Progress in Essential Oils

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Basil Oil: Part 1[a]

Basil oil is obtained by steam and water or steam distillation from *Ocimum basilicum* L., a tender, aromatic, annual herbaceous member of the Lamiaceae that is thought to originate from tropical Asia (Paton and Putievsky, 1996).

Although the center of diversity of basil is not known, it is widely cultivated in tropical and subtropical countries such as Comoro Islands, India, South Africa, Thailand, Vietnam, etc.; Mediterranean region climates such as Egypt, Israel, Italy, Turkey, United States, etc.; and temperate countries such as France, Hungary, Poland, etc. Basil is grown throughout the world as both a culinary herb and for use in traditional medicine. Its cultivation has taken place for more than 2,500 years. As a result, various cultivars have been selected based on its morphological traits, as well as its aromatic properties (Darrah, 1974). They can be categorized as: Group 1. large green leaf types; Group 2. large-medium-sized purple leaf types; Group 3. medium-sized green leaf types; Group 4. compact flower types; Group 5. Purple stem types; and Group 6. Colored flower types.

Oils of 14 basil cultivars of various origins were analyzed by Holm et al. (1989). The cultivars, which were grown in Finland, were found to exist in the following chemotypic forms:

1. linalool-rich and methyl chavicol-rich (four cultivars)
2. linalool-rich (four cultivars)
3. linalool- and eugenol-rich (one cultivar)
4. methyl cinnamate-rich (three cultivars)
5. 1,8-cineole-rich (two cultivars)

Maheshwari (1995) compared the composition of basil oil produced commercially in Madagascar and India with oils produced in the laboratory from plants introduced into India from Madagascar and Reunion. The composition of these oils, which were rich in linalool, can be seen in **T-1**.

Chalchat et al. (1999) examined the composition of oils produced from two linalool-rich chemotypes of *O. basilicum* L. found in Mali. The authors examined the composition of oils produced from both fresh and dried basil. The results obtained from the oils produced from dried basil by steam distillation can be found in **T-2**.

Gionfriddo et al. (2001) examined three different collections of *O. basilicum* obtained from different areas in Calabria (Italy). Oils produced from these plants in the laboratory were found to possess the following major components:

- linalool (38.0–48.7%)
- terpinen-4-ol (0.6–3.3%)
- eugenol (6.0–7.3%)
- methyl chavicol (1.8–6.0%)
- T-cadinol (5.2–9.0%)

Dhar (2002) reported that the composition of oils produced in India from three clones of Egyptian basil (rich in linalool) were as follows:

- low boilers (0.5–2.6%)
- 1,8-cineole + (Z)-β-ocimene (3.2–6.6%)
- (E)-β-ocimene (0.2–1.1%)
- linalool (49.0–53.7%)
- camphor (1.0–1.7%)
- borneol (t–0.5%)
- terpinen-4-ol (t–2.2%)
- methyl chavicol (4.2–7.3%)

T-1. Comparative percentage composition of methyl chavicol-rich basil of different origins

Compound	Madagascan oil	Indian oil	Experimental Reunion oil	Experimental Madagascan oil
low boilers	0.59	0.13	0.57	0.41
1,8-cineole + (Z)-β-ocimene	1.33	0.17	1.12	0.54
(E)-β-ocimene	0.07	0.09	1.66	0.75
linalool	1.17	16.18	2.23	6.67
camphor	0.29	0.15	0.55	1.27
borneol	0.04	0.20	0.12	0.18
terpinen-4-ol	t	0.93	t	t
methyl chavicol	86.23	73.09	84.05	74.21
anisaldehyde	0.02	0.30	t	t
geraniol	0.38	1.04	t	0.27
(E)-anethole + bornyl acetate	0.25	0.99	1.19	0.32
eugenol	0.13	t	0.02	0.14
methyl eugenol	1.95	0.14	0.45	2.51
β-elemene	0.42	0.27	0.55	1.14
β-caryophyllene	1.57	1.32	1.01	2.32
α-humulene	0.23	0.33	0.60	0.64
eugenyl acetate	t	t	0.61	0.39
p-methoxy-cinnamyl alcohol	t	0.61	t	t

t=trace (<0.01%)

[a]Read Part 2 of this article in the June 2014 issue of *Perfumer & Flavorist* Magazine; *www.perfumerflavorist.com/magazine/*.

anisaldehyde[†] (t–0.3%)
geraniol (0.1–1.7%)
(E)-anethole + bornyl acetate (0.3–1.4%)
eugenol (5.4–9.5%)
methyl (E)-cinnamate (0.2–0.3%)
geranyl acetate (0.3%)
β-elemene (1.6–3.0%)
β-caryophyllene (5.0–5.4%)
α-humulene (1.0–1.5%)
eugenyl acetate[†] (2.9–4.4%)
isoeugenyl acetate[†] (0.1–0.4%)

t=trace (<0.05%)
[*]correct isomer not identified
[†]incorrect identification

Omidbaigi et al. (2003) showed that water stress on basil plants resulted in a major change in the composition of essential oil obtained from them. The authors compared different irrigation regimes (100%, 85%, 70% and 55% of field capacity) on the oil yield and composition. Although they found that the oil yields were 1.12%, 1.04%, 1.26% and 0.99%, respectively, only the oil produced at the lowest level from the 55% field capacity showed the effect of irrigation on composition. A comparison in the compositions of oils produced from plants grown under 100% and 55% field capacity irrigation can be seen in **T-3**.

The aerial parts of *O. basilicum* that were collected near Agerola (Italy) were hydrodistilled to produce an oil that was screened for its antibacterial activity by Senatore et al. (2003). The composition of this oil, which was not found to possess any useful antibacterial properties, was determined to be as follows:

α-thujene (0.3%)
camphene (0.1%)
β-pinene (0.4%)
myrcene (0.1%)
β-phellandrene (1.2%)
1,8-cineole (0.3%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (0.8%)
linalool (0.8%)
borneol (0.1%)
methyl chavicol (85.7%)
bornyl acetate (0.1%)
methyl eugenol (0.2%)
β-elemene (0.1%)
β-caryophyllene (0.6%)
trans-α-bergamotene (1.0%)
germacrene D (1.3%)
spathulenol (0.3%)
T-cadinol (0.1%)

Trace amounts (<0.1%) of sabinene, terpinolene, camphor, α-humulene and γ-cadinene were also found in this oil.

