Progress in Essential Oils

Brian M. Lawrence, Consultant

Culantro Oil

Wild coriander, spiny coriander, South American cilantro or culantro oil is obtained from *Eryngium foetidum* L. It possesses a lot of similarity to cilantro oil obtained from the leaves of *Coriandrum sativum* L.

A survey of the more recent literature revealed that Leclercq et al. (1992) found that an oil of *E. foetidum* produced by steam distillation of the leaves contained:

octanal (0.1%)
p-cymene (0.3%)
nonanal (0.4%)
decanal (0.7%)
undecanal (0.5%)
2,4,6-trimethylbenzaldehyde (1.4%)
decanoic acid (3.5%)
dodecanal (1.0%)
(Z)-2-dodecenal (0.9%)
(E)-2-dodecenal (45.5%)
undecanoic acid (1.5%)
dodecanol (0.5%)
dodecanoic acid (8.6%)
2-dodecenoic acid * (15.5%)
(Z)-2-tetradecenal (0.4%)
(E)-2-tetradecenal (5.3%)

* correct isomer not identified

Trace amounts of α-pinene, β-pinene and α-phellandrene were also found in this oil.

An oil produced from the fresh leaves of *E. foetidum* which was found growing wild on Penang Hill (Malaysia) was analyzed by Wong et al. (1994). This oil was found to contain the following components:

hexanal (0.1%)
1,2,4-trimethylbenzene (0.1%)
2-octanone (0.1%)
(Z)-3-hexenol (0.1%)
nonanal (0.1%)
3,5,5-trimethyl-3-cyclohexen-1-one (0.1%)
decanal (1.7%)
isophorone [a] (0.1%)
safranal (0.1%)
terpinen-4-ol (0.1%)
(E)-2-decenal (0.1%)
phenylacetaldehyde (0.6%)
dodecanal (6.7%)
3,4-dimethylbenzaldehyde (0.4%)
(E)-2-undecenal (0.4%)
2-methylcrotonic acid (1.3%)
(E)-2-dodecenal (59.7%)
2,3,4-trimethylbenzaldehyde (1.8%)
tetradecanal (0.7%)
2-formyl-1,1,5-trimethylcyclohexa-2,4-dien-6-one (0.4%)
2,3,6-trimethylbenzaldehyde (9.6%)
(E)-2-tridecenal (4.6%)
γ-decalactone (0.2%)
2-formyl-1,1,5-trimethylcyclohexa-2,5-dien-4-ol (2.1%)
2-formyl-1,1,5-trimethylcyclohexa-2,4-dien-6-ol (3.5%)

[a] also known as 3,5,5-trimethyl-2-cyclohexen-1-one

Trace amounts (< 0.05%) of heptanal, p-cymene, octanal (E)-2 heptenal, 1,2,3-trimethylbenzene, hexanol, 1-octen-3-ol, (E,E)-2,4-heptadienal, benzaldehyde, 2-octylfuran, (E)-2-nonenal, (E,E)-2,4-dodecadienal and vanillin were also found in this lab distilled oil.

Pino et al. (1997) analyzed an oil of *E. foetidum* produced from plants grown in Cuba. The components characterized in this oil were:

tricyclene (0.2%)
octanal (0.2%)
p-cymene (0.3%)
γ-terpinene (0.2%)
octanol (0.2%)
6-campherenol (0.1%)
nonanal (3.4%)
trans-verbenol (0.2%)
(E)-2-nonenal (0.2%)
nonanol (0.1%)
2-decanone (0.2%)
decanal (0.4%)
2-undecanone (0.9%)
(E,Z)-2,4-decadienal (2.8%)
undecanal (2.5%)
2,4,5-trimethylbenzaldehyde (20.5%)
undecanol (0.5%)
daucene (0.1%)
decanoic acid (0.4%)
dodecanal (4.0%)
β-caryophyllene (0.3%)
trans-α-bergamotene (0.1%)
geranyl acetone (0.4%)
(E)-2-dodecenal (5.7%)
tridecanal (1.1%)
dodecanol (0.1%)
ar-curcumene (0.2%)
endo-1-bourbonanol (0.1%)
(E)-2-tridecenal (0.3%)
(Z)-nerolidol (0.3%)
carotol (9.9%)
tetradecanal (0.2%)
(E)-2-tetradecenal (0.7%)
(E)-γ-atlantone (0.1%)
(Z)-α-atlantone (1.3%)
(E)-2-pentadecenal (0.2%)
pentadecanol (0.2%)
(E)-α-atlantone (1.0%)
tetradecanoic acid (0.4%)
2-hexadecanone (0.4%)
hexadecanol (0.2%)
hexadecanoic acid (12.1%)
methyl (2,Z)-9,12-hexadecenoate (4.7%)

