Progress in Essential Oils

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Basil Oil

Putievsky (1995) determined the changes in major constituents of the oil isolated from basil (*Ocimum basilicum* L.) leaves based on their size. Using leaves whose length was between 0.6-9.5 cm, he found that the compositional changes were as follows:

1,8-cineole (1.8-4.4 percent)
linalool (34.0-50.0 percent)
β-caryophyllene (1.2-4.6 percent)
methyl chavicol (22.0-48.0 percent)
methyl eugenol (0.4-1.4 percent)
eugenol (4.1-7.4 percent)

The largest leaves were found to be richest in methyl chavicol and poorest in linalool.

Oils obtained by steam distillation and water distillation of the same batch of *O. basilicum* plants that were grown in Turkey were produced in 0.21 percent and 0.43 percent yield, respectively (Özek et al. 1995). The results of the analysis of the two oils can be found in Table I. As can be seen, there were some quantitative differences in the oil compositions in addition to yield differences; however, only minor qualitative differences were found.

In 1996, Qaisar et al. published a confused analysis of an oil of *O. basilicum*. However, based on the comments of the authors on the possible varietal or hybrid origin of this *Ocimum* species and the misidentifications based on GC elution order, this analysis should be ignored. It's only included for the sake of completeness of a literature review.

D'Alpaos et al. (1997) compared the compositions of basil oil with a supercritical fluid CO_2 extract and a soxhlet extract of dried powdered leaves of *O. basilicum*. The results of this study are summarized in Table II. The authors published the same results of this study in a second report (Pallado et al. 1997).

Bhattacharya et al. (1997) analyzed the oils of two genotypes of *O. basilicum* grown in India. As the oil compositions were very similar, the data were combined as follows:

α-thujene (0-0.05 percent)
α-pinene (0.08-0.23 percent)
camphene (0.02-0.13 percent)
sabinene (0.08-0.22 percent)
β-pinene (0.21-0.23 percent)
myrcene (0.41-0.82 percent)
α-phellandrene (0.04-0.05 percent)
α-terpinene (0-0.07 percent)
p-cymene (0.04-0.18 percent)
limonene (4.25-5.57 percent)
(Z)-β-ocimene (0.05-0.11 percent)
(E)-β-ocimene (0.60-1.91 percent)
γ-terpinene (0.06-0.18 percent)
trans-sabinene hydrate (0-0.07 percent)
cis-linalool oxide-furanoid (0.05-0.07 percent)
trans-linalool oxide-furanoid (0.05-0.09 percent)
terpinolene (0.06-0.23 percent)
linalool (44.09-49.82 percent)
camphor (0.81-2.35 percent)
borneol (0.14-0.53 percent)
terpinen-4-ol (0.41-2.63 percent)
α-terpineol (0.82-0.83 percent)
methyl chavicol (0.02-0.04 percent)
citronellol (0-0.05 percent)
geraniol (0-0.85 percent)
bornyl acetate (0.40-0.83 percent)
eugenol (20.18-27.07 percent)
methyl (E)-cinnamate (0-0.19 percent)
α-copaene (0.12-0.13 percent)
methyl eugenol (0.05-0.16 percent)
β-elemene (1.03-1.42 percent)
β-caryophyllene (0.11-0.19 percent)

Comparative percentage composition of the steam distilled and water distilled oils of *Ocimum basilicum* **T-1**

Compound	Steam distilled oil	Water distilled oil	Compound	Steam distilled oil	Water distilled oil
isovaleraldehyde	0.01	0.05	(Z)-2-hexenyl butyrate†	0.05	0.07
2-ethylfuran	0.01	0.02	α-humulene	1.18	0.50
α-pinene	0.46	0.63	(Z)-β-farnesene	0.36	0.09
camphene	0.05	0.07	α-terpineol	0.96	1.38
hexanal	t	0.03	germacrene D	3.62	1.32
β-pinene	0.93	1.17	γ-guaiene	4.26	1.34
sabinene	0.35	0.36	carvone	1.60	0.21
myrcene	0.26	0.34	γ-elemene	1.62	1.93
α-terpinene	0.03	0.05	germacrene A	0.15	0.07
limonene	0.26	0.35	neryl acetate	0.25	0.15
1,8-cineole	7.13	13.63	δ-cadinene	6.66	2.34
γ-terpinene	0.06	0.11	nerol	0.07	0.06
(E)-β-ocimene	0.02	0.04	β-damascenone*	0.17	0.08
p-cymene	0.03	0.05	(E)-anethole	0.63	0.23
terpinolene	0.04	0.05	calamenene*	0.06	0.17
(Z)-3-hexenyl acetate	t	0.01	geraniol	0.39	0.43
octenyl acetate*	0.03	0.06	geranyl acetone	0.14	0.08
fenchone	0.13	0.23	β-ionone*	0.16	0.09
α-cubebene	0.28	0.18	methyl (Z)-cinnamate	1.45	2.21
octyl acetate	0.17	0.01	methyl eugenol	0.82	0.84
α-copaene	0.36	0.14	nerolidol*	0.47	0.24
camphor	0.45	0.79	methyl (E)-cinnamate	12.66	16.72
β-bourbonene	0.38	0.30	spathulenol	1.67	1.20
β-cubebene	0.37	0.14	hexahydrofarnesyl acetone	0.44	0.13
linalool	17.71	24.25	eugenol	2.67	4.25
octanol	t	0.04	T-cadinol	7.14	5.27
linalyl acetate	0.24	0.15	thymol	0.10	0.02
bornyl acetate	0.42	0.30	carvacrol	0.68	0.44
β-elemene	8.16	3.59	β-eudesmol	0.30	0.28
α-guaiene	0.13	0.33			
β-caryophyllene	0.23	0.03			

*correct isomer not identified; †tentative identification

trans-α-bergamotene (0.76-2.60 percent)
α-humulene (0.33-0.45 percent)
bicyclogermacrene (0.28-1.01 percent)
β-bisobolene (0.91-1.99 percent)
γ-cadinene (0.09-0.30 percent)
δ-cadinene (0-0.02 percent)
(E)-nerolidol (0.09-0.22 percent)
caryophyllene oxide (0.13-0.32 percent)
humulene epoxide I (0.03-0.08 percent)
humulene epoxide II (0.05 percent)
T-cadinol (2.76-3.25 percent)
α-cadinol (0.37-0.59 percent)
β-bisabolol (0.04-0.05 percent)
α-bisabolol (0.05-0.15 percent)

