



Progress in Essential Oils

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Turmeric Leaf Oil

Although both turmeric rhizome oil and oleoresin have been items of commerce for many years, more recently Indian turmeric leaf oil has also become an item of commerce. According to Chempakam and Parthasarathy (2008), the area under turmeric cultivation is more than 150,000 hectares. Also, like many spice plants, numerous cultivars of turmeric have both been selected and developed.

Fresh leaves of *C. longa* were collected from Ile-Ife (Nigeria), cut into small pieces and hydrodistilled for 3 hr to yield a 0.5% oil. Analysis of this oil by GC/MS, ¹H-NMR and ¹³C-NMR revealed that the main constituents were as follows:

- α-pinene (2.2%)
- β-pinene + myrcene (6.3%)
- α-phellandrene (47.7%)
- δ-3-carene (1.2%)
- α-terpinene (1.8%)
- p-cymene (1.2%)
- limonene + 1,8-cineole (6.0%)
- γ-terpinene (2.0%)
- terpinolene (28.9%)
- β-sesquiphellandrene (0.8%)
- α-terpineol (< 0.2%)
- terpinen-4-ol (< 0.2%)
- sabinol* (< 0.2%)

* correct isomer not identified

Dried leaves of *C. longa* grown in Vietnam were steam distilled to produce an oil in 2.5% yield by Dung et al (1995). Using GC-FID and GC/MS as their method of analysis, the oil was found to possess the following composition:

- α-thujene (0.2%)
- α-pinene (3.5%)
- sabinene (0.2%)
- β-pinene (8.9%)
- myrcene (3.0%)
- α-phellandrene (24.5%)
- δ-3-carene (1.1%)

- p-cymene (13.2%)
- 1,8-cineole (15.9%)
- limonene (1.4%)
- (E)-β-ocimene (0.7%)
- γ-terpinene (1.3%)
- terpinolene (5.5%)
- linalool (0.7%)
- p-cymen-8-ol (1.2%)
- α-terpineol (0.8%)
- cis-sabinol (1.0%)
- 5-hydroxy-p-menth-6-en-2-one (0.6%)

Trace amounts (<0.1%) of camphene, α-terpinene, (Z)-β-ocimene and myrtenol were also characterized in this Vietnamese turmeric leaf oil.

The fresh leaves of mature turmeric plants cultivated in Bhutan were hydro-distilled to produce oils in 0.37–0.42% yield by Sharma et al. (1997). The oil, which was analyzed by GC-FID and GC/MS, was determined to contain the following constituents:

- α-thujene (0.1%)
- α-pinene (2.6%)
- sabinene (0.4%)
- β-pinene (7.2%)
- myrcene (1.8%)
- α-phellandrene (18.2%)
- δ-3-carene (0.9%)
- α-terpinene (0.4%)
- p-cymene (13.3%)
- 1,8-cineole (14.6%)
- limonene (3.3%)
- (Z)-β-ocimene (0.1%)
- (E)-β-ocimene (0.3%)
- γ-terpinene (1.0%)
- β-cymenene (0.1%)
- terpinolene (11.6%)
- linalool (1.2%)
- borneol (0.3%)
- p-cymen-8-ol (2.4%)
- terpinen-4-ol (0.8%)
- myrtenol (0.1%)
- α-terpineol (0.9%)
- cis-sabinol (1.0%)
- (E)-cinnamaldehyde (0.4%)
- thymol (0.2%)
- carvacrol (0.1%)

- 5-hydroxy-p-menth-6-en-2-one (0.6%)
- 6-hydroxy-p-menth-1-en-3-one (0.6%)
- β-caryophyllene (0.5%)
- α-humulene (0.2%)
- (E)-β-farnesene (0.2%)
- ar-curcumene (0.2%)
- zingiberene (0.5%)
- β-bisabolene (0.2%)
- β-sesquiphellandrene (0.4%)
- elemicin (0.1%)
- (E)-nerolidol (0.3%)
- caryophyllene oxide (0.4%)
- ar-turmerone (0.1%)
- α-turmerone (0.3%)
- germacrone (0.2%)
- curdione (0.5%)

Trace amounts (<0.1%) of toluene, camphene, camphor, myrtenol, cis-carvotanacetol, piperitone and β-turmerone were also characterized in this turmeric leaf oil of Bhutanese origin.

