Progress in Essential Oils

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Geranium Oil

A survey of the early literature reveals that methyl mercaptan was found as a trace component in geranium oil (Peyron 1961). Rajeswara Rao et al. (1992) determined the effect of different fertilization practices on the major constituents of geranium oil produced in Hyderabad (India). They found that the major constituents ranged in composition as follows:

cis- and *trans*-rose-oxides (1.55-1.68 percent)
menthone (0.52-0.61 percent)
isomenthone (5.94-6.16 percent)
linalool (6.35-6.62 percent)
citronellyl formate (7.54-8.02 percent)
geranyl formate (5.52-5.77 percent)
citronellol (34.30-35.30 percent)
nerol (0.39-0.50 percent)
geraniol (17.90-19.90 percent)
10-epi-γ-eudesmol (3.41-3.57 percent)
guaia-6,9-diene (0.28-0.35 percent)

Kaul et al. (1997) studied the effect of drying and the air headspace on geranium oil stored under a variety of conditions. They found that the lack of water removal and the storage of oil in a container only filled to 50 percent capacity had a marked effect on the oil composition; in particular there was a reduction in the geraniol, 10-epi-γ-eudesmol and geranyl formate contents with a corresponding increase in the citronellol content (see T-1).

Sastry et al. (2001) compared the effect of heaping or spreading of freshly harvested geranium herbage prior to distillation on the oil yield and composition of two cultivars (Kunti and Bipuli) grown at Kodaikanal (Uttar Pradesh, India). They found that if the herbage was spread out to dry it could be stored for a period of 6 h if necessary, whereas if it was either heaped or left for any longer times, the yield and composition would be detrimentally affected. The composition of each cultivar that was freshly distilled is shown in T-2.

In a follow-up report, Sastry et al. (2001) showed that there was a difference in the oil composition of geranium depending upon whether the uppermost leaves or the lower leaves were distilled. This finding held true for the three cultivars (Kunti, Bipuli or Hemanti) examined. The authors recommended that the top two leaves of geranium be harvested manually from all geranium branches and distilled every four

T-1 The effect of storage for 24 months on the percentage composition of selected components of Indian geranium oil held at ambient conditions

Compound	A	B	C	D
linalool	7.9	8.6	8.4	6.2
cis- and *trans*-rose oxide	1.0	1.2	1.4	1.2
menthone	0.6	1.4	1.4	1.2
isomenthone	7.3	6.0	5.9	6.4
citronellol	25.4	24.1	24.0	38.9
geraniol	21.9	19.1	19.2	9.7
citronellyl formate	6.0	7.2	7.4	8.0
geranyl formate	5.3	4.1	4.5	2.2
10-epi-γ-eudesmol	4.2	4.2	4.4	2.5

A = freshly distilled oil; B = oil filtered and dried over anhydrous Na_2SO_4 and stored in aluminum containers; C = oil filtered and dried over anhydrous Na_2SO_4 and stored in amber bottles; D = oil filtered, not dried and stored half filled in aluminum containers to five weeks in the semi-temperature conditions of the lower hills of southern India. Although the oils produced from the top two leaves gave a superior oil, the conclusion seems to be somewhat ridiculous given the low oil yield of geranium and the cost of the oil produced this way.

To assist in the expansion of geranium cultivation in India, Gupta et al. (2002) examined the micropropagation of stems and leaves of the commonly grown cultivars ('Hemanti,' 'Bipuli,' and 'Kunti'). They found that this micropropagation of organs in a modified Murashige and Skoog media produced 20 or more shoots within four weeks without callus formation. As a result, this procedure has been adopted for the multiplication of geranium cultivars in India for an intensive expansion of geranium oil production.

Geranium oils produced from plants harvested in Morocco over a full year (autumn, winter, spring and summer) were analyzed by Vernin et al. (2002). The components found in amounts greater than 0.1% in the oils can be seen in T-3. The authors also identified a number of trace constituents (< 0.1%) in the same oils. These trace compounds were octane, 2-butylfuran, nonane, tricyclene, 2-pentylfuran, *trans*-anhydrolinalool oxide and *cis*-linalool oxide (furanoid forms), terpinolene, neral, nerol, α-terpinyl formate, α-cubebene, α-copaene, δ-cadinene, *trans*-calamenene, geranyl isovalerate, geranyl hexanoate, citronellyl octanoate, 6,10,14-trimethyl-2-pentadecanone and geranyl nonanoate. (Z)-3-Hexenyl hexanoate was also found as a trace component in oil produced from plants harvested in the autumn. Vernin et al. also tentatively identified 4,5-dimethyl-2-vinyl-furan (< 0.1%), spathulenol (0.1%) and 1-endobourbonanol (0.1%) in all of the Moroccan oils. Using 16 selected components, Vernin et al. further compared geranium oil produced in four different locations in Morocco over the four seasons. These data are shown in T-4. It is of interest to note that the oils varied quite a lot depending upon the season in which the oil was produced and the location in Morocco where the oil was produced.

Percentage composition of the oils of Kunti and Bipuli cultivars of geranium **T-2**

Compound	Kunti	Bipuli
α-pinene	0.11	0.47
β-pinene	0.51	0.25
cis-rose oxide	0.35	0.28
trans-rose oxide	0.01	0.56
menthone	0.37	0.26
isomenthone	5.50	6.44
linalool	8.37	9.91
citronellyl formate	2.67	6.33
geranyl formate	1.63	5.68
α-terpineol	-	2.69
citronellol	9.97	20.33
geraniol	45.16	34.20
geranyl tiglate	0.69	0.81
10-epi-γ-eudesmol	3.75	6.57
2-phenethyl tiglate	0.55	0.47

Finally, Vernin et al. used Principal Component Analysis to compare geranium oils produced in Morocco, Reunion, China, Australia, Algeria, Tunisia, Madagascar and Tadjikistan. Unfortunately, because of the small sample set of some of the oils they were only able to classify Reunion oils (group 1) and the Chinese oils (group 2), whereas the Moroccan oils (group 3) and the Egyptian oils (group 4) were less defined forming a rather diffuse mix. The oils from Reunion and China were characterized by a high content of guaia-6,9-diene while those from Egypt and N. Africa contained elevated amounts of 10-epi-8-eudesmol. Furthermore, oils from China contained higher levels of citronellol and *cis*-rose oxide, oils from Morocco contained higher levels of geranyl formate and oils from Reunion were richer in geraniol.

Narayanan (2003) compared the composition of geranium oil of Bourbon and Indian origins. The results of this study can be seen in T-5.

Using a comprehensive GC-GC/MS technique, Shellie and Marriott (2003) analyzed a commercial oil of geranium of Egyptian origin obtained in Australia. The authors identified 65 components using two-dimensional separation space based on retention indices and component identity confirmation using mass spectra. Unfortunately, the authors only presented qualitative data. The components characterized were (Z)-3-hexenol, α-pinene, 6-methyl-5-hepten-2-one, myrcene, α-phellandrene, p-cymene, limonene, (Z)-β-ocimene, (E)-β-ocimene, *cis*-linalool oxide (presumably furanoid), terpinolene, *trans*-linalool oxide (presumably furanoid), linalool, *cis*-rose oxide, *trans*-rose oxide, menthone, citronellal, iso(iso)pulegol, isomenthone, terpinen-4-ol, neoisomenthol, α-terpineol, nerol, citronellol, neral, piperitone, geraniol, geranial, citronellyl formate, geranyl formate, α-cubebene, 2-phenethyl propionate, citronellyl acetate, α-copaene, α-ylangene, β-bourbonene, geranyl acetate, β-caryophyllene, *trans*-α-bergamotene, aromadendrene, α-guaiene, α-humulene, allo-aromadendrene, citronellyl propionate, germacrene D, γ-muurolene, geranyl propionate, δ-cadinene, *cis*-calamenene, citronellyl butyrate, α-agarofuran, germacrene B, geranyl butyrate, 2-phenethyl tiglate, 10-epi-γ-eudesmol, hinesol, γ-