A leaf oil of *O. basilicum* var. *purpurascens* produced by steam distillation from plants that were grown in northeastern Brazil was analyzed by de Vasconcelos Silva et al. (1998). It was found to contain the following components:

α-pinene (0.6 percent)
camphene (0.4 percent)
β-pinene (1.3 percent)
p-cymene (0.5 percent)
1,8-cineole (5.0 percent)
limonene (1.0 percent)
γ-terpinene (0.3 percent)
linalool (39.3 percent)
camphor (0.9 percent)
borneol (0.6 percent)
terpinen-4-ol (1.8 percent)
methyl chavicol (1.9 percent)
octyl acetate (2.3 percent)
bornyl acetate (0.9 percent)
δ-elemene (3.4 percent)
α-copaene (0.6 percent)
β-bourbonene (0.5 percent)
β-cubebene (2.0 percent)

Comparative percentage composition of basil oil and its extracts **T-2**

Compound	Oil	$SFCO_2$	SOX	Compound	Oil	$SFCO_2$	SOX
α-pinene	0.16	t	t	β-caryophyllene	48.70	1.08	19.80
sabinene	0.10	t	t	*trans*-α-bergamotene	6.76	9.60	3.00
β-pinene	0.25	0.14	t	α-humulene	6.00	0.62	0.65
1,8-cineole	0.43	4.80	1.42	bisabolene*	t	t	1.64
linalool	1.55	32.00	6.00	γ-cadinene	1.15	4.12	2.49
camphor	t	0.46	t	(Z)-γ-bisabolene	1.10	t	1.26
α-terpineol	0.16	0.93	t	spathulenol	1.50	0.62	t
methyl chavicol	0.68	11.40	t	caryophyllene oxide	1.25	t	t
lavandulyl acetate	0.55	0.78	t	cubenol	2.46	1.08	t
(Z)-methyl cinnamate	t	1.70	t	cadinol*	18.14	5.79	7.86
δ-elemene	t	t	t	hexadecene*	t	t	7.53
eugenol	4.00	12.40	21.60	octadecene*	t	t	1.80
α-copaene	0.99	9.68	t	docosene*	t	t	2.70
(E)-methyl cinnamate	2.50	1.40	4.40	nonacosane	t	t	2.18
δ-elemene	0.96	t	t	entriacontane	t	t	3.66
methyl eugenol	0.61	1.40	t	tritriacontane	t	t	8.90

*correct isomer not identified; oil = hydrodistilled oil; $SFCO_2$ = supercritical fluid extract; SOX = soxhlet extract (solvent not noted)

β-elemene (0.8 percent)
β-caryophyllene (0.8 percent)
trans-α-bergamotene (4.0 percent)
α-humulene (1.6 percent)
bicyclogermacrene (0.7 percent)
germacrene A (1.0 percent)
δ-guaiene (0.4 percent)
γ-cadinene (7.7 percent)
humulene epoxide II (1.5 percent)
α-muurolol (11.0 percent)
β-eudesmol (6.5 percent)

An oil from this same batch of leaves that was produced by a lab technique known as microwave distillation was found to contain only the following components:

1,8-cineole (2.4 percent)
cis-linalool oxide-furanoid (2.3 percent)
trans-linalool oxide-furanoid (3.2 percent)
linalool (79.6 percent)
camphor (2.0 percent)
terpinen-4-ol (4.3 percent)
α-terpineol (2.6 percent)

As can be seen, the method of oil isolation can have a masked effect on the composition of the oil.

A commercial sample of basil oil was screened for its antioxidant properties by Baratta et al. (1998). The oil used in this study was found to contain:

α-pinene (0.5 percent)
camphene (0.3 percent)
sabinene (0.1 percent)
β-pinene (0.6 percent)
myrcene (0.2 percent)
decane (t)
p-cymene (t)
1,8-cineole (2.8 percent)
limonene (0.5 percent)
(Z)-β-ocimene (t)
(E)-β-ocimene (0.9 percent)
fenchone (0.2 percent)
terpinolene (t)
linalool (1.1 percent)
α-fenchyl alcohol (t)
camphor (0.7 percent)
menthone (0.3 percent)
isomenthone (t)
borneol (0.1 percent)
menthol (0.4 percent)
methyl chavicol (86.1 percent)
(E)-anethole (0.1 percent)
bornyl acetate (0.2 percent)
menthyl acetate (t)
methyl eugenol (0.5 percent)
β-elemene (0.3 percent)
β-caryophyllene (0.1 percent)
trans-α-bergamotene (1.9 percent)
α-humulene (0.1 percent)
(E)-β-farnesene (0.1 percent)
(Z)-β-farnesene (0.2 percent)
γ-cadinene (0.3 percent)
spathulenol (0.2 percent)
T-cadinol (0.3 percent)

t = trace (< 0.1 percent)

Lee et al. (1999) compared the composition of the oils of four cultivars of basil that were produced from plants grown in South Korea. The results of this study