T-2. Percentage composition of two types of basil oil from different regions in Mali

Compound	Type 1 oils	Type 2 oils
α-pinene	0.2–0.8	0.1–0.2
α-thujene	t–0.2	-
camphene	t–0.2	0.1–0.2
β-pinene	0.2–1.3	0.1–0.2
sabinene	t–0.4	t–0.2
myrcene	0.2–0.9	1.3–1.6
α-terpinene	0.1–0.3	t
limonene	0.3–1.0	0.2–0.4
1,8-cineole	1.8–5.1	1.2–1.9
(Z)-β-ocimene	t–0.5	0.1–0.2
γ-terpinene	0.3–0.5	t–0.2
(E)-β-ocimene	0.8–2.6	1.1–4.1
p-cymene	0.2–0.4	0.1
terpinolene	0.1–0.5	0.1–0.2
(Z)-3-hexenol	-	t–0.2
fenchone	0.5–1.9	-
α-fenchyl acetate	0.2–0.4	0.2–0.4
camphor	0.2–0.4	-
linalool	42.7–60.5	61.7–73.1
bornyl acetate	-	0.1–0.2
α-fenchol	-	1.0–1.3
β-caryophyllene + β-elemene	4.3–8.7	3.2–4.6
α-farnesene[*]	2.0–5.5	-
α-humulene	0.1–0.2	0.2
methyl chavicol	1.2–12.2	0.3–2.4
borneol	-	0.3–1.0
(E)-β-farnesene	(0.3–0.7)	-
(Z)-β-farnesene	0.3–1.7	-
α-terpineol	0.6–1.7	0.5–0.7
δ-guaiene	0.3–0.7	0.4–0.8
α-terpinyl acetate	-	0.3–0.7
geranial	t–0.7	-
α-amorphene	1.0–3.1	1.9–3.2
nerol	0.1–0.4	0.1–0.2
geraniol	0.5–1.5	0.3–0.6
methyl eugenol	0.7–10.9	t–0.3
cubenol	0.1–0.5	1.2–1.8
nerolidol[*]	0.3–0.5	0.5–0.8
spathulenol	t–0.2	0.1–0.2
eugenol	2.6–21.2	3.2–12.8
T-cadinol	2.6–4.8	3.2–5.2
β-eudesmol	t–0.1	-

t=trace (<0.05%); [*]correct isomer not identified

The headspace volatiles of an oil of *O. basilicum* that were determined by Jirovetz et al. (2003) using GC-FID and GC/MS were found to be as follows:

1-hexen-3-ol (0.1%)
(E)-2-hexenal (0.1%)
(Z)-3-hexenol (0.4%)
(E)-2-hexenol (0.1%)
1-octen-3-ol (0.5%)
p-cymene (0.1%)
limonene (0.1%)
(Z)-β-ocimene (0.1%)
terpinolene (0.1%)
1,8-cineole (0.5%)
cis-linalool oxide[f] (0.1%)
trans-linalool oxidef (0.1%)
linalool (28.4%)
α-fenchol (0.2%)
camphor (13.1%)
borneol (0.3%)
terpinen-4-ol (1.3%)
myrtenal (0.2%)
α-terpineol (0.3%)

T-3. Comparative percentage composition of oils produced from plants grown under different irrigation regimes

Compound	Ia oil	Ib oil
α-thujene	-	0.7
sabinene	-	1.8
β-pinene	0.4	-
myrcene	2.2	4.2
1,8-cineole	3.6	16.5
(E)-β-ocimene	2.0	3.4
γ-terpinene	-	0.1
trans-sabinene hydrate	-	0.2
terpinolene	-	0.1
linalool	65.3	25.1
camphor	0.7	0.1
verbenol*	-	0.5
pinocarvone	-	0.9
δ-terpineol	-	0.5
terpinen-4-ol	0.3	0.2
methyl chavicol	2.7	6.6
decanal	-	0.7
geranial	0.8	0.6
bornyl acetate	0.5	1.3
eugenol	2.9	5.9
geranyl acetate	0.4	0.5
methyl eugenol	1.4	5.6
β-elemene	1.8	0.1
cis-α-bergamotene	0.3	0.5
trans-α-bergamotene	3.9	6.9
α-cadinene	-	0.4
(Z)-β-farnesene	0.6	1.0
α-humulene	0.3	0.4
γ-muurolene	1.9	2.2
germacrene D	-	0.1
allo-aromadendrene	0.8	0.6
bicyclogermacrene	0.7	0.5
α-selinene	1.2	2.1
γ-cadinene	-	0.1
cis-calamenene	-	0.3
spathulenol	0.4	<0.1
cubenol	0.6	0.8
β-eudesmol	4.1	5.7

Ia = 100% field irrigation capacity; Ib = 55% field irrigation capacity

methyl chavicol (0.9%)
nerol (0.2%)
neral (0.1%)
geraniol (3.8%)
geranial (0.3%)
myrtenol (0.8%)
thymol (0.1%)
δ-elemene (0.1%)
eugenol (0.1%)
methyl (Z)-cinnamate (34.5%)
methyl (E)-cinnamate (6.9%)
methyl eugenol (0.3%)
β-caryophyllene (1.0%)
α-bergamotene* (0.1%)
aromadendrene (0.4%)
(E)-β-farnesene (0.2%)
α-humulene (0.2%)
γ-muurolene (0.1%)
germacrene D (0.2%)
α-selinene (0.1%)
bicyclogermacrene (0.1%)
(E,E)-α-farnesene (0.1%)
α-bisabolene* (0.1%)
δ-cadinene (0.1%)
nerolidol* (0.1%)
globulol (0.1%)
spathulenol (0.1%)
caryophyllene oxide (0.1%)
T-cadinol (1.3%)
α-cadinol (0.1%)
α-eudesmol (0.1%)
α-bisabolol (0.1%)

*correct isomer not identified; [f]furanoid form

In addition, trace amounts (<0.05%) of hexanal, 2-hexanol, hexanol, (E,E)-2,4-hexadienal, 3-octanol, (Z)-3-hexenyl acetate, (E)-2-hexenyl acetate, α-thujene, camphene, sabinene, β-pinene, myrcene, δ-3-carene, α-terpinene, (E)-β-ocimene, γ-terpinene, *trans*-sabinene hydrate, fenchone, *trans*-verbenol, *cis*-verbenol, carvacrol, α-copaene, β-bourbonene, β-cubebene, α-gurjunene, β-gurjunene, an amorphene isomer, allo-aromadendrene, α-guaiene, ledene, α-cadinene, g-cadinene, germacrene B, guaiol, β-bisabolol, T-muurolol, α-muurolol and an isomer of α-bergamotol were characterized in this oil.