Comparative percentage composition of Moroccan geranium oil over the four seasons

T-3

Compound	Autumn oil	Winter oil	Spring oil	Summer oil
hexane	0.1	-	-	-
(E)-2-hexenal	0.1	t	t	t
α-pinene	0.6	0.5	0.5	0.7
1,8-cineole	0.2	0.2	0.2	0.2
myrcene	0.1	0.2	0.2	0.1
α-terpinene	0.1	t	t	t
cis-anhydrolinalool oxide	0.2	t	t	t
p-cymene	0.1	0.1	0.1	0.1
limonene	0.1	t	0.1	0.1
(Z)-β-ocimene	0.2	0.1	0.2	0.2
linalool	4.0	2.6	4.3	4.0
cis-rose oxide	0.1	0.1	0.1	0.1
trans-rose oxide	0.4	0.3	0.3	0.8
menthone	0.3	0.3	0.4	0.7
isomenthone	3.7	2.5	4.5	8.0
menthol	0.1	0.1	0.1	0.2
α-terpineol	0.2	0.1	0.2	0.4
citronellol	28.0	20.6	26.0	35.0
geranial	0.2	0.2	0.2	0.2
geraniol	18.0	19.0	22.0	11.0
citronellyl formate	8.1	8.4	8.3	8.1
geranyl formate	5.0	6.7	5.3	2.7
citronellyl acetate	0.2	0.1	0.2	0.3
geranyl acetate	0.6	1.0	0.7	0.4
α-bourbonene	0.4	0.5	0.3	0.3
β-bourbonene	0.7	0.9	0.7	0.6
β-caryophyllene	0.6	0.5	0.7	0.8
β-gurjunene	0.1	0.1	0.1	0.1
guaia-6,9-diene	0.2	0.2	0.2	0.3
citronellyl propionate	0.3	0.2	0.3	0.3
α-humulene	0.3	0.3	0.3	0.3
allo-aromadendrene	0.1	0.1	0.1	0.1
geranyl propionate	1.6	2.5	1.7	1.3
germacrene D + citronellyl isobutyrate	1.2	1.1	1.2	0.5
bicyclogermacrene	0.2	0.3	0.2	0.1
α-muurolene	0.1	0.1	0.2	0.2
(E)-nerolidol + geranyl butyrate	0.3	0.3	0.3	0.5
cis-calamenene	0.7	0.6	0.7	0.8
citronellyl butyrate	0.5	0.5	0.6	0.7
geranyl butyrate	0.2	0.1	0.5	0.5
2-phenethyl tiglate + citronellyl isovalerate	1.3	1.2	1.2	1.1
10-epi-γ-eudesmol	5.4	5.7	5.5	4.0
γ-eudesmol	0.3	0.3	0.3	0.3
furopelargone A	0.3	0.3	0.3	0.3
β-eudesmol	0.4	0.4	0.5	0.6
guaiol	0.3	-	-	-
geranyl valerate	0.1	0.1	0.1	0.2
citronellyl tiglate	0.3	0.2	0.3	0.4
geranyl tiglate	1.6	1.8	1.5	1.0
geranyl isohexanoate	0.2	0.2	0.2	0.2

Variation in selected components (%) of geranium oil produced in different regions of Morocco and different seasons **T-4**

Compound	Marrakech				Khemisset				Rabat				Agadir			
	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su	A	W	Sp	Su
limonene	0.1	0.3	0.2	0.1	0.1	0.5	0.2	0.1	0.2	0.4	0.1	0.1	0.2	0.4	0.1	0.1
linalool	3.1	2.2	5.2	2.8	2.0	3.4	3.9	1.6	2.4	3.4	3.9	1.6	1.9	1.0	3.2	5.8
cis-rose oxide	1.3	0.8	0.6	1.7	1.5	0.6	0.5	2.1	0.3	0.3	0.4	0.3	0.4	0.1	0.3	0.5
trans-rose oxide	0.6	0.4	0.3	0.5	0.7	0.3	0.3	1.0	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.3
menthone	0.4	0.2	0.3	0.5	0.4	0.3	0.6	0.7	0.2	0.2	0.2	0.2	0.4	0.3	0.3	0.4
isomenthone	4.4	3.9	4.3	5.2	5.5	5.3	5.5	7.6	4.2	3.9	4.3	4.8	4.0	3.4	5.2	5.4
citronellol	27.0	21.5	23.5	34.0	25.5	17.0	19.0	31.0	19.2	16.5	21.0	23.0	19.0	15.0	19.2	23.0
geranyl formate	4.3	7.0	6.0	3.0	4.1	9.2	7.2	2.7	7.3	11.0	6.2	5.0	6.8	11.0	8.4	4.8
geranyl acetate	0.6	1.0	0.7	0.4	0.7	1.2	1.2	0.4	0.7	1.3	1.1	0.4	0.6	1.3	0.8	0.4
β-bourbonene	0.7	0.9	0.7	0.6	1.0	1.4	1.1	0.5	0.6	1.2	0.7	0.5	0.4	1.0	0.8	0.4
β-caryophyllene	0.7	0.6	0.8	1.1	0.6	0.5	0.7	0.8	0.6	0.6	0.8	0.8	0.6	0.5	0.7	0.9
geranyl propionate	1.2	2.3	1.7	1.0	1.3	2.3	1.8	1.4	1.8	2.9	2.4	1.7	2.6	5.3	1.8	1.5
guaia-6,9-diene	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
germacrene D	1.2	1.0	1.5	1.6	1.2	1.0	1.2	1.6	1.2	1.0	1.4	1.6	1.3	1.0	1.3	1.6
cis-calamenene	0.8	0.7	0.7	1.1	1.2	0.8	1.0	1.5	0.7	0.6	0.9	1.1	0.5	0.5	0.7	0.8
10-epi-γ-eudesmol	5.6	5.6	6.0	6.5	5.0	5.0	6.1	6.3	5.9	6.4	6.4	6.2	5.5	6.4	5.6	5.5

A = autumn oil; W = winter oil; Sp = spring oil ; Su = summer oil

eudesmol, geranyl valerate, geranyl tiglate, citronellyl hexanoate, geranyl hexanoate, citronellyl heptanoate, citronellyl octanoate and geranyl octanoate.

An oil produced in the laboratory by hydrodistillation of dried geranium leaves (purported to be the same clone of plants that are used for commercial production of oil) by Damien Dorman and Deans (2004) was examined for its antimicrobial and *in vitro* antioxidant properties. The composition of the oil used in this study was as follows:

α-pinene (0.5 percent)
myrcene (0.2 percent)

Comparative percentage composition of Bourbon and Indian geranium oil **T-5**

Compound	Bourbon oil	Indian oil
linalool	9.51	11.33
rose oxide*	1.15	0.86
menthone	1.48	2.04
isomenthone	5.09	4.45
citronellol	19.95	23.20
geraniol	14.48	18.94
citronellyl formate	6.75	6.41
geranyl formate	3.68	3.91
10-epi-γ-eudesmol	-	3.93
citronellyl tiglate	0.18	0.11
geranyl tiglate	0.65	1.21

*correct isomer not identified

p-cymene (0.2 percent)
limonene (0.2 percent)
(E)-β-ocimene (0.1 percent)
cis-linalool oxide[†] (0.3 percent)
trans-linalool oxide[†] (0.2 percent)
linalool (6.6 percent)
menthone (1.8 percent)
isomenthone (5.8 percent)
α-terpineol (0.6 percent)
citronellol (32.9 percent)
geraniol (12.0 percent)
nerol (0.6 percent)
citronellyl formate (7.6 percent)
citronellyl acetate (0.3 percent)
α-cubebene (0.2 percent)
geranyl acetate (0.4 percent)
α-copaene (0.5 percent)
β-caryophyllene (1.2 percent)
aromadendrene (0.3 percent)
α-humulene (0.3 percent)
allo-aromadendrene (0.2 percent)
β-selinene (0.1 percent)
bicyclogermacrene (0.7 percent)
α-muurolene (0.2 percent)
δ-cadinene (0.2 percent)
calamenene[*] (0.3 percent)
geranyl tiglate (1.1 percent)