Rath et al. (2001) determined that turmeric leaf oil contained:

- α-pinene (2.6%)
- sabinene (0.3%)
- β-pinene (2.4%)
- myrcene (2.8%)
- α-phellandrene (47.1%)
- limonene + 1,8-cineole (11.2%)
- p-cymene (11.4%)
- γ-terpinene (2.0%)
- terpinolene (9.1%)
- borneol (0.3%)

In a follow-up report, Rath et al. (2002) repeated the above results and added α-terpineol (0.1%), piperitone (1.4%), thymol (0.6%), carvacrol (0.5%) and ar-curcumene (1.2%) as additional constituents of the leaf oil.

Garg et al. (2002) collected fresh aerial parts of one-year-old *C. longa* plants grown in Pantnagar (Uttarakhand, India) and subjected them to hydro-distillation for 4 hr to produce a pale yellow oil in a 2.8% yield. Analysis of the oil using GC-FID and GC/MS

revealed that it possessed the following composition:

α -thujene (4.5%)
 α -pinene (6.3%)
 α -terpinene (0.8%)
p-cymene (25.4%)
1,8-cineole (18.1%)
linalool (2.1%)
borneol (0.3%)
p-cymen-8-ol (0.5%)
terpinen-4-ol (0.7%)
myrtenal (0.6%)
cis-sabinol (7.4%)
 β -caryophyllene (0.9%)
 α -humulene (0.4%)
ar-curcumene (0.3%)
zingiberene (0.2%)
 β -bisabolene (0.5%)
 β -sesquiphellandrene (1.0%)
ar-turmerone (0.3%)
 α -turmerone (1.3%)
 β -turmerone (0.5%)

octane (0.6%)
 α -pinene (1.0%)
sabinene (0.1%)
 β -pinene (1.1%)
myrcene (1.7%)
 α -phellandrene (8.0%)
 δ -3-carene (0.8%)
 α -terpinene (0.8%)
p-cymene (2.1%)
1,8-cineole (9.5%)
(Z)- β -ocimene (0.1%)
(E)- β -ocimene (0.4%)
 γ -terpinene (0.4%)
cis-linalool oxide^f (0.1%)
trans-linalool oxide^f (0.2%)
terpinolene (26.4%)
linalool (1.2%)
2-nonanol (0.2%)
 α -fenchyl alcohol (0.2%)
trans-p-menth-2-en-1-ol (0.1%)
p-methylacetophenone (0.1%)
camphor (1.3%)
camphene hydrate (0.1%)
isoborneol (0.2%)

borneol (1.1%)
terpinen-4-ol (7.4%)
myrtenal (0.1%)
 α -terpineol (0.3%)
cis-sabinol (0.2%)
myrtenol (0.3%)
cis-carvotanacetol (0.5%)
cis-carveol (0.3%)
carvone (2.2%)
perilla ketone (2.1%)
geraniol (2.4%)
linalyl acetate (0.5%)
geranial (0.4%)
safrole (2.8%)
isobornyl acetate (0.2%)
undecanone^o (0.1%)
geranyl formate (0.3%)
thymol (0.7%)
carvacrol (0.1%)
sabinyl acetate^{*} (3.2%)
undecanol (0.2%)
linalyl propionate (1.1%)
cis-carvyl acetate (1.1%)
 δ -elemene (0.3%)

Leela et al. (2002) determined that the yield of oil from the leaves and flowers of *C. longa* grown in Kerala was 1.3% and 0.3%, respectively. The authors determined the composition of these two oils using GC-FID and GC/MS, the results of which are shown in **T-1**. In addition, trace amounts (<0.1%) of β -phellandrene, γ -curcumene and curcaphenol were also characterized one or both oils.

Chane-Ming et al. (2002) produced leaf and flower oils of *C. longa* that was grown in Plaine de Gregues (Reunion, France) in amounts of 0.5% and 0.15%, respectively. The results of the analysis of these two oils by a combination of chromatographic and spectroscopic techniques can be seen in **T-2**.

