Progress in Essential Oils

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Curry Leaf Oil

The curry leaf tree [*Murraya koenigii* (L.) Spreng.] is perennial, small and shrubby, and is a member of the Rutaceae family. It can be found growing wild in India, Sri Lanka and other Southeast Asian countries as undergrowth in forests, particularly throughout India and the Andaman islands (Joseph and Peter, 1985). *Murraya koenigii* is commonly cultivated both in India and Sri Lanka where it is used as an integral condiment of local cuisine. In India, a limited amount of oil is produced commercially from plantation-grown *M. koenigii*, particularly in the South where the tree is grown as a shrub. *Murraya koenigii* is not only valued for its characteristic aroma and use as a condiment but it is used in traditional medicine (Jain et al., 2012) in India, China and other Asian countries for a wide variety of treatments (Parthasarathy et al., 2008).

Mallavarapu et al. (2000) used a combination of GC-FID and GC/MS to analyze the composition of the leaf and fruit oils of *M. koenigii* harvested from a garden tree in Bangalore (Karnataka, India). A summary of the composition of the two oils can be seen in **T-1**. Trace amounts (0.05%) of tricyclene, δ-3-carene, p-cymenene, *cis*-sabinene hydrate and (E)-β-terpineol were also found in the fruit oil, while only *trans*-sabinene hydrate was characterized as a unique trace constituent of the leaf oil.

A leaf oil of *M. koenigii* of Bangladeshi origin was analyzed by Chowdhury and Yusuf (2008) using GC/MS only. They determined that the oil contained:

α-thujene (1.5%)
δ-3-carene[a] (54.2%)
camphene (0.1%)
myrcene (3.2%)
α-phellandrene (0.1%)
α-terpinene (2.4%)
m-cymene[b] (0.3%)
limonene (0.8%)

T-1. Comparative percentage composition of the leaf and fruit oils of *Murraya koenigi*

Compound	Leaf oil	Fruit oil
α-thujene	0.1	0.2
α-pinene	9.0	48.1
camphene	0.2	0.4
sabinene	0.2	0.1
β-pinene	1.5	7.1
myrcene	2.4	3.1
α-phellandrene	6.1	2.7
α-terpinene	0.2	0.2
p-cymene	0.1	0.1
limonene	5.1	3.5
β-phellandrene	49.0	23.1
(Z)-β-ocimene	0.6	0.2
(E)-β-ocimene	7.1	0.5
γ-terpinene	0.2	3.0
terpinolene	0.2	0.7
linalool	2.0	0.1
(Z)-β-terpineol	0.3	0.1
lavandulol	0.1	–
terpinen-4-ol	0.4	0.3
α-terpineol	0.6	0.2
decanal	0.1	0.1
nerol	0.1	0.1
geraniol	t	0.1
bornyl acetate	0.7	0.4
neryl acetate	0.1	0.2
α-copaene	0.1	–
β-elemene	0.2	t
β-caryophyllone	4.9	3.0
β-guijunene	t	0.1
aromadendrene	0.1	t
γ-gurjunene[a]	0.1	t
α-humulene	1.2	0.6
cis-β-guaiene[a]	0.1	–
α-selinene	0.2	0.1
δ-cadinene	0.1	0.1
elemol	0.3	–
(E)-nerolidol	0.3	0.1
spathulenol	0.1	–
caryophyllene oxide	0.1	–
globulol	0.2	t
T-cadinol	0.1	0.1
β-eudesmol	0.2	t
(E, E)-farnesol	0.2	t

a = tentative identification; t = trace (< 0.05%)

β-phellandrene (0.5%)
1,8-cineole (0.1%)
(E)-β-ocimene (0.2%)
γ-terpinene (2.7%)
cis-sabinene hydrate (1.5%)
linalool (0.2%)
terpinen-4-ol (2.8%)
α-terpinyl acetate (0.1%)
cis-piperitol (0.1%)
isobornyl acetate (0.1%)
β-elemene (1.9%)
β-caryophyllene (9.5%)
α-humulene (2.8%)
selina-4(14),11-diene (0.2%)
γ-elemene† (2.0%)
δ-cadinene (0.1%)
nerolidyl acetate (0.2%)
caryophyllene oxide (1.0%)

[a]should be α-pinene; [b]should be p-cymene; †incorrect identification

A commercial Indian oil of curry leaf was analyzed by GC/MS only (Anon, 2008). The composition was reported as follows:

α-thujene (0.1%)
α-pinene (13.6%)
camphene (0.2%)
sabinene (0.1%)
β-pinene (2.1%)
myrcene (2.3%)
α-phellandrene (5.6%)
α-terpinene (0.2%)
p-cymene (0.1%)
β-phellandrene (48.9%)
β-ocimene* (4.0%)
γ-terpinene (0.3%)
terpinolene (0.1%)
linalool (0.4%)
terpinen-1-ol (0.2%)
terpinen-4-ol (0.1%)
α-terpineol (0.1%)
cis-piperitol (0.1%)
carvone (0.1%)
lavandulyl acetate (0.6%)
α-copaene (0.3%)
β-bourbonene (0.2%)
β-caryophyllene (13.7%)
cis-α-bergamotene (0.2%)
aromadendrene (0.1%)
α-humulene (2.5%)
α-amorphene (0.1%)
germacrene D (0.8%)
β-selinene (0.1%)
bicyolgermacrene (0.4%)
δ-cadinene (0.1%)
nerolidol* (0.1%)
caryophyllene oxide (0.7%)

*correct isomer not identified

In addition, trace amounts (<0.05%) of an allo-ocimene isomer, lavandulol, *trans*-piperitol, safranal, piperitone, phellandral, bicycloelemene, α-cubebene, eugenol, α-gurjunene, α-muurolene, allo-aromadendrene, γ-cadinene, an isomer of α-farnesene, cadina-1,4-diene, α-cadinene, (Z)-3-hexenyl benzoate, spathulenol and α-cadinol were also reported to be constituents of this oil.

An oil produced from curry leaf purchased in the market of Thiruvananthapuram (Kerala, India) was analyzed by Padmakumari (2008) using GC-FID and GC/MS. The constituents characterized in this oil were as follows:

1-hepten-3-ol (0.1%)
α-pinene (6.6%)
camphene (0.1%)
β-pinene (1.9%)
α-phellandrene (0.8%)
p-cymene (0.1%)
limonene (9.5%)
(E)-β-ocimene (2.3%)
γ-terpinene (0.1%)
terpinolene (0.1%)
linalool (0.3%)
cis-p-menth-2-en-1-ol (0.1%)
β-terpineol* (0.1%)
borneol (0.3%)
decanal (0.2%)
octyl acetate (0.1%)
carveol* (0.1%)
neryl acetate (0.1%)
β-cubebene (0.1%)
β-elemene (0.1%)
β-caryophyllene (49.6%)
β-farnesene* (0.3%)
α-humulene (1.2%)
γ-muurolene (7.1%)
β-selinene (0.2%)
β-guaiene* (0.3%)
α-selinene (0.4%)
δ-cadinene (0.2%)
cadina-1,4-diene (0.1%)
caryophyllene alcohol (0.4%)
caryophyllene oxide (0.9%)
α-cedrene epoxide (0.1%)
cedrol (0.1%)
T-cadinol (0.3%)
globulol (0.3%)
bulnesol (1.2%)
(E,Z)-farnesol (0.3%)

*correct isomer not identified

Trace amounts (<0.05%) of hexanol, the furanoid form of *cis*-linalool oxide,

T-2. Comparative percentage composition of curry leaf oil produced either by microwave distillation or hydrodistillation

Compound	Microwave distilled oil	Hydrodistilled oil
α-pinene	0.2	1.8
β-pinene	0.2	1.2
α-phellandrene	0.1	0.2
β-thujene†	0.3	2.9
(E)-β-ocimene	0.3	0.8
α-terpineol	0.1	t
bornyl acetate	0.1	–
δ-elemene	0.3	0.9
α-cubebene	0.1	0.1
α-copaene	44.3	42.0
β-cubebene	t	0.1
α-cedrene	t	0.1
β-caryophyllene	8.7	8.6
β-gurjunene	25.5	23.3
isocaryophyllene	12.1	11.2
α-humulene	t	0.1
γ-muurolene	0.3	0.4
germacrene D	2.9	2.8
α-selinene	0.3	t
(E)-nerolidol	0.1	t
spathulenol	0.9	0.8
caryophyllene oxide	0.9	0.4
α-cadinol	t	–
valencene	1.3	0.5
γ-eudesmol	0.1	0.1

†incorrect identification; t = trace (< 0.05%)

lavandulol, α-terpineol, geraniol, carvacrol, α-terpinyl acetate, eugenol, β-sesquiphellandrene, an isomer of calamenene, elemol, (E)-nerolidol, viridiflorol, a bisabolol isomer, (Z,E)-farnesol and (E,E)-farnesol were also characterized in this oil.