[†]furanoid form; [*]correct isomer not identified

Analysis of the acidic/phenolic and basic fractions of Reunion geranium oil was performed by Vernin et al. (2004). The components characterized in the acidic/phenolic fraction were as follows:

isobutyric acid
methacrylic acid
butyric acid
2-methylbutyric acid
isovaleric acid
valeric acid
tiglic acid
isohexanoic acid
hexanoic acid
(E)-3-hexenoic acid
(E)-2-hexenoic acid
isoheptanoic acid
heptenoic acid[*]
2-methylhexenoic acid[*]
heptanoic acid
dimethyl-3-hexenoic acid[*]
2-furfuryl acid
2-methyl-3-hexenoic acid[*]
2,5-dimethyl-2-hexenoic acid[*]
3,5-dimethylhexanoic acid
benzoic acid
iso-octanoic acid
methyloctenoic acid[*]
octanoic acid
2-methyl-3-octenoic acid[*]
3-methyloctanoic acid
salicylic acid
dimethyloctenoic acid[*]
(Z)-chrysanthemic acid
(E)-chrysanthemic acid
nonanoic acid
3,7-dimethyloctanoic acid
α-camphenolic acid
citronellic acid
dihydrocampholenic acid
neric acid
isodecanoic acid
isogeranic acid
geranic acid
decanoic acid
2-decenoic acid[*]
3,7-dimethyl-6-oxo-octanoic acid
2,5,5-trimethyl-2,6-heptadienoic acid[*]
decanoic acid
dodecanoic acid
3,9-dimethyldecanoic acid
tridecanoic acid
2,4-octadienoic acid[*]
tetradecanoic acid
dimethyltetradecanoic acid[*]
pentadecanoic acid
6,9,12,15-docosatetaenoic acid[*]
isohexadecanoic acid
hexadecanoic acid
linoleic acid
linolenic acid
9-octadecenoic acid[*]

[*]correct isomer not identified

The authors reported that the main acids were geranic (20 percent), 3,7-dimethyl-6-oxo-octanoic (16.5 percent), citronellic (6 percent), 3,6-dimethyloctanoic (2.7 percent), 2-decenoic (2.5 percent), neric (2.4 percent), salicylic (2.0 percent) and (E)-chrysanthemic (1.6 percent). In the phenolic part they also characterized phenol, 4-methyl anisole, guaiacol and 2-methoxyacetophenone.

Analysis of the basic fraction led by Vernin et al. led to the identification of 2-isopropyl-4-methylpyridine and (Z)-3-(1-butenyl)-pyridine, 2-methyl-3-amino-1-pentene, citronellyl diethylamine, dimethyl sulphoxide and dimethyl sulphone. The authors noted that the acid fraction comprised 0.1 percent of the oil while the basic fraction was just 10 ppm of the oil.

Saxena et al. (2004) compared the composition of the oils of two Indian cultivars of geranium, one rich in geraniol (standard Indian geranium oil) and one rich in isomenthone (a variant found in the standard geranium plantings). The composition of the standard oil produced from the Kunti cultivar was determined to be as follows:

myrcene (0.1 percent)
(E)-β-ocimene (0.1 percent)
cis-linalool oxide[†] (0.2 percent)
trans-linalool oxide[†] (0.2 percent)
menthone (0.2 percent)
isomenthone (8.2 percent)
neoisomenthol (0.6 percent)
α-terpineol (0.3 percent)
citronellol (11.8 percent)
nerol (0.8 percent)

neral (0.9 percent)
piperitone (0.1 percent)
geraniol (31.9 percent)
citronellic acid (0.2 percent)
citronellyl acetate (0.1 percent)
neryl acetate (1.0 percent)
α-cubebene (0.2 percent)
geranyl acetate (0.6 percent)
decanoic acid‡ (2.4 percent)
α-copaene (0.3 percent)
β-bourbonene (0.4 percent)
undecanoic acid‡ (0.6 percent)
β-caryophyllene (0.5 percent)
guaia-6,9-diene (1.4 percent)
geranyl propionate (2.3 percent)
α-humulene (0.1 percent)
allo-aromadendrene (0.1 percent)
γ-muurolene (0.1 percent)
germacrene D (0.1 percent)
β-selinene (0.2 percent)
α-muurolene (0.4 percent)
γ-cadinene (0.1 percent)
δ-cadinene (3.2 percent)
geranyl butyrate (3.2 percent)
(E)-nerolidol (0.4 percent)
2-phenethyl tiglate (1.3 percent)
furopelargone B (0.8 percent)
spathulenol‡ (0.2 percent)
caryophyllene oxide (0.3 percent)
citronellyl valerate (0.3 percent)
10-epi-γ-eudesmol (5.2 percent)
geranyl valerate (0.1 percent)
α-muurolol (0.7 percent)
β-eudesmol (1.3 percent)
α-eudesmol (0.1 percent)
citronellyl tiglate (2.4 percent)
citronellyl isohexanoate (0.2 percent)
geranyl hexanoate (0.4 percent)
citronellyl isoheptanoate (0.2 percent)
citronellyl heptanoate (0.1 percent)
geranyl heptanoate (0.6 percent)
geranyl octanoate (0.3 percent)

†furanoid form; ‡tentative identification

Trace amounts (< 0.1 percent) of 6-methyl-5-hepten-2-one, p-cymene, (Z)-β-ocimene and menthol were also found in this same oil. The components identified in the oil of the isomenthone-rich geranium variant were as follows:

(Z)-3-hexenol (0.2 percent)
α-pinene (0.2 percent)
myrcene (0.3 percent)
p-cymene (1.1 percent)
limonene (1.3 percent)
menthone (2.7 percent)
isomenthone (63.1 percent)
neomenthol + borneol (2.7 percent)
neoisomenthol (0.6 percent)
α-terpineol (0.2 percent)
citronellol (0.2 percent)
nerol (0.2 percent)
neral (0.2 percent)
piperitone (0.2 percent)
geraniol (0.2 percent)
bornyl acetate (0.1 percent)
decanoic acid‡ (5.8 percent)
α-copaene (0.2 percent)
β-bourbonene (0.6 percent)
undecanoic acid‡ (2.1 percent)
β-caryophyllene (0.3 percent)
guaia-6,9-diene (1.8 percent)
geranyl propionate (0.2 percent)
α-humulene (0.1 percent)
allo-aromadendrene (0.1 percent)
γ-muurolene (0.1 percent)
germacrene D (0.2 percent)
β-selinene (0.2 percent)
α-muurolene (0.2 percent)
γ-cadinene (0.1 percent)
δ-cadinene (0.2 percent)
geranyl butyrate (0.1 percent)
(E)-nerolidol (0.5 percent)
2-phenethyl tiglate (2.1 percent)
furopelargone B (0.4 percent)
spathulenol‡ (0.1 percent)
caryophyllene oxide (0.1 percent)
geranyl isovalerate (0.1 percent)
citronellyl valerate (0.2 percent)
10-epi-γ-eudesmol (5.0 percent)
geranyl valerate (0.1 percent)
α-muurolol (0.4 percent)
β-eudesmol (1.2 percent)
α-eudesmol (0.1 percent)
citronellyl tiglate (1.5 percent)
citronellyl isohexanoate (0.1 percent)
citronellyl isoheptanoate (0.1 percent)
geranyl isoheptanoate (0.1 percent)
citronellyl heptanoate (0.1 percent)
geranyl heptanoate (0.1 percent)

‡tentative identification

In addition, trace amounts (< 0.1 percent) of α-phellandrene, (Z)-β-ocimene, (E)-β-ocimene, *cis*-linalool oxide and *trans*-linalool oxide (furanoid forms), geranyl hexanoate and geranyl octanoate were also found in this same oil.

L. Peyron, *Precursors of certain sulfur compounds encountered with essential oils*. Bull. Soc. France Physiol. Vegetale, **7**, 46-47 (1961).

