Progress in Essential Oils

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Peppermint Oil

Piccaglia et al. (1993) compared the oil compositions of the first and second cuttings over two seasons of the 'Italo-Mitcham' cultivar of peppermint grown in the experimental garden of the University of Bologna. The oils, which were produced by hydrodistillation, were obtained from first cutting (plants in full bloom) and second cutting in the autumn at maturity growth. The authors found that the first season's biomass harvest (ca 54 metric tonnes/ha) was much greater than that of the second season (33 tonnes/ha). The results of this study are summarized in **T-1**. Examination of these results revealed a compositional change in the second cutting oil versus the first cutting oil. It is believed that the photoperiodic effect of the short autumn days could be responsible for this biosynthetic change in the contents of menthone, menthofuran and menthyl acetate, particularly in the second season.

Culp et al. (1998) reported that the commercial samples of peppermint oil of U.S. origin that they examined by capillary GC coupled with online isotope ratio mas spectrometry contained the following constituents:

α-pinene (0.4–0.7%)
sabinene (0.2–0.3%)
β-pinene (0.6–0.8%)
p-cymene (0.2–0.3%)
limonene (0.1–1.5%)
1,8-cineole (0.2–5.7%)
menthone (17.8–22.5%)
menthol (43.7–55.0%)
pulegone (1.0–1.9%)
menthyl acetate (4.5–6.6%)
β-caryophyllene (1.7–2.3%)
germacrene D (0.5–2.1%)

Maffei and Scannerini (2000) determined that when peppermint plants (cv 'Italo-Mitcham') were exposed to only UV-B light, the menthone, menthofuran and menthyl acetate content of oil produced from them increased, while the menthol content decreased. Furthermore, the authors found that exposure of the plants to UVA light stimulated the biosynthesis of some monoterpenes such as menthol.

Khanuja et al. (2004) and Khanuja (2005) compared the composition of

T-1. Comparative percentage composition of peppermint oils produced from two harvest times over two seasons of the 'Italo-Mitcham' cultivar

Compound	Season 1		Season 2	
	A	B	A	B
α-pinene	0.8	0.7	0.4	0.4
sabinene	0.4	0.4	0.3	0.2
β-pinene	1.0	0.9	0.8	0.6
myrcene	0.3	0.2	0.1	0.1
α-phellandrene	0.2	t	0.1	0.1
α-terpinene	0.4	0.2	0.1	0.1
p-cymene	0.2	t	0.3	0.1
limonene	1.4	1.5	1.2	1.6
1,8-cineole	5.9	4.7	4.6	2.0
(Z)-β-ocimene	0.2	0.1	0.1	t
(E)-β-ocimene	t	t	t	t
γ-terpinene	0.3	0.3	0.3	0.2
p-menth-2-en-1-ol*	1.6	1.1	0.6	0.1
terpinolene	0.2	0.1	0.1	0.1
linalool	0.4	0.1	0.2	0.2
isopulegol	0.3	t	0.1	0.2
menthone	26.7	26.9	24.7	4.7
menthofuran	4.7	8.9	5.8	21.3
isomenthone	5.7	3.2	3.8	1.3
menthol	46.5	51.9	29.5	28.7
terpinen-4-ol	0.5	0.2	1.6	0.9
isomenthol	0.8	0.6	0.5	0.7
pulegone	3.9	1.8	1.5	0.5
piperitone	0.7	0.4	0.4	0.1
neomenthyl acetate	0.2	0.2	0.1	0.7
menthyl acetate	3.1	4.7	3.5	15.2
isomenthyl acetate	0.2	0.2	0.1	0.8
β-bourbonene	0.3	0.2	0.1	0.1
β-caryophyllene	2.1	0.8	0.9	0.3
α-humulene	0.4	0.2	0.2	0.2
germacrene D	2.4	1.2	0.8	0.4
germacrene B	0.3	t	0.1	0.1
caryophyllene oxide	t	t	t	t

A = First cutting oil from full flowering peppermint
B = Second cutting oil from maturity regrowth peppermint
* correct isomer not identified
t = trace (<0.05%)

peppermint oils produced from the following cultivars 'Kukrail,' 'Tushar,' 'Pranjal,' 'Madhuras' and the menthofuran-rich cultivar 'Indus.' The results of these studies are presented in **T-2**.