A second oil of curry leaf was analyzed by Padmakumari (2009). The constituents characterized in this oil were as follows:

3-buten-2-ol (0.1%)
1-hepten-3-ol (0.1%)
α-pinene (6.0%)
camphene (0.1%)
β-pinene (1.7%)
α-phellandrene (0.7%)
p-cymene (0.1%)
limonene (8.5%)
(E)-β-ocimene (2.2%)
γ-terpinene (0.2%)
terpinolene (0.1%)
linalool (0.3%)
cis-p-menth-2-en-l-ol (0.1%)
dihydrolinalool† (0.2%)
β-terpineol* (0.1%)
borneol (0.2%)
terpinen-4-ol (0.1%)
decanal (0.3%)
octyl acetate (0.1%)
carveol* (0.1%)
neryl acetate (0.2%)
β-cubebene (0.2%)
β-caryophyllene (45.9%)
β-farnesene* (0.7%)
α-humulene (1.2%)
γ-muurolene (9.1%)
guaiene* (0.5%)
eudesmane‡ (5.3%)
β-bisabolene (9.8%)
δ-cadinene (0.2%)
cadina-1,4-diene (0.1%)
caryophyllene alcohol (0.5%)
caryophyllene oxide (0.2%)
α-cedrene epoxide (0.1%)
cedrol (0.6%)
T-cadinol (0.3%)
globulol (0.3%)
bulnesol (1.7%)
bisabolol* (0.1%)

*correct isomer not identified; †does not occur naturally; ‡incorrect identification

T-3. Percentage composition of three different *Murraya koenigi* leaf oils from Uttarakhand

Compound	1	2	3
α-thujene	t	2.1	1.1
α-pinene	63.0	5.2	35.3
camphene	1.3	–	1.1
sabinene	0.1	48.1	24.6
β-pinene	7.3	t	5.1
myrcene	0.6	1.8	1.4
α-phellandrene	–	0.2	0.1
α-terpinene	–	2.9	1.2
p-cymene	0.1	0.5	0.5
limonene	4.1	1.1	3.3
(E)-β-ocimene	0.4	1.0	0.2
γ-terpinene	0.2	5.3	2.6
cis-sabinene hydrate	t	0.9	0.5
terpinolene	0.1	1.1	0.6
linalool	0.3	0.3	1.0
cis-p-menth-2-en-1-ol	–	0.4	0.2
trans-p-menth-2-en-1-ol	t	t	–
terpinen-4-ol	–	5.7	2.0
γ-terpineol	–	0.1	0.1
neral	–	–	1.2
bornyl acetate	0.6	0.2	0.6
α-cubebene	0.5	t	0.3
α-copaene	t	t	–
β-cubebene	t	0.5	0.1
β-elemene	0.5	1.9	0.5
β-longipinene	0.1	0.1	0.2
β-caryophyllene	4.8	7.3	5.0
β-copaene	–	0.3	t
α-humulene	1.0	1.5	1.1
γ-gurjunene	0.1	0.3	0.1
germacrene D	0.3	0.6	0.3
β-selinene	1.1	1.7	0.8
α-selinene	0.1	0.3	0.3
bicyclogermacrene	–	0.2	–
γ-cadinene	t	0.4	0.1
(E)-nerolidol	0.2	t	0.1
spathulenol	–	0.5	0.4
caryophyllene oxide	0.4	0.6	0.4

t = trace (< 0.05%)

Rajeswara Rao et al. (2011) surveyed the published literature (between 1925 and 2008) on the chemical composition profiles of curry leaf oils of diverse origins. The authors found that the oils could be categorized according to the following major constituents:

1. α-pinene-rich oils (38.4–68.6%) with β-pinene, sabinene, limonene, β-phellandrene, γ-elemene and β-caryophyllene as other main constituents
2. β-pinene-rich oils (21.7–70.0%) with α-pinene and β-caryophyllene as other main constituents
3. sabinene-rich oils (31.8–44.8%) with α-pinene, β-pinene, α-terpinene, β-phellandrene, γ-terpinene, β-caryophyllene, β-cubebene and terpinen-4-ol as other main constituents
4. δ-3-carene-rich oils (54.2%) with myrcene and β-caryophyllene as other main constituents
5. sabinene- and α-pinene-rich oils (34.0% and 27.3%) with limonene, β-caryophyllene and α-terpineol as other main constituents
6. β-phellandrene-rich oils (30.2–49.0%) with α-pinene, α-phellandrene, limonene, β-phellandrene, (E)-β-ocimene, β-caryophyllene and geraniol as other main constituents
7. β-phellandrene and α-pinene-rich oils (14.7–24.4% and 13.5–17.5%) with limonene sabinene, α-terpinene, β-caryophyllene, terpinen-4-ol, lavandulol, linalool,