B.R. Rajeswara Rao, A.K. Bhattacharya, P.N. Kaul and S. Ramesh, *Economics of cultivation and chemical composition of essential oil of rose geranium in relation to fertilizer application*. Indian Perfum., **36**(2), 113-116 (1992).

P.N. Kaul, B.R. Rajeswara Rao, A.K. Bhattacharya, G.R. Mallavarapu and S.I. Ramesh, *Changes in chemical composition of rose-scented geranium (Pelargonium sp.) oil during storage*. J. Essent. Oil Res., **9**, 115-117 (1997).

K.P. Sastry, K.R. Krishnan, S.M. Saleem and S. Kumar, *Influence of time and method of storage of harvested herbage before distillation on the oil content and quality of essential oil in rose-scented geranium (Pelargonium graveolens) chemotypes*. J. Med. Arom. Plant Sci., **22**, 352-355 (2001).

K.P. Sastry, K.R. Krishnan, S.M. Saleem, A.A. Naqvi and S. Kumar, *Differences in the quality of essential oil hydrodistilled from leaves from different positions on the growing branches of rose-scented geranium Pelargonium graveolens*. J. Med. Arom. Plant Sci., **22**, 34-36 (2001).

R. Gupta, S.K. Gupta, S. Banerjee, G.R. Mallavarapu and S. Kumar, *Micropropagation of elite cultivars of rose-scented geranium (Pelargonium graveolens L'tterit.) for industrial production of propagules*. Indian J. Biotechnol., **1**, 286-291 (2002).

G. Vernin, S. Chakib, R-M. Zamkotsian, G.M.F. Vernin, J-L. Larice and C. Parkanyi, *Classification of geranium essential oils by Chemometrics*. Rivista Ital. EPP05, **34**, 319 (2002).

P. Narayanan, *Comparison of quality of essential oils from south India*. FAFAI, **5**(1), 47-56 (2003).

R.A. Shellie and P.J. Marriott, *Comprehensive two-dimensional gas chromatography-mass spectrometry analysis of Pelargorlium graveolens essential oil using rapid scanning quadruple mass spectrometry*. Analyst, **128**, 879-883 (2003).

H.J. Damien Dorman and S.G. Deans, *Chemical composition, antimicrobial and in vitro antioxidant properties of Monarda citriodora var. citriodora, Myristica fragrans, Origanum vulgare ssp. hirtum, Pelargonium sp. and Thymus zygis oils*. J. Essent. Oil Res., **16**, 145-150 (2004).

G.A. Vernin, S. Chakib, G.M.F. Vernin and R.M. Zamkotsian, *Geranium (Pelargonium sp.) essential oil from Reunion. Minor compounds: acids, phenols, pyridines*. J. Essent. Oil Res., **16**, 26-18 (2004).

G. Saxena, S. Banerjee, R. Gupta, L-Ur-Rahrean, B.R. Tyagi, S. Kumar, G.R. Mallavarapu and S. Ramesh, *Composition of the essential oil of a new isomenthone-rich variant of geranium obtained from geraniol-rich cultivar of Pelagonium species*. J. Essent. Oil Res., **16**, 85-88 (2004).

Basil Oil

Oils produced in Lomé, Kpalimé, Atakpamé and Blitta (Togo) from *Ocimum basilicum* plants grown in vegetable gardens were all found to be rich in methyl chavicol by Sanda et al. (1998). The range in composition found was as follows:

α-pinene (0-0.3 percent)
sabinene (0-0.4 percent)
β-pinene (0-0.8 percent)
myrcene (0-0.5 percent)
limonene + 1,8-cineole (0-7.4 percent)
(Z)-β-ocimene (0-1.8 percent)
(E)-β-ocimene (0-2.3 percent)
γ-terpinene (0-0.2 percent)
terpinolene (0-0.2 percent)
linalool (0-3.2 percent)
trans-sabinene hydrate (0-0.9 percent)
camphor (0-1.0 percent)
terpinen-4-ol (0-0.5 percent)
methyl chavicol (83.8-88.6 percent)
methyl eugenol (0-0.5 percent)
α-copaene (0-1.4 percent)
β-elemene (0-0.4 percent)
β-caryophyllene (0-0.6 percent)
trans-α-bergamotene (0-4.4 percent)
α-humulene (0-3.2 percent)
germacrene D (0-0.3 percent)
β-selinene (0-0.3 percent)
bicyclogermacrene (0-0.6 percent)
α-muurolene (0-0.3 percent)
germacrene A (0.5-1.4 percent)
γ-cadinene (0-0.8 percent)
T-cadinol (0-1.0 percent)

Another oil produced from plants grown in Sokode′ (Togo) was determined to possess the following composition:

α-thujene (0.4 percent)
myrcene (0.4 percent)
limonene + 1,8-cineole (0.4 percent)
(E)-β-ocimene (0.7 percent)
γ-terpinene (0.2 percent)
p-cymene (0.5 percent)
terpinolene (1.4 percent)
cis-sabinene hydrate (0.9 percent)
linalool (41.2 percent)
camphor (0.3 percent)
terpinen-4-ol (2.3 percent)
methyl chavicol (22.2 percent)
β-elemene (1.2 percent)
β-caryophyllene (0.2 percent)
trans-α-bergamotene (7.6 percent)
α-humulene (0.4 percent)
germacrene D (0.8 percent)
β-selinene (0.6 percent)
bicyclogermacrene (0.4 percent)
α-muurolene (0.8 percent)
γ-cadinene (1.4 percent)
T-cadinol (0.4 percent)

Amvam Zollo et al. (1998) analyzed an oil produced from *O. basilicum* grown in Cameroon. The results of this analysis were as follows:

α-pinene (0.8 percent)
myrcene (2.1 percent)
limonene (10.4 percent)
1,8-cineole (3.1 percent)
(E)-β-ocimene (1.8 percent)
γ-terpinene (0.9 percent)
linalool (50.8 percent)
terpinen-4-ol (3.5 percent)
α-terpineol (1.2 percent)
eugenol (13.8 percent)
β-elemene (0.7 percent)
β-caryophyllene (2.2 percent)
α-humulene (0.5 percent)
germacrene D (2.2 percent)
bicyclogermacrene (0.8 percent)
δ-cadinene (1.0 percent)
bisabolene* (0.5 percent)
T-cadinol (3.4 percent)

*correct isomer not identified

In addition, trace amounts (< 0.1 percent) of α-thujene, sabinene, β-pinene, α-copaene, (E)-β-farnesene, (E,E)-α-farnesene, α-muurolol and α-cadinol were also found in the same oil.

Variance in percentage composition of the major constituents of the oils of three basil cultivars			T-6
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

Antonelli et al. (1998) used gamma rays and microwaves to treat dried basil leaves of Egyptian origin to reduce their microbiological contaminants. Analysis of a hexane extract produced from untreated leaves revealed the following composition:

α-pinene (0.29 percent)
camphene (0.02 percent)
β-phellandrene† (0.18 percent)
β-pinene (0.46 percent)
myrcene (0.10 percent)
p-cymene (0.03 percent)
1,8-cineole (5.14 percent)
γ-terpinene (0.01 percent)
cis-p-menth-2-en-1-ol (0.21 percent)
cis-linalool oxide-furanoid (0.08 percent)
trans-linalool oxide-furanoid (0.08 percent)
trans-p-menth-2-en-1-ol (0.07 percent)
linalool (14.92 percent)
camphor (1.41 percent)
borneol (0.72 percent)
menthol (0.07 percent)
terpinen-4-ol (0.88 percent)
α-terpineol (1.25 percent)
methyl chavicol (4.54 percent)
allyl phenol‡ (0.37 percent)
bornyl acetate (1.05 percent)
safrole‡ (0.05 percent)
neral (0.18 percent)
methyl (Z)-cinnamate (0.66 percent)
thymol (0.68 percent)
eugenol (12.13 percent)
α-cubebene (0.01 percent)
methyl (E)-cinnamate (9.08 percent)
elemene* (2.19 percent)
methyl eugenol (2.08 percent)
β-caryophyllene (1.24 percent)
α-bergamotene* (6.88 percent)
α-humulene (0.73 percent)
cadinene*‡ (0.35 percent)
β-cubebene‡ (2.42 percent)
β-farnesene (0.77 percent)
eremophilene‡ (0.39 percent)
β-bisabolene (0.22 percent)
γ-cadinene (3.77 percent)
calamenene* (2.31 percent)
myristicin‡ (1.34 percent)
trimethyltetrahydrobenzofuranone (0.65 percent)
spathulenol (1.04 percent)
α-muurolol (1.28 percent)
α-cadinol (9.89 percent)

