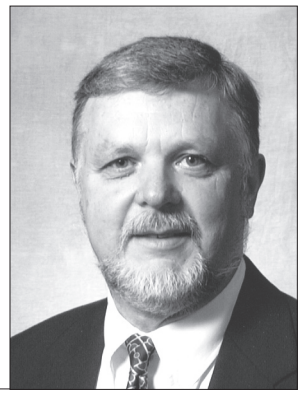

Progress in Essential Oils

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

Coriander Seed and Leaf Oils

In 1992, Nitz et al. used GC/MS to characterize the composition of a distilled oil of coriander and compare it with that of a supercritical fluid (SFC) extract of coriander. They found that the oil contained the following major compounds:

linalool (63%)
γ-terpinene (9%)
α-pinene (8%)
limonene (4%)
camphor (4%)
geranyl acetate (2%)

In addition, a number of minor components of lower odor thresholds were also identified, including:

hexanal (0.07%)
heptanal (0.04%)
octanal (0.02%)
nonanal (0.02%)
undecanal (0.03%)
dodecanal (0.01%)
(E)-2-heptenal (0.02%)
(E)-2-octenal (0.01%)
(E)-2-decenal (0.07%)
(E)-2-dodecenal (0.03%)
(E)-2-tetradecenal (0.05%)
(E,E)-2,4-decadienal (0.01%)
2-pentylfuran (0.01%)
2-hexylfuran (0.02%)
2-octylfuran (0.03%)
2-decylfuran (0.01%)
1-octen-3-one (0.01%)
3-octen-2-one (0.01%)
2,6-dimethylpyrazine (0.01%)
ethyl-dimethylpyrazine* (<0.01%)
furfuraldehyde (0.05%)
dihydroactinodiolide (0.02%)
safrole (0.11%)
4-vinylguaiacol (0.10%)
4-vinylphenol (0.08%)
dimethyldisulphide† (t)
dimethyltrisulphide† (t)

*correct isomer not identified
† tentative identification
t=trace (<0.01%)

In contrast, the aroma-rich components that were identified in the SFC extract were:

hexanal (0.03%)
heptanal (0.01%)
octanal (t)
nonanal (t)
decanal (0.03%)
dodecanal (0.01%)
(E)-2-heptenal (0.08%)
(E)-2-octenal (t)
(E)-2-decenal (0.04%)
(E,E)-2,4-decadienal (0.08%)
1-octen-3-one (t)
safrole (0.02%)

t=trace (<0.01%)

Three years later, Frank et al. (1995) reported that the main constituents of both lab prepared and commercial samples of coriander oil ranged as follows:

α-pinene (0.5-6.0%)
camphene (<0.5%)
β-pinene (<0.5%)
sabinene (<0.5%)
myrcene (0.2-0.8%)
limonene (1.3-6.3%)
γ-terpinene (2.7-7.7%)
p-cymene (0.6-5.9%)
terpinolene (<0.5%)
linalool (68.4-87.5%)
geranyl acetate (0.8-3.7%)
geraniol (0.4-3.5%)

Table I. Percentage composition of commercial coriander oil adulterated with (+)- limonene and racemic linalool

Compound	Genuine Coriander Oil	Commercial Oils 1	2	3
(4S)-(-)-limonene	50	38	12	7
(4R)-(+)-limonene	50	62	88	93
(3S)-(+)-linalool	10	33	27	34
(3R)-(-)-linalool	90	67	73	66

The authors also used both chiral GC analysis and GC-isotope ratio mass spectrometry to determine adulteration in the commercial oil samples. For example, they determined that the enantiomeric ratios of limonene and linalool of the commercial samples were sufficiently different from the ratios expected for authentic oils to prove adulteration with (+)-limonene and racemic linalool as shown in Table I.

Diederischen (1996) screened 237 accessions of coriander and determined that the main fruit oil components varied as follows:

α-pinene (6.5-28.9%)
γ-terpinene (0.7-35.4%)
camphor (0.4-6.3%)
linalool (19.8-82.0%)
geranyl acetate (1.3-12.4%)
geraniol (0.3-3.3%)

Although the chirality of linalool in coriander oil is well known, Casabianca and Graff (1996) confirmed that it possessed the following enantiomeric distribution:

(3R)-(-)-linalool (10-14.5%) :
(3S)-(+)-linalool (85.5-90%)

In 1997, Anitescu et al. used GC/MS to analyze and compare the composition of a commercial sample of coriander oil purchased in Romania with a steam distilled oil and a lab prepared supercritical fluid extract of Romanian grown coriander. The results of this comparative study are summarized in Table II.

In 1997, Worku and Franz compared the composition of oils obtained from the leaves, stems and dried fruits of coriander. Their results, which were obtained from GC/MS analysis, are found in Table III.

The headspace volatiles of coriander seedling plants were collected on Porapak Q and analyzed by GC/MS by Valterova

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Table II. Comparative percentage composition of two oils and a supercritical fluid extract of coriander

Compound	Oil A	Oil B	SFE
α-thujene	t	t	0.1
α-pinene	3.3	2.3	2.8
camphene	0.6	0.4	1.5
sabinene	0.1	0.3	0.9
β-pinene	1.0	0.3	0.9
6-methyl-5-hepten-2-one	0.1	0.1	0.1
myrcene	1.2	0.8	1.0
δ-3-carene	1.1	0.3	0.3
α-terpinene	0.1	0.1	0.1
p-cymene	4.9	4.0	4.0
limonene	2.4	2.3	2.7
1,8-cineole	t	0.1	0.1
γ-terpinene	4.6	3.5	3.5
cis-linalool oxide†	0.6	0.2	0.4
trans-linalool oxide†	0.8	0.3	0.4
linalool	63.8	62.8	61.9
camphor	5.5	5.6	5.6
borneol	0.1	0.1	0.1
menthol	t	0.1	0.1
terpinen-4-ol	0.6	0.5	0.5
p-cymen-8-ol	t	0.1	0.3
(Z)-3-hexenyl butyrate	t	0.1	0.2
α-terpineol	1.0	0.9	0.6
cis-dihydrocarvone	-	0.1	0.1
citronellol	0.1	0.3	0.2
neral	0.1	0.1	0.2
carvone	0.5	1.0	1.0
geraniol	1.8	2.8	2.2
geranial	t	0.1	0.2
(E)-anethole	0.7	0.4	0.4
thymol	t	0.1	0.1
carvacrol	t	0.1	0.2
geranyl formate	-	t	0.2
eugenol	0.1	2.6	1.4
neryl acetate	0.1	0.1	0.2
geranyl acetate	1.0	1.8	2.4
β-caryophyllene	t	2.1	0.8
α-humulene	t	0.3	0.2
eugenyl acetate	-	t	0.2
caryophyllene oxide	t	t	0.2