Percentage composition of the oils of four basil cultivars **T-3**

Compound	'Anise' oil	'Dark Opal' oil	'Lettuce-leaf' oil	'Sweet' oil
β-pinene	0.32	0.43	0.62	0.14
sabinene	0.21	0.23	0.35	0.08
myrcene	0.20	0.40	0.31	0.19
limonene	0.38	0.30	0.51	0.34
1,8-cineole	2.86	3.72	5.04	2.97
α-terpinene	0.19	t	0.40	t
(Z)-β-ocimene	1.74	1.32	2.02	1.15
terpinolene	0.31	0.24	0.39	0.32
3-hexenol*	0.11	0.10	0.14	0.17
linalool oxide*	0.06	t	t	0.09
1-octen-3-ol	0.07	t	t	0.13
sabinene hydrate*	0.15	0.16	0.31	t
octyl acetate	-	0.26	-	0.22
α-copaene	0.11	0.21	0.16	0.24
camphor	1.07	1.20	1.87	1.34
β-bourbonene	t	-	-	0.18
linalool	28.52	36.50	30.09	32.30
octanol	0.06	t	t	0.05
bornyl acetate	1.24	0.48	0.53	2.79
trans-α-bergamotene	5.40	2.05	2.33	2.89
β-elemene	3.05	5.87	4.56	2.01
β-caryophyllene	0.17	0.88	0.23	0.61
terpinen-4-ol	0.87	0.88	1.71	0.29
1-epi-bicyclosesqui-phellandrene	0.24	0.21	0.12	0.43
methyl chavicol	-	18.64	25.49	8.09
β-farnesene*	0.63	0.22	0.26	0.38
α-terpineol	0.67	0.72	0.97	1.28
borneol	0.46	0.26	0.21	1.01
β-cubebene‡	2.77	4.80	4.08	3.45
guaiene*	0.99	1.88	1.34	2.34
β-selinene	t	0.47	-	1.81
cadinene*	1.70	1.48	1.08	1.58
β-sesquiphellandrene	0.54	0.16	0.25	0.30
α-muurolene	t	t	-	0.18
nerol	t	0.12	t	0.14
geraniol	0.05	0.14	1.30	0.32
(Z)-methyl cinnamate	3.44	-	-	-
methyl eugenol	0.12	0.13	t	0.11
(E)-methyl cinnamate	23.12	0.36	2.71	-
eugenol	8.03	8.74	3.55	13.53
farnesol*	0.26	0.54	0.42	0.49

*correct isomer not identified; t = trace (< 0.01 percent); ‡ misidentification of germacrene D

are shown in Table III.

Kamada et al. (1999) compared the composition of oils isolated from a white flowered, a purple cultivar and sweet basil. In addition, the authors determined that the environment could have a marked effect on the quantitative composition of the oils. The variance in oil composition of the three basil cultivars is presented in Table IV.

The composition of a few oils produced from *O. basilicum* plants grown in Indiana from seed obtained in Brazil revealed that one group of accessions was rich in methyl (E)-cinnamate (46.3±0.5 percent) while the others contained various levels of linalool (17.2-47.3±1.39 percent) and methyl chavicol (40.12-50.5±1.70 percent) (Vieira 1999 and Vieira and Simon 2000). Vieira also examined the composition of some oils of

Variance in percentage composition of the major constituents of the oils of three basil cultivars **T-4**

Compound	White basil	Purple basil	Sweet basil
1,8-cineole	11.41-15.57	2.77-6.03	2.70-4.13
fenchone	1.98-2.81	t	-
terpinolene‡	19.29-23.64	20.00-27.34	36.00-38.27
camphor	13.77-14.83	-	t
terpinen-4-ol	0.39-0.44	1.27-1.42	-
α-terpineol	2.58-2.85	0.97-1.09	0.75-0.83
eugenol	14.53-16.05	19.20-32.53	14.24-22.65
elemene*	1.55-2.02	0.85-1.52	1.84-2.92
β-caryophyllene	2.57-3.49	t	t
α-bergamotene*	1.55-1.61	5.20-6.30	7.96-10.84
β-cubebene†	7.12-7.99	1.73-2.85	3.30-4.52
epi-bicyclophellandrene	3.81-4.51	5.40-7.41	4.81-5.77

‡ should be linalool not terpinolene; * correct isomer not identified; † incorrect identity based on elution order from a non-polar column

Percentage composition of various groups of oils of *Ocimum basilicum* **T-5**

Compound	Group 1	Group 2	Group 3	Group 4	Group 5
α-pinene	0-1.1	0-0.2	-	0.4-1.7	0.3
β-pinene	0-0.8	0-0.1	-	0.4-1.9	0.3
1,8-cineole	0.7-11.0	0.3-1.7	3.7	7.8-14.8	2.9
γ-terpineol†	0.8-2.6	<0.1-0.7	0.6	0.5-1.0	2.1
linalool	69.3-74.5	0.6-1.4	1.7	20.3-55.7	32.3
camphor	-	0-4.3	-	0-2.9	0.9
terpinen-4-ol	0-0.3	0-1.0	-	0-0.6	0.8
methyl chavicol	0.4-2.6	57.2-87.8	0.4	12.7-41.7	6.4
methyl (Z)-cinnamate	-	-	5.9	-	5.5
eugenol	0.6-3.5	0-0.6	-	0.1-0.4	1.0
β-elemene	0.9-1.2	0-1.0	-	0.7-1.9	-
methyl (E)-cinnamate	-	0-1.0	82.4	-	34.0
methyl eugenol	0.2-1.9	0-2.5	-	0.1-1.1	-
γ-elemene	1.6-4.4	0.8-4.5	-	1.6-1.9	0.4
α-humulene	0.3-0.6	0-0.8	-	0.4-1.1	0.3
β-cubebene†	0.8-2.3	0-1.7	-	1.0-1.8	1.7
β-bisabolene	1.2-2.5	0-1.4	0.2	1.4-1.7	1.9
α-farnesene*	-	0-2.0	-	-	-
α-gurjunene†	-	0-0.2	-	-	1.1
spathulenol	0.9-1.1	0.7-1.6	0.9	0.3-1.3	1.3

* correct isomer not identified; † incorrect identification based on elution order from a non-polar GC column; Group 1 = linalool-rich, Group 2 = methyl chavicol-rich, Group 3 = methyl (E)-cinnamate-rich, Group 4 = linalool/methyl chavicol-rich, Group 5 = linalool/methyl (E)-cinnamate-rich

O. basilicum from plants also grown in Indiana from various additional see sources. He found that the oils could be grouped as being rich in linalool, methyl chavicol, methyl (E)-cinnamate or combinations of these same compounds. A summary of Vieira's results can be seen in Table V.