The oil content and composition of *O. basilicum* plants harvested at two different times of the day over two seasons from the experimental garden of the Universidade Federal de Viçosa (Brazil) was the subject of study by Silva et al. (2003). It was found that the oil content was higher in January than in August and highest in the morning vs the afternoon. The oils, which were analyzed by GC/MS only, were found to contain the same constituents irrespective of the season or time of harvest. The composition was determined to be as follows:

1,8-cineol (1.2%)
linalool (21.2%)
terpinen-4-ol (1.3%)
α-terpineol (1.1%)
neral (4.9%)
geranial (8.5%)
2-undecanone (1.5%)
eugenol (32.6%)
methyl eugenol (3.6%)
trans-α-bergamotene (1.6%)
(E)-β-farnesene (1.1%)
α-muurolol (1.3%)
hexadecanol (2.8%)
hexadecanoic acid (5.8%)

The characterization of neral, geranial and eugenol probably indicates a hybrid rather than a pure *O. basilicum*.

Kumar et al. (2004) collected open pollinated seeds of *O. basilicum* from an experimental garden in Lucknow. The seeds were subsequently nursery raised and transplanted at a 60 m x 400 m spacing. From this planting, 30 randomly selected plants were harvested when in full flower, separated into flowers, stems and foliage. Fifteen of the 30 plants (flowers and leaves) were separately hydrodistilled oils and their oils were analyzed by GC-FID. The results revealed that the oils could be separated into two groups:

- Group I. Oils rich in methyl chavicol (>90%) and linalool (0.1–1.0%).
- Group II. Oils containing methyl chavicol (47.5–72.3%) and linalool (22.4–34.4%).

In addition, a number of minor constituents were also characterized in the oils at levels of 2.2–6.0% in the leaf oils and 2.2–7.8% in the flower oils. The range of minor constituents characterized by Kumar et al. was as follows:

citronellol (1.0–4.3%)
α-fenchyl alcohol (t–1.7%)
α-terpineol (t–2.2%)
β-ocimene* (0–0.5%)
α-fenchyl acetate (0–0.1%)
methyl (E)-cinnamate (0–0.1%)
myrcene (0–0.1%)
(Z)-3-hexenol (0–01%)
camphor (0–0.1%)
limonene (0–0.1%
p-cymene (0–0.1%)

t=trace (<0.05%); *correct isomer not identified

The volatiles of the Italian basil cultivar 'Gigante Napoletano,' which were obtained using the purge and trap technique, were analyzed using GC/MS only by De Luca et al. (2004). The volatiles, which were rich in linalool and methyl chavicol, were found to contain hexanal, 2,3-dimethyl-1-pentene, an isomer of 2-hexenal, octanal, 6-methyl-5-hepten-2-one, nonanal, 1-hexenol, an isomer of 3-hexenol, (E)-2-octenal, octyl acetate, α-pinene, camphene, β-pinene, α-phellandrene, myrcene, α-terpinene, limonene, an ocimene isomer, p-cymene, terpinolene, dimethyl sulfide, 2-ethylfuran, α-copaene, an isomer of α-bergamotene, γ-muurolene, β-cubebene, γ-elemene, γ-cadinene, cadina-1,3,5-triene, β-sesquiphellandrene, T- cadinol, 1,8-cineole, camphor, linalool, *cis*-sabinene hydrate, terpinen-4-ol, α-terpineol, methyl chavicol, 1,2-benzothiazole, methyl eugenol and eugenol.

Lucchesi et al. (2004) compared the oil composition of *O. basilicum* produced from plants grown in Reunion by either microwave distillation and hydrodistillation. The results of this GC/MS study can be seen in **T-4**. Examination of the data presented reveals that although the oil yields were similar, the production time for the microwave distilled oil was only 30 mins as compared to 270 min for hydrodistilled oil.

T-4. Comparative percentage composition of basil oil produced by two different isolation procedures

Compound	Microwave-distilled oil	Hydrodistilled oil
α-pinene	-	0.2
sabinene	-	0.4
β-pinene	-	1.1
myrcene	0.1	1.0
1,8-cineole	1.3	5.8
(E)-β-ocimene	0.2	2.0
γ-terpinene	-	0.2
cis-sabinene hydrate	0.1	-
terpinolene	-	0.3
linalool	25.3	39.1
camphor	0.3	0.3
borneol	0.6	0.9
terpinen-4-ol	0.1	0.4
α-terpineol	1.3	1.4
geraniol	0.5	0.5
bornyl acetate	0.7	1.1
eugenol	43.2	11.0
β-elemene	2.4	3.2
methyl eugenol	-	0.1
β-caryophyllene	1.0	-
trans-α-bergamotene	6.0	7.6
α-humulene	0.8	1.0
neryl propionate	-	0.8
γ-muurolene	2.8	4.2
bicyclogermacrene	1.4	1.8
δ-guaiene	0.9	1.0
γ-cadinene	2.2	3.1
cis-calamenene	-	1.4
eugenyl acetate	1.6	-
T-cadinol	5.6	6.7
cis-phytol	-	0.9
oil yield (fresh wt basis)	0.029%	0.028%
oil isolation time	30 min	270 min

A sample of Indian basil oil (methyl chavicol-rich) was reported (Anon, 2004) to possess the following composition:

α-pinene (0.03%)
sabinene (0.02%)
β-pinene (0.03%)
6-methyl-5-hepten-2-one (0.08%)
myrcene (0.02%)
(Z)-3-hexenyl acetate (0.02%)
limonene (0.02%)
1,8-cineole (0.04%)
β-ocimene* (0.04%)
octanol (0.03%)
linalool oxide I* (0.10%)
linalool oxide II* (0.16%)
6-methyl-3,5-heptadien-2-one (0.02%)
menthone (0.01%)
menthol (0.08%)
α-terpineol (0.02%)
methyl chavicol (74.27%)
nerol (0.03%)
neral (0.82%)
carvone (0.03%)
chavicol (0.04%)
geraniol (0.07%)
anisaldehyde (0.06%)
piperitone (0.02%)
geranial (1.26%)
(E)-anethole (0.08%)

eugenol (0.06%)
neryl acetate (0.03%)
α-copaene (0.06%)
β-elemene (0.06%)
methyl eugenol (0.05%)
α-gurjunene (0.06%)
β-caryophyllene (0.60%)
cis-α-bergamotene (0.66%)
β-sesquiphellandrene (0.08%)
α-humulene (0.15%)
allo-aromadendrene (0.02%)
ar-curcumene (0.03%)
germacrene D (0.31%)
β-bisabolene (0.11%)
γ-cadinene (0.01%)
δ-cadinene (0.03%)
(Z)-α-bisabolene (1.59%)
nerolidol* (0.02%)
3-methoxycinnamaldehyde (0.48%)
spathulenol (0.01%)
α-bisabolol (0.03%)