Soxhlet extracts of fresh and dried leaves of *M. piperita* (ex Oregon) using ethanol as the solvent were investigated by LC-MS-MS (Marin and Schippa, 2006). They confirmed the findings of earlier studies by showing that the level of monomenthyl succinate (FEMA# 3810) was present in peppermint leaves at levels of 150–450 ppb.

Jirovetz et al. (2007) screened the oils of some Bulgarian peppermint cultivar oils for their antifungal activity. The main components of the oils were characterized, as can be seen from the data presented in **T-3**. One of the cultivars was in fact an allopolyploid hybrid that does not meet the international nomenclatural requirement to be called a peppermint.

Oils were produced in the laboratory from germplasm accessions at the Central Institute of Medicinal and Aromatic Plants by Shasany et al. (2007). GC-FID and GC/MS analyses of the peppermint accessions were found to range as follows:

α-pinene (0.2–1.1%)
sabinene (0.4–4.8%)
β-pinene (0.8–3.7%)
p-cymene (0.1–1.0%)
limonene (0.2–11.5%)
1,8-cineole (0.1–7.1%)
γ-terpinene (0.1–1.1%)
menthone (10.1–31.9%)
menthofuran (5.2–13.3%)
menthol (11.9–32.7%)
pulegone (0.6–5.8%)
piperitone (0.5–2.3%)
menthyl acetate (0.4–10.3%)
β-caryophyllene (0.1–1.0%)

T-2. Comparative percentage composition of the oils of various Indian peppermint cultivars

Compound	'Kukrail'	'Tushar'	'Pranjal'	'Madhuras'	'Indus'
α-pinene	0.5	0.6	0.7	1.0	0.4
β-pinene	0.9	1.3	1.5	1.8	1.0
sabinene	1.0	0.8	0.9	1.0	0.9
myrcene	0.3	0.3	0.3	0.4	4.9
α-terpinene	0.2	0.1	0.1	0.2	0.1
limonene	2.9	2.7	3.2	3.5	4.5
1,8-cineole	4.9	5.1	5.3	6.4	8.8
γ-terpinene	0.2	0.2	0.2	0.3	0.3
p-cymene	0.3	0.1	0.1	0.4	0.3
3-octanol	0.1	0.3	0.3	0.3	0.1
menthone	21.3	28.3	28.3	24.3	2.0
menthofuran	8.7	9.7	8.4	6.3	27.2
isomenthone	4.0	4.4	4.1	4.1	0.6
menthyl acetate	7.9	4.8	3.8	4.1	2.3
neomenthol	3.9	2.9	3.3	2.8	4.8
β-caryophyllene	0.5	0.1	0.1	0.7	0.7
pulegone	3.0	2.4	2.8	2.2	15.4
menthol	28.8	26.8	26.2	31.2	14.4
piperitone	2.3	1.1	1.2	1.1	1.5
carvone	0.4	0.6	0.8	0.7	0.6

T-3. Percentage composition of the main components of Bulgarian peppermint cultivar oils

Compound	1	2	3	4
α-pinene	1.2	1.1	1.1	0.8
β-pinene	2.4	2.3	2.5	1.3
1,8-cineole	2.6	2.4	2.6	3.2
menthone	25.9	11.8	12.8	9.7
menthol	35.0	45.7	45.2	69.0
menthyl acetate	8.8	3.3	2.9	-
β-caryophyllene	3.6	3.9	3.3	3.2

1. 'Sofia' cultivar
2. '0012' cultivar
3. '0503' cultivar
4. Hybrid between *M. canadensis* x *M. piperita*

The main components of the leaf oils of three Indian cultivars that were collected from different parts of the plants were examined by Singh et al. (2008). The results of this study are shown in **T-4**. The authors noted that removal of the tops of the plants before distillation resulted in getting oils that were similar in composition to U.S. peppermint oil.