Tonzibo et al. (2000) reported the results of the analysis of *O. basilicum* oils produced in Abidjan (Ivory Coast) and Benin, a summary of which can be seen in Table VI. In addition, they also obtained *O. basilicum* plants from Korhogo (Ivory Coast). In an oil obtained from

Percentage composition of *Ocimum basilicum* oils produced from plants collected in the Ivory Coast and Benin **T-6**

Compound	Ivory Coast	Benin	Compound	Ivory Coast	Benin
α-pinene	1.2	0.1	*trans*-α-bergamotene	-	2.2
camphene	0.1	-	pinocarveol*	-	1.6
β-pinene	0.3	0.1	β-caryophyllene	1.0	-
sabinene	0.1	-	methyl chavicol	77.0	85.1
myrcene	1.3	0.4	α-terpineol	0.6	0.6
limonene	0.5	0.3	δ-guaiene	0.3	0.2
1,8-cineole	2.7	1.1	geranial	1.0	-
γ-terpinene	0.7	-	methyl eugenol	-	0.3
(E)-β-ocimene	2.3	3.0	cubebol	-	0.1
p-cymene	0.4	-	nerolidol*	0.8	0.2
terpinolene	0.3	-	T-cadinol	-	0.5
α-copaene	0.6	-	thymol	1.4	-
camphor	-	0.4	carvacrol	1.4	-
linalool	0.8	1.4			

* correct isomer not identified

these plants, the authors characterized the following constituents:

α-pinene (3.0 percent)
camphene (0.1 percent)
β-pinene (0.2 percent)
sabinene (< 0.1 percent)
myrcene (0.5 percent)
limonene (1.4 percent)
1,8-cineole (2.2 percent)
γ-terpinene (0.1 percent)
(E)-β-ocimene (0.1 percent)
p-cymene (0.2 percent)
terpinolene (0.1 percent)
linalool oxide* (0.1 percent)
α-fenchyl acetate (0.4 percent)
camphor (0.1 percent)
α-copaene (0.9 percent)
linalool (51.0 percent)
bornyl acetate (1.1 percent)
β-caryophyllene (2.6 percent)
(Z,Z)-α-farnesene (0.4 percent)
allo-aromadendrene (0.1 percent)
α-humulene (0.1 percent)
methyl chavicol (0.4 percent)
(E)-β-farnesene (0.4 percent)
α-terpineol (1.1 percent)
germacrene D (0.9 percent)
δ-guaiene (0.1 percent)
geranial (1.1 percent)
δ-cadinene (1.1 percent)
geraniol (0.1 percent)
caryophyllene oxide (0.1 percent)
nerolidol* (0.1 percent)
spathulenol (0.1 percent)
T-cadinol (< 0.1 percent)
thymol (26.1 percent)

*correct isomer not identified

Di Cesare et al. (2000) examined the effects of various drying procedures on basil leaves that had been blanched by hot water and steam. The drying procedures compared were microwave, hot air (50°C) and freeze drying. As can be seen from the results presented in Table VII, blanching and drying (not unexpectedly) caused a loss of volatiles. Also, as one might expect hot air and microwave drying caused a greater loss of volatiles than freeze drying.

Bahl et al. (2000) compared the composition of selected constituents of the whole plant and different plant parts of the Kusumohak cultivar of *O. basilicum* grown in India. The results of this comparative study can be seen in Table VIII.

Ehlers et al. (2001) compared the oils and supercritical fluid CO_2 extracts of basils of various origins using GC and GC/MS. Table IX shows their results, which appear to be incomplete analyses because less than 40 percent of the Egyptian and Albanian extracts and less than 60 percent of the Albanian and Egyptian oils were characterized.

Yayi et al. (2001) compared the major constituents of 12 samples of *O. basilicum* oil produced from plants collected throughout Benin. The oils, which can be divided into four groups, can be seen in Table X.

Using solid-phase microextraction combined with GC/MS Díaz-Maroto et al. (2002) determined the headspace volatiles of homogenized fresh basil leaves were as follows:

myrcene (0.8)[a]

Comparative composition (%) of the volatiles of basil leaves after a series of treatments **T-7**

Compound	Fresh leaves 1	2	3	4	Blanched leaves 2	3	4
(Z)-2-pentenol	0.12	-	-	-	-		
hexanal	0.16	-	-	-	-		
(E)-2-hexenal	2.18	-	1.26	-	-		
(Z)-3-hexenal	0.21	-	-	-	-		
1-octen-3-ol	0.35	-	0.57	-	-		
β-pinene	0.18	-	-	-	-		
myrcene	0.45	-	0.65	0.65	-	0.29	-
1,8-cineole	5.25	1.70	5.09	5.89	0.98	2.13	2.05
δ-3-carene†	0.64	-	0.74	0.68	-	0.33	-
linalool	38.51	13.49	43.10	43.83	9.85	30.19	24.06
camphor	0.63	0.37	0.23	0.51	0.65	0.56	-
α-terpineol	0.72	0.46	0.85	0.74	0.39	0.81	0.87
eugenol	36.53	32.14	39.45	34.61	27.20	31.59	34.01
α-humulene	0.69	-	-	-	-	-	-
germacrene B†	0.25	1.24	0.35	0.41	4.78	0.53	1.59
germacrene D	0.36	1.18	0.49	0.38	2.70	0.93	1.67

† incorrect identification based on the elution order from a non-polar column; 1. control, 2. microwave drying, 3. freeze drying, 4. air drying

Percentage composition of the major constituents of *Ocimum basilicum* oils produced from different plant parts **T-8**

Compound	Whole plant oil	Leaf oil	Flower oil	Stem oil
1,8-cineole	4.9	5.3	2.1	3.2
linalool	42.4	35.5	52.9	39.0
methyl chavicol	36.3	40.8	22.2	27.3
eugenol	2.5	3.9	2.7	3.1
(E)-methyl cinnamate	0.4	0.2	0.7	0.8
β-caryophyllene	0.2	0.2	0.2	0.2
methyl isoeugenol*	2.2	1.6	4.6	3.0

* correct isomer not identified

Comparative percentage composition of various oils and CO_2 extracts of *Ocimum basilicum* of various origins **T-9**