The turmeric 'Roma' cultivar that was grown in the Indo-Gangetic plains of India at a rate of 26,000 plants per hectare was harvested at 16 months. The leaves and flowers were separated into inflorescence, leaf laminas, leaf petioles and stems, as compared to the entire shoot. Oils produced separately by hydrodistillation from the various aerial plant parts were the inflorescence (0.12%), leaf laminas (0.70%), leaf petioles (0.05%) and stems (0.12%). Analysis of these oils using GC/MS only by Bansal et al. (2002) can be seen in **T-3**.

Raina et al. (2002) analyzed the leaf oil of the 'Roma' cultivar of turmeric which is widely grown in India. Using GC-FID and GC/MS the leaf oil was found to contain:

T-1. Comparative percentage composition of the leaf and flower oils of *Curcuma longa*

Compound	Leaf oil	Flower oil
α -pinene	2.1	0.4
β -pinene	2.8	0.1
myrcene	2.3	0.2
α -phellandrene	32.6	—
δ -3-carene	1.1	0.6
α -terpinene	1.3	0.1
p-cymene	5.9	1.6
β -phellandrene	3.2	t
1,8-cineole	6.5	4.1
(Z)- β -ocimene	0.2	—
(E)- β -ocimene	0.4	—
γ -terpinene	1.5	—
terpinolene	26.0	7.4
linalool	0.7	1.1
p-mentha-1,3,8-triene	0.2	0.3
p-methylacetophenone	0.1	0.3
p-cymen-8-ol	0.8	26.0
α -terpinenol	0.4	0.1
thymol	0.3	—
carvacrol	0.1	—
γ -curcumene	0.1	t
ar-curcumene	0.2	1.9
zingiberene	0.5	0.8
β -bisabolene	—	0.9
β -sesquiphellandrene	0.3	1.1
(E)-nerolidol	0.1	1.1
ar-turmerone	0.1	1.2
turmerone	0.9	1.0
carlone	0.2	0.3
6S,7R-bisabolone	0.1	0.4

t = trace (< 0.1%)

T-2. Comparative percentage composition of the leaf and flower oils of *Curcuma longa* from Reunion

Compound	Leaf oil	Flower oil
tricyclene	0.1	0.1
α-pinene	0.7	–
α-fenchene	0.1	0.8
sabinene	0.1	0.1
β-pinene	0.7	0.6
myrcene	1.4	2.1
δ-2-carene	0.1	0.2
α-phellandrene	2.8	3.6
δ-3-carene	1.2	1.7
α-terpinene	3.7	4.4
p-cymene	0.3	0.4
limonene	–	0.4
1,8-cinole	4.6	4.6
(Z)-β-ocimene	0.4	0.8
(E)-β-ocimene	0.7	1.8
γ-terpinene	0.4	0.8
terpinolene	76.8	67.4
linalool	0.7	0.5
p-mentha-1,3,8-triene	0.2	0.3
p-cymen-7-ol	–	0.2
p-cymen-8-ol	0.2	0.3
α-terpineol	0.3	0.3
2-undecanone	–	0.2
geranyl acetate	–	0.1
β-caryophyllene	0.1	0.2
(E)-β-farnesene	0.1	0.1
ar-curcumene	0.1	0.1
zingiberene	1.0	1.3
β-bisabolene	0.1	0.2
β-sesquiphellandrene	0.4	0.5
(E)-nerolidol	0.1	0.2
(Z)-γ-atlantone	0.1	0.9
germacrone	0.1	0.1

thymol acetate (0.1%)
decanoic acid (0.1%)
geranyl acetate (0.2%)
methyl eugenol (1.6%)
β-patchoulene (0.4%)
β-elemene (1.2%)
β-caryophyllene (0.6%)
γ-elemene (0.8%)
α-cadinene [†] (1.1%)
α-humulene (0.2%)
(E)-β-farnesene (0.2%)
α-patchoulene (1.3%)
ar-curcumene (0.2%)
curzerene (0.1%)
zingiberene (0.3%)
α-murolene (0.1%)
α-selinene (0.1%)
β-bisabolene (0.1%)
β-sesquiphellandrene (0.1%)
cis-sesquisabinene hydrate (0.1%)
germacrene B (0.1%)
(E)-nerolidol (0.6%)
ar-turmerol (0.1%)
caryophyllene oxide (0.6%)
curzerenone (0.1%)
cis-β-elemenone (0.1%)
trans-sesquisabinene hydrate (0.4%)
humulene epoxide II (0.1%)
T-cadinol (0.1%)
ar-turmerone (0.5%)
α-turmerone (0.6%)
β-bisabolol (0.3%)
germacrone (0.1%)
β-turmerone (0.2%)
geranyl hexanoate (0.2%)