*correct isomer not identified

An oil produced by hydrodistillation from *O. basilicum* collected from Mersin (Büyükeceli-Gülnar, Turkey) was determined to be the first example of a new chemotype of basil. The unusual composition was found by Ozcan and Chalchat (2004) to be as follows:

α-pinene (0.1%)
β-pinene (0.4%)
1-octen-3-ol (0.2%)
myrcene (3.3%)
p-cymene (0.3%)
1,8-cineole (3.2%)
(Z)-β-ocimene (2.0%)
(E)-β-ocimene (2.1%)
γ-terpinene (0.3%)
p-mentha-2,4(8)-diene (0.2%)
linalool (17.2%)
amyl isovalerate (0.2%)
1-octen-3-yl acetate (0.2%)
3-octyl acetate (0.3%)
(E,E)-allo-ocimene (3.0%)
camphor (0.1%)
δ-terpineol (<0.1%)
terpinen-4-ol (0.1%)
α-terpineol (0.8%)
linalyl acetate (55.2%)
lavandulyl acetate (0.3%)
neryl acetate (0.9%)
geranyl acetate (1.4%)
α-gurjunene (0.2%)
β-caryophyllene (1.2%)
α-copaene† (0.1%)
α-humulene (0.5%)
chrysanthenyl acetate† (0.3%)
germacrene D (0.5%)
δ-cadinene (0.2%)
elemol (2.9%)
caryophyllene oxide (0.1%)
viridiflorol (0.4%)
γ-eudesmol (0.2%)
β-eudesmol (0.2%)
α-eudesmol (0.2%)

†incorrect identification based on GC elution order

Pilania et al. (2005) examined the main component variation in oils of *O. basilicum* germplasm introduced into India. They found that the oils contained either methyl chavicol (73.7–86.6%), linalool (72.7–76.7%), methyl chavicol and linalool (62.1% and 26 .8%) or linalool and methyl chavicol (50.3–65.8% and 9.8–20.9%).

Kasali et al. (2005) reported finding a new chemotype of *O. basilicum* in Nigeria. The authors of this study must have been oblivious of the vast literature on basil oil as the oil composition on basil oil. Consequently, it is hardly important that it is new to Nigeria as the oil composition of the Nigerian basil is extremely common. The components identified in the oil were:

α-pinene (2.7%)
sabinene (1.2%)
β-pinene (2.1%)
myrcene (0.6%)

δ-3-carene (0.3%)
p-cymene (0.1%)
1,8-cineole (3.1%)
limonene (1.1%)
(E)-β-ocimene (0.3%)
γ-terpinene (1.2%)
fenchone (0.1%)
terpinolene (1.3%)
linalool (10.8%)
terpinen-4-ol (1.2%)
α-terpineol (0.4%)
methyl chavicol (60.3%)
linalyl acetate (0.2%)
methyl (Z)-cinnamate† (6.3%)
β-elemene (0.2%)
γ-muurolene (0.7%)
(E,E)-α-farnesene (0.2%)
α-bulnesene (0.1%)
γ-cadinene (0.4%)
T-cadinol (0.1%)

†misidentification of methyl (E)-cinnamate

As part of a screening program to examine the antimicrobial characteristics of Nepalese oils, Yonzon et al. (2005) determined that a sample of basil oil produced in Nepal contained the following major constituents:

1,8-cineole (5.8%)
p-cymene (1.2%)
linalool (37.1%)
bornyl acetate (1.5%)
α-bergamotene* (7.7%)
β-elemene (1.4%)
terpinen-4-ol (3.6%)
α-terpineol (1.1%)
germacrene D (2.5%)
geranyl acetate (1.1%)
α-amorphene (4.8%)
geraniol (8.9%)
eugenol (6.3%)

*correct isomer not identified

A commercial oil of basil that was screened against foodborne microbes was determined by Lopez et al. (2005) to possess the following headspace composition:

α-pinene (0.1%)
β-pinene (0.3%)
myrcene (0.2%)
limonene (0.2%)
1,8-cineole (6.5%)
(Z)-β-ocimene (0.9%)
fenchene (0.3%)
linalool (1.6%)
α-fenchol (0.2%)
camphor (1.1%)
menthone† (0.2%)
borneol (0.2%)
menthol† (1.6%)
methyl chavicol (82.0%)
α-fenchyl acetate (0.2%)
pulegone† (0.1%)
(Z)-anethole (0.1%)
bornyl acetate (0.2%)
(E)-anethole (0.4%)
safrole† (0.1%)
eugenol (0.5%)
methyl eugenol (0.2%)
β-caryophyllene (0.1%)
α-bergamotene* (2.0%)
α-humulene (0.1%)
β-cubebene (0.1%)
γ-cadinene (0.2%)

*correct isomer not identified; †incorrect identification

Oils produced from the Italian basil cultivars 'Genovese' and 'Foglia Lattuga' (lettuce leaf), which were isolated using a Likens-Nickerson (simultaneous distillation and solvent extraction) apparatus, were the subject of analysis by Elementi et al. (2006). The compositions of both oils, which were linalool-rich, can be

T-5. Comparative percentage composition of the oils of the basil cultivars 'Genovese' and 'Foglia Lattuga'