*correct isomer not identified; †misidentification of sabinene; ‡tentatively identified components, probably misidentified

The authors found that treatment with either gamma rays or microwaves caused some compositional differences. Gamma radiation using 5 or 10 kGy (from a 60 Co source) caused the most evident changes particularly increased in the content of linalool of ca. 190 percent and ca. 290 percent while microwaves caused a ca. 40 percent reduction in the linalool content and a 70 percent reduction in the methyl chavicol content. From a sensory standpoint, the odor associated with microwave treatment using 5 kGy was considered to be equivalent to the untreated product even though the composition had changed.

Although camphor is not a major constituent of basil oil, Tateo et al. (1999) determined that the amount found in five Italian samples of the oil was 0.4-0.9 percent. The authors also determined that the enantomeric distribution of camphor was as follows: (1S)-(-)-camphor (0-2.5 percent):(1R)-(+)-camphor (97.5-100 percent).

Putievsky et al. (1999) examined the oil composition of 14 accessions of *O. basilicum* and their F_1 and F_2 hybrid progenies. In the parent plants they found oils with linalool (60 percent), methyl chavicol (84 percent) and eugenol (26 percent) as major constituents. A survey of the hybrid plants revealed oils rich in linalool (90 percent), methyl chavicol (93 percent) and eugenol (34 percent). It is believed that the linalool-rich and methyl chavicol-rich oils could become useful commercial sources of these two compounds.

Murakami et al. (1999) used SPME to determine the headspace volatiles of the "sweet" and "cinnamon" cultivars of *O. basilicum* grown in Japan. The volatiles of "sweet" were found to be:

α-pinene (0.58 percent)
camphene (0.16 percent)
β-pinene (1.28 percent)
sabinene (0.71 percent)
δ-3-carene (0.30 percent)
myrcene (0.95 percent)
limonene (1.02 percent)
1,8-cineole (11.05 percent)
(Z)-3-hexenol (0.18 percent)
α-copaene (0.29 percent)
linalool (5.06 percent)
β-caryophyllene (0.64 percent)
α-humulene (2.25 percent)
linalyl propionate (0.84 percent)
methyl eugenol (11.93 percent)
(E)-methyl cinnamate (0.08 percent)

A number of other volatile components were misidentified so they have not been included. Some of the headspace volatiles in the "cinnamon" cultivar that were correctly identified were as follows:

α-pinene (0.27 percent)
β-pinene (0.80 percent)
sabinene (0.56 percent)
myrcene (0.72 percent)
limonene (0.71 percent)
1,8-cineole (9.82 percent)
(Z)-3-hexenol (0.17 percent)
linalool (13.00 percent)
α-humulene (2.23 percent)
linalyl propionate (0.91 percent)
(E)-methyl cinnamate (30.92 percent)
(E)-ethyl cinnamate (0.22 percent)

As with the previous analysis, the misidentified components of the oil were not included as they are merely confusing and inaccurate.

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 T-6.

Johnson et al. (1999) determined the effect of UV-B on the oils of sweet basil grown under controlled conditions. An oil produced from control plants not grown under UV-B treatment that was produced from small vegetative plants at the five-leaf stage was found to possess the following composition:

α-pinene (1.38 percent)
sabinene (1.27 percent)
β-pinene (2.43 percent)
myrcene (1.38 percent)
limonene (1.01 percent)
1,8-cineole (19.55 percent)
(E)-β-ocimene (4.41 percent)
cis-sabinene hydrate (0.45 percent)
terpinolene (0.59 percent)
linalool (47.09 percent)
camphor (0.71 percent)
borneol (0.52 percent)
α-terpineol (0.85 percent)
isobornyl acetate (1.12 percent)
eugenol (2.79 percent)
methyl eugenol (0.70 percent)
trans-α-bergamotene (6.21 percent)
(E)-β-farnesene (1.89 percent)
germacrene D (1.51 percent)
γ-cadinene (0.61 percent)

Moudachirou et al. (1999) found that oils produced from *O. basilicum* obtained from plants grown in Cotonou, Pobé and Savé (Benin) were examples of two chemotypes. The methyl chavicol-rich chemotypes had a composition range of:

α-pinene (t-0.2 percent)
β-pinene (0.1-0.5 percent)
sabinene (t-0.2 percent)
myrcene (t-0.2 percent)
α-terpinene (0-0.1 percent)
limonene (0.1-1.9 percent)
1,8-cineole (t-4.5 percent)
γ-terpinene (t-0.1 percent)
(E)-β-ocimene (0.2-0.4 percent)
p-cymene (t)
terpinolene (0-t)
cis-linalool oxide* (0-0.1 percent)
linalool (0-0.2 percent)
methyl chavicol (86.7-89.8 percent)
(E)-β-farnesene (0-0.2 percent)
α-terpineol (0-0.9 percent)
geranial (0-3.5 percent)
β-bisabolene (0-2.2 percent)
methyl eugenol (0-0.1 percent)
nerolidol* (0-0.2 percent)
eugenol (0-t)
T-cadinol (0-0.5 percent)
thymol (0-0.1 percent)

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

In contrast, the other chemotype possessed the following composition:

α-pinene (0.1 percent)
β-pinene (0.1 percent)
sabinene (< 0.1 percent)
myrcene (0.2 percent)

α-terpinene (0.1 percent)
limonene (0.4 percent)
1,8-cineole (1.4 percent)
γ-terpinene (0.5 percent)
(E)-β-ocimene (2.3 percent)
p-cymene (0.3 percent)
terpinolene (0.2 percent)
(Z)-3-hexenol (1.5 percent)
cis-linalool oxide* (0.5 percent)
linalool (45.3 percent)
methyl chavicol (1.0 percent)
(E)-β-farnesene (0.6 percent)
α-terpineol (1.8 percent)
geranial (0.8 percent)
geranyl acetate (0.3 percent)
nerol + calamenene* (0.2 percent)
geraniol (0.8 percent)
methyl eugenol (1.7 percent)
nerolidol* (0.1 percent)
eugenol (14.9 percent)
T-cadinol (5.0 percent)
thymol (< 0.1 percent)

*correct isomer not identified

Ocimum basilicum oil produced from plants grown in Guinea was analyzed by GC and GC/MS by Kéita et al. (2000). It was found to be a linalool-rich chemotype whose composition was as follows:

α-pinene (0.64 percent)
myrcene (0.62 percent)
α-terpinene (0.28 percent)
p-cymene (0.84 percent)
1,8-cineole (0.84 percent)
limonene (0.92 percent)
(E)-β-ocimene (1.85 percent)
γ-terpinene (0.56 percent)
trans-sabinene hydrate (0.59 percent)
linalool (67.84 percent)
terpinen-4-ol + α-terpineol (5.02 percent)
thymol (2.01 percent)
eugenol (9.70 percent)
trans-α-bergamotene (2.93 percent)
germacrene D (0.20 percent)

The oil isolated from the peltate glandular trichomes of *O. basilicum* by micro needle perforation of the glands was the subject of analysis by Maleci Bini et al. (2000). The components found in the oil isolated from 50 glands were as follows:

α-pinene (0.32 percent)
camphene (0.60 percent)
1-octen-3-ol (0.31 percent)
β-pinene (0.21 percent)
1,8-cineole (4.07 percent)
3,3,5-trimethylhexanol (0.34 percent)
linalool (4.74 percent)
camphor (0.40 percent)
(Z)-3-hexenyl butyrate (5.28 percent)
eugenol (63.84 percent)
α-copaene (0.51 percent)
methyl isoeugenol* (6.57 percent)
trans-β-bergamotene (1.89 percent)
α-bergamotene* (0.60 percent)
α-amorphene (2.63 percent)
γ-cadinene (4.51 percent)
trans-bergamota-2,12-diene (0.50 percent)
benzophenone (2.65 percent)

The characterization of 3,3,5-trimethylhexanol and benzophenone in the oil requires corroboration. As to this reviewer's knowledge 3,3,5-trimethylhexanol has not been unequivocally characterized as a natural occurring component of any oil. Also, as yet benzophenone has never to date been detected as a constituent of an oil of *O. basilicum*.