Compound	Albanian extract	Albanian oil	Egyptian 1 extract	Egyptian 1 oil	Egyptian 2 extract	Vietnamese oil
α-pinene	-	0.1	-	0.1	0.1	0.1
β-pinene	0.1	0.4	-	0.5	0.2	-
1,8-cineole	1.6	5.0	1.3	6.1	2.5	1.0
linalool	19.2	30.2	17.5	35.3	2.5	0.7
camphor	0.2	0.5	0.2	0.5	0.2	0.9
methyl chavicol	4.7	6.9	5.1	10.5	42.3	78.2
terpinen-4-ol	0.4	0.9	-	0.5	-	0.1
β-caryophyllene	0.4	0.4	0.4	0.6	1.4	0.2
geraniol	0.3	0.4	0.2	0.3	-	-
methyl eugenol	0.5	0.6	0.6	0.9	7.8	0.8
(E)-methyl cinnamate	3.8	6.9	0.4	0.5	0.2	-
eugenol	6.5	6.7	5.9	7.3	0.8	-

Comparative major component composition (%) of various *Ocimum basilicum* oils produced in Benin **T-10**

Compound	Group 1	Group 2	Group 3	Group 4
1,8-cineole	1.0	0.1-4.7	0.3-1.4	1.5-2.2
linalool	67.9	0.1-0.8	42.2-48.0	20.4-29.1
terpinen-4-ol	0.2	0.1	0.1-5.3	0.1-0.4
eugenol	4.3	0.1	5.5-15.0	0.4-1.7
β-caryophyllene	3.8	0.1-8.0	0.1	0.1-1.4
trans-α-bergamotene	7.0	0.1-3.6	6.7-14.9	1.3-2.2
T-cadinol	0.1	0.1-0.6	0.1-5.0	0.1-0.8
methyl chavicol	0.4	65.0-89.8	0.4-1.0	54.6-55.2

1,8-cineole (14.5)
trans-sabinene hydrate (0.7)
cis-linalool oxide-furanoid (2.9)
trans-linalool oxide-furanoid (2.9)
linalool (143.4)
camphor (1.9)
borneol (2.7)
terpinen-4-ol (5.1)
α-terpineol (< 0.1)
methyl chavicol (165.6)
geraniol (0.3)
(E)-anethole (1.3)
bornyl acetate (5.2)
(Z)-methyl cinnamate (4.2)
eugenol (13.1)
(E)-methyl cinnamate (25.3)
methyl eugenol (6.6)
α-copaene (3.0)
β-bourbonene (3.5)
β-elemene (9.3)
β-caryophyllene (5.9)
trans-α-bergamotene (101.1)
α-guaiene (6.7)
β-selinene (6.1)
1-epi-bicyclosesquiphellandrene (3.9)
α-bulnesene (9.4)
γ-cadinene (27.9)
spathulenol (2.8)
T-cadinol (13.7)

[a] = mg/kg fresh basil leaves

Díaz-Maroto et al. (2002) also examined the composition of an oil of basil produced by simultaneous distillation-extraction using methylene chloride as the solvent and compared it with a supercritical fluid CO_2 extract of the same batch of commercially available basil. The results of this study can be seen summarized in Table XI. The SFE was obtained at a temperature of 40°C under a pressure of 120 bar with a CO_2 density of 0.72 g/mL.

While screening a series of Israeli basil cultivars for wilt resistance, Dudai et al. (2002) examined their compositions. The results of these analyses revealed that oils from the cultivars could be grouped into oils rich in linalool and methyl chavicol or oils rich in linalool and eugenol. The composite analyses of these two groups of cultivars are shown in Table XII.

Rakic and Johnson (2002) compared the oil composition of one broad-leafed cultivar (French), one small-leaved cultivar (commercial) and one small-leaved cultivar (Greek type) grown in Chania (Crete, Greece). The oil compositions are presented in Table XIII.

The oils of *O. basilicum* produced from plants grown in Sahel and Cap-Bon (Tunisia) were analyzed by Bouzouita et al. (2002). The results of these analyses can be seen in Table XIV.

Slougui et al. (2003) determined the main components of oils produced from the leaves and flowers of *O. basilicum* grown experimentally in Ouargla (S.E. Algeria) as can be seen in Table XV.

Siano et al. (2003) examined the composition of oils produced from 'Rosso Ruffle' and 'Rosso Dark Opal' cultivars of *O. basilicum* grown in Reggio Calabia (Italy). The authors produced oils from plants harvested from July 11 to October 12 and the variation in the oil composition over this time period can be seen in Table XVI for both cultivars.

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Comparative percentage composition of an oil and a supercritcal fluid CO_2 extract of basil **T-11**

Compound	Oil	SFE	Compound	Oil	SFE
sabinene	0.37	0.09	eugenol	6.12	8.22
β-pinene	0.92	0.16	(E)-methyl cinnamate	5.96	8.71
myrcene	0.33	0.12	methyl eugenol	1.07	1.18
1,8-cineole	10.94	5.85	α-copaene	0.14	0.22
trans-sabinene hydrate	0.37	0.36	β-bourbonene	0.12	0.20
cis-linalool oxide†	0.59	0.30	β-elemene	0.71	1.45
trans-linalool oxide†	0.56	0.30	β-caryophyllene	0.25	0.41
linalool	35.99	30.73	α-bergamotene*	2.35	5.67
camphor	0.72	0.44	α-guaiene	0.26	0.61
borneol	0.21	0.29	β-selinene	0.26	0.46
terpinen-4-ol	0.98	0.94	1-epibicyclosesquiphellandrene	0.16	0.31
α-terpineol	1.07	0.82	β-cubebene	0.64	1.57
methyl chavicol	22.59	21.80	δ-guaiene°	0.28	0.73
geraniol	0.12	0.15	γ-cadinene	0.94	1.99
(E)-anethole	0.09	0.11	spathulenol	0.33	0.37
bornyl acetate	0.62	0.37	T-cadinol	3.09	3.59
(Z)-methyl cinnamate	0.85	1.17			

SFE = supercritical fluid CO_2 extract; * correct isomer not identified; † furanoid form; ° structure uncertain and not corroborated in the literature

Percentage composition of two groups of Israeli *Ocimum basilicum* cultivars **T-12**