Oil A = commercial oil
Oil B = steam distilled oil
SFE = supercritical fluid CO_2 extract
† = furanoid form
t = trace (<0.1%)

et al. (1997). As this study was performed to determine the attraction of a specific insect to lay her eggs on the plant, the analysis was directed only towards the monoterpene hydrocarbons. Valterova et al. characterized the following monoterpene hydrocarbons in the headspace:

α-pinene (23.6%)	α-terpinene (44.8%)
β-pinene (11.1%)	limonene (5.5%)
δ-3-carene (10.8%)	β-phellandrene (4.3%)

The authors also determined the enantiomeric distribution of the chiral hydrocarbons, with the exception of β-phellandrene, which they stated was too small to determine other than that the (-)-isomer predominated. The enantiomeric distribution of four other chiral hydrocarbons was as follows:

(IS,5S)-(-)-α-pinene (45%) : (IR,5R)-(+)-α-pinene (55%)

(IS,5S)-(-)-β-pinene (95%) : (IR,5R)-(+)-β-pinene (5%)

(3S)-(-)-δ-3-carene (0%) : (3R)-(+)-δ-3-carene (100%)

(4S)-(-)-limonene (61%) : (4R)-(+)-limonene (39%)

A lab-distilled oil of coriander produced from coriander seed obtained from the spice shelf in the UK was analyzed by GC/MS by Tiziana Baratta et al. (1998). The oil composition was determined to comprise of the following constituents:

tricyclene (t)	linalool (66.3%)
α-thujene (0.1%)	camphor (3.8%)
α-pinene (8.5%)	borneol (0.6%)
camphene (0.9%)	terpinen-4-ol (0.3%)
sabinene (0.3%)	α-terpineol (0.4%)
β-pinene (0.6%)	citronellol (t)
myrcene (0.9%)	geraniol (2.0%)
α-terpinene (0.1%)	(Z)-anethole (t)
p-cymene (2.2%)	carvacrol (t)
β-phellandrene (0.2%)	pinocarvyl acetate* (t)
limonene (1.9%)	geranyl acetate (2.7%)
γ-terpinene (7.1%)	β-caryophyllene (0.1%)
terpinolene (0.4%)	

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

The compositions of a diethylether extract and a supercritical fluid CO_2 extract of coriander were compared with that of an oil by Feicke et al. (1998) using GC. The results of this study are shown in Table IV.

Also in 1998, Bandoni et al. compared the composition of coriander seed oil produced by water distillation (hydrodistillation) and steam distillation. As can be seen from the data presented in Table V, the oils were quite similar. The authors also compared the composition of coriander seed oils produced from plants grown in three different provinces of Argentina (Cordoba, Buenos Aires and Mendoza) with commercial oils and some oils produced in Russia. A summary of their results can be seen in Table VI. Finally, Bandoni et al. compared the composition of freshly prepared coriander oil with that of an aged oil as shown in Table VII.

The following year, Benyoussef et al. (1999) examined the composition of an oil and two extracts produced from

Table III. Effect of distillation process on oil composition of coriander

Compound	Hydrodistilled Oil	Steam Distilled Oil
α-pinene	1.2	3.7
camphene	0.2	0.6
sabinene	0.1	0.1
β-pinene	0.1	0.4
myrcene	0.5	0.8
limonene	1.1	2.0
γ-terpinene	2.2	4.1
p-cymene	0.3	0.7
terpinolene	0.3	0.5
linalool	81.8	75.7
camphor	4.8	4.5
geranyl acetate	2.0	3.2
geraniol	3.2	2.0

Table IV. Comparative percentage composition of some coriander oils

Compound	Argentinean Oils	Russian Oils	Commercial Oils
a-pinene	1.0-2.7	3.9-4.8	2.7-6.5
camphene	0.1-0.4	0.6-0.9	0.5-1.2
sabinene	0.1-0.2	0.1-0.2	0.1-0.3
β-pinene	0.1-0.3	0.4-0.6	0.2-0.5
myrcene	0.4-0.5	0.6-0.8	0.6-1.0
limonene	0.9-1.1	2.4-5.1	1.8-2.6
1,8-cineole	0.1	0.1-0.2	0.1-0.2
γ-terpinene	2.8-5.0	3.3-4.4	4.1-5.1
p-cymene	0.3-1.5	1.7-3.0	0.7-1.7
terpinolene	0.2-0.3	0.4-0.5	0.5-0.6
nonanal	0-0.1	-	-
cis-linalool oxide†	t-0.2	0.2-0.4	t-0.2
trans-linalool oxide†	t-0.2	0.2-0.3	t-0.2
decanal	0-0.4	-	t-0.3
linalool	76.3-83.7	71.0-72.6	68.9-76.3
camphor	3.2-4.8	4.1-5.4	4.4-4.8
terpinen-4-ol	0.1-0.3	0.2-0.3	0.1-0.2
α-terpineol	0.3-0.6	0.4-0.9	0.3-0.4
geranyl acetate	0.8-2.0	2.4-3.9	2.6-3.8
geraniol	2.0-3.2	1.2-1.8	1.4-2.0

† furanoid form
t=trace (<0.1%)

Table V. Comparative percentage composition of oils produced from various organs of coriander

Compound	Leaf Oil	Stem Oil	Dried Fruit Oil
nonane	0.1	-	-
α-pinene	-	-	0.9
camphene	-	-	0.2
β-pinene	-	-	0.1
myrcene	-	-	0.4
limonene	-	-	1.1
decanal†	0.6	0.3	-
β-phellandrene	-	-	0.1
p-cymene	0.3	0.3	0.3
γ-terpinene	-	-	1.0
linalool oxide*	0.6	0.3	-
α-terpinene‡	-	-	0.4
linalool	0.6	4.0	85.7
nonanal	0.4	0.3	-
(Z)-2-nonenal	0.1	-	-
decanal	27.3	-	-
camphor	-	-	6.2
cis-linalool oxide (pyranoid)	0.4	-	-
decanol	5.1	16.6	-
(E)-2-decenol †††	49.2	50.8	-
geraniol	-	-	t
undecanal	1.5	3.5	-
neral	-	-	0.1
sabinyl acetate*	-	-	0.1
(E)-2-undecenal	3.3	6.8	-
dodecanal	1.2	1.4	-
geranyl acetate	-	0.2	3.2
(E)-2-dodecenal	5.8	8.8	-
(E)-2-tridecenal	2.5	5.3	-