Shatar and Altantseteg (2000) examined the composition of an oil of *O. basilicum* produced from plants grown in Mongolia. The composition of this oil was determined to be as follows:

α-pinene (0.2 percent)
camphene (< 0.1 percent)
β-pinene (0.1 percent)
sabinene (0.9 percent)
myrcene (0.2 percent)
α-phellandrene (< 0.1 percent)
α-terpinene (0.1 percent)
limonene (0.3 percent)
β-phellandrene (0.1 percent)
1,8-cineole (0.8 percent)
(Z)-β-ocimene (0.1 percent)
(E)-β-ocimene (0.6 percent)
p-cymene (0.3 percent)
terpinolene (0.2 percent)
1-octen-3-ol (0.3 percent)
α-copaene (0.1 percent)
camphor (1.7 percent)
linalool (23.8 percent)
octanol (0.1 percent)
cis-α-bergamotene (1.1 percent)
β-elemene (2.0 percent)
terpinen-4-ol (0.5 percent)
methyl chavicol (52.0 percent)
α-humulene (0.5 percent)
α-terpineol (0.5 percent)
borneol (0.8 percent)
germacrene D (1.3 percent)
carvone (0.5 percent)
δ-cadinene (0.1 percent)
(E)-anethole (0.1 percent)
geraniol (0.1 percent)
methyl eugenol (1.1 percent)
(E)-nerolidol (0.4 percent)
cubenol (0.7 percent)
spathulenol (0.1 percent)
eugenol (0.1 percent)
T-cadinol (4.4 percent)
α-cadinol (0.2 percent)
β-eudesmol (0.4 percent)

Miele et al. (2001) reported that the Genovese Gigante cultivar of *O. basilicum* is considered to be the best cultivar for pesto manufacture in Italy. They determined that the main components were eugenol and methyl eugenol. They also found that the taller plants (> 16 cm height) possessed oils richer in eugenol than methyl eugenol, whereas the situation was opposite in smaller plants (3.5-6.5 cm height). As a result, because of the potential risk in ingesting large amounts of methyl eugenol, the authors noted that as pesto contains ca. 10 g of basil, use of leaves for pesto manufacture from the taller plants was recommended.

An oil of *O. basilicum* of Bulgarian origin was found to be rich in (-)-linalool by Jirovetz et al. (2001). The constituents found in this oil in decreasing amounts can be seen as follows:

linalool (71.4 percent)
(Z,E)-α-farnesene (6.5 percent)
1,8-cineole (5.6 percent)
T-cadinol (2.8 percent)
germacrene D (1.7 percent)
citronellol (1.2 percent)
bornyl acetate (1.1 percent)
β-elemene (0.9 percent)
geraniol (0.8 percent)
α-terpineol (0.6 percent)
α-bisabolol (0.6 percent)
β-caryophyllene (0.6 percent)
α-humulene (0.4 percent)
geranyl acetate (0.4 percent)
terpinolene (0.4 percent)
β-pinene (0.3 percent)
methyl chavicol (0.3 percent)
nerol (0.2 percent)
cis-linalool oxide* (0.2 percent)
(Z,E)-farnesol (0.2 percent)
trans-linalool oxide* (0.2 percent)
neryl acetate (0.2 percent)
(Z)-β-ocimene (0.1 percent)
sabinene (0.1 percent)
eugenol (0.1 percent)
α-pinene (0.1 percent)
limonene (0.1 percent)
borneol (0.1 percent)
α-terpinyl acetate (0.1 percent)
terpinen-4-ol (0.1 percent)
(E)-β-ocimene (0.1 percent)
1-octen-3-ol (0.1 percent)
γ-cadinene (0.1 percent)
germacrene B (0.1 percent)
p-cymene (0.1 percent)
myrcene (0.1 percent)
γ-terpinene (0.1 percent)

*correct isomer not identified

Trace amounts (< 0.1 percent) of 1-octen-3-yl acetate, camphor, α-copaene, *trans*-α-bergamotene, a calamenene isomer, hexanol, linalyl acetate, α-cadinene, 1-hexen-3-ol and (E)-methyl cinnamate were also found in this same oil.

An oil of basil that was produced in the Hyderabad region of India was found (Kothari et al. 2001) to possess the following composition:

(Z)-3-hexenol (0.10 percent)
α-pinene (0.46 percent)
camphene (0.16 percent)
sabinene (0.37 percent)
β-pinene (0.43 percent)
δ-3-carene (0.07 percent)
1,8-cineole (5.50 percent)
(E)-β-ocimene (0.05 percent)
γ-terpinene (0.42 percent)
linalool (29.90 percent)
isoborneol (0.94 percent)
borneol (3.50 percent)
myrtenol (0.17 percent)
bornyl acetate (1.65 percent)
eugenol (33.50 percent)
(Z)-methyl cinnamate (0.11 percent)
isoeugenol* (0.08 percent)
β-elemene (1.00 percent)
(Z)-cinnamyl acetate (0.13 percent)
(E)-β-farnesene (5.90 percent)
α-amorphene (0.39 percent)
α-humulene (0.26 percent)
α-muurolene (1.05 percent)
(E,E)-α-farnesene (1.35 percent)
δ-guaiene† (1.20 percent)
cubenol (0.35 percent)
(Z)-nerolidol (0.26 percent)
spathulenol (0.22 percent)
T-cadinol (3.40 percent)
β-eudesmol (0.39 percent)

*correct isomer not identified; †also known as α-bulnesene

Bucar et al. (2001) determined the methyl chavicol content of oils produced from different basil cultivars. They found the methyl chavicol contents to range according to the cutting (harvest) time either in July or August in Graz (Austria) e.g. 'Siam Queen' (80.4 percent and 83.4 percent), 'Green Ruffles' (47.0 percent and 46.1 percent), 'Miltelgrossblattriges' (42.7 percent and 43.2 percent) and 'A folia di Lattuga' (31.9 percent and 31.7 percent).

An oil of *O. basilicum* produced in Egypt was found by Hifnawy et al. (2001) to possess the following composition:

α-pinene (0.1 percent)
β-pinene (0.2 percent)
sabinene (0.1 percent)
myrcene (0.1 percent)
limonene (0.1 percent)
1,8-cineole (1.2 percent)
octyl acetate (0.2 percent)
linalool (0.1 percent)
α-farnesene* (0.5 percent)
β-caryophyllene (1.6 percent)
methyl chavicol (91.1 percent)
germacrene D (0.5 percent)
α-terpineol (0.7 percent)
α-humulene (1.7 percent)
methyl eugenol (0.5 percent)
α-bisabolol (0.1 percent)

*correct isomer not identified

More recently, Sanda et al. (2001) analyzed three oils of *O. basilicum* produced from plants harvested at different stages of maturity in Togo. The analyses, which were performed using a combination of GC and GC/MS, revealed that the oils contained the following components:

α-thujene (0-0.23 percent)
myrcene (0.55-0.66 percent)
α-phellandrene (0-0.32 percent)
limonene (0.14-0.22 percent)
1,8-cineole (1.97-2.46 percent)
(Z)-β-ocimene (0-0.30 percent)
terpinolene (0-0.06 percent)
linalool (2.97-4.03 percent)
camphor (1.02-1.98 percent)
borneol (0-0.22 percent)
terpinen-4-ol + bornyl acetate (0.26-0.36 percent)
methyl chavicol (80.74-83.48 percent)
methyl eugenol (0.23-0.31 percent)
β-elemene (1.10-1.42 percent)
trans-α-bergamotene (0.50-0.70 percent)
α-guaiene (0.55-0.60 percent)
α-humulene (0.28-0.35 percent)
(E)-β-farnesene (0-0.21 percent)
germacrene D (0-0.21 percent)
β-selinene (0-0.32 percent)
bicyclogermacrene (0-0.45 percent)
germacrene A (0.41-1.10 percent)
γ-cadinene (0.71-0.99 percent)
α-muurolol (0.72-1.10 percent)

Koumaglo (2002) reported that the main components of the oils of two different chemotypes of *O. basilicum* produced in Togo were as follows:

Chemotype 1:	1,8-cineole (33 percent)
	linalool (39 percent)
	methyl isoeugenol (6 percent)
Chemotype 2:	linalool (3 percent)
	methyl chavicol (89 percent)

Vincenzi et al. (2002) determined that Italian basil oil contained an average of 1,8-cineole (8.0 percent).

