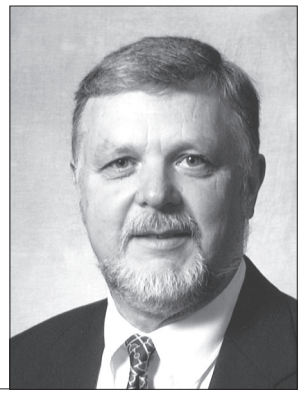

Progress in Essential Oils

By Brian M. Lawrence, R.J. Reynolds Tobacco Company

Ocimum gratissimum oil

A sample of *O. gratissimum* obtained from Zhanjiang (Guangdong, China) was analyzed by Zhu et al. (1993) using GC/MS. Its composition was determined to be as follows:

limonene (0.10%)
1,8-cineole (0.11%)
geraniol (0.10%)
eugenol (69.94%)
α-copaene (1.12%)
β-bourbonene (0.53%)
β-elemene (0.69%)
β-caryophyllene (7.43%)
β-cubebene (0.78%)
γ-muurolene (2.55%)
eremophilene (0.10%)
γ-cadinene (1.13%)
δ-cadinene (4.79%)

Two years later, Zhu et al. (1995) analyzed another oil produced from Chinese grown *O. gratissimum*. The oil, which is used as a source of eugenol, was determined to possess the following composition:

3-hexenal* (0.10%)
3-hexenol (0.30%)
hexanol (0.10%)
sabinene (0.10%)
7-octen-4-ol† (0.20%)
myrcene (0.10%)
(Z)-β-ocimene (1.48%)
(E)-β-ocimene (0.10%)
trans-sabinene hydrate (0.12%)
octanol (0.10%)
linalool (0.19%)
terpinen-4-ol (0.42%)
α-terpineol (0.10%)
eugenol (95.67%)
β-bourbonene (0.10%)
β-caryophyllene (0.31%)
β-cubebene (0.22%)
caryophyllene oxide (0.09%)

*correct isomer not identified
†unusual constituent, identity requires corroboration

An oil of *O. gratissimum* produced from plants grown in Andhra Pradesh (India) was analyzed by Bhattacharya et al. (1996) by GC (retention indices and co-injection) are found to contain:

sabinene (0.19%)
p-cymene (0.19%)
limonene (1.98%)
linalool (0.53%)
α-terpineol (0.86%)
geraniol (0.28%)
eugenol (87.68%)
methyl eugenol (0.64%)
α-copaene (0.76%)
β-caryophyllene (1.84%)
methyl isoeugenol* (0.18%)
α-humulene (0.13%)
germacrene D (0.13%)
β-selinene (2.82%)
β-bisabolene (0.10%)
caryophyllene oxide (0.07%)
γ-eudesmol (0.15%)

*correct isomer not identification

Although in eugenol-rich *O. gratissimum* oil the linalool content was found to be 2.5%, Ravid et al. (1997) determined that it existed solely as the (3R)-(-)-linalool enantiomer.

Vahirua-Lechat et al. (1997) examined the chemical composition of the oils of a few members of the Labiatae family. Within this study, the authors analyzed the leaf and flower oils of *O. gratissimum* produced from plants grown in Tahiti using GC/MS. They found that the oils ranged in composition accordingly:

(Z)-3-hexenol (t-0.17%)
α-pinene (0.18-0.26%)
sabinene (0.17-0.34%)
myrcene (0.20-0.34%)
(Z)-β-ocimene (5.49-15.62%)
(E)-β-ocimene (0.16-0.82%)
γ-terpinene (t-0.28%)
linalool (t-0.57%)
terpinen-4-ol (0.19-0.87%)
methyl chavicol (t-0.64%)
verbenone (t-0.40%)
eugenol (71.14-81.95%)
α-copaene (t-0.87%)
β-bourbonene (0.17-0.53%)
β-elemene (0.03-0.42%)
β-caryophyllene (0.79-2.18%)
α-humulene (t-0.20%)
germacrene D (2.88-8.45%)
β-bisabolene (t-0.22%)
δ-cadinene (0.13-0.48%)
caryophyllene oxide (t-1.07%)
T-cadinol (t-0.29%)
α-cadinol (t-0.81%)

t = <0.01%

This same year, Chalchat et al. (1997) analyzed four oils of *O. gratissimum* produced from plants grown in four different locations in Benin. The oils, which were all rich in thymol, were found to contain:

α-pinene (0.07-0.65%)
α-thujene (0-2.00%)
camphene (0-0.09%)
β-pinene (t-0.30%)
sabinene (t-0.60%)
δ-3-carene (0-0.10%)
α-phellandrene (0-0.10%)
myrcene (0.20-3.00%)
α-terpinene (0.10-0.90%)
limonene (0.30-0.70%)
1,8-cineole (0.50-2.80%)
(Z)-β-ocimene (0.08-0.25%)
γ-terpinene (1.10-6.60%)
(E)-β-ocimene (0.09-0.35%)
p-cymene (3.60-17.45%)
terpinolene (0.05-0.08%)
α-thujone (0-0.50%)
α-p-dimethylstyrene (0-1.90%)
cis-sabinene hydrate (0.70-4.20%)
citronellal (0-0.10%)
oct-7-en-4-ol† (0-1.90%)
α-copaene (0.20-1.00%)
camphor (0-0.20%)
β-bourbonene (0-0.30%)
trans-sabinene hydrate (0.50-1.00%)
linalool (0.40-2.80%)
β-caryophyllene (2.20-4.60%)
terpinen-4-ol (0-0.80%)
methyl thymol (0-1.90%)
umbellulone (0-0.50%)
α-humulene (0.20-3.90%)
α-terpineol (0-4.80%)
methyl chavicol (0-5.50%)
borneol (0-0.30%)
β-selinene (0-5.30%)
α-selinene (0-1.60%)
7-epi-α-selinene (0-0.70%)
δ-cadinene (0-0.50%)
germacrene B (0-1.50%)
p-cymen-8-ol (0.30-0.70%)
caryophyllene oxide (0.7-1.50%)
thymol (42.70-65.40%)
carvacrol (0.80-1.80%)

†idenity requires corroboration
t = <0.5%

Yusuf et al. (1998) used GC and GC/MS to examine the composition of a thymol-rich and an eugenol-rich *O.*

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Table I. Comparative percentage composition of an oil and two extracts of *Ocimum gratissimum*

Compound	Oil	Hexane Extract	$SFCO_2$ Extract
α-thujene	2.6	-	-
α-pinene	1.3	-	-
sabinene	0.9	-	-
β-pinene	0.7	-	-
myrcene	3.3	t	-
p-cymene	9.3	0.5	-
limonene	2.1	t	-
γ-terpinene	5.8	0.1	-
trans-sabinene hydrate	1.0	t	-
α-p-dimethylstyrene	1.6	-	-
terpinolene	0.3	-	-
linalool	0.3	t	-
terpinen-4-ol + *cis*-sabinene hydrate	4.5	0.9	-
p-cymen-8-ol methyl ether	1.2	1.4	1.8
thymol	32.6	89.0	72.4
carvacrol	2.1	2.9	8.4
eugenol	0.8	0.5	1.4
methyl eugenol	0.1	0.1	0.4
α-copaene	0.4	-	-
β-caryophyllene	4.5	0.9	1.8
trans-β-bergamotene	1.3	0.1	-
α-humulene	1.0	t	-
3,4-dimethoxyacetophenone	1.6	1.7	5.7
α-amorphene	0.1	-	-
β-selinene	5.0	1.2	3.8
γ-cadinene	1.2	-	-
caryophyllene oxide	4.7	0.5	2.5
humulene epoxide II	0.7	-	0.6
α-cadinol	0.3	-	0.4
caryophylla-3,8(13)-dien-5β-ol*	0.2	-	0.3

*correct isomer not identified
t = <0.1%

gratissimum of Bangladeshi origin. The thymol-rich chemotype was found to contain:

(Z)-3-hexenol (t)
α-thujene (2.0%)
α-pinene (0.8%)
camphene (0.1%)
sabinene (0.4%)
β-pinene (0.5%)
myrcene (2.6%)
α-phellandrene (0.3%)
δ-3-carene (0.1%)
α-terpinene (1.2%)
p-cymene (7.7%)
limonene (1.1%)
β-phellandrene (0.1%)
(Z)-β-ocimene (0.2%)
(E)-β-ocimene (0.2%)
γ-terpinene (12.3%)
cis-sabinene hydrate (0.3%)
terpinolene (1.5%)
α-p-dimethylstyrene (t)
linalool (0.3%)
p-mentha-1,3,9-triene (t)
α-thujone (0.1%)
cis-p-menth-2-en-1-ol (t)
borneol (0.2%)
terpinen-4-ol (1.4%)
p-cymen-8-ol (0.4%)
methyl thymol (0.2%)
thymol (58.2%)
carvacrol (0.9%)
eugenol (0.1%)
α-copaene (t)
β-elemene (0.1%)
β-caryophyllene (0.6%)
trans-α-bergamotene (t)
α-humulene (0.1%)
germacrene D (t)
β-selinene (1.1%)
α-selinene (0.7%)
7-epi-α-selinene (0.2%)
caryophyllene oxide (0.5%)
humulene epoxide II (0.1%)
isolongifoliol (0.1%)

t = <0.1%

In contrast, the composition of the eugenol chemotype was determined to be as follows:

1-octen-3-ol (0.1%)
3-octanone (t)
myrcene (0.4%)
3-octanol (0.1%)
(E)-3-hexenyl acetate (t)
(Z)-β-ocimene (18.1%)
(E)-β-ocimene (0.8%)
linalool (0.6%)
allo-ocimene* (0.4%)
(E)-myroxide (0.1%)
p-mentha-1,5-dien-8-ol (0.1%)
trans-p-mentha-2,8-dien-1-ol (0.7%)
α-cubebene (t)
eugenol (66.5%)
α-copaene (0.8%)
β-bourbonene (0.2%)
β-cubebene (0.4%)
β-elemene (0.1%)
isocaryophyllene (t)
β-caryophyllene (2.1%)
β-gurjunene (0.1%)
α-humulene (0.2%)
germacrene D (2.9%)
(E,E)-α-farnesene (0.1%)
δ-cadinene (0.3%)
spathulenol (0.2%)
caryophyllene oxide (0.2%)
14-hydroxy-9-epi-β-caryophyllene (0.2%)
(E)-coniferyl alcohol (0.2%)

*correct isomer not identified
t = 0.1%

Pino et al. (1998) compared the composition of a hydrodistilled oil, a hexane extract and a supercritical fluid CO_2 extract of *O. gratissimum* grown in Cuba. A summary of the results of

these GC/MS analyses can be seen in Table I.

Also in 1998, Jirovetz et al. analyzed leaf and flower oils of *O. gratissimum* produced from plants harvested in Cameroon using GC and GC/MS. The oils were found to contain the following constituents:

bisabolol* (0.2-0.5%)
borneol (0.1-0.3%)
γ-cadinene (0.1-0.3%)
δ-cadinene (0-0.2%)
camphene (0.2%)
δ-3-carene (0.1-0.4%)
carvacrol (0.3-0.9%)
β-caryophyllene (0.9-1.3%)
caryophyllene oxide (0.5-4.3%)
1,8-cineole (1.6-14.1%)
α-copaene (0.5-0.7%)
β-cubebene (0.3-0.5%)
p-cymene (6.3-8.5%)
α-p-dimethylstyrene (0.1-0.4%)
dehydro-p-cymene (0.4-1.3%)
3,9-epoxy-p-mentha-1,8-diene (0.5-1.1%)
eremophillene (0.4-1.2%)
eugenol (0-0.4%)
farnesene* (0.4-0.8%)
2-hexenal* (0.1-0.5%)
3-hexenol* (0-0.3%)
1-hexen-3-ol (0-0.2%)
isoborneol (0.2-0.3%)
limonene (1.5-2.6%)
linalool (0.6-0.7%)
myrcene (0.8-2.3%)
(Z)-β-ocimene (0.2-0.3%)
(E)-β-ocimene (0.8-0.9%)
1-octen-3-ol (0.1-0.4%)
α-phellandrene (1.9-3.4%)
α-pinene (0.4-1.1%)
β-pinene (0.3-1.2%)
sabinene (0.6-0.7%)
sabinene hydrate* (0.1-0.3%)
α-terpinene (0.1-1.1%)
γ-terpinene (2.1-14.3%)
terpinen-4-ol (0.5-3.3%)
α-terpineol (1.4-1.7%)
terpinolene (1.9-2.3%)
α-thujene (0.4-2.2%)
α-thujone (0.5-0.6%)
thymol (41.1-47.7%)
fatty acids and their esters (2.6-3.1%)

*correct isomer not identified

Amvan Zollo et al. (1998) screened numerous oils of Cameroonian origin for their antifungal activity. Among the oils screened was one produced from *O. gratissimum*. This oil, which was analyzed by GC and GC/MS, was determine to contain:

α-thujene (3.5%)
α-pinene (1.1%)
camphene (0.1%)
sabinene (0.7%)
β-pinene (0.4%)
myrcene (3.2%)
α-phellandrene (0.3%)
δ-3-carene (0.2%)
α-terpinene (2.8%)
p-cymene (7.0%)
limonene (1.1%)
(Z)-β-ocimene (0.6%)
(E)-β-ocimene (0.2%)
γ-terpinene (20.0%)
terpinolene (0.2%)
trans-sabinene hydrate (1.0%)
fenchone (0.2%)
linalool (0.4%)
terpinen-4-ol (1.0%)
α-terpineol (t)
thymol (46.2%)
carvacrol (0.2%)
δ-elemene (t)
α-copaene (0.4%)
β-elemene (0.2%)
β-caryophyllene (2.3%)
α-humulene (0.3%)
allo-aromadendrene (0.2%)
guaiene* (1.5%)
α-selinene (0.7%)
γ-cadinene (1.0%)
δ-cadinene (0.8%)
spathulenol (t)
caryophyllene oxide (0.4%)
T-muurolol (0.4%)
T-cadinol (0.1%)

*correct isomer not identified
t = <0.1%

The following year, Yayi et al. (1999) used a combination of GC and GC/MS to examine the composition of the oils of seven collections of *O. gratissimum* from across Benin. The composition of these oils ranged as follows:

α-thujene (1.1-8.2%)
α-pinene (t-2.6%)
camphene (0-0.3%)
sabinene (0.6-1.5%)
β-pinene (0.3-0.9%)
myrcene (3.3-5.9%)
α-phellandrene (0-0.4%)
δ-3-carene (0.1-0.3%)
α-terpinene (0-3.0%)
p-cymene (13.5-47.1%)
limonene + 1,8-cineole (1.4-2.2%)
(Z)-β-ocimene (t-0.6%)
(E)-β-ocimene (t-0.3%)
γ-terpinene (2.2-30.1%)
cis-sabinene hydrate (0-1.5%)
α-p-dimethylstyrene (1.1-1.7%)
terpinolene (t-0.2%)
linalool (t-0.5%)
myrcenol (0-0.3%)
borneol (0-0.4%)
terpinen-4-ol (0-1.0%)
α-terpineol (0-0.3%)
α-fenchyl acetate (0-2.5%)
thymol (2.3-32.0%)
carvacrol (0-0.4%)
δ-elemene (0-t)
α-copaene (t-0.7%)
β-elemene (0-0.1%)
β-caryophyllene (1.7-14.5%)
α-humulene (0.2-1.6%)
γ-muurolene (0-2.3%)
germacrene D (0-10.0%)
β-selinene (1.0-3.3%)
δ-cadinene (0.1-1.2%)
caryophyllene oxide (0.2-3.7%)

t = <0.1%

Also in 1999, Martins et al. used a combination of GC, GC/MS and NMR (both ^{1}H- and ^{13}C-) to analyze an oil produced from *O. gratissimum* collected from the West African island of Sâo Tomé. The results of this analysis are as follows:

α-thujene (1.2%)
α-pinene (3.8%)
camphene (0.2%)
3-octanone (0.1%)
β-pinene (0.4%)
sabinene (0.4%)
myrcene (3.6%)
α-phellandrene (0.2%)
α-terpinene (0.2%)
δ-3-carene (0.2%)
p-cymene (12.5%)
p-mentha-1,3,8-triene† (0.1%)
(Z)-β-ocimene (0.4%)
limonene (1.5%)
β-phellandrene (0.1%)
γ-terpinene (5.8%)
trans-sabinene hydrate (1.1%)
α-p-dimethylstyrene (2.0%)
terpinolene (0.1%)
linalool (0.5%)
α-thujone (0.3%)
camphor (0.1%)
terpinen-4-ol (1.3%)
α-terpineol (0.3%)
methyl thymol (1.5%)
thymyl acetate (0.2%)
thymol (48.1%)
carvacrol (1.0%)
α-copaene (0.1%)
β-caryophyllene (1.6%)
trans-α-bergamotene (0.5%)
α-humulene (0.4%)
germacrene D (0.3%)
bicyclogermacrene (1.9%)
β-bisabolene (4.0%)
β-sesquiphellandrene (0.2%)
(E)-nerolidol (0.4%)

† incorrect identity based on elution order

De Vasconcelos Silva et al. 1999) used microwave extraction(30g samples) in methylene chloride to determine the change in composition of *O. gratissimum* harvested hourly throughout the day in Brazil. The two major volatiles (1,8-cineole and eugenol) were found to vary considerably over a single day (see Table II). Some other constituents also varied throughout the day as shown below:

α-pinene (0-3.7%)
myrcene (0-1.6%)
linalool (0-7.9%)
terpinen-4-ol (0-2.5%)
α-terpineol (0-1.8%)
β-elemene (0-8.3%)
β-caryophyllene (0-11.6%)
β-maaliene (0-13.4%)

The authors advised that, because of the wide variation in oil composition, diurnal fluctuation studies should done on plants grown for their oils in equatorial regions of the world

Table II. Diurnal fluctuation in two major volatile constituents of *Ocimum gratissimum* depending upon harvesting time of day

Time of Harvest	1,8-cineole content (%)	eugenol content (%)
8:00 a.m.	52.1	14.0
9:00 a.m.	32.4	32.4
10:00 a.m.	27.4	29.0
11:00 a.m.	7.0	90.6
12:00 p.m.	-	98.0
1.00 p.m.	2.5	91.9
2:00 p.m.	-	80.3
3:00 p.m.	60.7	27.5
4.00 p.m.	32.5	67.0
5:00 p.m.	75.5	11.4
6:00 p.m.	22.5	39.5

so that the optimum oil composition can be produced. In this case, for eugenol-rich oils produced in Fortaleza (Brazil), noon was found to be the ideal harvesting time.

An oil of *O. gratissimum* prepared in the lab from wild growing plants collected in Guinea was subjected to analysis by Keita et al. (2000) using a combination of GC and GC/MS. This oil was found to contain:

α-thujene (5.33%)
α-pinene (1.34%)
sabinene (0.51%)
camphene (0.12%)
myrcene (4.63%)
α-terpinene (3.62%)
p-cymene (12.04%)
limonene (0.90%)
γ-terpinene + *trans*-sabinene hydrate (16.73%)
fenchone (1.54%)
borneol (0.35%)
terpinen-4-ol (1.30%)
thymol (46.13%)
β-caryophyllene (1.73%)
germacrene D (1.19%)
T-cadinol (0.24%)
β-eudesmol (0.31%)

Five clones of *O. gratissimum* of Brazilian origin were grown in the United States. Oils from these five clones were subjected to analysis by GC and GC/MS by Viera and Simon (2000). The major components found in these clonal oils can be seen in Table III.

More recently, Yayi et al. (2001) examined a larger number of samples (20) of *O. gratissimum* of Benin origin for their variation in major components. The ten most prevalent constituents were found to vary. As a result, the authors classified them into three groups as shown in Table IV.

Finally, it is interesting to note that oils produced from *O. gratissimum* of West African origin appear to be mainly of the thymol-chemotype, whereas the commercially more important oil is the eugenol-chemotype.

L-F.Zhu, Y-H. Li, B-L. Li, B-Y. Lu and N-H. Xia, *Aromatic plants and essential oil constituents.* p.99, Hai Feng Publ. Co., Peace Book Co., Ltd., Hong Kong (1993).

L-F. Zhu, Y-H. Li, B-L. Li, B-Y. Lu and W-L. Zhang, *Aromatic plants and essential oil constituents (Supplement 1).* p. 62, Hai Feng Publ. Co., Peace Book Co., Ltd, Hong Kong (1995).

A. K. Bhattacharya, P. N. Kaul and B. R. Rajeswara Rao, *Essential oils of Ocimum gratissimum L. and Ocimum tenuifolium (syn. Ocimum sanctum L.) grown in Andhra Pradesh.* Indian Perfum, *40(3)*, 73-75 (1996).

U. Ravid, E. Putievsky, I. Katzir and E. Lewinsohn, *Enantiomeric composition of linalool in the essential oils of Ocimum species and in commercial basil oils.* Flav. Fragr. J., *12*, 293-296 (1997).

I. Vahirua-Lechat, G. Lamaty and J-M. Bessiére, *Études chimiques des huiles essentielles de quelques labiées de Polynésie Français.* Rivista Ital. EPPOS, *(Numero Speciale)*, 703-711 (1997).

J-C. Chalchat. M. Moudachirou and E. Yayi, *Composition chimique d'huiles essentielles d'origine béninoise: Ocimum basilicum, O. canum et O. gratissimum.* Rivista Ital. EPPOS, *(Numero Speciale)*, pp. 551-560 (1997).

M. Yusuf, J. Begum. L. Mondello and I. Stagno d'Alcontres, *Studies on the essential oil bearing plants of Bangladesh. Part VI. Composition of the oil of Ocimum gratissimum L.* Flav. Fragr. J., *13*, 163-166 (1998).

J. A. Pino, J. Garcia and M. H. Martinez, *A comparison between the oil, solvent extract and supercritical carbon dioxide extract of Ocimum gratissimum L.* J. Essent. Oil Res., *10*, 575-577 (1998).

L. Jirovetz, G. Buchbauer and M. B. Ngassoum, *Aroma compounds of leaf and flower essential oils of the spice plant Ocimum gratissimum L. from Cameroon.* Ernährung, *22*, 395-297 (1998).

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

E. Yayi, M. Moudachirou and J-C. Chalchat, *Essential oil of Ocimum gratissimum from Benin*. J. Essent. Oil Res., *11*, 529.531 (1999.)

A. P. Martins, L. R. Salgueiro, R. Vila, F. Tomi, S. Canigueral, J. Casanova, A. Proença da Cunha and T. Adzet, *Composition of the essential oils of Ocimum canum, O. gratissimum and O. minimum.* Planta Med., *65*, 187-189 (1999).

M. G. de Vasconcelos Silva, A. A. Craveiro, F. J. Abreu Matos, M. L.L. Machado and J. W. Alencar, *Chemical variation during daytime of constituents of the essential oil of Ocimum gratissimum leaves.* Fitoterapia, *70*, 32-34 (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).

R. F. Viera and J. E. Simon, *Chemical characterization of basil (Ocimum spp.) found in the markets and used in traditional medicine in Brazil.* Econ. Bot., *54*, 207-216 (2000).

E. Yayi, M. Moudachirou and J-C. Chalchat, *Chemotyping of three Ocimum species from Benin: O. basilicum, O. canum and O. gratissimum.* J. Essent. Oil Res., *13*, 13-17 (2001).

Cinnamon Oil

The headspace of *Cinnamomum zeylanicum* bark was determined by Vernin et al. (1994) to contain the following components:

α-pinene (0.18%)
p-cymene (13.00%)
α-copaene (0.40%)
benzaldehyde (5.90%)
linalool (0.40%)
bornyl acetate (0.90%)
linalyl acetate (0.48%)
salicylaldehyde (0.58%)
borneol + α-terpineol (0.68%)
2-phenethyl acetate (0.35%)
(E)-cinnamaldehyde (41.50%)
(E)-cinnamyl acetate (0.24%)
eugenol (t)

t = <0.01%

Using HPLC as the method of analysis, Ehlers et al. (1995) identified the following constituents in cinnamon bark oil:

(E)-cinnamic acid (t)
(E)-cinnamyl alcohol (0-2.0%)
(E)-cinnamaldehyde (27.7-56.0%)
(E)-2-methoxycinnamaldehyde (0.2-0.7%)
eugenol (5.6-33.9%)
(E)-cinnamyl acetate (3.2-6.8%)

t = <0.1%

Oils produced from the inner bark of *C. zeylanicum* grown in Parana (Brazil) were analyzed by GC and GC/MS by Koketsu et al. (1997). The results of these analyses are shown in Table V.