† should be octanal
‡ should be terpinolene
††† should be (E)-2-decenal
*correct isomer not identified
t=trace (<0.1%)

coriander grown in Algeria. As can be seen from their results, which are shown in Table VIII, the hexane extract was very low in linalool and rich in myristic acid unlike the oil or the ethanolic extract. Also, it must be noted that the analyses were not very complete as only 86.2%, 68.6% and 78.8% were identified in the oil, hexane extract and supercritical fluid CO_2 extract, respectively,

Tateo et al. (1999) determined that the content of camphor in coriander oil was 5.1-5.4%. Its enantiomeric distribution was found to be:

(IS)-(-)-camphor (86.3-87.6%) :
(IR)-(-)-camphor (12.4-13.7%)

This same year, Cadwallader et al. (1999) examined a methylene chloride extract of *C. sativum* leaves (cilantro) that were freshly harvested and a second extract produced from cilantro leaves purchased at the grocery store using GC/MS and retention indices. Their results can be seen summarized in Table IX.

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Cassia Oil

In 1988 Frey used a technique of selective ion monitoring GC/MS to determine adulteration of cassis oil from China.

He determined that phenylpentadienal was an impurity in synthetic cinnamaldehyde of Chinese origin. As synthetic cinnamaldehyde is the common adulterant of cassia oil, if the amount of phenylpentadienal in an adulterated cassia oil can be determined, then the amount of adulteration with synthetic cinnamaldehyde can be accurately calculated. Frey was able to determine an adulteration level of as little as 2% synthetic cinnamaldehyde by quantifying the mass fragments m/e 158, 129 and 128.

More recently, Zhu et al. (1996) reported that synthetic cinnamaldehyde produced in China had the following composition:

benzaldehyde (0.95%)
benzyl alcohol (16.26%)
(Z)-cinnamaldehyde (0.97%)
(E)-cinnamaldehyde (74.4%)
eugenol (3.73%)
(E)-cinnamyl alcohol (0.57%)
phenylpentadienal (1.73%)
(E)-cinnamic acid (0.97%)

They also proposed that the addition of synthetic cinnamaldehyde to cassia oil could be determined from selective ion monitoring GC/MS using m/e fragments of 164 (to detect benzaldehyde), 158 (to detect phenylpentadienal) and 108 (to detect eugenol). In addition, Zhu et al. analyzed an authentic sample of cassia oil by GC/MS and found that it contained:

styrene (0.09%)
benzaldehyde (0.74%)
camphene (0.03%)
salicylaldehyde (0.17%)
2-phenethyl alcohol (0.37%)
acetophenone (0.08%)
3-phenylpropanol (0.54%)
borneol + 2-methylbenzofuran (0.12%)
(Z)-cinnamaldehyde (0.58%)
2-methoxybenzaldehyde (0.42%)
2-phenethyl acetate (2.29%)
(E)-cinnamaldehyde (78.60%)
(E)-cinnamyl alcohol (0.04%)
α-copaene (0.13%)
coumarin (1.85%)
(E)-cinnamyl acetate (0.20%)
(Z)-2-methoxycinnamaldehyde (0.17%)
(E)-2-methoxycinnamaldehyde (12.26%)
nerolidol* (0.12%)
(E)-2-methoxycinnamyl acetate (0.06%)
benzyl benzoate (0.07%)

*correct isomer not identified

In 1994, Vernin et al. analyzed the headspace of ground cassia bark using GC/MS. They found that this headspace contained the following constituents:

α-pinene (0.10%)
limonene (0.28%)
p-cymene (0.82%)
α-copaene (0.67%)
benzaldehyde (23.80%)
linalool (0.05%)
bornyl acetate (0.62%)
linalyl acetate (0.44%)
salicyaldehyde (1.27%)
borneol + α-terpineol (3.80%)
hydrocinnamaldehyde (0.69%)
2-phenethyl acetate (0.96%)
(Z)-cinnamaldehyde (0.21%)
2-phenethyl alcohol (0.24%)
2-methoxybenzaldehyde (0.82%)
(E)-cinnamaldehyde (39.50%)
(E)-cinnamyl acetate (0.24%)

The following year, Jayatilake et al. (1995) examined the composition of the oil produced from 25 samples of cassia bark. They found that the major components of the oils ranged as follows:

(E)-cinnamaldehyde (92.0-98.0%)
(Z)-cinnamaldehyde (0.8-2.7%)
β-caryophyllene (0.4-3.6%)
coumarin (0.1-1.6%)
α-ylangene (0.1-2.7%)

Table VI. Comparative percentage composition of aged coriander oil

Compound	Typical Oil	Aged Oil
α-pinene	1.0-6.5	2.3
myrcene	0.4-1.0	0.1
γ-terpinene	2.2-5.1	0.1
p-cymene	0.3-3.0	3.8
cis-linalool oxide†	0.1-0.4	4.9
trans-linalool oxide†	0.1-0.3	4.3
camphor	2.1-4.4	nd
linalool	68.9-83.7	64.0

nd = not determined
† = furanoid form

In addition, reduced amounts (amounts not given) of the following constituents were also identified in cassia bark oil:

β-phellandrene
3-phenylpropanal
(E)-cinnamyl alcohol
δ-cadinene
benzaldehyde

Also in 1995, Ehlers et al. used HPLC to determine that the main constituents of Chinese cassia oil were:

(E)-cinnamyl alcohol (0.1-0.9%)
(E)-cinnamaldehyde (68.2-71.9%)
(E)-2-methoxycinnamaldehyde (0.5-9.4%)
(E)-cinnamyl acetate (5.6-6.0%)

The authors also analyzed a supercritical CO_2 extract of Chinese cassia. The components identified in three replicate extracts were:

(E)-cinnamic acid (t)
(E)-cinnamyl alcohol (0.3%)
(E)-cinnamaldehyde (73.9-74.4%)
(E)-2-methoxycinnamaldehyde (1.4-4.6%)
coumarin (0.2-1.0%)

t=trace (<0.01%)

Miller et al. (1995) used solvent assisted supercritical fluid extraction, GC/MS analysis combined with principal component analysis to differentiate between cinnamon and cassia. The 12 constituents selected for the statistical analysis were benzaldehyde, benzyl benzoate, β-caryophyllene, caryophyllene oxide, cinnamaldehyde, cinnamyl acetate, cinnamyl alcohol, coumarin, eugenol, 2-methoxycinnamaldehyde, δ-cadinene and β-phellandrene. Miller et al. distinguished cinnamon from cassia by the presence of eugenol, absence of δ-cadinene, the lower amount of coumarin and the higher amount of benzyl benzoate. This use of principal component analysis was a bit surprising because it is relatively easy to differentiate between two oils because of differing minor component compositions.