Trace amounts (< 0.05%) of cumene and limonene were also characterized in this oil.

Oils produced in the laboratory from *E. foetidum* plants that were col-

lected from two sites in Sao Tomé and Principe (Portuguese territory) were analyzed by Martins et al. (2003). The results of this comparative study can be seen in **T-1**.

Cardozo et al. (2004) produced an oil from the leaves of *E. foetidum* collected from the Botanic Garden in Merida (Venezuela). Analysis of this oil using both GC-FID and GC/MS revealed that it contained the following components:

α-pinene (2.4%)
myrcene (0.3%)
mesitylene [a] (0.2%)
p-cymene (0.9%)
limonene (0.3%)
1,8-cineole (0.6%)
γ-terpinene (3.8%)
linalool (0.3%)
camphor (0.7%)
terpinen-4-ol (0.2%)
α-terpineol (0.1%)
methyl chavicol (0.3%)
decanal (1.4%)
pulegone (0.1%)
(E)-anethole (0.6%)
2-octylfuran (0.1%)
2,4,6-trimethylbenzaldehyde (1.9%)
2,4,5-trimethylbenzaldehyde (27.7%)
dodecanal (7.3%)
β-caryophyllene (0.5%)
(E)-2-dodecenal (27.5%)
tridecanal (1.2%)
dodecanol (2.3%)
carotol (8.8%)
tetradecanal (0.7%)
3-dodecenal * (5.2%)

* correct isomer not identified
[a] also known as 1,3,5-trimethylbenzene

Eyres et al. (2005) produced an oil of *E. foetidum* from plants grown in Fiji. Using a combination of GC-olfactometry, two dimensional GC coupled with time-of-flight mass spectrometry (GCxGC-TOFMS), the authors identified the following oil constituents:

nonane (0.1%)
undecane (0.3%)
α-pinene (0.2%)
sabinene (0.1%)
β-pinene (0.1%)
myrcene (0.1%)
1,2,3-trimethylbenzene (0.3%)
p-cymene (0.5%)
1-methyl-2-ethylbenzene (0.1%)
limonene (0.1%)
γ-terpinene (0.1%)
1-undecene (0.1%)
1,8-cineole (0.3%)
trans-linalool oxide [f] (0.1%)
α-pinene oxide (0.2%)
cis-limonene oxide (0.1%)
trans-limonene oxide (0.1%)
caryophyllene oxide (1.1%)
hexanol (0.1%)
dodecanol (0.7%)
(Z)-3-hexenol (0.1%)
(E)-2-dodecenol (0.8%)
carotol (0.1%)
6-campherenone (0.1%)
nonanal (0.2%)
decanal (1.3%)
undecanal (0.1%)
dodecanal (7.8%)
tetradecanal (0.4%)
(E)-2-hexenal (0.1%)
(E)-2-undecenal (0.1%)
(E)-2-dodecenal (63.5%)
(E)-2-tridecenal (0.2%)
(E)-2-tetradecenal (14.1%)
(Z)-2-dodecenal (1.3%)
(Z)-2-tetradecenal (0.1%)
(Z)-4-dodecenal (0.4%)
(Z)-4-tetradecenal (0.1%)
2,4,6-trimethylbenzaldehyde (0.1%)
2,4,5-trimethylbenzaldehyde (2.4%)
(E,E)-2-4-dodecadienal (0.1%)