Also in 1997, Möllenbeck et al. analyzed an oil of cinnamon of Madagascan origin by GC and GC/MS. They found that the oil contained the following components:

α-pinene (0.8%)
camphene (0.4%)
β-pinene (0.5%)
α-phellandrene (3.0%)
α-terpinene (1.8%)
β-phellandrene (7.4%)
p-cymene (3.5%)
camphor (t)
linalool (3.9%)
β-caryophyllene (0.6%)
terpinen-4-ol (11.6%)
(Z)-ocimenol (1.8%)
hydrocinnamaldehyde (t)
(Z)-cinnamaldehyde (t)
caryophyllene oxide (0.5%)
(E)-cinnamaldehyde (41.3%)
eugenol (10.0%)
(E)-cinnamyl acetate (3.2%)
(E)-cinnamyl alcohol (0.9%)
benzyl benzoate (2.5%)

t = <0.1%

Furthermore, using chiral GC the enantiomeric distribution of linalool and terpinen-4-ol were determined to be:

(3R)-(-)-linalool (95%) :
(3S)-(+)-linalool (5%)

Table III. Major components (%) found in the oils of five clones of *Ocimum gratissimum*

Compound	1	2	3	4	5
α-pinene	4.7	-	11.0	-	9.1
sabinene	0.7	-	1.7	-	1.2
myrcene	2.6	0.4	6.0	0.6	5.2
α-terpinene	3.5	-	4.6	-	2.5
p-cymene	9.9	-	28.4	-	42.5
γ-terpinene	26.6	-	22.0	-	9.8
linalool	0.2	0.4	0.1	0.5	0.3
thymol	32.8	0.1	12.7	-	9.6
eugenol	0.1	60.3	-	39.9	2.8
β-caryophyllene	7.2	1.8	2.9	1.1	2.3
β-cubebene	0.3	-	0.2	-	0.2
β-bisabolene	4.1	27.3	3.4	41.5	7.1

(4R)-(-)-terpinen-4-ol (69%) :
(4S)-(+)-terpinen-4-ol (31%)

A commercial oil of cinnamon that was screened for its antimicrobial and antioxidant properties by Baratta et al. (1998) was reported to possess the following composition:

camphene (0.2%)
myrcene (t)
α-phellandrene (t)
α-terpinene (0.7%)
p-cymene (0.4%)
1,8-cineole (0.2%)
limonene (13.2%)
linalool (2.9%)
dihydrolinalool (t)†
hydrocinnamaldehyde (0.3%)
(Z)-cinnamaldehyde (0.4%)
cuminaldehyde (0.2%)
(E)-cinnamaldehyde (68.4%)
linalyl acetate (2.7%)
(E)-cinnamyl alcohol (1.0%)
eugenol (4.4%)
(E)-cinnamyl acetate (2.8%)
eugenyl acetate (0.9%)
benzyl benzoate (0.6%)

t = <0.1% †not a natural contituent

Table IV. Major component composition of *Ocimum gratissimum* from Benin

Compound	Group I	Group II	Group III
α-thujene	0.1-0.6	0.1-8.0	2.0-8.2
α-pinene	0.1-0.3	0.7-1.9	0.7-2.6
myrcene	0.1-1.0	2.2-5.6	2.8-5.2
α-terpinene	0.1-0.5	0.1-3.6	0.9-2.8
1,8-cineole	1.7-3.2	0.2-1.8	0.2-2.2
γ-terpinene	0.2-4.5	13.3-22.6	2.8-15.9
p-cymene	0.5-4.7	4.6-25.1	10.3-37.2
β-caryophyllene	1.3-4.6	0.6-3.6	1.5-5.9
germacrene D	3.2-5.6	0.7-4.3	0.5-4.6
thymol	54.0-65.4	23.1-34.1	8.5-42.7

Table V. Percentage composition of the bark oil of *Cinnamomum zeylanicum* of Brazilian origin

Compound	Bark Oil
α-pinene	1.24-1.54
camphene	0.63-0.77
β-pinene	0.43-0.57
α-phellandrene	0.77-1.13
α-terpinene	1.05-1.38
limonene	1.34-1.63
1,8-cineole + β-phellandrene	4.96-5.86
p-cymene	2.22-3.88
terpinolene	t
α-ylangene	t
benzaldehyde	t-0.61
linalool	6.87-6.91
β-caryophyllene	2.55-2.60
terpinen-4-ol	0.84-1.16
α-humulene	t
α-terpineol	1.38-1.83
safrole	t
caryophyllene oxide	t
(E)-cinnamaldehyde	54.74-58.42
eugenol	11.86-14.85
benzyl benzoate	1.97-2.01

t = <0.01%

The occurrence of dihydrolinalool and such a high level of limonene infers that the oil used in this screening study was adulterated.

Cinnamon bark oil produced from Madagascan cinnamon was analyzed by Chalchat and Valade (1998) using modern analytical techniques. It was found to contain the following components:

α-pinene (0.75%)
α-thujene (0.10%)
camphene (0.43%)
β-pinene (0.33%)
sabinene (0.05%)
δ-3-carene (0.06%)
α-phellandrene (0.49%)
myrcene (0.09%)
α-terpinene (0.37%)
limonene (1.03%)
β-phellandrene (3.26%)
(Z)-β-ocimene (0.04%)
γ-terpinene (0.08%)
(E)-β-ocimene (t)
p-cymene (2.32%)
terpinolene (0.08%)
camphor (15.23%)
benzaldehyde (0.29%)
linalool (3.20%)
β-caryophyllene (2.45%)
terpinen-4-ol (1.17%)
α-humulene (0.52%)
α-terpineol (1.59%)
hydrocinnamaldehyde (0.07%)
(Z)-methyl cinnamate (0.72%)
(Z)-cinnamaldehyde (0.52%)
methyl eugenol (0.31%)
(E)-cinnamaldehyde (52.23%)
(Z)-cinnamyl acetate (4.10%)
eugenol (2.89%)
2-methoxycinnamaldehyde (0.46%)
benzyl benzoate (1.59%)

t = <0.01%

This same analysis was also reported in 2000 by Chalchat and Valade.

Also in 1998, some commercial samples of cinnamon bark oil of Sri Lankan origin were analyzed using GC and GC/MS by Jirovetz et al. The oils were chemically characterized as follows:

(E)-cinnamaldehyde (61.4-75.6%)
eugenol (5.9-7.2%)
β-caryophyllene (3.2-13.1%)
limonene (2.4-7.4%)
linalool (2.1-4.2%)
benzyl benzoate (0.9-1.2%)
α-phellandrene (0.6-0.8%)
α-pinene (0.4-0.6%)
p-cymene (0.2-1.7%)
(E)-cinnamyl acetate (0.1-1.1%)
(Z)-cinnamaldehyde (0.2-0.5%)
caryophyllene oxide (0-0.7%)
1,8-cineole (0.1-0.3%)
camphene (0.1-0.2%)
β-pinene (0.1-0.2%)
β-phellandrene (0-0.1%)
γ-terpinene (0-0.1%)
(E)-β-ocimene (0-0.2%)
terpinolene (0-0.3%)
myrcene (0-0.1%)
terpinen-4-ol (0.1-0.4%)
borneol (0-0.2%)
cis-linalool oxide* (0-0.2%)
δ-3-carene (0-0.1%)
α-terpinene (0-0.4%)
eugenyl acetate (0.1-0.6%)
α-terpineol (0.1-0.8%)
safrole (0.1-0.3%)
(E)-cinnamyl alcohol (0.1-0.8%)
α-humulene (0.1-0.6%)
γ-cadinene (0-0.4%)
(Z)-β-ocimene (0-0.2%)

*correct isomer not identified

Cinnamon bark oil of unknown origin was analyzed by Reichling et al. (1999) and found to contain the following components:

α-pinene (0.02%)
benzaldehyde (0.31%)
myrcene (0.04%)
δ-3-carene (0.12%)
α-terpinene (0.08%)
p-cymene (9.88%)
linalool (2.47%)
linalyl acetate (3.08%)
cinnamaldehyde† (69.56%)
eugenol (5.26%)
cinnamyl acetate† (4.68%)

† (E)-form

An oil of cinnamon was screened against head lice by Lahlou et al. (2000); however, it was not found to be as effective as other oils screened. The composition of the oil used in this study was as follows:

α-thujene (0.6%)
α-pinene (0.6%)
β-pinene (0.1%)
α-phellandrene (0.2%)
p-cymene (0.2%)
1,8-cineole (0.1%)
limonene (0.3%)
linalool (3.4%)

Table VI. Comparative percentage composition of the oil of tarragon produced from French and Russian accessions

Compound	"French" Oil	"Russian" Oil
α-pinene	0.36	1.10
camphene	0.10	2.51
β-pinene	0.05	0.10
sabinene	0.15	2.22
myrcene	3.34	0.75
1,8-cineole + β-phellandrene	6.14	11.33
(Z)-β-ocimene	2.79	10.31
γ-terpinene	0.15	0.12
(E)-β-ocimene	0.02	7.16
cis-linalool oxide†	-	2.87
trans-linalool oxide†	-	1.09
cis-sabinene hydrate	-	0.01
linalool	-	0.47
methyl chavicol	81.40	47.20
γ-elemene	0.10	0.10
nerol	0.10	0.10
2-phenethyl alcohol	0.02	0.25
eugenol	-	3.43
methyl eugenol	-	4.30

† furanoid type

α-terpineol (15.0%)
geranyl acetate (5.8%)
(E)-cinnamaldehyde (61.2%)
eugenol (2.4%)
β-caryophyllene (2.2%)

The occurrence of such high levels of α-terpineol and geranyl acetate in cinnamon oil is highly questionable.

This author (Lawrence) analyzed an oil of *C. zeylanicum* of Sri Lankan origin using GC and GC/MS. It was determined that the major components of this oil were:

α-pinene (1.6%)
camphene (0.4%)
β-pinene (0.4%)
sabinene (0.1%)
myrcene (1.7%)
α-phellandrene (1.0%)
α-terpinene (0.9%)
limonene (4.1%)
β-phellandrene (0.1%)
γ-terpinene (0.1%)
(E)-β-ocimene (0.1%)
p-cymene (1.3%)
α-copaene (0.3%)
benzaldehyde (0.1%)
linalool (2.0%)
β-caryophyllene (3.6%)
α-humulene (0.6%)
α-terpineol (0.4%)
hydrocinnamaldehyde (0.6%)
(Z)-cinnamaldehyde (0.4%)
2-methoxybenzaldehyde (0.1%)
caryophyllene oxide (0.2%)
(E)-cinnamaldehyde (67.4%)
(E)-cinnamyl acetate (4.6%)
eugenol (4.2%)
(E)-cinnamyl alcohol (0.3%)
benzyl benzoate (0.7%)

G. Vernin, C. Vernin, J. Metzger, L. Pujol and C. Parkanyi, *GC/MS analysis of cinnamon and cassia essential oils: A comparative study*. In: *Spices, Herbs and Edible Fungi*. Edit. G. Charalambous, pp. 411-425, Elsevier, Amsterdam (1994).

Table VII. Comparative chemical composition (%) of oils of *Artemisia dracunculus*

Compound	Georgian Plant Oil	Danish Plant Oil	Georgian Plant Oil
α-pinene	0.5	0.5	0.8
sabinene	1.1	38.9	48.6
α-phellandrene	-	t	t
α-terpinene	-	0.6	0.4
limonene + β-phellandrene	1.7	0.5	1.6
(Z)-β-ocimene	5.5	5.7	1.9
(E)-β-ocimene	6.2	5.4	10.5
terpinolene	0.2	0.3	7.3
fenchone	t	-	t
terpinen-4-ol	t	2.0	0.9
methyl chavicol	79.3	0.3	0.8
methyl eugenol	0.4	18.0	1.8
β-caryophyllene	t	t	t
germacrene D	t	1.1	0.2
elemicin	0.5	1.2	16.1
isoelemicin*	t	13.7	t

* correct isomer not identifed
t = <0.1%

D. Ehlers, S. Hilmer and S. Bartholomae, *Hochdruckflüssig-chromatographische Untersuchung von Zimt-CO2-Hochdruckextrakten in Vergleich mit Zimtölen.* Z. Lebensm. Unter Forsch., *200*, 282-288 (1995).

M. Koketsu, S. L. Gonçalves, R. L. de Oliveira Godoy, D. Lopes and N. Morsbach, *Oleos essenciais de cascas e folhas de canels (Cinnamomum verum Presl.) cultivada no Parana*. Cienc. Technol. Aliment., *17*, 281-285 (1997).

S. Möllenbeck, T. König, P. Schreier, W. Schwab, J. Rajaonarivony and L. Ranarivelo, *Chemical composition and analyses of enantiomers of essential oils from Madagascar.* Flav. Fragr. J., *12*, 63-69 (1997).

M. T. Barata, H. J. D. Dorman, S. G. Deans, A. C. Figueiredo, J. G. Barroso and G. Ruberto, *Antimicrobial and antioxidant properties of some commercial essential oils*. Flav. Fragr. J., *13*, 235-244 (1998).

J. C. Chalchat and I. Valade, *Plantes à huiles essentielles d'origine Malagache: composition chimique des huiles essentielles de Cinnamomum zeylanicum, angustifolium, camphorata et fragrans.* Rivista Ital. EPPOS, *(Numero Speciale)*, 729-740 (1998).

L. Jirovetz, G. Buchbauer, M. B. Ngassoum and R. Eberhardt, *Analysis and quality control of the essential oil of the leaves of Cinnamomum zeylanicum from Cameroon.* Ernährung, *22*, 443-445 (1998).

J. Reichling, M. Harkenthal and R. Saller, *Wirkung ausgewählter ätherischer Öle.* Erfahrungsheilkunde, *6*, 357-366 (1999).

J. C. Chalchat and I. Valade, *Chemical composition of leaf oils of Cinnamomum from Madagascar: C. zeylanicum Blume, C. camphora L., C. fragrans Baillon and C. angustifolium*. J. Essent. Oil Res., *12*, 537-540 (2000).

M. Lahlou, R. Berrada, A. Agoumi and M. Hmamouchi, *The potential effectiveness of essential oils in the control of human head lice in Morocco.* Internat. J. Aromatherap., *10*, 108-123 (2001).

B. M. Lawrence, unpublished information.

Table VIII. Comparative percentage composition of tarragon oil produced from three types harvested at three different growth stages

	Georgian			Danish			Siberian		
Compound	1	2	3	1	2	3	1	2	3
sabinene	0.73	0.86	0.71	29.96	38.90	44.57	17.29	48.58	29.96
myrcene	0.53	0.18	0.25	0.65	1.59	1.62	0.85	1.92	0.95
limonene	2.02	1.73	1.60	0.36	0.46	0.28	1.12	1.57	1.02
(Z)-β-ocimene	5.56	5.53	4.98	1.43	5.75	3.58	0.98	1.86	1.13
(E)-β-ocimene	5.32	6.21	5.74	2.44	5.42	3.05	7.45	10.45	3.95
terpinolene	-	-	-	0.35	0.27	0.43	5.18	7.33	2.46
terpinen-4-ol	0.23	-	-	1.80	1.96	1.76	2.65	0.89	2.05
methyl chavicol	78.70	79.40	81.20	0.36	0.26	0.27	0.63	0.75	1.54
geranyl acetate	-	-	-	0.69	0.66	1.03	0.85	1.03	2.31
methyl eugenol	0.49	0.44	0.27	24.40	18.00	8.92	3.66	1.84	3.24
germacrene D	-	-	-	0.72	1.05	0.95	0.04	0.23	0.20
elemicin	0.43	0.45	0.28	5.29	1.23	4.85	54.90	16.10	40.80
methyl isoelemicin*	0.18	0.13	0.08	1.25	1.04	1.06	0.51	0.90	0.39
isoelemicin*	0.14	0.12	0.17	11.30	13.70	18.70	0.31	0.11	0.33

* correct isomer not identified
1 = beginning of flower formation
2 = advanced flower formation
3 = intensive flowering

Tarragon Oil

In 1991, Klyuev and Bukharin compared the composition of tarragon oil produced from plants of French and Russian origin grown in Russia. The oil compositions can be seen summarized in Table VI.