Kwon et al. (1996) isolated salicylaldehyde from a bark extract of *C. Cassia*. Although this seems like just another constituent (salicylaldehyde), the authors determined that salicylaldehyde inhibited farnesyl protein transferase activity, which according to the authors is "an enzyme which

Table VII. A comparison of the percentage composition of an oil, a diethyl ether extract and a supercritical fluid CO_2 extract of coriander

Compound	SDE	EXT	SFE
α-thujene	0.07	0.08	0.06
α-pinene	6.75	8.07	5.73
camphene	0.84	1.00	0.71
sabinene	0.37	0.45	0.28
β-pinene	0.51	0.62	0.47
myrcene	0.90	1.10	0.65
α-terpinene	0.04	0.05	0.04
p-cymene	1.13	1.27	0.89
limonene	1.93	2.35	1.90
γ-terpinene	6.63	8.23	7.27
trans-sabinene hydrate	0.07	0.08	0.10
linalool oxide (furanoid)*	0.13	0.04	0.09
terpinolene	0.53	0.51	0.54
linalool	59.02	63.33	63.48
camphor	3.30	3.49	3.43
citronellal	0.06	0.06	0.05
borneol	0.13	0.16	0.12
terpinen-4-ol	0.15	0.14	0.17
α-terpineol	0.25	0.24	0.29
citronellol	0.09	0.08	0.09
geraniol	2.18	2.22	2.51
geranial	0.07	0.03	0.08
(E)-anethole	0.03	0.04	0.03
neryl acetate	0.07	0.08	0.09
geranyl acetate	2.50	3.07	3.12
β-caryophyllene	0.07	0.08	0.10
sedanolide	0.04	0.04	0.04

SDE = simultaneous distillation/extraction
EXT – diethyl ether extract
SFE = supercritical fluid CO_2 extract
*correct isomer not identified

catalyzes the transfer of the farnesyl group from farnesyl pyrophosphate into cysteine 186 at the C-terminal of the RAS protein". This process is considered to be mandatory and critical for promotion the RAS oncogene towards tumor formation. As a result, the authors believed that such farnesyl protein transferase inhibitors could lead to the development of effective tumor treatment therapeutic agents.

In 1998, Li et al. compared the composition of the leaf and bark oils of *C. cassia* grown in Yunnan province (China) using GC/MS as their method of analysis. A summary of the results of this study are shown in Table X. As can be seen from the results, there are some unexplained anomalies in the data; nevertheless, this is the first detailed analysis of *C. cassia* leaf oil that has appeared in the literature.

An oil of *C. cassia* produced in China was subject to GC and GC/MS analysis by Li and Yuan (1999). The results of this analysis are as follows:

styrene (0.07%)
benzaldehyde (0.03%)
p-cymene (0.98%)
benzyl alcohol (0.02%)
salicylaldehyde (1.01%)
phenylacetaldehyde (0.34%)
benzyl formate (0.08%)
acetophenone (0.06%)
2-pehnethyl alcohol (0.14%)
hydrocinnamyl alcohol (0.09%)
menthol (0.10%)
2-phenethyl acetate (0.15%)
terpinen-4-ol (0.09%)
methyl salicylate (6.17%)
2-methylbenzofuran (0.13%)
2-phenylpropanal (0.05%)
benzylidenemalonaldehyde† (0.12%)
2-methoxybenzaldehyde (0.93%)
(E)-cinnamaldehyde (67.21%)
(E)-cinnamyl alcohol (1.02%)
eugenol (0.99%)
α-copaene (0.23%)
α-cubebene (0.11%)
vanillin (0.30%)
β-caryophyllene (5.58%)
benzofuran (0.34%)
(E)-cinnamyl acetate (3.47%)
ethyl cinnamate (0.27%)
β-cubebene (0.07%)
(E)-cinnamic acid (0.23%)
γ-cadinene (0.07%)
δ-cadinene (0.05%)
(E)-2-methoxycinnamaldehyde (7.40%)
(Z)-nerolidol (0.25%)
(9H)-fluren-9-ol† (0.06%)
adamantane† (0.22%)

† component identities require corroboration

The same analysis was also reported by Li et al. in 2000.

More recently, Gong et al. (2001) developed a new technique for the qualitative and quantitative analysis of two-dimensional data obtained from GC/MS analyses of cinnamon bark grown in four different geographic regions of China. The authors also used an iterative optimization procedure specially developed to resolve co-eluting peaks. They pointed out that the chemometric resolution techniques of data manipulation was a very promising tool for the analysis of complex samples. Unfortunately, they used cinnamon as the test material for these techniques without comparing the procedure with well-known analytical methodologies to show the value of this highly complex approach.

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M-S. Zhu, S. Liu, R-J. Lao and Y-L. Bu, *GC/MS detection of synthetic cinnamic aldehyde added to cassia oil.* Acta Pharm. Sinica, *31*, 461-465 (1996).

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L-L. Li and W-J. Yuan, *Cinnamon oil analysis by GC and GC/MS.* Fujian Fenxi Ceshi, *8*, 1121-1125 (1999).

L-L. Li and W-J. Yuan, *Cinnamon oil analysis by GC and GC/MS.* Yaowu Fenxi Zazhi, *20(2)*, 116-118 (2000).

F. Gong, Y-Z. Liang, Q-S. Xu and F-T. Chau, *Gas chromatography-mass spectrometry and chemometric resolution applied to the determination of essential oils in cortex Cinnamomi*. J. Chromatogr., *905*, 193-205 (2001).

Tea Tree Oil

In 1993, Southwell et al. measured the major component contents of tea tree oil produced in two regions of north-eastern New South Wales (Australia). They found that the oils were rich in the following components:

α-pinene (2.5-2.8%)
α-terpinene (7.6-8.3%)
1,8-cineole (4.1-5.3%)
γ-terpinene (18.4-18.9%)
terpinen-4-ol (39.0-42.0%)
α-terpineol (3.3-3.5%)
sesquiterpenes (<5.0%)

The following year, Butcher et al. (1994) examined the intraspecific variation in the leaf oils of *M. alternifolia*. They screened 109 trees found in 11 populations covering the natural range of tea tree in northeastern New South Wales. It was of interest to note that the oil yield ranged from 2.5-8.8% with lowest oil yields being found in oils rich in terpinolene. Butcher et al. found considerable variation in oil composition both between and within populations. There were oils that were rich in either terpinen-4-ol, 1,8-cineole or terpinolene. The oils could be divided into five forms, e.g.:

	Type	A	B	C	D
1,8-cineole	0.1-11%	36-48%	67-71%	30-36%	17-34%
terpinolene	nd	nd	nd	10-18%	28-57%
terpinen-4-ol	>30%	<30%	<30%	15-20%	1-2%

nd=no data

It was a shame that the authors did not publish their compositional data as they drew statistical conclusions from data to which the reader was not exposed.