Compound	Group 1	Group 2	Compound	Group 1	Group 2
linalool	41.0-57.6	47.3-55.9	β-elemene	0-1.7	0-1.6
methyl chavicol	0-9.8	19.1-26.1	borneol	0-1.4	0-1.3
eugenol	13.3-31.2	3.1-8.9	(E)-β-ocimene	0.1-1.3	0.1-0.6
methyl eugenol	0-7.1	0-0.3	α-guaiene	0-0.8	0-0.6
1,8-cineole	3.5-11.5	2.8-7.1	myrcene	0.1-0.2	0.1-0.2
trans-α-bergamotene	0.1-9.9	t-6.3	linalool	t-0.2	t
			camphor	0.1-1.1	0.1-0.8
germacrene D	2.8-6.5	2.5-4.8	geraniol	0-1.7	0-0.6
α-cadinol	2.6-5.2	2.1-5.4	β-caryophyllene	0-0.2	0-0.7
γ-cadinene	0-3.7	1.5-2.7	(E)-β-farnesene	0-0.8	-
bornyl acetate	0.5-2.1	0.5-1.1	α-humulene	0-0.8	0-1.0
α-terpineol	0-1.2	0.7-1.3			

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Percentage composition of the oils obtained from three different basil cultivars grown in Chania (Crete, Greece) **T-13**

Compound	Broad-leaved cultivar oil	Narrow-leaved cultivar 1 oil	Narrow-leaved cultivar 2 oil	Compound	Broad-leaved cultivar oil	Narrow-leaved cultivar 1 oil	Narrow-leaved cultivar 2 oil
α-pinene	2.32	2.72	2.68	borneol	0.21	0.38	-
sabinene	2.31	1.84	2.64	terpinen-4-ol	-	5.04	-
β-pinene	3.94	2.75	4.62	α-terpineol	1.64	1.40	1.78
myrcene	4.25	2.30	3.02	isobornyl acetate	0.40	0.76	0.60
limonene	1.51	2.49	1.48	eugenol	8.36	5.20	5.44
1,8-cineole	26.03	16.31	30.41	methyl eugenol	1.95	4.01	18.29
(E)-β-ocimene	3.42	-	0.57	*trans*-α-bergamotene	4.04	12.07	6.43
trans-sabinene hydrate	0.90	2.36	0.88	α-humulene	0.39	0.44	0.52
terpinolene	0.33	0.57	0.73	(E)-β-farnesene	0.39	0.70	1.25
linalool	34.16	33.86	15.09	germacrene D	1.22	1.96	0.85
camphor	1.50	1.09	1.97	bicyclogermacrene	0.33	0.66	0.23
				γ-cadinene	0.72	1.17	0.53

Comparative percentage composition of basil oils produced in Tunisia **T-14**

Compound	Sahel oil	Cap-Bon oil	Compound	Sahel oil	Cap-Bon oil
α-pinene	0.7	0.1	(Z)-methyl cinnamate	2.9	0.5
sabinene	0.5	0.1	camphene‡	-	0.1
β-pinene	1.2	0.2	eugenol	-	3.3
myrcene	1.4	0.1	(E)-methyl cinnamate	10.8	4.1
α-terpinene	0.2	t	β-elemene	0.7	0.7
p-cymene	0.4	t	methyl eugenol	-	3.4
1,8-cineole	13.9	5.4	*trans*-α-bergamotene	0.6	2.6
γ-terpinene	0.4	0.1	α-guaiene	0.2	0.3
cis-linalool oxide†	0.4	0.2	α-humulene	-	0.5
trans-linalool oxide†	0.5	-	germacrene D	0.5	0.5
linalool	57.9	32.2	α-bulnesene	-	0.3
camphor	-	0.6	α-amorphene	0.5	1.2
borneol	-	0.5	(Z)-α-bisabolene	-	0.4
terpinen-4-ol	1.9	1.0	spathulenol	-	0.3
α-terpineol	0.8	-	caryophyllene oxide	-	0.3
methyl chavicol	-	32.4	α-cubebene‡	0.1	0.6
α-fenchyl acetate	0.2	-	bicyclosesquiphellandrene‡	-	2.8
bornyl acetate	-	0.7	α-cadinol	0.7	-

† furanoid form; ‡ incorrect identification based on GC elution order; t = trace (< 0.1 percent)

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M.C. Díaz-Maroto, M.S. Pérez-Coello and M.D.

Main components (%) of the leaf and flower oils of *Ocimum basilicum* grown in Algeria **T-15**

Compound	Leaf oil	Flower oil	Compound	Leaf oil	Flower oil
α-pinene	0.36	0.07	linalool	44.5	50.1
camphene	0.03	0.14	camphor	0.87	0.82
sabinene	0.03	0.02	α-copaene	0.08	0.06
β-pinene	0.02	0.02	methyl chavicol	4.32	3.79
1,8-cineole	0.67	0.33	(E)-methyl cinnamate	2.27	2.39
p-cymene	0.02	0.06	eugenol	38.42	36.35

Percentage composition of the oils of two cultivars of *Ocimum basilicum* grown in Italy **T-16**

Compound	cv. Rosso Ruffle oil	cv. Rosso Dark Opal oil	Compound	cv. Rosso Ruffle oil	cv. Rosso Dark Opal oil
α-pinene	0.12-0.60	0.11-0.51	terpinen-4-ol	0.33-0.45	0.20-0.28
camphene	0.01-0.04	0.02-0.11	α-terpineol	1.36-1.74	0.83-1.17
sabinene	0.12-0.56	0.17-0.40	methyl chavicol	4.48-10.00	0.22-1.97
β-pinene	0.45-1.54	0.43-1.04	α-fenchyl acetate	0.02-0.04	0.01-0.02
myrcene	0.59-2.30	0.45-1.17	bornyl acetate	0.03-0.08	0.20-0.46
α-terpinene	0.04-0.12	0.03-0.07	δ-elemene	0.02-0.06	0.03-0.08
p-cymene	0.01-0.03	0.01-0.03	eugenol	6.46-15.40	8.91-16.95
limonene	0.28-0.79	0.30-0.72	β-elemene	0.45-0.91	0.43-0.84
1,8-cineole	10.26-16.02	8.37-11.24	methyl eugenol	0.05-0.58	0.25-2.24
(Z)-β-ocimene	0.01-0.02	0.01-0.02	*trans*-α-bergamotene	3.12-5.69	0.22-0.41
(E)-β-ocimene	0.02-0.09	0.07-0.18	α-humulene	0.24-0.47	0.11-0.44
γ-terpinene	0.08-0.20	0.06-0.10	γ-humulene	0.11-0.24	0.06-0.11
p-menth-2-en-1-ol*	0.02-0.06	0.02-0.09	germacrene D	0.74-1.09	0.93-1.53
terpinolene	0.04-0.15	0.08-0.15	germacrene B‡	0.62-1.22	0.29-0.52
trans-sabinene hydrate	0.53-1.00	0.52-1.09	α-farnesene*	0.67-1.51	0.78-1.29
linalool	38.63-51.46	53.09-64.36	γ-cadinene	0.42-0.92	0.22-0.38
α-fenchol	0.02-0.04	0.03-0.05	calamenene*	0.21-0.39	0.05-0.09
camphor	0.02-0.06	0.84-1.16	cubenolol	0.21-0.38	0.11-0.15
borneol	0.29-0.38	0.21-0.34	T-cadinol	1.17-2.43	0.75-1.04