Also in 1991, Zani et al. found that tarragon oil contained the following major components:

α-pinene (1.00%)
p-cymene (2.47%)
1,8-cineole (6.88%)
γ-terpinene (5.69%)
methyl chavicol (77.50%)
eugenol (0.28%)
methyl eugenol (0.53%)

Two years later, Kostrzewa and Karwowska analyzed an oil of tarragon produced in Poland using a combination of analytical techniques. The compounds identified in this study were as follows:

α-thujene (0.13%)
α-pinene (0.71%)
camphene (0.36%)
β-pinene + sabinene (7.42%)
myrcene (0.36%)
α-phellandrene (0.60%)
α-terpinene (0.63%)
limonene (0.54%)
(Z)-β-ocimene (0.22%)
(E)-β-ocimene (0.43%)
γ-terpinene (1.15%)
p-cymene (0.20%)
terpinolene (0.20%)
allo-ocimene* (0.43%)
menthone (0.22%)
isomenthone (0.05%)
α-copaene (0.46%)
trans-sabinene hydrate (0.42%)
β-bourbonene (0.21%)
linalool (1.85%)
cis-sabinene hydrate (0.03%)
α-bergamotene* (2.60%)
β-elemene (1.25%)
terpinen-4-ol (1.63%)
isobornyl acetate (2.55%)
menthol (0.52%)
α-humulene (1.28%)
methyl chavicol (6.88%)
citronellyl acetate (2.77%)
(E)-β-farnesene (0.94%)
geranyl acetate (0.80%)
citronellol (t)
geraniol (0.04%)
nerolidol* (0.48%)
elemicin (42.98%)
isoelemicin* (0.71%)

*correct isomer not identified
t = <0.01%

In 1995, Montagut et al. reported that the main components of an oil of fresh French tarragon leaves were:

limonene (2.0%)
(Z)-β-ocimene (9.0%)
(E)-β-ocimene (10.0%)
methyl chavicol (77.0%)

The authors also pointed out that freeze drying or air drying the fresh leaves caused a loss in oil content of 7.3% and 27.6%, respectively.

As part of a screening program for the antimicrobial activity of essential oils, Bourrel et al. (1995) determined the chemical composition of the oils used in their screening program. As a result, the tarragon oil sample used in this study was examined by GC/MS and was found to possess the following composition:

α-pinene (0.3%)
β-pinene (0.3%)
p-cymene (0.2%)
limonene (2.7%)
linalool (0.2%)
methyl chavicol (70.7%)
(E)-anethole (0.3%)
eugenol (0.6%)
methyl eugenol (1.7%)
caryophyllene oxide (4.2%)
lauric acid (0.5%)
palmitic acid (4.1%)
linoleic acid (0.5%)
oleic acid (1.1%)

Also, in 1995, Venskutonis analyzed oils from *A. dracunculus* grown in Lithuania from plants obtained from Georgia, Denmark and Siberia. A summary of the oil compositions can be found in Table VII. These analyses were completed using GC and GC/MS.

Table IX. Comparative percentage composition of French and Russian tarragon oils

Compound	French Oil	Russian Oil
α-pinene	0.51	0.28
camphene	0.05	-
β-pinene	0.09	0.42
sabinene	0.06	41.34
myrcene	0.13	2.69
α-terpinene	-	0.48
limonene	2.26	-
β-ocimene*	10.00	12.65
γ-terpinene	8.89	7.52
terpinolene	0.09	0.19
(Z)-3-hexenyl acetate	-	0.23
allo-ocimene*	0.17	0.23
(E)-4-hexenol†	-	0.18
trans-sabinene hydrate	-	0.14
citronellol	-	0.31
linalool	0.04	0.15
isobornyl acetate	0.14	-
terpinen-4-ol	-	1.32
citronellyl formate	-	2.25
methyl chavicol	74.46	-
α-terpineol	-	0.16
germacrene D	0.28	0.98
(Z,Z)-α-farnesene	0.16	-
(E,E)-α-farnesene	0.09	-
geranyl acetate	-	1.47
methyl eugenol	0.79	6.27
methyl cinnamate‡	0.25	-
eugenol	0.28	-
elemicin	0.28	17.16

* correct isomer not identified
† unusual essential constituent, identify requires corroboration
‡ probably (E)-form

A year later, Venskutonis et al. (1996) compared the composition of oils produced from *A. dracunculus* grown from plants of Georgian, Danish and Siberian origins in Lithuania. The Siberian and Georgian tarragon were grown from seedlings, while the Danish tarragon was grown from seed. A summary of the changes in composition of the main constituents of the three tarragon oils can be seen in Table VIII. As can be seen, the Georgian oil was a typical methyl chavicol-rich oil, while the Danish oil was rich in sabinene and elemicin. Other constituents that were found in the oils were as follows:

Georgian Oil:

(E)-2-hexenal (0.05%)	β-caryophyllene (0.11%)
cis-carveol (0.04%)	caryophyllene oxide (0.24%)
geranial (0.01%)	farnesol* (0.04%)

*correct isomer not identified

Danish Oil:

(E)-2-hexenal (0.06%)	methyl geranate (0.40%)
(Z)-3-hexenyl acetate (0.02%)	neryl acetate (0.05%)
δ-3-carene (0.01%)	α-cubebene (0.01%)
4-methyl-3-pentenylfuran (0.02%)	β-caryophyllene (0.07%)
trans-p-menth-2-en-1-ol (0.11%)	α-humulene (0.04%)
p-menthadien-7-ol* (0.03%)	β-ionone† (0.02%)
cis-p-menth-2-en-1-ol (0.07%)	γ-elemene (0.09%)
allo-ocimene* (0.02%)	β-bisabolene (0.06%)
p-menthadien-7-ol* (0.07%)	(E)-nerolidol (0.36%)
citronellal (0.04%)	T-cadinol (0.22%)
menthol (0.02%)	α-cadinol (0.22%)
pulegone (0.03%)	farnesol* (0.04%)
geranial (0.03%)	α-bisabolol (0.3%)

*correct isomer not identified
† presumed (E)-isomer

Siberian oil:

(E)-2-hexenal (0.03%)	α-cubebene (0.03%)
δ-3-carene (0.02%)	β-caryophyllene (0.04%)
trans-p-menth-2-en-1-ol (0.05%)	α-humulene (0.04%)
p-menthadien-7-ol* (0.08%)	germacrene B (0.08%)
cis-p-menth-2-en-1-ol (0.04%)	(E)-nerolidol (0.08%)
p-menthadien-7-ol* (0.08%)	caryophyllene oxide (0.20%)
menthol (0.02%)	T-cadinol (0.11%)
cis-carveol (0.04%)	α-cadinol (0.02%)
geranial (0.03%)	farnesol* (0.11%)

*correct isomer not identified

Also in 1996, Pino et al. analyzed an oil from *A. dracunculus* grown in Cuba. Using a combination of GC and GC/MS, the authors identified the following components:

α-thujene (0.94%)	methyl salicylate (0.02%)
α-pinene (0.21%)	α-terpineol (0.12%)
sabinene (4.53%)	methyl chavicol (0.49%)
β-pinene (0.73%)	citronellol (2.10%)
α-phellandrene (0.13%)	perillaldehyde (0.02%)
α-terpinene (0.88%)	geranial (0.05%)
p-cymene (0.88%)	bornyl acetate (0.02%)
β-phellandrene (0.77%)	(E)-cinnamyl alcohol (0.08%)
(Z)-β-ocimene (0.30%)	carvacrol (0.08%)
(E)-β-ocimene (0.25%)	α-cubebene (0.02%)
γ-terpinene + *trans*-sabinene hydrate (2.43%)	α-ylangene (0.04%)
	methyl eugenol (17.61%)
α-,p-dimethylstyrene (0.01%)	β-caryophyllene (0.51%)
terpinolene (0.54%)	(E,Z)-α-farnesene (0.27%)
cis-sabinene hydrate (0.34%)	(E)-β-farnesene (0.02%)
linalool (0.14%)	α-humulene (0.29%)
cis-rose oxide (0.07%)	(Z)-β-farnesene (0.34%)
trans-rose oxide (0.02%)	α-himachalene (1.59%)
menthone (0.10%)	δ-cadinene (0.11%)
isomenthone (0.03%)	elemicin (53.03%)
terpinen-4-ol (3.95%)	isoelemicin* (2.60%)

*correct isomer not identified

In addition to comparing the morphological characters and, in particular, the secretery structures of French and Russian tarragon, Tomitaka et al. (1997) compared the oil compositions of oils produced from both plant types. The results of their comparative study are shown in Table IX. As can be seen, the typical difference on oil composition for both tarragon types confirms the results of previous studies that have been reviewed earlier (Lawrence 1988 and 1990).