^{*} correct isomer not identified; [†]furanoid form; [‡]incorrect identification

T-3. Comparative percentage composition of oils produced from various plants parts of the aerial growth *Curcuma aromatica* grown in the Indo-Gangetic plains

Compound	Inflorescence oil	Leaf lamina oil	Leaf petiole oil	Stem oil	Entire shoot oil
α-pinene	0.5	0.8	–	–	0.3
β-pinene	1.8	2.6	1.0	0.2	1.5
myrcene	14.6	45.6	26.2	5.8	23.0
1,8-cinole	4.4	11.5	12.5	10.6	9.8
γ-terpinene	6.8	–	9.1	0.6	4.1
p-cymene	10.9	23.6	19.9	1.3	13.9
linalool	0.9	0.9	0.9	0.1	0.7
p-cymen-8-ol	0.4	0.2	0.5	0.1	0.3
terpinen-4-ol	0.9	0.4	0.3	3.3	1.2
myrtenol	0.5	0.1	0.5	0.4	0.4
ar-curcumene	0.9	0.3	0.2	5.3	1.7
zingiberene	2.3	0.2	0.8	0.2	0.9
ar-turmerone	1.7	0.5	0.7	4.7	1.9
α-turmerone	7.9	9.1	3.9	29.6	12.6
β-turmerone	3.9	1.3	1.1	14.7	5.5

Fresh leaves of the *C. longa* 'Roma' and 'Kasturi' cultivars that were grown in Orissa (India) were hydrodistilled for 6 hr by Behura and Srivastava (2004). The main constituents of the leaf oils of the two cultivars as determined by GC-FID and retention times with authentic compounds can be seen in **T-4**.

Raina et al. (2005) used both GC-FID and GC/MS to examine the composition of a leaf oil of *C. longa* that was produced in the laboratory in 0.65% yield from plants grown in the Field Station of CIMAP in Pantnagar (Uttarakhand, India). The constituents characterized in the oil were:

α-thujene (0.1%)
α-pinene (2.3%)
camphene (0.1%)
sabinene (0.3%)
β-pinene (1.8%)
myrcene (0.1%)
2-octanol (3.0%)
(Z)-3-hexenyl acetate (0.1%)

α -phellandrene (53.4%)
 δ -3-carene (1.0%)
 α -terpinene (0.9%)
p-cymene (4.8%)
limonene (2.0%)
1,8-cineole (8.5%)
(Z)- β -ocimene (0.1%)
(E)- β -ocimene (0.4%)
 γ -terpinene (2.2%)
terpinolene (11.5%)
linalool (0.8%)
trans-p-menth-2-en-1-ol (0.1%)
camphor (0.2%)
p-cymen-8-ol (0.2%)
 α -terpineol (0.1%)
cis-sabinol (0.4%)
2-decanol (0.3%)
cis-carvotanacetol[†] (0.1%)
cis-carveol (0.1%)
neral (0.9%)
geranial (0.1%)
geranyl formate (0.1%)
undecanol (1.0%)
 β -elemene (0.3%)
 β -caryophyllene (0.2%)
 γ -elemene (0.1%)
 β -farnesene^{*} (0.2%)
zingiberene (0.1%)
 α -selinene (0.2%)
 β -sesquiphellandrene (0.1%)
ar-turmerol (0.1%)
viridiflorol (0.2%)
humulene epoxide II (0.1%)
T-cadinol (0.1%)
ar-turmerone (0.6%)
germacrone (0.3%)
(E)- α -atlantone (0.1%)
heptyl salicylate[†] (0.1%)

^{*}correct isomer not identified; [†]incorrect identification

In addition, trace amounts (<0.1%) of the furanoid form of *cis*-linalool oxide, p-methylacetophenone, terpinen-4-ol,

T-4. Percentage composition of the main constituents of the leaf oils of two turmeric cultivars

Compound	'Roma' oil	'Kasturi' oil
α -pinene	—	2.8
β -pinene	—	4.0
myrcene	5.3	48.8
limonene	3.6	2.5
1,8-cinole	3.4	6.4
(E)- β -ocimene	—	2.0
p-cymene	—	4.3
terpinolene	87.8	10.1
eugenol	—	1.3
farnesol*	—	1.8

*correct isomer not identified

myrtenal, myrtenol, perilla ketone, linalyl acetate, isobornyl acetate, geranyl acetate, β -patchoulene, an α -bergamotene isomer, germacrene D, caryophyllene oxide and *trans*-sesquibinene hydrate were also characterized in this oil.