* correct isomer not identified; ‡ incorrect identification, should be bicyclogermacrene

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Cananga Oil

Cananga oil is obtained from the flowers of *Cananga odorata* (Lam.) J.D. Hook. et T. Thompson. It is produced commercially in Indonesia and to a much lesser extent in Vietnam.

An oil of cananga was subjected to chiral GC studies by König et al. (1994). They found that the enantiomeric distribution of δ-cadinene was:

(+)-δ-cadinene (94 percent): (-)-δ-cadinene (6 percent)

An oil produced from *C. odorata* flowers that were collected in Vietnam was analyzed by Phan et al. (2001). The components identified in this oil were as follows:

p-cresyl methyl ether (2.1 percent)
methyl benzoate (1.4 percent)
linalool (21.3 percent)
benzyl acetate (1.5 percent)
geraniol (0.7 percent)
α-copaene (0.2 percent)
geranyl acetate (6.2 percent)
β-caryophyllene (7.3 percent)
α-humulene (2.2 percent)
β-cubebene‡ + germacrene D + δ-cadinene (27.8 percent)
farnesene* (2.0 percent)
δ-cadinene (0.3 percent)
T-muurolol (1.2 percent)
α-cadinol (1.6 percent)
farnesol* (2.3 percent)
benzyl benzoate (13.4 percent)
farnesyl acetate* (1.1 percent)
benzyl salicylate (0.8 percent)

*correct isomer not identified; ‡incorrect identification based on GC elution order

Using a combination of GC and ^{13}C-NMR, Kubeczka and Formacek (2002) analyzed an oil of cananga and found that it contained the following constituents:

α-pinene (0.14 percent)
sabinene (0.15 percent)
myrcene (0.43 percent)
α-terpinene (0.14 percent)
γ-terpinene (0.20 percent)
p-cresyl methyl ether (2.56 percent)
α-cubebene (0.28 percent)
α-ylangene (0.21 percent)
α-copaene (1.76 percent)
linalool (5.58 percent)
β-ylangene (0.32 percent)
β-guaiene* (0.89 percent)
β-caryophyllene (38.17 percent)
cadina-3,5-diene (0.40 percent)
α-elemene + methyl chavicol (0.49 percent)
α-humulene (9.18 percent)
γ-muurolene (2.69 percent)
(Z,Z)-α-farnesene (4.38 percent)
germacrene D (8.33 percent)
bicyclosesquiphellandrene (1.10 percent)
α-muurolene (1.49 percent)
bicyclogermacrene (0.51 percent)
(E,E)-α-farnesene (3.75 percent)
δ-cadinene (5.96 percent)
geranyl acetate (1.49 percent)
cadina-1,4-diene (0.26 percent)
α-cadinene (0.26 percent)
calamenene* (0.13 percent)
geraniol (1.45 percent)
caryophyllene oxide (0.13 percent)
methyl eugenol (0.07 percent)
nerolidol* (0.06 percent)
cubenol (0.43 percent)
epi-cubenol (0.22 percent)
elemol (0.36 percent)
eugenol (0.53 percent)
T-cadinol (0.45 percent)
T-muurolol (0.61 percent)
α-muurolol (0.37 percent)
α-cadinol (1.07 percent)
(E,E)-farnesyl acetate (0.08 percent)
(E,E)-farnesol (0.80 percent)
benzyl benzoate (1.96 percent)
benzyl salicylate (0.07 percent)

*correct isomer not identified

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Lovage Oil

The enantiomeric ratio of β-phellandrene in lovage root oil was found by Casabianca (1996) using chiral GC to be as follows:

(4R)-(+)-β-phellandrene (100 percent): (4S)-(-)-β-phellandrene (0 percent)

Gora et al. (1997) found that the main constituents of Polish lovage root oil were pentylcyclohexa-1,5-diene (11.3 percent) and 3-butylidene phthalide (47.0 percent).

Valterova et al. (1997) examined the monoterpene hydrocarbon content of small lovage plants. The compounds identified in the headspace above the plants using Porpak Q as the trapping agent were as follows:

α-pinene (8.2 percent)
camphene (1.8 percent)
β-pinene (2.8 percent)
sabinene (3.9 percent)
δ-3-carene (1.0 percent)
myrcene (9.3 percent)
α-phellandrene (0.5 percent)
α-terpinene (0.3 percent)
limonene (3.0 percent)
β-phellandrene (60.5 percent)
(Z)-β-ocimene (6.4 percent)
γ-terpinene (1.2 percent)
(E)-β-ocimene (0.2 percent)
p-cymene (0.7 percent)
terpinolene (0.1 percent)

Using chiral GC analysis the authors also determined the enantiomeric ratio

Comparative percentage composition of an oil produced by SDE and the headspace produced by SPME and Tenax adsorption of dried lovage roots **T-17**