[f] furanoid form

Comparative percentage composition of two *Eryngium foetidum* oils from Sao Tomé and Principe **T-1**

Compound	Oil 1	Oil 2
α-pinene	3.1	0.2
β-pinene	0.2	-
myrcene	1.0	0.3
p-cymene	2.4	0.4
limonene	0.3	0.1
γ-terpinene	3.4	0.9
nonanal	0.4	0.1
trans-verbenol	0.6	0.3
myrtenal	0.3	-
decanal	1.3	2.4
(E, Z)-2,4-decadienal	0.9	0.4
2,3,4-trimethylbenzaldehyde	2.2	0.3
2,3,6-trimethylbenzaldehyde	23.7	5.5
α-copaene	0.5	0.3
dodecanal	4.1	9.8
β-caryophyllene	0.5	0.4
(E)-2-dodecenal	15.9	37.5
dodecanol	0.9	0.7
ar-cucumene	0.5	0.1
γ-muurolene	0.3	0.3
β-himachalene	0.2	-
tetradecanal	1.7	2.8
(E)-2-tetradecenal	18.7	25.3
14-hydroxy-α-muurolene	2.4	0.3

In addition, trace amounts (< 0.05%) of tridecane, α-copaene, *trans*-α-bergamotene, germacrene A, *cis*-linalool oxide-furanoid, (E)-2-tetradecenol, 1-octen-3-ol, linalool, (E)-nerolidol, eugenol, 2-undecanone, β-ionone isomer, (E)-2-decenal and (E)-2-hexadecenal were also found in this oil. Furthermore, the authors found that (E)-2-dodecenal, which was the most abundant component, contributed the greatest odor activity. Other important contributors to the aroma of the oil were eugenol, a trimethylbenzaldehyde isomer, β-ionone, (Z)-4-dodecenal, dodecanal and (E)-2-tetradecenal.

An oil produced from *E. foetidum* grown in an experimental garden in Lucknow (U.P., India) was determined by Bagchi et al. (2005) to contain the following major components:

α-pinene (< 0.1%)
linalool (0.8%)
decanal (3.0%)
undecanal (0.7%)
1.3.5-trimethylbenzaldehyde (10.8%)
dodecanal (9.3%)
(E)-2-dodecenal (45.9%)
(E)-2-tridecenal (7.9%)

An oil produced from the leaves of *E. foetidum* that were collected in the vicinity of Mahendranagar (western Nepal) were analyzed by GC and GC/MS (Thakuri et al., 2006). The constituents characterized in this oil were:

α-pinene (0.5%)
myrcene (0.5%)
2,3,5-trimethylbenzene (0.1%)
γ-terpinene (0.8%)
cis-sabinene hydrate (0.1%)
nonanal (0.2%)
trans-vetrocitral ‡ (0.3%)
α-thujone ‡ (0.6%)
geijerene ‡ (0.7%)
menthofuran ‡ (0.1%)
(E)-4-decenal (2.3%)
p-cymen-8-ol (0.1%)
neothujyl alcohol ‡ (0.3%)
carvacrol (0.2%)
2,3,4-trimethylbenzaldehyde (1.3%)
2,3,6-trimethylbenzaldehyde (7.4%)
α-terpinyl acetate(0.1%)
β-elemene (0.2%)
β-longipinene ‡ (0.6%)
dodecanal (10.7%)
α-humulene (0.5%)
(E)-2-dodecenal (58.1%)
ar-curcumene (0.3%)
δ-cadinene (0.1%)
germacrene B (0.9%)
germacrene D-4-ol (1.3%)
carotol (0.7%)
humulene epoxide II (0.6%)
10-epi-γ-eudesmol ‡ (0.9%)
(E)-2-tridecenal (6.7%)
(E,E)-farnesol (0.2%)
α-bisabolol oxide A ‡ (0.2%)

‡ mistaken identifications

Trace amounts (< 0.05%) of limonene, linalool, isoborneol, carvacryl acetate and caryophyllene oxide were also identified in this oil.