Compound	'Genovese' oil	'Foglia Lattuga' oil
(E)-2-hexenal	0.1–0.7	0–0.7
α-pinene	0.3–1.1	0.2–1.4
camphene	0–0.5	0–0.4
sabinene	0.2–0.9	0.2–0.7
β-pinene	0.3–1.8	0–1.5
1-octen-3-ol	0.2–1.0	0.2–0.7
myrcene	0.3–4.2	0.3–1.2
limonene	0.1–1.7	0.1–0.9
1,8-cineole	6.2–21.4	5.1–18.0
(E)-β-ocimene	0–2.6	0–1.2
γ-terpinene	0–0.4	0–0.9
cis-sabinene hydrate	0–0.2	0–0.4
isoterpinolene†	0–0.6	0–0.4
linalool	41.5–60.9	20.8–60.3
camphor	0.1–1.5	0–2.0
isoborneol	0.1–1.3	0.1–0.3
menthone	0.1–0.4	0–0.2
terpinen-4-ol	0–0.6	0–0.2
α-terpineol	0.5–2.8	0.5–1.4
methyl chavicol	0–30.6	0.1–49.2
bornyl acetate	0.1–0.8	0–0.4
eugenol	0.8–25.2	0.3–19.9
methyl eugenol	0–2.9	0.1–0.4
trans-α-bergamotene	1.6–7.3	1.4–8.0
α-guaiene	0.1–0.2	0–0.2
(Z)-β-farnesene	0–1.5	0.1–0.6
α-humulene	0.1–0.2	0.1–0.2
(E)-β-farnesene	0.1–0.4	0.2–0.5
cis-muurola-4(14),5-diene	0.1–0.4	0.1–0.5
germacrene D	0.4–2.7	0.2–2.1
bicyclogermacrene	0.2–1.2	0–1.0
germacrene A	0–0.6	0–1.0
α-bulnesene	0–0.9	0–1.0
(E,E)-α-farnesene	0–0.3	0–0.2
γ-cadinene	0.5–2.3	0.5–2.3
calamenene*	0–0.1	0–0.2
β-sesquiphellandrene	0.1–0.4	0–0.5
1,10-di-epi-cubenol	0–1.8	0.1–0.5
T-cadinol	0.5–3.9	1.0–4.5

*correct isomer not identified; †incorrect identification seen in **T-5**. The results show that the oil composition of several selections of the two cultivars is quite varied particularly with respect to the methyl chavicol, 1,8-cineole and eugenol contents. This shows that oil compositions are strongly influenced by cross-pollination of basil cultivars when the cultivars are known to possess different oil compositions.

Aerial parts of green and purple cultivars of *O. basilicum* that were grown in Isfahan (Iran) were found to possess oil yields of 0.2% and 0.5%, respectively, when hydrodistilled for 3 hr. Analysis of these oils by Sajjadi (2006) using GC/MS only revealed that the composition of the green cultivar oil was:

1-octen-3-ol (0.3%)
methyl chavicol (40.5%)
neral (18.5%)
geranial (27.6%)
β-caryophyllene (1.6%)
trans-α-bergamotene (0.8%)
α-humulene (1.1%)
caryophyllene oxide (5.4%)
humulene epoxide II (1.8%)

Sajjadi also reported that the composition of the purple cultivar oil was as follows:

1-octen-3-ol (0.4%)
1,8-cineole (2.4%)
linalool (20.1%)
terpinen-4-ol (0.8%)
methyl chavicol (52.4%)
β-caryophyllene (1.2%)
trans-α-bergamotene (5.2%)
α-humulene (0.5%)
germacrene D (1.8%)
germacrene A (0.7%)
γ-cadinene (1.8%)
spathulenol (0.9%)
caryophyllene oxide (1.4%)
humulene epoxide II (0.3%)
T-cadinol (5.9%)
β-eudesmol (0.2%)

A commercial sample of basil oil that was purchased in Italy was screened in guinea pig and rat plasma for its antiplatelet activity and inhibition of the clotting reaction. The oil, which was analyzed by GC-FID and GC/MS by Tognolini et al. (2006), was determined to possess the following composition:

α-pinene (0.1%)
camphene (0.1%)
β-pinene (0.5%)
myrcene (0.3%)
1,8-cineole (5.1%)
(Z)-β-ocimene (0.6%)
γ-terpinene (0.1%)
terpinolene (0.1%)
linalool (49.9%)
camphor (0.6%)
borneol (0.1%)
terpinen-4-ol (0.4%)
α-terpineol (0.7%)
methyl chavicol (2.0%)
nerol (0.3%)
bornyl acetate (1.2%)
α-copaene (0.2%)
β-bourbonene (0.2%)
β-cubebene (0.1%)
β-elemene (3.3%)
methyl eugenol (0.2%)
β-caryophyllene (0.9%)
trans-α-bergamotene (4.1%)
β-humulene (1.0%)
germacrene (1.9%)
β-selinene (0.4%)
bulnesene* (1.5%)
γ-cadinene (2.5%)
eugenyl acetate (0.3%)
(Z)-nerolidol (0.7%)
calamenene* (0.2%)
germacrene B (0.5%)
spathulenol (0.2%)
1,10-di-epi-cubenol (0.8%)
T-cadinol (4.1%)
β-eudesmol (0.3%)

*correct isomer not identified

An oil of *O. basilicum* produced from plants growing wild in the upper Brahmaputra Valley area of upper Assam (India) was analyzed by Parkayasthra and Nath (2006). Its composition was quite unusual and, as the authors authenticated the taxonomic origin, this must be the example of yet another chemotype or a hybrid between *O. basilicum* and *O. americanum* L. The components identified in this oil were:

tricyclene (0.1%)
α-thujene (0.1%)
α-pinene (5.4%)
camphene (4.7%)
1-octen-3-ol (1.4%)
β-pinene (0.2%)
myrcene (1.6%)
(Z)-3-hexenyol acetate (0.1%)
α-phellandrene (0.4%)
α-terpinene (0.2%)
p-cymene (0.1%)
1,8-cineole (0.2%)
β-phellandrene (0.6%)
limonene (7.6%)
γ-terpinene (1.2%)
trans-sabinene hydrate (0.2%)
terpinolene (1.1%)
cis-sabinene hydrate (0.3%)
camphor (42.1%)
isoborneol (0.3%)
borneol (1.3%)
terpinen-4-ol (0.6%)
myrtenal (0.1%)
α-terpineol (0.3%)
myrtenol (3.3%)
myrtenyl acetate (0.2%)
α-copaene (0.2%)
β-elemene (1.0%)
β-caryophyllene (3.3%)
γ-maaliene (0.2%)
β-gurjunene (1.4%)
trans-α-bergamotene (0.6%)
α-humulene (0.3%)
germacrene D (0.2%)
β-selinene (5.6%)
α-selinene (4.3%)
γ-cadinene (0.2%)
δ-cadinene (0.5%)
globulol (0.2%)
α-muurolol (0.1%)
α-cadinol (0.2%)

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

De Masi et al. (2006) determined the main components of lab-distilled oils produced from 11 cultivars of basil that are grown in Italy. Their results are summarized in **T-6**.