In 1999, Olszewska-Kaczynska and Jaroszewska compared the composition of tarragon oil produced from plants originally of French and Polish origins. They produced leaf oils from plants harvested at three different dates (July 9th, August 13th and September 12th), although the state of maturity of the plants was not noted. The results of this study can be seen in Table X. It was of interest to note that at the three dates the authors pulled up the plants to obtain the leaves. After leaf separation and oil production they also produced oils from the roots and rhizomes of these same two tarragon types and subsequently also analyzed these oils, the results of which are shown in Table XI. It is of further interest to note that the commonly encountered French tarragon oil that is rich in methyl chavicol has a rhizome/root oil that is rich in elemicin as this component is generally the major constituent of the seed sown or wild *A. dracunculus*.

Antonelli and Fabbri (1999) used a silica gel pre-fractionation of Italian tarragon oil prior to GC and GC/MS analysis to characterize the following constituents in the oil:

α-pinene (0.94%)
camphene (0.06%)
sabinene (0.08%)
β-pinene (0.12%)
myrcene (0.17%)
limonene (3.03%)
1,8-cineole (t)
(Z)-β-ocimene (9.19%)
(E)-β-ocimene (8.97%)
terpinolene (0.05%)
linalool (0.10%)
(E,E)-allo-ocimene (0.13%)
methyl chavicol (75.07%)
eugenol (0.16%)

Table X. Comparative percentage composition of the leaf oils of tarragon produced from two types (French and Polish) harvested at three different times

	French			Polish		
Compound	July 9	Aug 13	Sept 12	July 9	Aug 13	Sept 12
α-pinene	2.19	1.25	1.90	0.46	0.51	0.40
camphene	0.16	0.12	0.07	0.23	0.21	0.16
β-pinene†	2.68	2.45	1.17	28.70	26.00	20.80
myrcene	0.29	1.50	0.40	1.73	1.98	1.84
α-terpinene	t	0.11	0.03	0.19	0.28	0.24
limonene	5.31	4.95	3.82	0.20	0.78	0.51
1,8-cineole	4.54	6.76	11.90	1.21	3.00	3.33
γ-terpinene	0.05	t	0.06	0.33	0.58	0.47
p-cymene	3.92	6.39	10.20	0.68	2.43	2.90
menthone	0.05	0.19	0.04	0.19	0.31	0.23
linalool	0.19	0.24	0.13	0.26	0.38	0.31
α-terpineol	0.37	0.20	0.20	0.52	0.41	0.39
β-caryophyllene	0.14	0.16	0.12	0.05	1.07	0.94
methyl chavicol	58.80	57.10	61.90	6.55	8.06	6.06
borneol	0.03	0.04	0.03	0.27	0.29	0.19
α-humulene	0.42	0.02	0.03	3.84	3.69	3.25
elemicin	14.00	5.66	2.70	43.50	44.00	43.80

† this is probably sabinene or mixed sabinene/β-pinene
t = <0.01%

Table XI. Comparative percentage composition of the root/rhizome oil of tarragon produced from two types (French and Polish) harvested at three different times

	French			Polish		
Compound	July 9	Aug 13	Sept 12	July 9	Aug 13	Sept 12
α-pinene	0.10	0.19	0.19	0.70	0.84	0.10
camphene	0.09	0.10	0.09	t	0.07	0.08
β-pinene†	0.30	0.37	0.38	2.00	2.44	1.39
myrcene	0.60	0.86	0.52	1.00	1.10	0.17
α-terpinene	0.05	0.05	0.03	t	0.09	0.07
limonene	0.30	0.34	0.53	2.00	2.14	0.24
1,8-cineole	0.30	0.36	0.53	2.10	2.77	0.06
γ-terpinene	t	t	t	t	t	0.56
p-cymene	0.36	0.36	0.51	2.00	2.55	0.19
menthone	t	t	0.05	0.10	0.10	0.05
linalool	0.10	0.12	0.20	0.10	0.12	0.03
α-terpineol	2.20	2.23	1.95	0.20	0.25	0.32
β-caryophyllene	1.20	1.30	0.83	0.40	0.53	0.25
methyl chavicol	4.00	3.90	5.53	24.00	22.00	6.57
borneol	t	t	0.04	t	0.05	0.04
α-humulene	t	0.08	0.08	0.40	0.42	0.43
elemicin	55.80	59.20	56.70	52.00	51.50	71.60

† this is probably sabinene or mixed sabinene/β-pinene
t = <0.01%

Table XII. Comparative percentage composition of the spikelets, raceme and spathe oils of palmarosa

Compound	Spikelet Oil	Raceme Oil	Spathe Oil
α-pinene	-	-	0.03
myrcene	0.03	0.09	-
limonene + 1,8-cineole	-	0.04	-
(E)-β-ocimene	0.04	0.17	-
cis-linalool oxide †	0.05	0.03	-
linalool	2.00	3.14	1.08
citronellol	0.07	0.03	-
terpinen-4-ol	0.13	-	-
methyl chavicol	-	0.10	-
citronellol + nerol	t	0.22	0.29
geraniol	84.16	72.23	73.40
geranyl formate	0.03	0.03	-
geranyl acetate	0.47	18.22	10.54
β-elemene	0.05	-	-
β-caryophyllene	1.14	0.44	0.59
α-humulene	0.08	0.11	-
β-selinene	0.03	-	-
geranyl isobutyrate	0.06	-	0.08
β-bisabolene	-	-	0.15
δ-cadinene	0.04	-	-
geranyl butyrate	0.16	0.15	0.24
(E)-nerolidol	-	-	0.21
caryophyllene oxide	0.83	0.16	0.39
geranyl isovalerate	0.08	0.06	-
geranyl valerate	0.12	0.05	0.08
(Z,Z)-farnesol	0.09	0.05	0.16
(E.Z)-farnesol	7.20	2.83	8.56
geranyl hexanoate	1.75	0.67	2.41
geranyl heptanoate	0.05	-	-

† furanoid form

t = <0.01%

spikelet = a secondary spike, a cluster of one or more racemes on which flowers are borne, and spathes

raceme = an indeterminate inflorescence with lengthened axis and equally stalked flowers

spathe = a bract-like envelope leaf-like structure

(E)-methyl cinnamate (0.04%)
methyl eugenol (0.46%)
β-caryophyllene (0.09%)
4-methoxycinnamaldehyde (0.10%)
7-methoxy coumarin (t)

t = <0.01%

An oil of French tarragon produced in North Carolina was analyzed by GC and GC/MS (Lawrence) and found to contain the following constituents:

Table XIII. Comparative main component composition (%) of palmarosa cultivar and mutant oils

Compound	Cultivar Oils	Mutant Oils
myrcene	0.09-0.17	t-0.34
1,8-cineole	0.06-0.09	t-0.58
γ-terpinene	0.16-0.27	0.01-0.62
6-methyl-5-hepten-2-one	1.00-2.20	0.12-2.34
linalool	1.11-2.11	0.60-3.28
β-caryophyllene	0.19-0.30	0.06-2.76
geranyl acetate	1.89-3.55	5.50-38.04
nerol	0.07-0.10	0.05-0.88
geraniol	83.61-86.30	42.37-88.06
elemol	0.82-1.71	0.05-6.84

α-pinene (1.21%)
camphene (0.08%)
β-pinene (0.14%)
sabinene (0.08%)
myrcene (0.18%)
limonene (3.58%)
(Z)-β-ocimene (9.59%)
(E)-β-ocimene (10.22%)
p-cymene (0.06%)
terpinolene (6.07%)
(Z,Z)-allo-ocimene (0.31%)
(E,E)-allo-ocimene (0.07%)
linalool (0.10%)
β-caryophyllene + terpinen-4-ol (0.16%)
citronellyl acetate (0.07%)
methyl chavicol (72.86%)
nerol (0.10%)
geraniol (0.09%)
methyl eugenol (0.03%)
(E)-methyl isoeugenol (0.04%)
eugenol (0.12%)
elemicin (0.33%)
(E)-isoelemicin (0.15%)

B. M. Lawrence, *Progress in Essential Oils.* Perfum. Flavor., *13(2)*, 49-50 (1988); *15(2)*, 75-76 (1990).

N. A. Klyuev and P. D. Bukharin, *Composition of tarragon (Artemisis dracunculus L.) essential oil*. Izv. Timiryazevsk. S-kh. Akad., *(3)*, 186-188 (1991).