A commercial oil of peppermint purchased in Poland was determined by Golebiowski et al. (2008) to possess the following major constituents:

α-pinene (2.2%)
β-pinene (2.3%)
menthone (23.5%)
isomenthone + neomenthol (16.6%)
menthol (49.4%)
isomenthyl acetate† (3.1%)

† misidentification of menthyl acetate

A commercial oil of peppermint produced from the cultivar 'Krasnodarskaya 2' was analyzed by Kurilov et al. (2009). It was determined to possess the following composition:

α-pinene (0.8%)
β-pinene (0.9%)
p-cymene (0.1%)
limonene (0.7%)
1,8-cineole (2.9%)
γ-terpinene (0.4%)
terpinolene (1.1%)
menthone (32.5%)
menthol (34.4%)
pulegone (0.3%)
piperitone (0.7%)
menthyl acetate (13.0%)
β-bourbonene (2.6%)
β-cubebene (0.9%)
aromadendrene (2.7%)
γ-muurolene (0.8%)
germacrene D (1.2%)
α-muurolene (2.7%)
γ-cadinene (0.4%)
spathulenol (0.6%)
T-cadinol (0.2%)

It is of interest to note that neither isomenthone or menthofuran were characterized in this peppermint oil.

An oil of peppermint that was produced in the Kennewick area at the lower end of the Yakima Valley, Washington (U.S.A.) was the subject of analysis by Schmidt et al. (2009a). The constituents characterized in this oil were as follows:

α-pinene (0.7%)
sabinene (0.5%)
β-pinene (1.1%)
myrcene (0.2%)
3-octanol (0.2%)
limonene (2.6%)
1,8-cineole (5.3%)
γ-terpinene (0.4%)
cis-sabinene hydrate (0.3%)
terpinolene (0.2%)
linalool (0.3%)
trans-sabinene hydrate (0.1%)
menthone (23.4%)
isomenthone (3.7%)
neomenthol (3.2%)
menthofuran (3.7%)
menthol (40.7%)
α-terpineol (0.4%)
neoisomenthol (0.5%)
pulegol* (0.2%)
pulegone (1.9%)
carvone (0.2%)
piperitone (0.6%)
neomenthyl acetate (0.3%)
(E)-anethole (0.1%)
isomenthyl acetate (0.2%)
menthyl acetate (4.2%)
β-bourbonene (0.2%)
β-elemene (0.1%)
β-caryophyllene (1.7%)
(E)-β-farnesene (0.2%)
germacrene D (0.9%)

* correct isomer not identified

In addition, trace amounts (<0.05%) of α-thujene, camphene, α-phellandrene, (E)-β-ocimene, isopulegol, and an isomer of isopulegone were characterized in this oil.

Schmidt et al. (2009b) compared the composition of a 50-year-old sample of Bulgarian peppermint oil with that of a fresh peppermint oil produced in the United States using GC-FID and GC/MS. The comparative results of this study are reported in **T-5**. Based on these results, it can be concluded that the historical sample of the oil, which was probably produced from the 'Bulgaro-Mitcham' cultivar, was chemically stable and must have been well-stored under controlled conditions. Also, the Bulgarian oil contained trace (<0.05%) amounts of hexanol, camphene and α-phellandrene, while the American oil contained trace amounts of camphene, a-phellandrene, an isomer of isopulegol and an isomer of isopulegone.