An oil produced in the laboratory by hydrodistillation from *O. basilicum* grown in Serbia was the subject of analysis by Bozin et al. (2006). Using a combination of GC-FID and GC/MS the oil was found to contain the following components:

α-pinene (0.2%)
camphene (0.1%)
sabinene (0.1%)
1-octen-3-ol (0.1%)
β-pinene (0.4%)
trans-isolimonene (2.0%)
p-cymene (0.1%)
limonene (1.9%)
1,8-cineole (3.4%)
(Z)-β-ocimene (0.6%)
trans-linalool oxide[f] (0.1%)
camphene (0.2%)
linalool (24.2%)
α-thujone (0.5%)
allo-ocimene* (0.1%)
camphor (0.3%)
menthone (0.6%)
1,4-dimethoxybenzene (0.3%)
borneol (0.1%)
menthofuran (0.1%)
methyl chavicol (45.8%)
pulegone (0.1%)
dihydroedulan II (0.4%)
carvacrol (0.3%)
α-copaene (0.3%)

T-6. Percentage composition of the main components of oils produced from 11 Italian cultivars of basil

Cultivar	1,8-Cineole	Linalool	Methyl chavicol	Eugenol	Methyl eugenol	Methyl (E)-cinnamate
'Foglia di Lattuga' (ML)	5.8	43.6	34.4	4.5	0.2	-
'Foglia di Lattuga' (LO)	4.3	40.6	35.3	5.9	0.3	-
'Red Ruffle'	13.9	42.2	7.5	12.6	0.4	-
'Dark Red Opal'	9.0	61.0	2.0	12.6	1.3	-
'Cinnamon'	3.9	40.7	10.3	2.6	t	23.9
'Genovese' (LO)	8.0	54.6	-	17.3	0.1	-
'Giandi Foglie Valentino'	7.4	33.5	36.4	2.6	t	-
'Genovese' (ML)	8.5	55.9	-	17.9	0.1	-
'Genovese' (LL)	7.3	60.1	0.4	16.2	0.1	-
'Fine Verde'	2.1	63.6	-	15.1	0.1	-
'Greco Apalla'	7.5	47.0	0.3	15.8	0.2	-

ML = medium height, lanceolate leaves; LO = large height, ovate leaves; LL = large height lanceolate leaves; t = trace (<0.05%)

3-dodecanone (0.2%)
β-cubebene (0.6%)
β-elemene (1.9%)
isocaryophyllene (0.1%)
β-caryophyllene (4.5%)
α-guaiene (0.7%)
aromadendrene (0.3%)
α-humulene (0.6%)
β-selinene (0.8%)
δ-cadinene (3.6%)
(Z)-β-farnesene (0.2%)
ledol (0.2%)
caryophyllenol* (0.3%)
spathulenol (0.6%)
caryophyllene oxide (0.1%)
viridiflorol (0.1%)
vulgarone B (0.2%)
(E,E)-farnesol† (0.1%)
nonadecane (0.1%)
1-eicosene (0.2%)
eicosane (0.2%)

ffuranoid form
*correct isomer not identified
†incorrect identification based on GC elution order

T-7. Comparative percentage composition of basil oil produced from leaves harvested at different times of the day, and the effect of drying them at 60°C

	Fresh leaf harvest time			Dry leaf harvest time
Compound	**8:00 AM**	**12:00 PM**	**4:00 PM**	**8:00 AM**
myrcene	0.7	-	-	-
1,8-cineole	6.5	1.8	-	3.5
(Z)-β-ocimene	2.6	2.8	2.0	-
linalool	49.7	43.0	45.2	63.1
camphor	-	-	-	1.1
borneol	-	-	-	0.9
terpinen-4-ol	2.1	1.0	1.8	5.0
α-terpineol	1.0	-	-	0.9
geraniol	0.9	1.4	1.3	2.2
bornyl acetate	-	-	-	0.7
eugenol	29.4	39.4	41.2	9.9
trans-α-bergamotene	2.6	4.3	3.9	6.7
germacrene D	0.8	1.0	1.1	-
α-bulnesene	-	0.8	-	-
γ-cadinene	0.7	1.0	-	1.5
α-cadinol	3.0	3.4	3.6	4.5

The characterization of menthone, menthofuran, pulegone, α-thujone, 1,4-dimethoxybenzene and vulgarone B requires corroboration as these compounds have never been unequivocally characterized in basil oil before.

Carvalho Filho et al. (2006) examined the effect of harvest time of *O. basilicum* during the day on the oil composition of fresh leaves as shown in **T-7**. In addition, the authors showed that on drying the leaves at various temperatures (40°–60°C) prior to oil isolation, its composition changed (see limited data in **T-7**). Low levels of β-elemene, geranyl acetate, spathulenol, cubenol and phytol were also found in oils produced from leaves harvested at 12:00 PM and 4:00 PM that were dried either at 50°C or 60°C.

Viera and Simon (2006) analyzed the oils of 13 accessions of *O. basilicum* using GC-FID and GC/MS. As expected, the oils were rich in linalool, methyl chavicol, methyl (E)-cinnamate or combinations of components. The compositions of the oils that were found to be rich in methyl chavicol and linalool can be seen in **T-8** and **T-9**. The Dark Opal is a Group 2 cultivar; the Thai and Siam Queen are Group 4 cultivars. The oils containing combinations of components are found in **T-10**. Finally, an oil of basil known as Purdue methyl (E)-cinnamate was found to contain the following:

1,8-cineole (3.7%)
γ-terpineol‡ (0.6%)
linalool (1.7%)
methyl chavicol (0.4%)
methyl (Z)-cinnamate (5.9%)
methyl (E)-cinnamate (82.4%)
β-bisabolene (0.2%)
spathulenol (0.9%)

‡does not occur naturally

Oils produced in the lab from *O. basilicum* plants collected from a garden in Yaoundé (Cameroon) and Brazzaville (Congo) were analyzed by Tchoumbougnang et al. (2006). The oil from the Cameroonian plants was found to be rich in linalool while the oil from

T-8. Comparative percentage composition of methyl chavicol-rich oils of *Ocimum basilicum*