Two years later, Southwell et al. (1996) determined that the 1,8-cineole content of tea tree oil was inversely proportional to the terpinen-4-ol content. They also noted that a 1,8-cineole content in the oil of greater than 15% was undesirable because of the concomitant decrease in the terpinen-4-ol content.

Table VIII. Comparative percentage composition of an oil and two extracts of Algerian coriander

Compound	Oil	Hexane Extract	Ethanol Extract
α-pinene	0.1	-	t
myrcene	0.2	-	0.5
p-cymene	0.2	-	t
γ-terpinene	0.6	-	t
1,8-cineole	0.1	-	0.5
linalool	70.2	5.4	62.6
camphor	1.8	-	1.8
terpinen-4-ol	0.5	-	0.3
α-terpineol	0.3	-	t
octanal†	2.2	-	1.5
dodecane	0.5	t	0.2
geranyl acetate	1.6	t	2.3
dodecanal	0.5	-	0.3
β-caryophyllene	0.2	t	0.2
α-humulene	0.8	-	0.5
nerolidol*	0.5	-	t
myristic acid	5.9	63.2	7.8

*correct isomer not identified t=trace (<0.1%)
† incorrect identification based on elution order

Table IX. Comparative composition of the volatiles of two cilantro sample extracts

Compound	Store Bought Cilantro	Fresh Cilantro
(Z)-3-hexenal	2.20[a]	-
(E)-2-hexenal	0.38	-
nonanal	0.13	-
(E)-2-nonenal	0.47	-
(E)-4-decenal	t	-
decanal	10.60	5.56
(E)-2-decenal	59.20	2.41
decanol	0.39	0.06
(E)-2-decenol	2.23	-
undecanal	0.23	0.35
(E)-2-undecenal	3.96	0.57
dodecanal	0.38	1.03
(E)-2-dodecenal	22.30	9.10
tridecanal	-	0.06
(E)-2-tridecenal	2.99	1.09
tetradecanal	0.18	-
(E)-2-tetradecenal	44.90	14.20
(E)-2-pentadecenal	6.49	4.65
(E)-2-hexadecenal	4.86	1.93

[a]mg/g fresh wt. basis t=trace (<0.1%)

Table X. Comparative percentage composition of the leaf and bark oils of *Cinnamomum cassia*

Compound	Leaf Oil	Bark Oil	Compound	Leaf Oil	Bark Oil
α-pinene	0.05-0.36	0.10-0.25	salicylaldehyde	0.05-0.42	0.04-0.85
camphene	0.04-0.05	0.05-0.10	2-phenethyl alcohol	0.11-0.27	t-0.16
β-pinene	0.04-0.15	0.14-0.22	benzyl alcohol	t-0.05	-
myrcene	0.02-0.03	t-0.10	acetophenone	t-0.1	0-0.6
α-phellandrene	0.01-0.06	t-0.13	eugenol	0.04-0.06	0.03-1.08
limonene	0.13-0.24	0.14-0.29	(Z)-isoeugenol	0.14-0.28	0.12-0.66
1,8-cineole	0.05-0.08	0.06-1.07	(E)-cinnamyl acetate	4.50-12.50	0.60-5.10
δ-3-carene†	0.03-0.05	t-0.07	γ-muurolene	t	t-0.50
p-cymene	0.11-0.19	0.04-0.18	anisaldehyde	0.58-1.02	t
camphor	0.07-0.15	0-0.08	2-phenethyl acetate	t-1.55	-
benzaldehyde	1.42-1.48	0.50-1.10	β-bisabolene	t-0.06	t-0.18
linalool	0.11-0.23	0.08-0.16	β-bisabolol	t	t-0.35
terpinolene†	t	0-0.04	α-muurolol	0-0.08	0-0.24
β-caryophyllene	0.16-0.20	t-0.27	coumarin	0.03-0.08	t-0.45
α-humulene	t-0.03	0-0.15	(E)-cinnamic acid	0.80-2.48	0.12-3.10
β-elemene	-	t-0.06	(E)-2-methoxycinnamaldehyde	8.40-10.50	t-2.50
isoborneol	0-0.20	0-0.27	hydrocinnamic acid	0.18-0.51	0-0.24
borneol	0.15-0.41	0.06-1.27	4-hydroxy-2-phenethyl alcohol	0-0.12	0-0.10
α-terpineol	t-0.10	0.07-2.05	caryophyllene oxide	0.15-0.17	0-0.10
geraniol	t	0.08-0.31	patchoulene†	0.06-0.07	0-0.04
carvone	0.57-0.64	0-0.34	octanoic acid	t	0-t
2-methoxybenzaldehyde‡	0.08	0-0.12	3-phenylpropyl acetate	0.21-0.43	0.05-0.22
safrole	-	t-0.20	nonanoic acid	t-0.10	0-t
γ-elemene	0-t	0-0.41	guaicol	t	0-0.08
δ-cadinene	t	t-0.13	(E)-cinnamyl alcohol	0.15	0.05-0.13
β-cadinene	-	t-0.10	(E)-ethyl cinnamate	0.11-0.27	t-0.14
hydrocinnamaldehyde‡	0.88-0.89	0-0.24	benzyl benzoate	0.07-0.15	t-0.38
phenylacetaldehyde	0.07-0.16	t-0.27	methyl alaninate†	t-0.05	-
methyl eugenol	0.14-0.15	t-0.05	guaicyl cinnamate†	t	t
(E)-cinnamaldehyde	64.10-68.30	80.40-88.50	decanoic acid	t	0-t
α-copaene	0.41-0.49	0.23-0.68	undecanoic acid	0-0.05	0-0.11
hydrocinnamaldehyde‡	0.67-0.83	0-0.22	dodecanoic acid	t-0.04	0-t
vanillin†	t	t-0.10	benzoic acid	0.07-0.11	0.07-0.10
2-methoxybenzaldehyde‡	0-0.12	0-0.10	salicylic acid	t-0.10	0.10-0.20

t=trace (<0.01%)
† misidentification based on elution order
‡ compounds listed twice