selin-11-en-4α-ol and caryophyllene oxide as other main constituents
8. β-caryophyllene-rich oils (20.5–53.9%) with β-phellandrene, (E)-β-ocimene, aromadendrene, α-selinene, α-humulene, *cis*-β-guaiene, bicyclogermacrene, selin-11-en-4α-ol, α-cadinol and caryophyllene oxide as other main constituents
9. β-caryophyllene and β-gurjunene rich oils (28.7% and 21.4%) with β-elemene and β-phellandrene as other main constituents
10. β-caryophyllene and a cadinene isomer (26.3% and 18.2%) with sabinene, α-pinene, α-phellandrene, limonene, isosafrole and cadinol isomers as other main constituents
11. β-phellandrene and β-caryophyllene-rich oils (30.2–33.3% and 23.8–24.2%) with α-pinene, limonene, α-phellandrene, α-phellandrene, (E)-β-ocimene and aromadendrene as other main constituents
12. β-caryophyllene and β-pinene-rich oils (30.0% and 28.6%) and β-gurjunene as another main constituents
13. isocaryophyllene and limonene-rich oils (11.7% and 11.3%) and β-elemene, β-caryophyllene, junipene and α-eudesmol as other main constituents
14. (Z)-β-ocimene and α-copaene-rich oils (28.5%) and (20.2%) and α-pinene, β-pinene, γ-terpinene and (E)-β-ocimene as other main constituents

Hema et al. (2011) used GC/MS to examine the composition of an ethanolic extract of *M. koenigii* leaves. However, the study did not add any useful information that could be of value in the oil composition so its inclusion is merely for the sake of thoroughness.

Erkan et al. (2012) compared the composition of the oils produced in 0.82–0.84% either by microwave distillation or hydrodistillation of the fresh leafed-branches of *M. koenigii* from Jamaica. The results of the analysis of the two oils are shown in **T-2**.

Verma et al. (2013) collected 58 populations of *M. koenigii* from various locations at different altitudes in the western Himalayan region of Uttarakhand (India) during the spring season. The shade-dried leaves from each population were separated from the stems and each was subjected to hydrodistillation for 3 hr. The oil content was found to range from a low of 0.14% to a high of 0.80%. Each oil was separately analyzed by GC-FID and GC/MS. The results showed that the major components of the oils were α-pinene, sabinene, β-pinene and β-caryophyllene. The oils were either rich in α-pinene (27 of 58), sabinene (eight of 58) or both (23 of 58). Typical examples of three different oils can be seen in **T-3**.

Balasubramanian et al. (2014) used GC/MS to examine a methanolic extract of curry leaves. They found that the

T-4. Comparative percentage composition of curry leaf oil produced by hydrodistillation with and without microwave assistance

Compound	Oil 1	Oil 2
sabinene	t	0.2
β-pinene	0.1	–
α-phellandrene	0.1	0.3
myrcene	0.1	–
δ-3-carene	0.1	–
α-terpinene	–	0.2
p-cymene	0.1	–
1,8-cineole	–	0.1
β-phellandrene	2.5	–
γ-terpinene	0.1	–
trans-sabinene hydrate	0.2	2.0
δ-2-carene†	0.2	–
linalool	–	9.8
terpinolene	0.2	–
terpinen-1-ol	–	1.9
terpinen-4-ol	2.1	17.6
α-terpineol	0.3	–
dodecane	0.2	–
cis-piperitol	–	0.9
bornyl acetate	0.5	0.1
lavandulyl acetate	–	2.6
δ-elemene	0.1	–
α-cubebene	0.6	0.2
(Z)-jasmone	–	0.5
β-elemene	–	2.6
γ-muurolene	0.1	–
α-copaene	1.7	–
α-gurjunene	0.2	–
β-caryophyllene	–	19.5
α-neocalitropsene†	–	0.2
β-copaene	41.5	–
aromadendrene	0.6	0.2
premnaspirodiene†	0.1	–
α-humulene	8.4	5.0
germacrene D	–	0.1
β-selinene	4.9	0.1
α-selinene	10.0	6.1
γ-cadinene	1.3	–
δ-cadinene	–	0.6
viridiflorene[a]	0.9	–
(Z)-nerolidol	0.7	1.0
caryophyllene oxide	0.2	3.6
globulol	0.4	–

oil 1 = conventional hydrodistillation; oil 2 = microwave assisted hydrodistillation; †identity requires corroboration; [a]incorrect identification major components of the extract were sesquiterpenoids and alkaloids.

Azid et al. (2014) compared the composition of curry leaf oils produced either by conventional or microwave assisted hydrodistillation from leaves collected in Selangor (Malaysia). The authors analyzed the oils using both GC-FID and GC/MS and their results can be found summarized in **T-4**. In addition, the authors reported finding trace (<0.05%) amounts of α-pinene, (Z)-and (E)-β-ocimene, the furanoid form of *cis*-linalool oxide and an unknown sesquiterpene alcohol in one of the hydrodistilled oils. The obvious differences in the compositions of the two oils supposedly from the same batch of curry leaves do not make sense. Both oils should have a lot of similarities in their compositions; consequently, this study is suspect in terms of curry leaf oil composition.

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