Tyagi and Malik (2011) examined the antimicrobial activity (using food spoilage microorganisms) of the oil of *M. piperita* of Indian origin with that of its headspace. They found that the vapor of the peppermint oil was a potent inhibitor of food spoilage microbial growth. The composition of the oil was determined by GC-FID and GC/MS to be as follows:

α-pinene (4.8%)
camphene (0.3%)
β-pinene (5.7%)
β-phellandrene† (2.8%)
sabinene (0.1%)
δ-3-carene (0.4%)
myrcene (1.3%)
limonene (10.6%)
1,8-cineole (3.6%)
3-octanone (0.2%)
o-cymene† (0.6%)
terpinolene (0.3%)
3-octanol (3.5%)
perillene (0.1%)
hexyl isovalerate (0.1%)
limonene oxide* (0.1%)
isomenthone (14.8%)
α-bourbonene (0.5%)
linalool (0.1%)
menthyl acetate (6.6%)
isopulegol (3.0%)
germacrene D[a] (0.3%)
isomenthol[b] (6.4%)
β-caryophyllene (0.8%)
neoisomenthol (1.5%)
menthol (19.1%)
pulegone (2.3%)
pinocarveol* (0.2%)
thujol† (0.4%)
geranyl formate† (0.6%)
neryl acetate† (0.4%)
copaene[c] (0.1%)
α-terpineol (0.8%)
sabinyl acetate† (0.2%)
piperitone (2.1%)
carvone (0.3%)
cubenol† (0.2%)
muurolene[d] (0.1%)
myrtenol (0.2%)
carveol[e] (0.2%)
p-cymen-8-ol (0.1%)

T-4. Percentage composition of the main components of the oils produced from the top, the lower part and the whole plant of three Indian peppermint cultivars

	'Pranjal'			'Tushar'			'Kukrail'		
Compound	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
limonene	3.9	3.1	1.1	4.0	3.9	1.9	3.0	3.0	2.2
1,8-cineole	7.5	5.9	5.4	6.7	5.1	4.4	6.0	4.9	5.4
menthone	19.5	41.9	16.8	21.3	33.6	15.6	23.1	46.8	26.3
menthofuran	6.8	2.9	1.5	7.8	7.6	3.8	6.7	6.9	3.9
isomenthone	3.5	5.1	3.8	4.0	4.8	3.9	3.4	5.5	4.5
menthyl acetate	5.5	0.5	7.2	6.7	2.6	13.5	6.1	2.1	3.7
neomenthol	3.3	1.6	4.3	3.3	2.7	6.2	3.9	1.7	3.2
pulegone	3.5	5.0	1.9	4.1	5.0	2.3	2.9	3.5	2.6
menthol	33.4	21.1	48.5	30.2	22.6	36.1	30.7	16.1	39.1
piperitone	0.4	3.1	1.1	0.4	4.0	2.0	0.4	3.0	2.2
carvone	0.1	0.5	0.4	0.1	0.5	0.4	0.2	0.5	0.9

1. Whole herb oil
2. Top leaves oil
3. Lower leaves oil

neryl acetate (0.1%)
carveol[f] (0.1%)
verbenone[†] (0.1%)
caryophyllene oxide (0.2%)
epi-globulol (0.8%)
spathulenol (0.2%)

[*] correct isomer not identified
[†] incorrect identification based on GC elution order
[a] should be α-copaene
[b] should be neomenthol
[c] should be germacrene D
[d] should be α-muurolene
[e] should be *trans*-carveol
[f] should be *cis*-carveol

It should be noted that this was a particularly peculiar peppermint oil because of the lack of menthone and menthofuran, the low menthol content and the high limonene content. As a result, it is probably an adulterated peppermint oil. Analysis of the headspace of the same peppermint oil using SPME-GC/MS reveals that it contained the following:

α-pinene (17.3%)
camphene (1.1%)
β-pinene (13.9%)
β-phellandrene[†] (5.8%)
δ-3-carene (1.3%)
myrcene (3.8%)
limonene (18.4%)
3-octanone (0.6%)
o-cymene[†] (1.2%)
terpinolene (0.6%)
3-octanol (2.0%)
hexyl isovalerate (0.6%)
isomenthone (9.0%)
menthyl acetate (6.6%)
isopulegol (1.8%)
isomenthol[a] (1.8%)
menthol (4.8%)
piperitone (2.1%)

[†] incorrect identification based on GC elution order
[a] should be neomenthol

T-5. Comparative percentage composition of 50-year-old Bulgarian and fresh American peppermint oils

Compound	Bulgarian oil	American oil
(Z)-3-hexenol	0.1	-
α-thujene	0.1	t
α-pinene	0.9	0.7
sabinene	0.4	0.5
β-pinene	1.2	1.1
myrcene	0.1	0.2
3-octanol	0.2	0.2
p-cymene	0.6	-
limonene	1.9	2.6
1,8-cineole	6.5	5.3
γ-terpinene	0.5	0.4
cis-sabinene hydrate	0.5	0.3
terpinoline	0.1	0.2
linalool	0.6	0.3
menthone	21.8	23.4
isomenthone	4.5	3.7
neomenthol	3.3	3.2
menthofuran	1.2	3.7
menthol	40.9	38.0
terpinen-4-ol	1.8	2.7
isomenthol	0.7	0.5
α-terpineol	0.3	0.4
neoisomenthol	0.2	0.5
pulegol*	0.1	0.1
pulegone	1.1	1.9
carvone	-	0.2
piperitone	0.6	0.6
neomenthyl acetate	0.1	0.3
isomenthyl acetate	0.2	0.2
menthyl acetate	2.9	4.2
carvacrol	0.1	-
neoisomenthyl acetate	0.2	0.2
β-bourbonene	0.3	0.2
β-caryophyllene	1.3	1.7
(E)-β-farnesene	0.1	0.2
germacrene D	0.3	0.9
mentholactone	0.2	-
bicyclogermacrene	0.2	-
caryophyllene oxide	0.1	0.1
globulol	0.4	-

* correct isomer note identified

Padalia et al. (2011) analyzed the oils produced from Indian peppermint cultivars grown at different elevations in Uttarakhand (India). The oils were found to range in composition as follows:

α-pinene (0.2–0.9%)
β-pinene (0.4–1.3%)
sabinene (0–0.3%)
myrcene (0–3.0%)
α-terpinene (0–0.3%)
limonene (1.4–2.9%)
1,8-cineole (5.5–8.9%)
(Z)-β-ocimene (0–0.5%)
γ-terpinene (0–1.7%)
p-cymene (0–0.2%)
terpinolene (o–t)
3-octanol (0–1.2%)
1-octen-3-ol (0–0.1%)
menthone (4.5–22.8%)
cis-sabinene hydrate (0–1.1%)
menthofuran (0.4–14.6%)
isomenthone (1.0–3.9%)
β-bourbonene (0–0.1%)
linalool (0–0.6%)
cis-p-menth-2-en-1-ol (0–t)
α-cubebene (0–t)
menthyl acetate (1.7–9.5%)
isopulegol (0–0.6%)
β-caryophyllene (0.9–4.9%)
neomenthol (1.5–4.9%)
terpinen-4-ol (0.1–2.3%)
menthol (32.8–47.8%)
pulegone (t–1.2%)
(E)-β-farnesene (t–0.5%)
α-humulene (0–0.1%)
γ-muurolene (0–t)
α-terpineol (t–0.5%)
germacrene D (0–1.7%)
piperitone (0.2–1.8%)
carvone (0–0.5%)
myrtenol (0–0.1%)
caryophyllene oxide (0–0.3%)
viridiflorol (0–0.9%)
germacrene D-4-ol (0–0.1%)
spathulenol (0–0.3%)
β-eudesmol (0–0.1%)