Bishop and Thornton (1997) evaluated the antifungal activity of tea tree oil. The oils that they screened contained the following major components:

α-thujene (0.8%)
α-pinene (2.3%)
β-pinene (0.7%)
α-terpinene (0.8%)
myrcene (9.0%)
limonene (0.9%)
1,8-cineole (3.4%)
γ-terpinene (19.4%)
p-cymene (2.9%)
terpinen-4-ol (37.4%)
α-terpineol (2.5%)

Also in 1997, another oil of tea tree was screened for its cytotoxicity using human cell lines (Hayes et al. 1997). The main constituents of this oil were:

α-pinene (2.6%)
α-terpinene (8.6%)
p-cymene (3.6%)
limonene (1.2%)
1,8-cineole (4.3%)
γ-terpinene (19.2%)
terpinolene (3.5%)
terpinen-4-ol (39.3%)
α-terpineol (3.0%)

The increasing use of tea tree oil has resulted in increase of undesirable side effects of its use such as allergic contact dermatitis and localized skin irritation (de Groot and Wayland 1992, Selvaag et al. 1994). In 1997, Southwell et al. screened a number of tea tree oil constituents for their skin irritancy. In addition to an initial oil screening, other components of the oil screened were α-pinene, β-pinene, α-terpinene, limonene, p-cymene, 1,8-cineole, γ-terpinene, terpinolene, terpinen-4-ol, α-terpineol, a sesquiterpene hydrocarbon fraction of the oil and a sesquiterpene alcohol fraction of the oil. Using 28 panelists for the initial oil-screening test, they found that three had a severe allergic reaction to tea tree oil. One panelist was found to exhibit a positive reaction to the α-terpinene, while all three had a positive reaction to the sesquiterpene hydrocarbon fraction, and only one had a reaction with the sesquiterpene alcohol fraction.

Three years later, Harkenthal et al. (2000) found that an oxidized tee tree oil possessed a sensitivity capacity greater than freshly distilled oil. Analysis of the oil revealed a crystalline oxidation product, which was characterized as p-menthan-1,2,4-triol, a degradation product that had been previously characterized in *M. linariifolia* oil (Jones et al. 1940), which was formed by the oxidation of terpinen-4-ol. Additionally, Harkenthal et al. showed that ascaridole, another oxidation product, was also an imported allergen. Finally, the authors noted that beside p-menthan-1,2,4-triol and ascaridole, α-phellandrene, α-terpinene and terpinolene were also found to be allergens.

In 1998, Zhang and Gu analyzed an oil of *M. alternifolia* produced from leaves harvested from trees growing in the Guangdong Forestry Research Institute arboretum. Using GC/MS as their method of analysis the authors determined that the oil had the following composition:

α-pinene (0.72%)
α-thujene (1.73%)
β-pinene (0.71%)
sabinene (0.55%)
myrcene (0.80%)
α-phellandrene (0.35%)
α-terpinene (9.44%)
limonene (1.74%)
β-phellandrene (1.49%)
1,8-cineole (3.22%)
γ-terpinene (18.82%)
p-cymene (2.91%)
terpinolene (0.23%)
trans-p-menth-2-en-1-ol (0.33%)
aromadendrene (0.25%)
terpinen-4-ol (39.43%)
α-terpineol (2.81%)
α-muurolene (0.56%)
bicyclogermacrene (0.50%)
cis-piperitol (0.11%)
δ-cadinene (1.81%)
nerol (0.55%)
p-cymen-8-ol (0.59%)
calamenene* (0.48%)
palustrol (2.19%)
cubebol (0.07%)
globulol (2.00%)
viridiflorol (1.05%)

*collect isomer not identified

The following year, Cornwell et al. (1999) compared the major components of a methanolic extract of mature leaves of *M. alternifolia* with a steam-distilled oil also produced from mature leaves. A summary of their results can be seen in Table XI.

Also in 1999, Hethelyi et al. examined the composition of five samples of tea tree oil available in Hungary. They found that the oils ranged in composition as follows:

Table XI. Comparative main component composition (%) of a methanolic extract and an oil of *Melaleuca alternifolia*

Compound	Methanolic Extract	Steam-distilled Oil
(+)-sabinene	0.43	trace
(-)-sabinene	0.27	trace
α-terpinene	4.88	8.99
p-cymene	0.80	1.77
γ-terpinene	17.00	19.50
1,8-cineole	4.44	4.73
terpinolene	2.60	3.41
(+)-terpinen-4-ol	30.62	27.43
(-)-terpinen-4-ol	16.49	14.77

α-pinene (2.6-2.8%)
β-pinene (1.4-1.8%)
α-terpinene (12.4-12.9%)
1,8-cineole (3.4-6.6%)
γ-terpinene (19.0-20.8%)
p-cymene (3.4-4.0%)
terpinen-4-ol (40.1-50.0%)
α-terpineol (2.2-3.5%)
aromadendrene (0.5-0.7%)
α-humulene (0.5-0.7%)
ledene (1.6-2.0%)
δ-cadinene (1.4-2.1%)
α-muurolene (0.4-0.7%)
palustrol (0.4-0.5%)
globulol (0.4-0.6%)

A sample of tea tree oil was subjected to analysis by Reichling et al. (1999). Using a combination of GC and GC/MS this German commercial oil sample was found to contain:

α-thujene (1.09%)
α-pinene (2.76%)
sabinene (0.05%)
β-pinene (1.13%)
myrcene (0.62%)
α-phellandrene (0.45%)
α-terpinene (10.33%)
p-cymene (3.36%)
1,8-cineole (3.81%)
γ-terpinene (19.45%)
terpinolene (3.74%)
2-phenethyl alcohol (15.26%)
linalool (3.23%)
terpinen-4-ol (40.78%)
α-terpineol (3.05%)
β-caryophyllene (0.34%)
aromadendrene (1.46%)
allo-aromadendrene (0.45%)
β-bulnesene (0.20%)
viridiflorene (1.55%)

The occurrence of 2-phenethyl alcohol in this oil makes it very suspect. In this reviewer's view, this oil was adulterated.