Krüger et al. (2002) examined the chemical variability of 270 accessions in the Gatersleben (Germany) *Ocimum* species data bank. They found that oils produced from the accessions possessed main components such as linalool (max. 71 percent); methyl chavicol (max. 92 percent); neral/geranial (max. 80 percent); 1,8-cineole (max. 25 percent) and camphor (max. 63 percent); thymol (max. 35 percent); (E)-methyl cinnamate (max. 77 percent); eugenol (max. 80 percent); methyl eugenol (max. 79 percent); methyl isoeugenol (max. 36 percent) and elemicin (max. 47 percent). It is a shame that the authors did not identify the species names of the accessions; although one can guess that the oils rich in linalool, methyl chavicol and (E)-methyl cinnamate probably originated from *O. basilicum*.

An oil produced from *O. basilicum* grown in Bangladesh was the subject of analysis by Mondello et al. (2002). Using a combination of GC retention indices on polar and non-polar capillary GC columns and GC/MS the oil was found to contain the following constituents:

α-thujene (0.1 percent)
α-pinene (0.3 percent)
sabinene (0.1 percent)
β-pinene (0.4 percent)
myrcene (0.2 percent)
p-cymene (0.8 percent)
limonene (2.5 percent)
1,8-cineole (0.9 percent)
(E)-β-ocimene (0.2 percent)
γ-terpinene (0.5 percent)
cis-sabinene hydrate (0.4 percent)
cis-linalool oxide[†] (0.1 percent)
trans-linalool oxide[†] (0.1 percent)
terpinolene (0.1 percent)
linalool (29.7 percent)
cis-p-menth-2-en-1-ol (0.1 percent)
trans-pinene hydrate (0.1 percent)
camphor (0.1 percent)
terpinen-4-ol (5.7 percent)
α-terpineol (0.2 percent)
(E)-2-hexenyl butyrate (0.2 percent)
methyl chavicol (0.1 percent)
nerol (0.8 percent)
citronellol (0.1 percent)
neral (1.2 percent)
geraniol (27.4 percent)
geranial (2.0 percent)
bornyl acetate (0.1 percent)
geranyl formate (0.2 percent)
methyl geranate (0.1 percent)
trans-carvyl acetate (0.3 percent)
α-cubebene (0.1 percent)
neryl acetate (0.3 percent)
α-copaene (0.1 percent)
geranyl acetate (13.8 percent)
β-elemene (0.9 percent)
β-caryophyllene (0.5 percent)
α-guaiene (0.7 percent)
trans-α-bergamotene (0.1 percent)
α-humulene (0.4 percent)
germacrene D (0.9 percent)
β-selinene (0.1 percent)
bicyclogermacrene (0.4 percent)
α-bulnesene (1.6 percent)
δ-cadinene (0.1 percent)
(E)-nerolidol (0.1 percent)
longipinanol[t] (0.1 percent)
spathulenol (0.7 percent)
caryophyllene oxide (0.2 percent)
humulene epoxide II (0.2 percent)
α-eudesmol (0.3 percent)
epi-α-bisabolol (0.2 percent)
14-hydroxy-α-humulene[t] (0.2 percent)

[†]furanoid form; [t] = tentative identification

In addition, trace amounts (< 0.1 percent) of camphene, 1-octen-3-ol, 6-methyl-5-hepten-2-one, (Z)-3-hexenyl acetate, α-terpinene, (Z)-β-ocimene, 1-octen-3-yl acetate, citronellal and γ-cadinene were also found in this same oil.

Bouzouita et al. (2003) screened a few Tunisian oils for their antimicrobial activity. One of the oils screened was basil. In addition to finding that it possessed remarkable activity against the bacteria and fungi against which it was screened, the composition of the oil was determined to be as follows:

α-pinene (0.4 percent)
sabinene (0.1 percent)
β-pinene (0.6 percent)
myrcene (0.3 percent)
α-terpinene (0.1 percent)
limonene (0.3 percent)
1,8-cineole (8.7 percent)
(E)-β-ocimene (0.1 percent)
γ-terpinene (0.2 percent)
terpinolene (0.2 percent)
linalool (32.5 percent)
camphor (0.5 percent)
borneol (0.4 percent)
terpinen-4-ol (0.8 percent)
α-terpineol (1.0 percent)
methyl chavicol (34.0 percent)
bornyl acetate (0.5 percent)
(Z)-methyl cinnamate (0.6 percent)
eugenol (1.7 percent)
(E)-methyl cinnamate (4.2 percent)
β-elemene (0.5 percent)
methyl eugenol (1.5 percent)
β-caryophyllene (0.6 percent)
trans-α-bergamotene (3.2 percent)
α-guaiene (0.2 percent)
α-humulene (0.5 percent)
germacrene D (1.0 percent)
α-bulnesene (0.6 percent)
α-amorphene (1.1 percent)
(Z)-α-bisabolene (0.3 percent)
α-cadinol (1.3 percent)

de Vasconcelos Silva et al. (2003) analyzed three oils of *O. basilicum* that were produced from plants grown in northeastern Brazil. Two of the oils were found to be rich in linalool and methyl chavicol e.g.

camphene (0-0.9 percent)
sabinene (0-1.6 percent)
1,8-cineole (7.4-11.0 percent)
limonene (0-0.7 percent)
cis-sabinene hydrate (0-0.8 percent)
cis-linalool oxide† (0-2.8 percent)
trans-linalool oxide† (0-2.6 percent)
linalool (16.8-42.5 percent)
camphor (0.9-1.7 percent)
terpinen-4-ol (2.1-3.3 percent)
methyl chavicol (33.1-52.2 percent)
bornyl acetate (0-0.8 percent)
trans-α-bergamotene (0-1.5 percent)
α-muurolene (0-0.8 percent)
γ-cadinene (1.1-1.2 percent)
4-methoxycinnamaldehyde (0-2.9 percent)
humulene epoxide II (0-0.9 percent)
α-muurolol (2.3-2.5 percent)

The other oil was found to be rich in linalool and sesquiterpenes as shown below.