Rana (2008) analyzed an oil produced from fresh leaves of *E. foetidum* purchased at a market in Imphal (Manipur, N.E. India). The composition of this oil was determined to be as follows:

octane (0.1%)
ethyl acetate † (0.1%)
3-hexenol ° (0.1%)
myrcene (0.1%)
1,3,5-trimethylbenzene (0.1%)
6-camphenone (0.1%)
undecane (0.1%)
nonanal (0.3%)
trans-verbenol (0.1%)
decenal [a] (1.7%)
hydroquinone ‡ (0.4%)
cyclohexanone ‡ (0.1%)
undecanol (0.4%)
2,3,4-trimethylbenazldehyde (0.8%)
2,3,6-trimethylbenzaldehyde (16.6%)
undecenol [a] (0.2%)
dodecenal [a] (8.9%)
β-caryophyllene (0.2%)
(E)-β-farnesene (0.1%)
(E)-2-dodecenal (38.9%)
(E)-2-dodecenol (1.6%)
2,4-bis-(1,1-dimethylethyl)-phenol † (0.5%)
2,4-dodecadienal ° (0.1%)
caryophyllene oxide (0.7%)
carotol (0.3%)
tetradecanal (1.2%)
3-dodecenal ° (1.1%)
dodecyl acrylate ‡ (1.9%)
decyl acetate ‡ (0.2%)
neophytadiene (0.3%)
phytol (0.1%)

° correct isomer not identified
† contaminant
‡ incorrect identification based on GC elution order
[a] (E)-2-isomer

Oils produced from *E. foetidum* leaves obtained in Can Tho City

(Southern Vietnam) by water distillation were analyzed by Thi et al. (2008) using only GC/MS. They were found to possess the following composition:

decanal (0.9–1.3%)
safrole [a] (0–0.5%)
undecanal (0–0.2%)
1,3,5-trimethylbenzaldeyhde (0–0.2%)
duraldehyde [b] (3.1–5.8%)
dodecanal (7.0–11.5%)
(Z)-2-dodecenal (1.0–1.4%)
(E)-2-dodecenal (57.8–67.1%)
cyclododecane [†] (4.1–7.2%)
dodecanoic acid (2.3–3.9%)
tetradecanal (0–1.3%)
(E)-2-dodecenoic acid (1.8–3.4%)
2-tetradecenal [°] (9.0%)

[a] probably a mistyping of safranal
[b] decanal
[°] correct isomer not identified
[†] incorrect identification based on GC elution order

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Vietnamese Coriander Leaf Oil

Although no oil is being produced commercially from Vietnamese coriander leaf (cilantro) *Persicaria odorata* (Lour.) Sojak (syn. *Polygonum odoratum* Lour.), it is of interest to note the similarities and differences between its volatiles with those of the leaf or herb oil of *Coriandrum sativum.*

Kuebel and Tucker (1988) reported that the so-called Vietnamese coriander leaf is readily available in the United States. Dung et al. (1995) isolated an oil of *P. odorata* from plants collected in the Tinh Gia area of Thanh Hoa province and the Sapa area of Lao Cai province (Vietnam) using steam distillation. Analysis of the oil by GC and GC/MS revealed that it possessed the following composition:

nonane (< 0.1%)
myrcene (0.7%)
undecane (1.3%)
nonanol (0.1%)
decanal (4.9%)
decanol (1.7%)
undecanal (0.3%)
undecanol (0.2%)
α-copaene (0.3%)
β-elemene (1.4%)
dodecanal (11.4%)

decyl acetate (1.3%)
isocaryophyllene (0.2%)
β-caryophyllene (36.5%)
cis-α-bergamotene (0.9%)
α-humulene (3.9%)
dodecanol (0.6%)
(Z,E)-α-farnesene (0.9%)
α-selinene (0.6%)
(E,E)-α-farnesene (1.7%)
δ-cadinene (0.4%)
(Z)-nerolidol (0.6%)
caryophyllene oxide (8.2%)
dodecyl acetate (2.8%)
α-muurolol (1.7%)
juniper camphor [a] (1.4%)
11-drimen-7-ol (3.0%)
(E)-phytol (0.9%)

