found in *C. recutita* oil.

Using chiral GC analysis, Hara et al. (1999) determined the enantiomeric ratios of selected constituents of mandarin oil. They found the following distributions:

(1R,5R)-(+)-α-pinene (70.1 percent):(1S,5S)-(-)-α-pinene (29.9 percent)
(1R,5R)-(+)-β-pinene (96.3 percent):(1S,5S)-(-)-β-pinene (3.7 percent)
(4R)-(+)-limonene (98.3 percent):(4S)-(-)-limonene (1.7 percent)
(3S)-(+)-linalool (94.2 percent):(3R)-(-)-linalool (5.8 percent)
(4R)-(+)-α-terpineol (59.3 percent):(4S)-(-)-α-terpineol (40.7 percent)
(3R)-(+)-citronellal (91.8 percent):(3S)-(-)-citronellal (8.2 percent)

Dugo et al. (2001) examined the enantiomeric ratios of selected constituents of a number of mandarin oils produced commercially in Sicily. Using chiral GC analysis, they determined the following ratios:

(1R,5R)-(+)-α-pinene (97.0–98.8 percent):(1S,5S)-(-)-α-pinene (1.2–3.0 percent)
(1R,5R)-(+)-sabinene (76.2–83.4 percent):(1S,5S)-(-)-sabinene (16.6–23.8 percent)
(4R)-(+)-limonene (97.7–98.5 percent):(4S)-(-)-limonene (1.5–2.3 percent)
(3S)-(+)-linalool (80.2–87.3 percent):(3R)-(-)-linalool (12.7–19.8 percent)
(4S)-(+)-terpinen-4-ol (10.0–19.2 percent):(4R)-(-)-terpinen-4-ol (81.8–90.0 percent)
(4R)-(+)-α-terpineol (23.2–32.2 percent):(4S)-(-)-α-terpineol (67.8–76.8 percent)

The enantiomeric distribution of some selected compounds of mandarin oil produced in Uruguay was the subject of study by Lorenzo et al. (2002), as can be seen below.

(3S)-(+)-linalool (96.0 percent):(3R)-(-)-linalool (4.0 percent)
(4R)-(+)-α-terpineol (94.4 percent):(4S)-(-)-α-terpineol (5.6 percent)
(1R,5R)-(+)-sabinene (97.3 percent):(1S,5S)-(-)-sabinene (2.7 percent)
(1R,5R)-(+)-β-pinene (63.3 percent):(1S,5S)-(-)-β-pinene (36.7 percent)
(4R)-(+)-limonene (99.4 percent):(4S)-(-)-limonene (0.6 percent)

Catalfamo et al. (2004) determined that the major enantiomers found in mandarin oils produced from two cultivars were (1R,5R)-(+)-β-pinene, (1R,5R)-(-)-sabinene, (4R)-(+)-limonene, (3S)-(+)-linalool, (4R)-(-)-terpinen-4-ol and (4S)-(-)-α-terpineol.

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Spike Lavender Oil

König et al. (1994) determined that (+)-(E)-α-bisabolene was the predominant enantiomer found in spike lavender oil.

Barazandeh (2002) analyzed oils produced from fresh and dried flowers of spike lavender that was grown in Iran. The range in oil composition found between the two oils can be seen as follows:

α-thujene (0.1 percent)
α-pinene (1.2–1.4 percent)
camphene (0.4–0.5 percent)
1-octen-3-ol (0.3 percent)
sabinene (0.8–0.9 percent)
β-pinene (1.9–2.2 percent)
myrcene (1.3–1.4 percent)
hexyl acetate (0.1–0.2 percent)
α-phellandrene (0.1 percent)
δ-3-carene (0.3–0.4 percent)
α-terpinene (0.1 percent)
p-cymene (0.1 percent)
1,8-cineole (18.8–20.9 percent)
(Z)-β-ocimene (3.4–4.2 percent)
(E)-β-ocimene (1.0–1.3 percent)
γ-terpinene (0.1 percent)
trans-sabinene hydrate (0.8–0.9 percent)
terpinolene (0.4–0.5 percent)
linalool (30.6–31.9 percent)
camphor (4.4–4.5 percent)
hexyl butyrate (0.1 percent)
borneol (8.9–10.1 percent)
lavandulol (0.3 percent)
terpinen-4-ol (2.1–2.3 percent)
α-terpineol (2.3–2.5 percent)
hexyl 2-methylbutyrate (0.2 percent)
linalyl acetate (2.9–3.4 percent)
(E)-anethole (0.1 percent)
lavandulyl acetate (0.8 percent)
hexyl tiglate (0.1 percent)
hexyl hexanoate (0.1–0.2 percent)
cis-α-bergamotene (0.1 percent)
β-caryophyllene (0.8 percent)
trans-α-bergamotene (0.1 percent)
(Z)-β-farnesene (0.1 percent)
(E)-β-farnesene (3.9–4.8 percent)
germacrene D (0.4 percent)
β-bisabolene (0.1 percent)
caryophyllene oxide (0.1 percent)
T-cadinol (0.1 percent)
α-bisabolol (2.1–2.6 percent)