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)
β-elemene (0.8 percent)
β-caryophyllene (4.0 percent)
α-humulene (1.6 percent)
bicyclogermacrene (0.7 percent)
germacrene A (1.0 percent)
α-bulnesene (0.4 percent)
γ-cadinene (7.7 percent)
humulene epoxide II (1.5 percent)
1-epi-cubenol (2.3 percent)
α-muurolol (11.0 percent)
β-eudesmol (0.5 percent)

†furanoid form

The headspace volatiles of the dried and ground leaves of *O. basilicum* grown experimentally in Brazil were analyzed using SPME and GC/MS (Sartoratto and Augusto 2003). Their results were as follows:

1,8-cineole (1.05 percent)
fenchone (0.53 percent)
linalool (32.60 percent)
camphor (10.10 percent)
terpinen-4-ol (0.99 percent)
α-terpineol (3.90 percent)
eugenol (28.10 percent)
β-bourbonene (0.23 percent)
β-elemene (1.92 percent)
β-caryophyllene (2.00 percent)
β-bergamotene* (1.66 percent)
α-guaiene (0.29 percent)
α-humulene (0.77 percent)
germacrene D (5.49 percent)
δ-guaiene (0.68 percent)
δ-cadinene (0.29 percent)
T-muurolol (5.81 percent)
α-eudesmol (0.24 percent)
α-cadinol (0.38 percent)

*correct isomer not identified

A sample of basil oil produced from plants grown in Egypt was screened for its antifungal activity by Edris and Farrag (2003). The oil used in this screening study was analyzed by GC and GC/MS and found to possess the following composition:

α-pinene (0.53 percent)
sabinene (0.50 percent)
β-pinene (1.13 percent)
myrcene (1.12 percent)
limonene (0.54 percent)
1,8-cineole (10.26 percent)
terpinolene (0.17 percent)
linalool (55.78 percent)
terpinen-4-ol (0.17 percent)
cis-piperitol (0.68 percent)
methyl chavicol (0.89 percent)
trans-piperitol (0.13 percent)
linalyl acetate (0.11 percent)
eugenol (12.15 percent)
β-elemene (0.70 percent)
methyl eugenol (3.79 percent)
β-caryophyllene (0.12 percent)
α-humulene (0.42 percent)
caryophyllene oxide (0.42 percent)
viridiflorol (0.62 percent)

K. Sanda, K. Koba, P. Nambo and A. Gasset, *Chemical investigation of Ocimum species growing in Togo*. Flav. Fragr. J., **13**, 226-232 (1998).

P.H. Amvam Zollo, L. Biyiti, F. Tchoumbougnang, C. Menut, G. Lamaty and Ph. Bouchet, *Aromatic plants of tropical central Africa. XXXII. Chemical composition and antifungal activity of 13 essential oils from aromatic plants of Cameroon*. Flav. Fragr. J., **13**, 107-114 (1998).

A. Antonelli, C. Fabbri and E. Boselli, *Modifications of dried basil (Ocimum basilicum) leaf oil by gamma and microwave irradiation*. Rivista Ital. EPPOS (Numero Speciale), 272-279 (1997); Food Chem., **63**, 485-489 (1998).

F. Tateo, M. Bonini, E. DeDominicis and V. Fumagalli, *Update on enantiomeric composition of (1R)-(+)- and (1S)-(-)- camphor in essential oils by enantioselective gas chromatography*. Anal. Commun., **36**, 149-151 (1999).

E. Putievsky, A. Paton, E. Lewinsohn, U. Ravid, D. Haimovich, I. Katzir, D. Saadi and N. Dudai, *Crossability and relationship between morphological and chemical varieties of Ocimum basilicum L*. J. Herbs Spices Med. Plants, **6**, 11-24 (1999).

Y. Murakami, H. Hisano, T. Kiyomatsu and K. Ishimaru, *Volatile compounds analyzed by SPME method in Ocimum in vivo and in vitro varieties*. Japan J. Food Chem., **6**, 28-33 (1999).

C.B. Johnson, J. Kirby, G. Naxakis and S. Pearson, *Substanial UV-B mediated induction of essential oils in sweet basil (Ocimum basilicum L.)*. Phytochemistry, **51**, 507-510 (1999).

M. Moudachirou, E. Yayi, J-C. Chalchat and C. Lartigue, *Chemical features of some essential oils of Ocimum basilicum L. from Benin*. J. Essent. Oil Res., **11**, 779-782 (1999).

S.M. Kéita, C. Vincent, J-P. Schmit and A. Bélanger, *Essential oil composition of Ocimum basilicum L., O. gratissimum L. and O. suave L. in the Republic of Guinea*. Flav. Fragr. J., **15**, 339-341 (2000).

L Maleci Bini, L. Gentili, B. Tirillini and R. Pellegrino, *Secretion constituents of leaf glandular trichomes of Ocimum basilicum L.* In: *Flavor and Fragrance Chemistry*. Edits., V. Larzotti and O. Taglialatela-Scafati, pp. 143-150, Kluwer Academic Publ. (2000).

S. Shatar and S. Altantseteg, *Essential oil composition of some plants cultivated in Mongolian climate*. J. Essent. Oil Res., **12**, 745-750 (2000).

M. Miele, R. Dondero, G. Ciarallo and M. Mazzei, *Methyl eugenol in Ocimum basilicum L. cv. Genovese Gigante*. J. Agric. Food Chem., **49**, 517-521 (2001).

L. Jirovetz, G. Buchbauer, A. Stoyanova and A. Balinova, *Analysis, chemotype and quality control of the essential oil of a new cultivated basil (Ocimum basilicum L.) plant from Bulgaria*. Sci. Pharm., **69**, 85-89 (2001).

S.K. Kothari, A.K. Bhattacharya, C.P. Singh and K. Singh, *Ocimum basilicum – an exotic introduction*. Indian Perfum., **45**, 247-251 (2001).

F. Bucar, G. Müller and D. Weissenbacher, *Investigations of basil cultivars on estragole content*. In: *Biologically Active Phytochemicals in Food*., pp. 277-279, Royal Soc. Chem., London, UK (2001).

M.S. Hifnawy, O.A. Rashwan and M.A. Rabeh, *Comparative chemical and biological investigations of certain essential oils belonging to families Asteraceae, Lamiaceae and Graminae*. Bull. Fac. Pharm. Cairo Univ., **39**(2), 35-53 (2001).

K. Sanda, K. Koba, K. Akpagana and T. Tchepan, *Teneur et composition chimique de l'huile essentiale de Ocimum basilicum L. et Ocimum gratissimum L. a differentes periodes de recolte apres semis*. Rivista Ital. EPPOS, **31**, 3-7 (2001).

H.K. Koumaglo, *Bilan et perspectives de la production des huíles essentielles au Togo*. In: *5e Colloque, Produits Naturels d'origine végétale*. Edits., G. Collin and F-X. Garneau, p. 173-178, Univ. Chicoutimi, Quebec (2002).

M. DeVincenzi, M. Silano, A. DeVincenzi, F. Maialetti and B. Scazzocchio, *Constituents of aromatic plants: eucalyptol*. Fitoterapia, **73**, 269-275 (2002).

H. Krüger, S.B. Wetzel and B. Zeiger, *The chemical variability of Ocimum species*. J. Herbs Spices Med. Plants, **9**, 335-344 (2002).

L. Mondello, G. Zappia, A. Cotroneo, I. Bonaccorsi, J.U. Chowdhury, M. Yusuf and G. Dugo, *Studies on the essential-oil bearing plants of Bangladesh. Part VIII. Composition of some Ocimum oils O. basilicum L. var. purpurascens; O. sanctum L. green; O. sanctum L. purple; O. americanum L., citral type; O. americanum L. camphor type*. Flav. Fragr. J., **17**, 335-340 (2002).

N. Bouzouita, F. Kachouri, M. Hamdi and M.M. Chaabouni, *Antimicrobial activity of essential oils from Tunisian aromatic plants*. Flav. Fragr. J., **18**, 380-383 (2003).

M.G. de Vasconcelos Silva, F.J. de Abreu Matos, M.I.L. Machado and A.A. Craveiro, *Essential oils of Ocimum basilicum L. O. basilicum var. minimum L. and O. basilicum var. purpurascens Benth. grown in northeastern Brazil*. Flav. Fragr. J., **18**, 13-14 (2003).

A. Sartoratto and F. Augusto, *Application of headspace solid phase microextraction and gas chromatography to the screening of volatile compounds from some Brazilian aromatic plants*. Chromatographia, **57**, 351-356 (2003).

A.E. Edris and E.S. Farrag, *Antifungal activity of peppermint and sweet basil essential oil and their major aroma constituents on some plant pathogenic fungi from the vapor phase*. Nahrung, **47**, 117-121 (2003). ■