Chowdhury et al. (2005) used GC/MS only to analyze a turmeric leaf oil produced from dry leaves by hydrodistillation from plants grown in Chittagong (Bangladesh). The constituents that were correctly characterized in this oil were:

α -thujene (0.1%)
 α -pinene (1.4%)
sabinene (0.3%)
myrcene (5.0%)
 δ -3-carene (0.2%)
 α -phellandrene (6.9%)
 α -terpinene (4.9%)
o-cymene^a (1.5%)
limonene (2.9%)

1,8-cineole (7.8%)
 β -ocimene^b (1.3%)
 γ -terpinene (0.6%)
terpinolene (52.1%)
linalool (0.6%)
p-mentha-1,3,8-triene (0.2%)
carveol^c (2.8%)
terpinen-4-ol (0.2%)
p-cymen-8-ol (1.2%)
 β -caryophyllene (0.2%)
 β -farnesened (0.5%)
ar-curcumene (0.2%)
zingiberene (1.1%)
 β -bisabolene (0.3%)
germacrone (0.2%)

^ap-isomer; ^b(E)- β -isomer; ^c*cis*-isomer; ^d(E)-isomer

In addition, a large number of so-called constituents were misidentified and so they are not included in this review.

Pande and Chanotiya (2006) analyzed an oil produced by steam distillation

T-5. Comparative percentage composition of turmeric leaf oils produced using different methods

Compound	VD oil	R oil	HD oil
α -pinene	0.8	0.3	0.5
camphene	0.4	0.1	0.1
sabinene	0.1	—	—
β -pinene	0.2	—	0.1
myrcene	1.8	0.8	0.9
2-octanol	0.1	—	t
α -phellandrene	3.1	1.4	1.4
δ -3-carene	1.2	0.6	0.6
α -terpinene	3.9	1.8	1.7
p-cymene	0.9	0.5	0.5
limonene	2.0	1.0	1.0
1,8-cineole	7.9	1.9	1.3
(Z)- β -ocimene	0.9	0.9	t
(E)- β -ocimene	0.6	0.4	t
γ -terpinene	0.4	0.2	0.2
terpinolene	57.6	42.5	33.0
2-nonanone	—	—	t
linalool	1.1	0.3	0.4
p-mentha-1,3,8-triene	0.5	0.3	0.3
camphor	0.9	0.4	0.2
camphene hydrate	0.4	0.2	0.3
isoborneol	0.3	—	—
borneol	0.3	—	t
myrtenal	0.4	0.3	0.5
terpinen-4-ol	0.4	0.2	0.4
p-cymen-8-ol	1.1	1.1	2.0
α -terpineol	0.4	0.2	0.5
<i>cis</i> -sabinol	0.3	—	0.2
p-methylacetophenone	0.1	—	0.2
myrtenol	0.2	0.2	—
2-undecanone	0.3	0.2	0.3

T-5. Comparative percentage composition of turmeric leaf oils produced using different methods (Cont.)

Compound	VD oil	R oil	HD oil
carvacrol	0.1	—	0.1
δ-elemene	—	—	0.1
β-elemene	0.1	0.5	0.4
β-caryophyllene	0.8	3.1	2.4
γ-elemene	0.1	0.9	0.8
α-humulene	0.1	0.3	0.2
(E)-β-farnesene	—	0.2	0.1
ar-curcumene	0.4	1.5	1.5
zingiberene	2.4	14.7	10.9
β-bisabolene	0.3	1.9	1.5
β-sesquiphellandrene	0.9	5.9	4.7
(E)-γ-bisabolene	—	—	0.1
cis-sesquisabinene hydrate	t	0.1	0.4
germacrene B	0.4	1.8	2.0
(E)-nerolidol	0.1	0.4	0.6
ar-turmerol	—	0.1	0.1
caryophyllene oxide	0.2	0.4	0.6
curzerenone	—	0.1	0.4
cis-β-elemenone	0.4	1.4	2.5
trans-sesquisabinene hydrate	0.3	1.0	2.5
ar-turmerone	—	—	0.2
α-turmerone	0.1	0.6	1.2
β-bisabolol	—	—	0.2
β-turmerone	—	—	0.2
germacrone	1.6	4.8	9.8
curdione	0.1	0.6	1.0
(6S,7R)-bisabolene	0.1	0.5	1.2
farnesol*	—	—	0.1