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Galangal Oil

A limited amount of galangal oil is produced annually in India from the rhizomes of *Alpinia galangal* (L.) Willd. Air-dried and coarsely ground rhizomes of *A. galangal* that were obtained from the herbal garden of Hamdard University (Delhi, India) were hydrodistilled to produce an oil in 0.04%. Analysis of this oil using GC and GC/MS revealed that it contained the following major components:

1,8-cineole (57.0%)
linalool (3.1%)
citronellyl acetate (3.4%)
geranyl acetate (10.2%)
β-caryophyllene (5.4%)
tridecane (1.5%)
docosane (4.3%)
docosan-8-ol (4.9%)
tricosanol (5.2%)

Nirmala Menon (2006) collected *A. galangal* plants from two different locations from around Thiruvananthapuram (Kerala, India) and separated each collection into plant parts (rhizomes, leaves, roots and stems). Oils produced from each plant part were analyzed by GC-FID and GC/MS and the results of this study can be seen in **T-6**. A survey of this data reveals that two distinct chemical forms were found from these two collections of *A. galangal*. The rhizome oil that is rich in 1,8-cineole is the one that is normally encountered in commerce. Nirmala Menon also determined that main component of the root oil was α-fenchol, while that of the stem oil was cubenol.

Raina et al. (2007) collected rhizomes from six locations (Pathanamthitta, Thrissur, Wynaad, Kottayam and Palakkad) in Kerala (India). At each location, fresh rhizomes were collected at

T-6. Comparative percentage composition of the rhizome and leaf oils of two collections of *Alpinia galanga*

Compound	Collection 1		Collection 2	
	Rhizome oil	Leaf oil	Rhizome oil	Leaf oil
3-hexenol*	0.7	0.2	-	0.3
hexanol	0.2	0.3	-	0.4
α-pinene	0.2	1.1	2.9	0.8
camphene	0.1	2.1	3.5	1.1
myrcene	0.4	0.9	0.3	0.1
β-pinene	2.1	3.9	6.5	0.2
limonene	3.6	3.6	3.2	1.9
1,8-cineole	10.8	6.5	30.3	2.3
γ-terpinene	-	0.5	-	0.2
fenchone	0.3	0.7	0.3	-
linalool	0.9	0.5	3.1	0.1
α-fenchol	0.7	1.2	0.1	0.5
nonanal	0.8	0.7	0.2	0.1
camphor	2.8	2.3	5.0	1.5
borneol	0.8	1.2	-	0.3
terpinen-4-ol	1.2	0.7	0.5	0.3
myrtenal	0.5	t	-	t
α-terpineol	2.5	2.7	8.9	1.2
myrtenol	1.8	t	0.2	t
cis-carveol	0.3	-	0.1	-

the time of flowering. An aliquot (500 g) of each rhizome that was cut into small pieces and was separately hydrodistilled for 4 h to produce oils in yields of 0.27–0.62%. Analyses of these oils using GC-FID and GC/MS revealed that they had the following range in composition:

α-thujene (0–1.0%)
α-pinene (5.4–7.4%)
camphene (0–0.5%)
β-pinene (1.6–1.9%)
myrcene (0.6–0.8%)
limonene (0.2–0.3%)
1,8-cineole (60.5–72.5%)
γ-terpinene (0.8–1.2%)
p-cymene (0.4–0.7%)
terpinolene (0–0.1%)
fenchone (0.2–0.4%)
α-fenchyl acetate (0.1–0.5%)
camphor (t–0.1%)
linalool (0.2–0.8%)
bornyl acetate (0.3–0.4%)
terpinen-4-ol (2.0–2.4%)
β-caryophyllene (t–0.3%)
β-farnesene* (0.2–1.0%)
α-terpineol (1.1–3.8%)
borneol (0.4–1.2%)
geranyl acetate (1.2–1.5%)
β-bisabolene (0.1–0.6%)
geraniol (0.3–0.5%)
methyl eugenol (0.6–2.2%)
nerolidol* (0.6–2.1%)
methyl cinnamate* (0.1–2.5%)
caryophyllene oxide (0.9–1.1%)
β-sesquiphellandrene† (1.0–2.9%)
eugenol (0.8–2.8%)
farnesol* (t–0.5%)