[a] also known as selin-7(11)-en-4-ol

An oil produced from *P. odorata* plants cultivated in Myrtleford (NSW, Australia) was the subject of analysis by Hunter et al. (1997). The components characterized in this oil were as follows:

undecane (1.1%)
(E)-β-ocimene (0.1%)
6-methyl-5-hepten-2-one (0.1%)
3-hexenol [°] (0.3%)
6-methyl-5-hepten-2-ol (0.2%)
decanal (27.7%)
β-caryophyllene (3.8%)
undecanal (0.1%)
α-humulene (1.5%)
dodecanal (44.1%)
decanol (10.9%)
undecanol (0.3%)
tetradecanal (0.4%)
dodecanol (2.6%)
caryophyllene oxide (0.2%)

[°] correct isomer not identified

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

Starkenmann et al. (2006) determined that the green, citrus, orange peel, coriander leaf-like odors of *P. odorata* plants were caused by (Z)-3-hexenal, (Z)-3-hexenol, decanal, undecanal and dodecenal. They also isolated and identified 3-sulfanylhexanal and 3-sulfanylhexanol for the first time in the plant. Although no quantitative data were presented, the author also identified hexanal, (E)-2-hexenal, hexanol, (E,E)-2-4-heptadienal, 6-methyl-5-hepten-2-ol, benzyl alcohol, 2-phenethanol, eugenol, decanol, undecanol, dodecanol, β-caryophyllene and α-humulene as volatiles of *P. odorata*.

Percentage composition of the oils produced from the different coriander plant parts **T-2**

Compound	ULO	BLO	FO	SO	RO
heptanal	0.1	0.7	0.1	0.2	0.4
α-thujene	t	t	t	0.2	t
α-pinene	t	0.2	-	0.1	0.1
sabinene	0.1	0.8	t	0.1	0.5
β-pinene	t	0.2	t	4.3	0.1
decanal	0.1	0.7	t	0.1	0.4
α-phellandrene	0.5	t	t	0.3	t
α-terpinene	t	t	0.4	0.2	t
p-cymene	t	0.2	t	0.3	0.1
(E)-2-decenal	1.0	t	0.8	-	t
γ-terpinene	1.2	t	2.4	0.1	0.3
cis-linlool oxide [f]	t	t	-	-	0.4
linalool	0.1	t	t	-	t
geijerene	-	t	-	t	0.1
(Z)-myroxide	5.3	3.0	7.5	8.4	1.5
camphor	t	0.4	1.4	0.2	1.6
(E)-2-undecenal	0.1	0.5	t	0.1	0.3
borneol	0.2	1.7	0.2	1.2	1.0
terpinen-4-ol	t	t	0.1	t	t
α-terpineol	0.1	0.9	t	-	0.6
methyl chavicol	-	t	-	0.8	-
terpinolene [†]	0.5	-	0.4	-	t
dodecanal	t	-	0.2	t	t
nerol	t	t	0.1	-	-
citronellol	t	t	0.1	-	t
β-caryophyllene [†]	0.1	-	t	-	t
geraniol	0.2	-	0.1	0.2	-
(E)-2-dodecenal	49.2	29.4	43.9	51.5	18.1
(E)-anethole	0.1	t	0.2	-	t
tridecanal	2.2	-	2.0	1.4	t
geranial	1.4	0.8	0.8	0.4	0.4

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Cilantro, or Coriander Herb, Oil

Because of Central and South American influence in food products in the United States, the use of cilantro has increased substantially over the past 20 years. In addition, the use of cilantro oil (leaf or herb oil of *Coriandrum sativum* L.) in processed food products has also seen a rapid increase.