This same year, Harkenthal et al. (1999) reported that a sample of Australian tea tree oil contained the following constituents:

α-thujene (0.90%)
α-pinene (2.30%)
β-pinene (1.10%)
myrcene (0.77%)
α-phellandrene (0.48%)
α-terpinene (10.50%)
p-cymene (2.00%)
1,8-cineole (2.30%)
limonene (0.88%)
γ-terpinene (21.67%)
terpinolene (3.59%)
terpinen-4-ol (39.30%)
α-terpineol (2.62%)
aromadendrene (0.63%)
viridiflorene (1.10%)
δ-cadinene (1.10%)

The authors also determined that this oil possessed strong antimicrobial properties.

Table XII. Comparative percentage composition of freshly distilled and aged tea tree oil

Compound	Fresh Oil	Aged Oil
α-pinene	2.4	2.8
β-pinene	1.4	1.6
α-terpinene	11.2	5.2
p-cymene	2.0	11.5
1,8-cineole	3.9	3.9
γ-terpinene	21.0	13.7
terpinolene	3.5	2.8
terpinen-4-ol	37.6	35.0
α-terpineol	2.1	3.4
aromadendrene	0.7	0.8
viridiflorene	1.0	1.3
δ-cadinene	1.1	1.2

Hethelyi et al. (2000) repeated their 1999 analysis in a second publication.

Also in 2000, Harkenthal et al. compared the composition of freshly distilled tea tree oil with that of an oil of 2 months old that had been stored at room temperature at the end of the summer in Germany in natural light (on a windowsill). Over this two-month period the authors determined that the peroxide number had increased from 25-500ppm. A summary of this oil composition (shown in Table XII) reveals that the p-cymene content had drastically increased, whereas the contents of α-terpinene, γ-terpinene and terpinolene had decreased.

This same year, Griffin et al. used a couple of batches of tea tree oil supplied by one of the large distillers. They compared their oils with the ISO standard as shown in Table XIII. As can be seen, the standard is fairly wide thereby allowing four seasonal and clonal variations in planting stock from which the oil is obtained.

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M. Harkenthal, J. Reichling, H. K. Geiss and R. Saller, *Comparative study on the in vitro antibacterial activity of Australian tea tree oil, cajuput oil, niaouli oil, manuka oil, kanuka oil and eucalyptus oil*. Pharmazie, *54*, 460-463 (1999).

Table XIII. Percentage composition of some samples of tea tree oil and the ISO standard for it

Compound	Tea Tree Oil	ISO Standard
α-pinene	1.4-2.8	1.0-6.0
sabinene	0.4-0.7	t-3.5
α-terpinene	6.6-8.3	5.0-13.0
p-cymene	3.2-3.9	0.5-12.0
limonene	0.9-1.3	0.5-4.0
1,8-cineole	3.9-4.4	15.0 (max.)
γ-terpinene	16.3-20.0	10.0-28.0
terpinolene	3.0-3.6	1.5-3.0
terpinen-4-ol	37.1-44.4	30.0 (min.)
aromadendrene	1.4-1.5	t-0.7
δ-cadinene	1.3-1.4	t-8.0
globulol	0.4-0.5	t-3.0
viridiflorol	0.2-0.3	t-1.5)

ISO t=trace (<0.5%)

E. Hethelyi, G. Takacs, M. Palfine Ledniczky and J. Domokos, *Gas chromatographic investigation of the biologically active components of Melaleuca species and of natural cosmetic components containing tea tree oil*. Olaj Szappan Kozmet., *49(1),* 25-37 (2000).

Table XV. Comparative percentage composition of *Balsamita major* leaf and flower oils

Compound	Leaf Oil	Flower Oil
α-pinene	0.12-0.25	0.13-0.15
camphene	t-0.14	t-0.10
sabinene	0.41-0.87	0.48-0.66
β-pinene	0.13-0.19	0.12-0.14
myrcene + dehydro-1, 8-cineole	t-0.23	t-0.12
p-cymene	0.18-0.29	0.16-0.21
limonene + 1,8-cineole	2.88-5.42	2.82-3.75
phenylacetaldehyde	t-0.13	0.12-0.13
2-methylbutyl 2-methyl-butyrate	t-0.18	0.37-0.45
α-thujone	10.79-16.10	9.04-10.78
β-thujone	1.09-2.21	1.03-1.06
trans-p-mentha-2,8-dien-1-ol	0.87-2.05	1.25-1.40
cis-p-mentha-2,8-dien-1-ol	0.45-0.92	0.48-0.50
trans-verbenol	t-0.17	t-0.16
pinocarvone	t-0.18	0.22-0.28
cis-dihydrocarvone	0.30-0.78	0.52-0.54
verbenone + *trans*-piperitol	0.48-0.78	0.13-0.19
trans-carveol	t-0.33	0.13
cis-carveol	0.19-0.38	0.20-0.33
carvone	51.83-68.01	59.50-61.67
cis-chrysanthenyl acetate	0.40-0.79	0.50-0.85
trans-carvone oxide	0.20-0.54	0.18-0.20
trans-carvyl acetate	0.11-0.45	0.19-0.30
cis-carvyl acetate	0.15-0.91	0.39-0.43
α-copaene	t-0.39	0.18-0.21
4-epi-cubebol	0.23-1.10	0.51-0.90
β-bisabolene	1.26-4.45	1.01-1.07
cis-calamenene	0.36-1.50	0.73-0.85
δ-cadinene	0.42-1.53	0.85-1.00
1-epi-cubenol	0.11-0.36	0.29-0.32
T-muurolol	0.34-2.19	2.16-3.77
selin-11-en-4α-ol	0.14-0.69	1.03-1.24
methyl isocosate	t-0.43	0.62-1.08
methyl 4-hydroxy-4, 5-dihydroisocosate	0.13-0.43	0.80-1.80

t=trace (<0.1%)

M. Harkenthal, B. M. Hausen and J. Reichling, *1,2,4-trihydroxymenthane, a contact allergen from oxidized tea tree oil.* Pharmazie, 55, 153-154 (2000).

M. Harkenthal, G. Layh-Schmitt and J. Reichling, *Effect of Australian tea tree oil on the viability of the wall-less bacterium Mycoplasma pneumoniae*. Pharmazie, 55, 380-384 (2000).

Balsamite or Costmary Oil

The oil of costmary is obtained from *Balsamita major* (L.) Desf. (syn. *Chrysanthemum balsamita* (L.) Baill. var *balsamita*; *Pyrethrum majus* (Desf.) Tzvelev. Occasionally it can be found as an item of commerce.

In 1979, Wolbis examined the composition of three morphotypes of *Chrysanthemum balsamita* L. Her findings can be found summarized in Table XIV.