* correct isomer not identified
t = trace (<0.05%)
† incorrect identification based on GC elution order

T-6. Comparative percentage composition of the rhizome and leaf oils of two collections of *Alpinia galanga* (continued)

Compound	Collection 1		Collection 2	
	Rhizome oil	Leaf oil	Rhizome oil	Leaf oil
α-fenchyl acetate	4.8	20.7	7.2	0.2
carvone	0.2	0.4	0.2	0.1
geranial	0.8	1.1	0.9	0.8
bornyl acetate	0.4	0.8	-	0.5
methyl cinnamate	2.7	0.5	2.5	0.4
α-terpinyl acetate	0.5	1.2	0.9	0.5
α-cubebene	0.9	0.9	-	0.2
α-copaene	0.1	2.6	0.6	0.1
β-elemene	0.1	1.6	-	0.5
α-gurjunene	0.3	0.4	0.6	0.2
β-caryophyllene	5.8	2.1	1.5	40.5
β-gurjunene	0.4	0.4	-	0.6
α-cedrene	0.4	2.6	-	1.2
α-bergamotene*	0.2	0.1	0.1	0.1
α-farnesene*	1.6	1.9	0.8	2.5
α-guaiene	0.5	-	0.1	1.2
allo-aromadendrene	0.2	1.2	0.3	0.3
α-humulene	0.1	-	0.1	t
germacrene D	1.8	2.3	-	0.5
β-bisabolene	0.6	0.8	0.5	0.3
pentadecane	0.5	0.3	0.3	0.1
cubenol	9.5	0.8	0.3	0.2
γ-cadinene	1.5	0.3	0.2	0.2
δ-cadinene	0.4	0.5	-	0.2
(E)-nerolidol	0.4	1.3	0.1	0.5
carotol	26.7	0.6	0.5	0.2
caryophyllene oxide	0.6	0.9	0.1	7.2
guaiol	-	0.2	-	0.1
γ-eudesmol	-	-	0.6	0.5
β-eudesmol	0.3	4.3	0.2	2.3
α-cadinol	0.4	0.1	-	0.2
α-bisabolol	0.1	0.1	0.2	0.5
(Z,Z)-farnesol	0.3	0.1	0.2	0.2
(Z,E)-farnesol	0.7	0.3	0.1	0.4
α-eudesmol	0.3	0.6	0.2	0.2
(E,E)-farnesol	0.3	0.7	0.2	0.5

t = trace (<0.1%)

A lab-distilled rhizome oil of *A. galangal*, which was produced from rhizomes collected from Nawinna (Sri Lanka) was the subject of analysis by Arambewala et al. (2007) using GC-FID and GC/MS. The oil, which contained zerumbone (44.8%) as the major constituent and only 6.3% 1,8-cienole, may be yet another example of a chemical form of *A. glanga* that has not achieved commercial importance.

Acetone extracts of shade-dried powdered *A. galanga* rhizomes of south Indian origin were determined by Lathra et al. (2008) to contain 1'-acetoxychavicol acetate, 1'-acetoxyeugenol acetate, 1'-hydroxychavicol acetate, *trans*-p-coumaryl methyl ether, *trans*-p-coumaryl diacetate and *trans*-p-coumaryl alcohol. This was the first time that these bioactive compounds have been isolated as non-volatile components of Indian *A. galanga*.