Eyres et al. (2005) used a combination of comprehensive two-dimensional gas chromatography coupled with time-of-flight mass spectrometry to analyze an oil produced from coriander leaves cultivated in Fiji. The components characterized in this oil were:

nonane (1.5%)
decane (0.1%)

Percentage composition of the oils produced from the different coriander plant parts **T-2 (Contd.)**

Compound	ULO	BLO	FO	SO	RO
p-cymen-7-ol [a]	0.3	-	0.2	t	2.2
thymol	t	-	t	0.2	-
geranyl formate	0.6	0.3	0.8	1.6	0.4
(E,E)-2,4-decadienal	0.7	1.9	0.6	0.6	1.1
δ-cadinene	-	t	-	t	0.1
(E)-2-undecenol	0.4	t	t	-	t
eugenol	2.9	0.8	3.2	2.1	0.9
(E)-2-tridecenal	12.0	5.1	12.1	10.3	5.4
neryl acetate	3.9	1.3	2.5	3.5	1.1
methyl eugenol	-	t	-	t	0.2
β-caryophyllene	t	0.2	-	0.2	0.2
α-humulene	0.1	t	0.1	0.2	t
germacrene D	0.1	0.3	t	0.2	0.3
2-tridecanone	0.2	t	-	t	t
bicyclogermacrene	0.1	0.5	0.1	0.4	0.3
γ-cadinene	6.2	4.2	7.7	4.9	5.9
sesquicineole	0.7	-	0.9	0.3	t
cadina-1,4-diene	0.4	0.4	0.5	1.5	0.8
(Z)-3-butylidene phthalide	0.1	0.2	0.5	t	t
globulol	0.1	0.6	0.1	0.4	0.4
T-cadinol	0.1	0.4	0.1	0.2	0.2
(E)-2-tetradecenal	0.3	1.1	0.2	1.2	0.6

ULO = upper leaves oil
BLO = basal leaves oil
FO = flower oil
SO = stem oil
RO = root oil
[†] incorrect identification based on GC elution order
t = trace (< 0.1%)
[*] correct isomer not identified
[a] also known as cumin alcohol
[f] furanoid form

undecane (0.1%)
α-thujene (0.1%)
α-pinene (0.1%)
sabinene (0.3%)
β-pinene (0.2%)
myrcene (0.1%)
p-cymene (0.7%)
limonene (0.1%)
γ-terpinene (0.3%)
1,8-cineole (1.1%)
hexanol (0.1%)
nonanol (0.1%)
decanol (19.6%)
undecanol (0.3%)
dodecanol (0.2%)
(E)-2-hexenol (0.6%)
(E)-2-decenol (26.0%)
(E)-2-undecenol (2.0%)
(E)-2-dodecenol (4.6%)
(E)-2-tridecenol (0.1%)
(E)-2-tetradecenol (0.9%)
(Z)-3-hexenol (1.0%)
linalool (0.2%)
terpinen-4-ol (0.1%)
cyclodecanol (0.1%)
octanal (0.8%)
nonanal (0.2%)
decanal (6.6%)
undecanal (1.0%)
dodecanal (3.0%)
tridecanal (0.3%)
tetradecanal (1.0%)
pentadecanal (0.1%)
hexadecanal (0.1%)
(E)-2-hexenal (0.3%)
(E)-2-decenal (9.1%)
(E)-2-undecenal (1.2%)
(E)-2-dodecenal (5.4%)
(E)-2-tridecenal (0.4%)
(E)-2-tetradecenal (7.0%)
(E)-2-pentadecenal (0.7%)
(E)-2-hexadecenal (0.4%)

(Z)-2-decenal (0.2%)
(Z)-2-dodecenal (0.1%)
(Z)-2-tetradecenal (0.1%)
(Z)-4-decenal (0.2%)
(Z)-4-dodecenal (0.1%)
(Z)-4-tetradecenal (0.1%)
(Z)-3-hexenyl acetate (0.1%)