Stroebel et al. (1987). analyzed an oil of *B. major* (carvone-type) and found that it contained the following components:

α-pinene
camphene
sabinene
β-pinene
1,8-cineole
limonene
γ-terpinene
linalool
α-thujone
β-thujone
trans-pinocarveol
citronellal
terpinen-4-ol
dihydrocarvone*
cis-carveol
carvone
carvacrol
bornyl acetate
trans-carvyl acetate
cis-carvyl acetate
α-terpinyl acetate
α-copaene
β-caryophyllene
(E)-β-farnesene
β-cubebene
zingiberene
γ-cadinene
cadinol*
T-muurolol

*correct isomer not identified

Although the authors did not present any quantitative data, they did present a chromatogram which showed that the major components other than carvone were limonene, α-thujone, β-cubebene, γ-cadinene and T-muurolol.

The camphor-rich and carvone-rich chemotypes of *B. major* have been analyzed by GC/MS by Hanganu et al. (1995). The components identified in the camphor-chemotype were as follows:

camphene
1,8-cineole
(Z)-β-ocimene
α-thujone
β-thujone
camphor (69.6%)
borneol
menthol
carvone
bornyl acetate
isocaryophyllene
caryophyllene

In contrast, the carvone-rich chemotype was found to contain:

α-pinene
camphene
limonene
1,8-cineole
(Z)-β-ocimene
α-thujone (14.2%)
camphor (11.4%)
menthol
dihydrocarvone*
carvone (31.4%)
farnesol*

*correct isomer not identified

As can be seen, the authors only listed quantitative data for components found in amounts exceeding 10%.

Two years later, Gleizez and Marculescu (1997) also analyzed oils of the two chemotypes of *B. major* produced from plants grown in Romania. Unfortunately, the authors also

did not present any quantitative data. Also, this reviewer has eliminated some of the components purported to have been found based on prior knowledge of naturally occurring constituents. As a result, using GC/MS as their method of identification the camphor-chemotype was determined to contain:

camphene
p-cymene
limonene
1,8-cineole
γ-terpinene
camphor
chrysanthenone
verbenone
isoamyl isovalerate
β-bisabolene
borneol
bornyl acetate
hexadecanal
octadecanal
farnesol*
hexahydrofarnesyl acetone
hexadecanoic acid

*correct isomer not identified

Furthermore, the authors found that the carvone-chemotype contained:

α-pinene
camphene
sabinene
β-pinene
myrcene
p-cymene
limonene
1.8-cineole
γ-terpinene
α-thujone
dihydrocarvone*
chrysanthenol*
pinocarvone
trans-pinocarveol
verbenol*
α-copaene
cyperene
β-caryophyllene
α-humulene
(E)-β-farnesene
zingiberene
γ-cadinene
spathulenol
(E)-nerolidol
T-muurolol
(E,E)-farnesyl acetate
hexahydrofarnesyl acetone

*correct isomer not identified

Recently, Bylaite et al. (2000) compared the composition of the leaf and flower oils of *B. major* grown in Lithuania using GC and GC/MS. The results of these analyses are summarized in Table XV. In addition, the authors also characterized a number of trace constituents (<0.01%), which can be seen listed as follows:

α-thujene
S-methyl pentathioate
benzaldehyde
p-mentha-1,3,8-triene
isoamyl butyrate
2-methylbutyl isobutyrate
α-terpinene
butyl 2-methylbutyrate
3-methyl-2-butenyl 2-methylbutyrate
trans-pinocarveol
cis-verbenol
borneol
p-mentha-1,5-dien-ol
terpinen-4-ol
trans-p-mentha-1(7),8-dien-2-ol
α-terpineol
p-cymen-8-ol
cis-piperitol
methyl chrysanthemate
2-phenethyl acetate
bornyl acetate
α-terpinyl acetate
δ-elemene
(Z)-jasmone
β-caryophyllene
α-muurolene
cubebol
trans-calamenene
cadina-1,4-diene
(E)-nerolidol
spathulenol
caryophyllene oxide
trans-sesquilavandulol
β-eudesmol
trans-sesquilavandulyl acetate
6,10,14-trimethyl-2-pentadecanone
methyl costate

Table XIV. Comparative percentage composition of the oils of three morphotypes of *Chrysanthemum balsamita*

Compound	Type 1	Type 2	Type 3
α-pinene	0.33-0.62	0.29-0.66	0.20-0.61
camphene	3.63-5.93	2.70-5.29	1.88-9.86
1,8-cineole	0.04-0.13	0.09-0.17	0.06-0.19
limonene	0.16-0.23	0.27-0.53	0.10-0.26
p-cymene	0.27-0.57	0.34-0.59	0.05-0.25
α-thujone	0.48-1.56	27.80-45.72	0.70-3.89
β-thujone	0-0.55	3.87-6.77	0-0.64
camphor	81.31-87.87	34.90-47.32	84.98-91.77
bornyl acetate	1.88-3.60	2.96-5.30	1.03-1.65
isoborneol	0.34-0.71	0.62-0.69	0-0.57
borneol	0.87-1.63	0.35-2.45	0.16-0.74
carvone	0.61-1.12	0.68-1.20	0-0.46

Finally, this reviewer (Lawrence) examined a lab-produced oil from plant material grown in North Carolina using GC and GC/MS. The main constituents of this oil were found to be:

α-pinene (0.3%)
camphene (0.2%)
β-pinene (0.3%)
sabinene (0.7%)
myrcene (0.2%)
limonene (3.1%)
1,8-cineole (2.7%)
γ-terpinene (0.2%)
p-cymene (0.3%)
α-thujone (5.9%)
β-thujone (0.7%)
camphor (2.7%)
carvone (60.6%)
β-bisabolene (2.0%)
T-muurolol (1.9%)

M. Wolbis, *Investigation of Chrysanthemum balsamita L. Studies of the volatile oil with consideration of the botanical characteristics of the taxon.* Acta Polon. Pharm. *36*, 707-714 (1979).

A. Strobel, K. Knobloch and E. Ziegler, *Essential oils from Chrysanthemum balsamita L.* Z. Naturforsch. C. Biosci., *42*, 502-506 (1987).

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M. Gleizez and A. Marculesu, *Establishing the chemical composition of the chemical infraspecific taxons of Chrysanthemum balsamita L.* Farmacia (Bucharest), *45(4)*, 53-59 (1997).

E. Bylaite, R. Venskutonis, J. P. Roozen and M. A. Posthumus, *Composition of essential oil of costmary (Balsamita major (L.) Desf.) at different growth phases.* J. Agric Food Chem., *48*, 2409-2414 (2000).

B. M. Lawrence, unpublished information. ■