VD oil = vacuum-distilled oil; R oil = residual oil; HD oil = hydrodistilled oil; t = trace (< 0.1%); *correct isomer not identified

T-6. Comparative percentage composition of the oils of two turmeric cultivars

Compound	NBH-1 oil	NBH-18 oil
α-pinene	1.8	1.8
myrcene [†]	t	3.0
β-pinene	3.6	1.2
α-phellandrene	3.5	65.8
1,8-cineole	2.2	1.8
sabinene [†]	0.5	0.7
p-cymene	33.1	8.2
γ-terpinene	—	1.6
terpinolene	3.3	8.4
linalool	1.1	—
sabinene hydrate*	—	0.1
terpinen-4-ol	0.5	0.2
thuj-4(10)-en-3-ol [†]	—	0.5
1,2,8,9-diepoxy-p-menthane [†]	11.1	0.6
α-humulene	—	t
zingiberene	t	t
α-bisabolol	1.2	1.1
ar-turmerone	—	t

*correct isomer not identified; t = trace (< 0.1%); [†]incorrect identification

in 0.15% yield from fresh leaves collected from turmeric plants cultivated in Nainital district (Uttarakhand, India).

Analysis this oil by GC-FID and GC/MS revealed that it had the following composition:

sabinene (0.8%)
β-pinene (0.1%)
myrcene (1.1%)
δ-2-carene (0.7%)
α-phellandrene (0.8%)
δ-3-carene (1.2%)
α-terpinene (1.4%)
p-cymene (1.3%)
1,8-cineole (6.2%)
(Z)-β-ocimene (0.3%)
terpinolene (71.2%)
linalool (0.1%)
p-methylacetophenone (0.4%)
myrtenol (0.8%)
p-cymen-9-ol (4.2%)
(Z)-tagetenone ^a (0.8%)
(E)-tagetenone ^a (0.3%)
(Z)-β-farnesene (0.1%)
(E)-β-farnesene (0.4%)
ar-curcumene (0.1%)
zingiberene (1.2%)
(E, E)-α-farnesene (0.4%)
β-sesquiphellandrene (0.1%)
(Z)-nerolidol (0.5%)

^aalso known as ocimenone

The author's also characterized α-pinene, (E)-β-ocimene, γ-terpinene and (Z)-methyl jasmonate as trace (<0.1%) constituents of this oil.

Kiran Babu et al. (2007) examined the composition of turmeric leaf oils produced by water distillation under vacuum, the residual oil produced from the same leaves by water distillation after the vacuum was removed and an oil produced by conventional means (it is assumed that this was a normal hydro-distilled oil) using GC-FID and GC/MS. The oil yields for the three processes were 0.25% (vacuum-distilled oil), 0.07% (residual oil) and 0.28% (hydrodistilled oil). The results of this study are presented in T-5.

Singh et al. (2012) compared the composition of the leaf oils of two different turmeric cultivars ('NBH-1' and 'NBH-18') grown at the National Botanic Garden (Lucknow, Uttar Pradesh, India). The oils, which were analyzed by GC/MS only, possessed different compositions, as can be seen in T-6.

Parveen et al. (2003) analyzed the leaf oil of the 'Kasturi' cultivar of

turmeric that was cultivated at the Ayub Agricultural Research Institute (Faisalabad, Pakistan). The analysis, which was weak, reported the identification of nine constituents, although only α -pinene (1.5%), β -pinene (3.6%), β -phellandrene (2.5%), 1,8-cineole (10.3%) and p-mentha-1,3,8-triene (1.8%) were correctly identified.

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