F. Zani, G. Massimo, S. Benvenuti, A. Bianchi, A. Albasini, M. Melegari, G. Vampa, A. Bellotti and P. Mazza, *Studies on the genotoxic properties of essential oils with Bacillus subtilis rec-assay and Salmonella/microsome reversion assay.* Planta Med., 57, 237-241 (1991).

E. Kostrzewa and K. Karawowska, *Flavor and aroma components of tarragon plants cultivated in Poland.* Pr. Inst. Lab. Badaw. Przem. Spozyw., *48*, 43-57 (1993).

M. Montagut, L. Cabrero, Ph. Dallet and J-P. Dubost, *Influence des procédés de conservation (déshydratation et surgélation) sur la teneur en huile essentialle et le profil aromatique de l'estragon*. Bull. Soc. Pharm. Bordeaux, *134*, 99-106 (1995).

C. Bourrel, G. Vilarem, G. Michel and A. Gaset, *Étude des propriétés bacteriostatiques et fongistatiques en milieu solide de 24 huiles essentielles préamblement analysées.* Rivista Ital. EPPOS, *No. 16*, 3-12 (1995).

P. R. Venskutonis, *Essential oil composition of some herbs cultivated in Lituania*. In: *Flavours, Fragrances and Essential Oils*. Proceedings of the 13th International Congress of Flavours, Fragrances and Essential Oils, Istanbul, Turkey, October 1995. Edit. K. H. C. Baser, *Vol.* 2, pp. 108-123, Anadolu Univ. Press, Eskisehir, Turkey (1995).

P. R. Venskutonis, J. W. Gramshaw, A. Dapkevicius and M. Baranauskiene, *Composition of volatile constituents in tarragon (Artemisia dracunculus L.) at different vegetative periods*. In: *Flavor Science, Recent Developments*. Edits., A. J. Taylor and D. S. Mottram, pp. 46-51, Royal Society of Chemistry, Cambridge (1996).

J. Pino, A. Rosado, M. T. Correa and V. Fuentes, *Chemical composition of the essential oil of Artemisia dracunculus L. from Cuba.* J. Essent. Oil Res., *8*, 563-564 (1996).

Y. Tomitaka, M. Kimura, K. Asano and H-O. Boo, *Morphological characters and the essential oil in Artemisia dracunculus (French tarragon) and A. dracunculoides (Russian tarragon).* J. Agric. Sci., Tokyo Nogyo Daigaku, *41*, 229-238 (1997).

I. Olsezewska-Kaczynska and I. Jaroszewska, *Chemical differences between tarragon cultivated in Poland and French tarragon.* Herba Pol. *45(3)*, 173-178 (1999).

A. Antonelli and C. Fabbri, *Essential oils: SPE fractionation*. Chromatographia, *49*, 125-130 (1999).

B. M. Lawrence, unpublished information.

Palmarosa oil

In 1998, Mallavarapu et al. used a combination of GC and GC/MS to analyze four palmarosa oils produced from plants raised from seeds obtained from four different growing areas in India. The results of these analyses can be seen summarized as follows:

tricyclene (t)
α-pinene (t-0.1%)
camphene (t-0.2%)
6-methyl-5-hepten-2-one (t-0.5%)
β-pinene (0-0.2%)
myrcene (0.6-1.3%)
α-phellandrene (t-0.1%)
α-terpinene (0-0.1%)
p-cymene (t)
limonene + 1,8-cineole (0.2-0.6%)
(Z)-β-ocimene (0-0.4%)
(E)-β-ocimene (1.3-3.1%)
γ-terpinene (0-t)
cis-linalool oxide† (t-0.1%)
trans-linalool oxide† (t-0.1%)
terpinolene (t-0.1%)
linalool (2.6-4.5%)
camphor (t-0.1%)
citronellal (t)
isopulegol (0-t)
borneol (t-0.1%)
terpinen-4-ol (t-0.1%)
α-terpineol (t-0.2%)
methyl chavicol (t)
citronellol + nerol (0.1-0.2%)
neral (0.1-0.8%)
piperitone (0-t)
geraniol (74.5-81.8%)
geranial (0.5-1.9%)
citronellyl formate (t)
neryl formate (t-0.1%)
geranyl formate (t-0.1%)
citronellyl acetate (t-0.1%)
neryl acetate (t)
geranyl acetate (0.5-10.7%)
β-cubebene (t)
β-elemene (0.1%)
β-caryophyllene (0.9-2.6%)
trans-α-bergamotene (t-0.1%)
geranyl propionate (t-0.1%)
α-humulene (0.1-0.4%)
(E)-β-farnesene (t-0.1%)
β-selinene (t-0.2%)
α-selinene (t)
geranyl isobutyrate (0.1-0.3%)
β-bisabolene (0-t)
δ-cadinene (t-0.1%)
geranyl butyrate (0.1-0.2%)
elemol (0.2-1.0%)
caryophyllene oxide (0.1-1.8%)
geranyl isovalerate (t)
geranyl valerate (t-0.3%)
(Z,Z)-farnesol (0.1-1.0%)
(E,Z)-farnesol (0.5-6.1%)
geranyl hexanoate (0.2-0.6%)
farnesyl acetate* (0-t)
geranyl heptanoate (0-0.1%)

*correct isomer not identified
† furanoid form
t = 0.1%

Two years later, Delespaul et al. (2000) screened a number of essential oils for their antifungal activity. Among the oils screened was palmarosa. This oil was found to contain the following major components:

(E)-β-ocimene (0.1%)
linalool (0.6%)
nerol (0.2%)
geraniol (85.4%)

geranyl formate (0.5%)	geranyl acetate (9.2%)
citronellyl acetate (2.3%)	β-caryophyllene (0.3%)
neryl acetate (0.8%)	geranyl hexanoate (0.3%)

This same year, Srivastava et al. (2000) examined the major components of some mutants of palmarosa produced by gamma rays and chemical induction. The authors used four major cultivars from which the mutants were created. Oils produced from the mutants were compared with the oils obtained from the cultivars for their major constituents. A summary of these results can be seen in Table XII. It was of interest to note that, although the cultivars had oil yields of 0.51-0.74%, the mutant oil yields ranged from 0.73-3.00%.

Also in 2000, Dubey et al. compared the oil composition of different organs of palmarosa. A summary of the results of this combination GC and GC/MS analysis can be seen in Table XIII.

More recently, Lawrence examined the major component composition of a commercial sample of palmarosa oil using a combination of GC and GC/MS. The oil was determined to contain the following constituents:

myrcene (0.3%)	neral (0.4%)
limonene (1.1%)	geranial (0.3%)
1,8-cineole (0.4%)	neryl acetate (1.3%)
(E)-β-ocimene (1.4%)	geranyl acetate (7.3%)
p-cymene (0.1%)	nerol (0.6%)
linalool (2.7%)	geraniol (81.4%)
β-caryophyllene (1.2%)	caryophyllene oxide (0.3%)
α-humulene (0.1%)	(E,Z)-farnesol (0.5%)

G. R. Mallavarapu, B. R. Rao, P. N. Kaul, S. Ramesh and A. K. Bhattacharya, *Volatile constituents of the essential oils of the seeds and herb of palmarosa (Cymbopogon martini (Roxb.) Wats. var. motia Burk.).* Flav. Fragr. J., *13*, 167-169 (1998).

Q. Delespaul. V. G. de Billerbeck, C. G. Roques, G. Michel, C. Marquier-Vinuales and J-M. Bessière, *The antifungal activity of essential oils as determined by different screening methods.* J. Essent. Oil Res., *12*, 256-266 (2000).

H. K. Srivastava, G. K. Satpute and A. A. Naqvi, *Induced mutants in M2 generation and selection for enhanced essential oil yield and quality in palmarosa (Cymbopogon martini (Roxb.) Wats. var. martini).* J. Essent. Oil Res., *12*, 501-506 (2000).

V. S. Dubey, G. R. Mallavarapu and R. Luthra, *Changes in the essential oil content and its composition during palmarosa (Cymbopogon martini (Roxb.) Wats var. motia) inflorescence development.* Flav. Fragr. J. *15*, 309-314 (2000).

B. M. Lawrence, unpublished information. ■