Compound	Kew basil oil	Thai basil oil	Thai Siam queen basil oil	Comoros basil oil
α-pinene	-	0.2	-	-
β-pinene	-	0.1	-	-
1,8-cineole	1.4	1.7	0.9	0.3
γ-terpineol‡	0.5	0.7	t	0.5
linalool	0.6	1.4	0.8	0.6
camphor	-	4.3	3.0	-
terpinen-4-ol	-	1.0	0.8	-
methyl chavicol	87.8	74.4	57.2	86.4
methyl (Z)-cinnamate	-	-	-	-
eugenol	-	-	-	0.1
β-elemene	0.5	0.3	-	0.8
methyl (E)-cinnamate	-	1.0	0.8	-
methyl eugenol	0.9	-	-	2.5
β-caryophyllene	1.3	-	-	-
γ-elemene	1.3	4.5	3.1	0.8
α-humulene	-	0.2	0.3	0.8
β-cubebene†	-	0.5	0.7	1.7
β-bisabolene	-	1.4	0.9	0.2
α-farnesene*	-	1.3	1.0	2.0
α-gurjunene†	-	0.2	-	0.1
spathulenol	1.0	1.6	1.2	0.7

*correct isomer not identified
†incorrect identification based on GC elution order;
‡does not occur naturally

the Congolese plants was found to be rich in methyl chavicol as shown in **T-11**.

H.H. Darrah, *A comparative study of the epidermal organs of twenty-five cultivars of* Ocimum *(The basils).* Paper No. 26, 13 p., presented at VI International Congress of Essential Oils, Sept. 8–12, San Francisco, CA (1974).

Y. Holm, A.R. Siira and R. Hiltunen, *A chemical study on various basil chemotypes cultivated in Finland.* Planta Med., **55**, 635 (1989).

M.L. Maheshwari, *Quality and Chemistry of Essential Oils.* In: *Advances in Horticulture. Vol. 11, Medicinal and Aromatic Plants*. Edits., K.L. Chadha and R. Gupta, pp. 145–197, Malhotra Publ. House, New Delhi, India (1995).

A. Paton and E. Putievsky, T*axonomic problems and cytotaxonomic relationships between and within varieties of* Ocimum basilicum *and related species (Labiatae).* Kew Bull., **51**, 509–524 (1996).

J-C. Chalchat, R-P. Garry, L. Sidibé and M. Harama, *Aromatic Plants of Mali (1): Chemical Composition of Essential Oils of* Ocimum basilicum *L.* J. Essent. Oil Res., **11**, 375–380 (1999).

F. Gionfriddo, C. Mangiola, A. Pirello and R. Manganaro, *Studio preliminare sulla compozione degli oil essenziali di alcane piante officinali calabresi.* Essenz. Deriv. Agrum., **71**, 67–70 (2001).

A.K. Dhar, *Sweet basil* Ocimum basilicum*—a review*. J. Med. Arom. Plant Sci., **24**, 738–755 (2002).

R. Omidbaigi, A. Hassani and F. Sefidkon, *Essential oil content and composition of sweet basil* (Ocimum basilicum) *at different irrigation regimes*. J. Essent. Oil Bear. Plants, **6**, 104–108 (2003).

F. Senatore, R. De Fusco, A. Grassia, C. Ornella Moro, D. Rigano and F. Napolitano, *Chemical composition and antibacterial activity of essential oils from five culinary herbs of the Lamiaceae family growing in Campania, southern Italy.* J. Essent. Oil Bear. Plants, **6**, 166–173 (2003).

L. Jirovetz, G. Buchbauer, M.P. Shafi and M.M. Kaniampady, *Chemotaxonomical analysis of the essential aroma compounds of four different* Ocimum *species from southern India.* Eur. Food Res. Technol., **217**, 120–124 (2003).

F. da Silva, R.H.S. Santos, E.R. Diniz, L.C.A. Barbosa, V.W.D. Casali and R.R. de Lima, *Teore compasçã do óleo essencial de manjeriçã* (Ocimum basilicum *L.) em dois horários e duas épocas de colheita.* Rev. Bras. Plant Med., **6**(1), 33–38 (2003).

B. Kumar, M. Yaseen, N.K. Patra, H.K. Srivastava, A.A. Naqvi and P. Ram, *Chemotypic variation in morphologically homogenous gene pool of Indian basil.* Indian Perfum., **48**(3), 289–297 (2004).

S. DeLuca, M. Quinto, G. Colelli, D. Centonze and M.L. Amodio, *GC-MS characterization of* Ocimum basilicum *var. gigante napoletano. A preliminary study of the volatile in function of different controlled atmospheric storage*. Poster presented at 35th International Symposium on Essential Oils, Giardini Naxos, Sept. 25–Oct. 2, Messina, Italy (2004).

T-9. Comparative percentage composition of linalool-rich oils of *Ocimum basilicum*

Compound	Dark Opal basil oil	Sweet Fine basil oil	Purdue linalool basil oil
α-pinene	1.1	0.1	-
β-pinene	0.8	0.3	-
1,8-cineole	11.0	2.0	0.7
γ-terpineol‡	0.9	0.8	2.6
linalool	69.3	70.6	74.5
camphor	-	-	-
terpinen-4-ol	-	0.2	0.3
methyl chavicol	1.3	2.6	0.4
methyl (Z)-cinnamate	-	-	-
eugenol	0.6	3.5	0.8
β-elemene	1.0	0.9	1.2
methyl (E)-cinnamate	-	-	-
methyl eugenol	0.6	0.2	-
β-caryophyllene	-	-	-
γ-elemene	1.6	4.4	1.9
α-humulene	0.5	0.6	0.3
β-cubebene†	0.8	1.2	2.3
β-bisabolene	1.2	1.6	2.5
α-farnesene*	-	-	-
α-gurjunene†	-	-	-
spathulenol	1.0	1.1	0.9

*correct isomer not identified
†incorrect identification based on GC elution order
‡does not occur naturally

T-10. Comparative percentage composition of oils of *Ocimum basilicum* that contain mixed major components