An oil of spike lavender of Spanish origin was analyzed using capillary GC and ^{13}C-NMR by Kubeczka and Formacek (2002). The components characterized in this oil were as follows:

α-pinene (0.89 percent)
camphene (0.32 percent)
β-pinene (1.01 percent)
sabinene (0.22 percent)
limonene (1.01 percent)
1,8-cineole (28.26 percent)
3-octanone (0.07 percent)
p-cymene (0.35 percent)
trans-linalool oxide† (6.41 percent)
cis-linalool oxide† (0.36 percent)
camphor (12.93 percent)
linalool (47.85 percent)
terpinen-4-ol + β-caryophyllene (0.67 percent)
lavandulol (0.28 percent)
α-humulene (0.17 percent)
α-terpineol (0.66 percent)
borneol (1.23 percent)
germacrene D (0.05 percent)

geraniol (0.16 percent)
caryophyllene oxide (0.25 percent)

†furanoid form

Salido et al. (2004) collected the flowering spikes of spike lavender from three different locations in Spain over the full-flowering and fruiting stages. Oils produced from the six samples were analyzed by GC and GC/MS, and their compositions are summarized as follows:

(Z)-3-hexenol (t–0.1 percent)
hexanol (t–0.1 percent)
α-pinene (0.6–1.9 percent)
camphene (0.4–0.6 percent)
sabinene (0.3–0.8 percent)
β-pinene (0.8–2.6 percent)
3-octanone (t–0.2 percent)
myrcene (0.3–0.8 percent)
α-phellandrene (t–0.1 percent)
α-terpinene (0.1 percent)
p-cymene (t–0.2 percent)
limonene (0.2–0.9 percent)
1,8-cineole (28.0–34.9 percent)
(Z)-β-ocimene (0.1–0.3 percent)
(E)-β-ocimene (t–0.1 percent)
γ-terpinene (0.1–0.2 percent)
cis-sabinene hydrate (0.2–0.5 percent)
cis-linalool oxide† (t–0.6 percent)
terpinolene + *trans*-linalool oxide† (0.3–0.6 percent)
linalool (27.2–43.1 percent)
α-campholenal (0.1–0.3 percent)
camphor (10.8–23.2 percent)
pinocarvone (0.1–0.2 percent)
borneol (0.9–3.6 percent)
δ-terpineol (0.4–1.2 percent)
terpinen-4-ol (0.3–0.5 percent)
p-cymen-8-ol (0.2–0.4 percent)
α-terpineol (0.8–1.6 percent)
myrtenal + myrtenol (0.2–0.4 percent)
verbenone (0.1 percent)
trans-carveol (t–0.1 percent)
bornyl formate (t–0.2 percent)
hexyl isovalerate (0–0.2 percent)
carvone (0–0.1 percent)
bornyl acetate (t–0.1 percent)
cuminyl alcohol (t–0.1 percent)
β-caryophyllene (0.5–1.9 percent)
trans-α-bergamotene (0.1–0.2 percent)
(E)-β-farnesene (0.2–0.7 percent)
germacrene D (0.3–1.0 percent)
β-bisabolene (0.3–0.5 percent)
γ-cadinene (0.1–0.2 percent)
δ-cadinene (t–0.1 percent)
(E)-α-bisabolene (0.5–2.3 percent)
caryophyllene oxide (0.3–0.7 percent)
T-cadinol (0.2–0.5 percent)
α-bisabolol (t–0.8 percent)

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

Trace amounts (< 0.1 percent) of (E)-2-hexenol, tricyclene, α-thujene, thuja-2,4(10)-diene, 1-octen-3-ol, α-humulene and α-cadinol also were found in all of these spike lavender oils.

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