Trace amounts (< 0.05%) of tridecane, δ-3-carene, terpinolene, 1-undecene, 1-tridecene, pentylbenzene, α-amorphene, 2-pentylfuran, 2-hexylfuran, *cis*- and *trans*-linalool oxide (furanoid), (E)-2-caren-4-ol, α-terpineol, 2-nonanone, camphor, 2-tridecanone, β-ionone isomer, (E)-2-nonenol, (E)-3-hexenol, (Z)-2-hexenol, 1-octen-3-ol, eugenol, heptanal, (E)-2-nonenal, (Z)-2-undecanal, (Z)-4-undecenal, tridecenal isomer, phenylacetaldehyde, 1-octen-3-yl acetate, 3-octyl acetate and decyl acetate were also found in this oil.

Using GC-O the authors further determined that the odor-impact components of cilantro oil were (Z)-2-decenal, (E)-2-dodecenal, (E)-2-dodecenal, β-ionone, eugenol and (E)-2-decenal. Although (E)-2-decenol was the most abundant component of the cilantro oil analyzed, it did not contribute much to the overall aroma of the oil.

Pérez et al. (2007) characterized the volatile components of an aquaeous extract of coriander plants (*Coriandrum sativum* L.) using a PDMS-DVB fibre combined with GC/MS. The components characterized were as follows:

benzaldehyde (0.13) [a]
cis-linalool oxide [f] (0.39)
trans-linalool oxide [f] (0.34)
linalool (0.65)
camphor (0.56)
borneol (0.61)
terpinen-4-ol (0.18)
4-isopropenyl toluene [†] (0.18)
α-terpineol (0.99)
neral (0.57)
geraniol (1.30)
geranial (0.92)

[f] furanoid form
[a] µg/g
[†] incorrect identification based on GC elution order

Coriander plants grown in the vicinity of Korba (northeastern Tunisia) were harvested and the whole plants were separated into 100 gram quantities of upper leaves, basal leaves, flowers, stems and roots. Oils produced from each of these plant parts were analyzed by Msaada et al. (2007) using GC-FID and GC/MS. A summary of their results can be seen in **T-2.**

In addition, trace amounts (< 0.1%) of δ-3-carene, limonene, 1,8-cineole (E)-β-ocimene, umbelulone, p-cymen-8-ol, *cis*-dihydrocarvone, (E)-β-farnesene, β-selinene and eugenyl acetate were found in one or more of the oils.

The compositions of the free and glycosidically bound volatiles of cilantro (coriander herb) were compared with a water-distilled oil from the same batch of coriander herb obtained from a local market in Trivandrum (Kerala, India). Using

Comparative percentage composition of the free and bound volatiles of coriander herb **T-3**

Compound	Free volatiles	Bound volatiles
3-butenol	-	0.33
butanol	-	0.10
2-pentanol	-	0.91
isoamyl alcohol	-	0.10
amyl alcohol	0.27	0.46
4-methyl-2-pentanol	-	1.97
2-hexanol	-	0.49
3-methyl-2-pentanol	0.14	-
furfural	0.07	-
(E)-2-hexenol	-	0.03
hexanol	0.02	-
(Z)-3-hexenol	12.84	-
4-heptanol	-	0.12
ethyl disulphide [†]	0.46	-
α-pinene	0.09	-
camphene	0.01	-
3,5,5-trimethylhexanal	0.02	-
heptanol	-	2.30
sabinene	0.89	-
octanal	-	0.17
p-menth-2-en-1-ol [*]	0.02	-
decane	0.02	-
phenylacetaldehyde	0.03	0.05
(E)-3-octenal	0.06	-
γ-terpinene	5.92	-
octanol	11.45	0.22
1-nonen-3-ol	2.27	-
1,4-diethylbenzene	0.02	-
cis-rose oxide	-	0.10
tetrahydrolinalool [‡]	-	5.72
1,2-diethylbenzene	4.69	-
linalool	6.25	74.50
2-butene-1,4-diol	2.56	-
2-phenethyl alcohol	0.77	0.29
2-ethylphenol	1.49	-
2-methyloctanol	2.31	-
cyclooctanol [‡]	1.84	-
β-terpineol [*]	2.97	-
(E)-2-nonenal	3.61	-
lavandulol	2.80	-
nonanol	1.57	-