Compound	Oil	Headspace SPME	Headspace Tenax	Compound	Oil	Headspace SPME	Headspace Tenax
α-pinene	0.41	0.76	0.19	terpinen-4-ol	0.04	-	-
camphene	0.14	0.23	-	α-terpineol	0.02	-	-
sabinene	0.11	0.35	0.11	α-terpinyl acetate	1.55	0.82	0.37
β-pinene	0.84	1.14	0.37	α-copaene	0.22	0.50	0.73
myrcene	0.11	0.19	0.59	β-farnesene*	0.02	0.05	-
octanal	0.11	0.03	0.13	germacrene D	0.02	0.04	-
α-phellandrene	0.07	0.17	0.18	β-selinene	0.75	0.77	0.73
α-terpinene	0.02	-	-	δ-cadinene	0.59	0.36	0.32
p-cymene	0.03	-	-	germacrene B	0.10	0.42	-
β-phellandrene	3.41	1.37	9.15	α-cadinol	0.16	-	-
limonene	0.25	-	-	propylidene phthalide	0.09	-	-
β-ocimene*	0.21	1.50	1.32	(Z)-butylidene phthalide	2.25	0.12	-
γ-terpinene	0.10	0.30	1.32	(E)-butylidene phthalide	0.25	-	-
terpinolene	0.18	0.85	1.04	sedanolide+	83.74	1.33	-

* correct isomer not identified; + also known as 3-butyl-3a,4,5,6-tetrahydrophthalide

of seven of the monoterpene hydrocarbons, the results of which were as follows:

(1R, 5R)-(+)-α-pinene (34 percent): (1S, 5S)-(-)-α-pinene (66 percent)

(3R)-(+)-camphene (47 percent): (3S)-(-)-camphene (53 percent)

(1R, 5R)-(+)-β-pinene (77 percent): (1S, 5S)-(-)-β-pinene (23 percent)

(1R, 5R)-(+)-sabinene (70 percent): (1S, 5S)-(-)-sabinene (30 percent)

(1R, 6R)-(+)-δ-3-carene (100 percent): (1S, 6S)-(-)-δ-3-carene (0 percent)

(4R)-(+)-limonene (53 percent): (4S)-(-)-limonene (47 percent)

(4R)-(+)-β-phellandrene (99 percent): (4S)-(-)-β-phellandrene (1 percent)

Dauksas et al. (1999) used supercritical fluid CO_2 extraction to isolate and examine the main constituents of the above ground parts of *Levislicum officinale*. The authors used a solvent recirculating system with two separators that were operated using two different sets of parameters. The yield of extract from the two separators for extraction of the leaves and stems was 1.59 percent and 0.13 percent, respectively. The main components in the larger extract were β-phellandrene (< 0.1 percent), α-terpinyl acetate (26.4 percent) and phthalides (35.6 percent). It was also found that the lovage seed extracts from the two separators were 4.77 percent and 0.15 percent, respectively, and the major constituents of the larger extract were β-phellandrene (17.4 percent), α-terpinyl acetate (2.8 percent) and phthalides (28.3 percent). Furthermore, on examination of the parameters used for extraction, the authors found that the flow rate of CO_2 did not affect the recovery of α-terpinyl acetate, while its solubility was affected by CO_2 pressure and temperature. However, the effect of CO_2 pressure and temperature on the solubility of phthalides was found to be considerably much more than the effect on α-terpinyl acetate.

Bylaite et al. (2000) obtained the volatiles of the leaves, stems, flowers, seeds and roots of lovage (grown in Lithuania) by dynamic headspace and GC. Unfortunately, the authors presented an unusal set of quantitative data that was more complex than necessary, as a result only the qualitative data will be reviewed. In addition, the authors characterized a number of constituents previously unreported as constituents of lovage. These compounds were 2-methyl-2-propenal, (Z)-salvene, isolimonene, isoamyl 2-methylbutyrate, 2-octanone, isoamyl isovalerate, 2-ethyl-2-hexenal, 4-nonanone, 6-methyl-5-hepten-2-one, 2-nonanone, α-thujone, p-metha-1,3,8-triene, β-thujone, *trans*-sabinene hydrate, hexylbenzene, 6-undecanone, propionic acid, (E)-2-nonenal, 2-methyl-6-methylene-octa-1,7-dien-3-one, methyl thymol, butyric acid, p-2-butyl anisole, methyl chavicol, α-humulene, valeric acid, decanol, α-phellandrene epoxide, p-mentha-1,3-dien-7-al, 7-epi-α-selinene, octanoic acid, nonanoic acid, carvacrol, 4-pentylphenol, 5-hydroxy-p-menth-6-en-2-one and benzoic acid.

Of the above listed compounds, only 2-octanone, 2-nonanone, hexylbenzene, (E)-2-nonenal,

Comparative percentage composition of lovage root extracted with two different solvent systems **T-18**

Compound	Pentane/diethyl ether extract	Methylene chloride extract	Compound	Pentane/diethyl ether extract	Methylene chloride extract
α-pinene	1.14	1.57	α-terpinyl acetate	1.22	1.28
camphene	0.19	0.31	α-copaene	0.08	0.22
sabinene	0.30	0.17	germacrene D	0.08	0.08
β-pinene	1.50	1.99	β-farnesene*	0.06	0.18
myrcene	0.24	0.07	β-selinene	0.17	1.13
octanal	0.19	0.27	δ-cadinene	0.27	0.43
α-phellandrene	0.21	0.11	germacrene B	0.08	0.11
β-phellandrene	1.53	2.90	propylidene phthalide	0.14	0.06
δ-3-carene	-	0.31	(Z)-butylidene phthalide	5.19	3.84
γ-terpinene	0.25	0.08	(E)-butylidene phthalide	0.07	0.73
terpinolene	1.83	2.34	sedanolide	63.12	57.52
terpinen-4-ol	0.24	-			

* correct isomer not identified

butyric acid, p-2-butyl anisole, 7-epi-α-selinene and hexanoic acid were found in lovage root headspace. Finally, it should be noted that the authors reported that dibutyl phthalate was a constituent of lovage. This was in error because this compound is a plasticizer that does not occur naturally.

Majchrzak et al. (2001) compared the composition of an oil produced by simultaneous distillation-extraction with the headspace of dried lovage roots (of Polish origin) produced either by SPME (using PDMS fibre) or purge and trap with Tenax as the absorbent. The results of these comparative analyses are presented in Table XVII. The authors also compared the composition of two extracts of the same batch of dried lovage roots. The extract analyses, which were produced either by pentane-diethylether or methylene chloride, can be seen in Table XVIII. It is of interest to note that the solvent extracts are quite similar even though the polarity of the two solvent systems are dissimilar.

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