Compound	Purple Ruffles basil oil	Green Ruffles basil oil	Mammoth basil oil	Sweet basil oil	Cinnamon basil oil
α-pinene	1.7	1.5	0.6	0.4	0.3
β-pinene	1.9	1.5	0.4	0.4	0.3
1,8-cineole	14.7	14.8	7.8	8.4	2.9
γ-terpineol‡	0.9	0.5	1.0	0.9	2.1
linalool	38.1	20.3	34.1	55.7	32.3
camphor	-	2.9	0.2	0.3	0.9
terpinen-4-ol	-	0.5	0.4	0.6	0.8
methyl chavicol	12.7	41.5	41.7	16.4	6.4
methyl (Z)-cinnamate	-	-	-	-	5.5
eugenol	0.4	0.3	0.1	1.8	1.0
β-elemene	1.9	0.7	0.9	1.1	-
methyl (E)-cinnamate	-	-	-	-	34.0
methyl eugenol	1.1	0.2	0.1	0.2	-
β-caryophyllene	-	-	-	-	-
γ-elemene	10.9	3.6	2.4	1.6	0.4
α-humulene	1.1	0.6	0.4	0.5	0.3
β-cubebene†	1.8	1.4	1.4	1.0	1.7
β-bisabolene	1.7	1.4	1.5	1.7	1.9
α-farnesene*	-	-	-	-	-
α-gurjunene†	-	-	-	-	1.1
spathulenol	1.3	0.3	0.5	0.9	1.3

*correct isomer not identified
†incorrect identification based on GC elution order
‡does not occur naturally

T-11. Comparative percentage composition of basil oil produced from plants from two West African regions

Compound	Cameroonian oil	Congolese oil
α-thujene	0.3	-
α-pinene	1.4	-
sabinene	0.2	0.2
β-pinene	1.6	0.5
myrcene	1.7	0.3
p-cymene	0.1	-
limonene	17.1	0.4
1,8-cineole	8.5	7.7
(Z)-β-ocimene	0.8	-
γ-terpinene	0.3	-
cis-sabinene hydrate	0.2	-
terpinolene	0.6	-
linalool	46.0	20.9
camphor	-	0.9
borneol	0.2	-
terpinen-4-ol	3.6	-
α-terpineol	0.4	-
trans-α-bergamotene	0.8	2.2
α-humulene	0.4	-
(E)-β-farnesene	0.3	-
allo-aromadendrene	0.3	-
germacrene D	0.2	0.1
α-selinene	0.1	-
γ-cadinene	0.2	0,.3
δ-cadinene	0.2	0.1
T-cadinol	0.1	0.8
T-muurolol	0.5	0.1
α-cadinol	0.5	-
methyl chavicol	0.8	57.9
chavicol	-	1.1

M.E. Lucchesi, F. Chemat and J. Smadja, *Solvent-free microware extraction of essential oil from aromatic herbs: comparison with conventional hydrodistillation.* J. Chromatogr., A. **1043**, 323–327 (2004).

Anon, *Basil oil (Indian).* Indian Perfum., **48**, 405 (2004).

M. Ozcan and J-C. Chalchat, *Essential oil composition of a new chemotype of basil (*Ocimum basilicum *L.) cultivated in Turkey.* J. Essent. Oil Bear. Plants, **1**, 155–159 (2004).

D.S. Pilania, S.K. Pareek, P. Suneja and A. Kumar, *Characterization of French basil (*Ocimum basilicum *L.) germplasm for essential oil yield and quality under stress environment*. Indian Perfum., **49**, 49–55 (2005).

A.A. Kasali, A.O. Eshilokum, S. Adeola, P. Winterhalter, H. Knapp, B. Bonnlander and W.A. Koenig, *Volatile oil composition of new chemotype of* Ocimum basilicum *L. from Nigeria.* Flav. Fragr. J., **20**, 45–47 (2005).

M. Yonzon, D.J. Lee, T. Yokochi, Y. Kawano and T. Nakahara, *Antimicrobial activities of essential oils of Nepal*. J. Essent. Oil Res., **17**, 107–111 (2005).

P. Lopez, C. Sanchez, R. Batlle and C. Nerin, *Solid- and vapor-phase antimicrobial activities of six essential oils: susceptibility of selected foodborne bacterial and fungal strains*. J. Agric. Food Chem., **53**, 6939–6946 (2005).

S. Elementi, R. Neri and L.F. D'Antuono, *Biodiversity and selection of "European" basil (*Ocimum basilicum *L.) types*. Acta Hort., **723**, 99–104 (2006).

S.E. Sajjadi, *Analysis of the essential oils of two cultivated basil (*Ocimum basilicum *L.) from Iran*. Daru, **14**(3), 128–130 (2006).

M. Tognolini, E. Barocelli, R. Bruni, A. Bianchi, M. Chiavarini and M. Impicciatore, *Comparative screening of plant essential oils: phenylpropanoid moiety as basic core for antiplatelet activity.* Life Sci., **78**, 1419–1432 (2006).

J. Parkayastha and S.C. Nath, *Composition of the camphor-rich essential oil of* Ocimum basilicum *L. native to Northeast India*. J. Essent. Oil Res., **18**, 332–334 (2006).

L. De Masi, P. Siviero, C. Esposito, D. Castaldo, F. Siano and B. Latta, *Assessment of agronomic, chemical and genetic variability in common basil (*Ocimum basilicum *L.).* Eur. Food Res. Technol., **223**, 273–281 (2006).

B. Bozin, N. Mimica-Dukic, N. Simin and G. Anackov, *Characterization of the volatile composition of essential oils of some Lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils*. J. Agric. Food Chem., **54**, 1822–1828 (2006).

J.L.S. Carvalho Filho, A.F. Blank, P.B. Aves, P.A.D. Ehlert, A.S. Melo, S.C.H. Cavalcanti, M. de F. Arrigoni-Blank and R. Silva-Mann, *Influence of the harvesting time, temperature and drying period on basil (*Ocimum basilicum *L.) essential oil*. Rev. Bras. Farmacognosia, **16**, 24–30 (2006).

R.F. Viera and J.E. Simon, *Chemical characterization of basil (*Ocimum *spp.) based on volatile oils*. Flav. Fragr. J. **21**, 214–221 (2006).

F. Tchoumbougnang, P.H. Amvam Zollo, F. Avlessi, G.A. Alitonou, D.K. Sohounhloue, J.M. Ouamba, A. Tsomambet, N. Okemy-Andissa, E. Dagne, H. Agnaniet, J.M. Bessiere and C. Menut, *Variability in the chemical compositions of the essential oils of five* Ocimum *species from tropical African area*. J. Essent. Oil Res., **18**, 194–199 (2006).