Comparative percentage composition of the free and bound volatiles of coriander herb **T-3 (Contd.)**

Compound	Free volatiles	Bound volatiles
borneol	2.16	-
(E,E)-2,4-decadienal	2.31	-
5-decanol	1.78	-
terpinen-4-ol	-	0.16
(Z)-4-decenal	0.32	-
α-terpineol	-	0.23
decanal	1.77	-
2-decanol	9.57	-
1,3,5-triethylbenzene	0.17	-
nerol	0.62	-
neral	0.05	-
8-methyl-2-nonenal *	0.02	-
geraniol	-	0.11
(E)-2-decenal	0.02	-
(E)-decenol	3.76	-
decanol	-	0.14
undecenal	0.15	-
(E)-2-undecenal	0.01	-
(E)-2-undecenol	0.02	-
undecanol	-	0.40
10-methyl-2-undecenal *	0.42	-
(E)-2-dodecenal	0.34	-
(E)-2-dodecenol	1.32	-
dodecanol	-	1.02
12-tridecenal ◊	0.23	-
tridecanal	0.22	-
nerolidol	0.03	0.46
11-methyl-2-dodecenal *	0.04	-
(E)-2-tridecenal	0.01	-
tridecanol	0.19	-
13-tetradecenal ◊	0.15	-
tetradecanal	0.14	-
12-methyl-2-tridecenal *	0.12	-
(E)-2-tetradecenal	0.05	-
(E)-2-tetradecenol	0.37	-
pentadecanal	0.07	-
hexadecanal	0.02	-

* correct isomer not identified
† probable contaminant
‡ does not exist naturally
◊ incorrect nomenclature

a combination of GC-FID and GC/MS and retention indices on the two GC columns of differing polarity, Padmakumari (2008) characterized more than 90 constituents. A summary of his findings on the free and bound volatiles can be seen in **T-3.** For comparison purposes, the oil was found to possess the following composition:

(E)-2-methyl-2-butenal (9.48%)
3-methyl-2-butenal (0.11%)
hexanal (0.04%)
furfural (0.06%)
(Z)-3-hexenol (0.69%)
nonane (0.14%)
ethyl disulphide † (0.22%)
octanal (0.29%)
(E,E)-2,4-heptadienal (0.15%)
phenylacetaldehyde (0.03%)
hexylfuran (0.03%)
nonanal (0.30%)
linalool (0.22%)
(Z)-4-decenal (0.03%)
1-decen-3-ol (0.05%)
decanal (8.01%)
(E)-2-decenal (2.04%)
(E)-2-decenol (23.60%)
decanol (7.74%)
undecanal (0.96%)
(Z)-2-decenol (0.03%)
9-methyl-2-decenal ° (0.01%)
(E)-2-undecenal (0.20%)
(E)-2-undecenol (0.15%)
undecanol (2.11%)
4-dodecenal ° (0.16%)
dodecanal (6.14%)
10-methyl-2-undecenal (0.02%)
(E)-2-dodecenal (2.83%)
(E)-2-dodecenol (10.56%)
12-tridecenal (0.03%)
tridecanal (0.51%)
11-methyl-2-dodecenal ° (0.02%)
(E)-2-tridecenal (0.25%)
(E)-2-tridecenol (0.12%)
tridecanol (0.75%)
13-tetradecenal Δ (0.06%)
tetradecanal (2.66%)
(E)-2-tetradecenal (4.82%)
(E)-2-tetradecenol (6.27%)
2,4-hexadecadienal ° (0.11%)
pentadecanal (0.10%)
(E)-2-pentadecenal (0.21%)
pentadecanol (0.26%)
hexadecanal (0.09%)

° correct isomer not identified
† probable contaminant
Δ incorrect nomenclature, probably is (Z)-2-tetradecenal

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