Yant et al. (2009) described the isolation of galangal acetate (syn. 1'-acetoxy chavicol acetate and dihydrogalangal acetate (syn. 1'-acetoxy dihydrochavicol acetate) from galangal roots purchased at market in Cincinnati (Ohio, U.S.A.). Fresh rhizomes of *A. galanga* that were collected from Imphal (Manipur, India) were chopped into small pieces and hydrodistilled for 5 h to yield an oil in 0.73% by Rana et al. (2010). Analysis of this oil using both GC-FID and GC/MS revealed that it possessed the following composition:

α-thujene (0.1%)
α-pinene (1.1%)
β-pinene (1.5%)
myrcene (0.9%)
α-terpinene (0.8%)
1,8-cineole (53.4%)
terpinolene (0.2%)
linalool (0.1%)
trans-p-mentha-2,8-dien-1-ol (0.5%)
cis-p-mentha-2,8-dien-1-ol (0.3%)
trans-p-mentha-2-en-1-ol (0.1%)
terpinen-4-ol (2.9%)
p-cymen-8-ol (0.1%)
α-terpineol (2.1%)

chavicol (0.5%)
bornyl acetate (0.1%)
trans-carvyl acetate (0.2%)
chavicol acetate (5.9%)
eugenol (0.5%)
cis-carvyl acetate (0.3%)
carvacryl acetate
geranyl acetate (0.5%)
methyl eugenol (0.5%)
β-caryophyllene (1.2%)
trans-α-bergamotene (0.1%)
valencene (0.4%)
α-humulene (0.2%)
(E)-β-farnesene (0.4%)
germacrene D (0.9%)
pentadecane (0.1%)
β-bisabolene (0.8%)
7-epi-α-selinene (0.8%)
β-sesquiphellandrene (5.0%)
eugenyl acetate (1.9%)
(E)-nerolidol (0.4%)
caryophyllene oxide (0.3%)
viridiflorol (0.1%)
zingiberenol (1.6%)
T-muurolol (0.5%)
hexadecanoic acid (0.2%)

Trace amounts (<0.05%) of sabinene, *cis*-sabinene hydrate p-mentha-1,3,8-triene, (E)-cinnamyl acetate, spathulenol and α-cadinol were also found in this oil.

Leaves, flowers and rhizomes of *A. galanga* were collected from an experimental field in Patnagar and Purara (Uttarakhand, India) by Padalia et al. (2010). The Patnagar region (Tarai) is considered to be subtropical, while the Purara region (mid-hills) is considered to be sub-temperate. Oils produced from 1 kg of the fresh rhizomes from each growing area by hydrodistillation were analyzed by GC-FID and GC/MS. The constituents characterized in the oils are shown in **T-7**. Examination of the data reveals that the oil compositions were quite different. Unfortunately, the authors did not report the age of the plants grown and whether they were produced from the same or different selections. The leaf oil of the plants grown in the subtropical area contained 1,8-cineole (23.0%), camphor (23.0%) and α-terpineol as major components while the leaf oil from plants grown in the sub-temperate area contained β-pinene (25.1%, 1,8-cineole (26.3%) and camphor (10.7%) as major components. In contrast, the major constituents of the subtropical flower oil were β-pinene (12.8%), 1,8-cineole and methyl (E)-cinnamate (19.7%), while the major constituents of the sub-temperate flower oil were β-pinene (10.5%), 1,8-cineole (9.4%), *cis*-sabinene hydrate (8.3%) and methyl (E)-cinnamate (7.1%).

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R.C. Padalia, R.S. Verma, V. Sundaresan and C.S. Chanotiya, *Chemical diversity in the genus* Alpinia *(Zingiberaceae): Comparative composition of four* Alpinia *speciase grown in northern India. iChem. Biodiversity,* **7**, 2076–2087 (2010).

Kapurkachri Oil

Kapurkachri, or spiked ginger lily (as the plant is known in English), is *Hedychium spicatum* Buch.-Ham. Ex J.E. Smith (syn. *H. album* Buch.-Ham.). The powdered dried rhizome is used in the preparation for *abir*, a fragrant colored powder that is used in religious festivals and ceremonies. In certain areas in northern India, the powdered rhizome is used in conjunction with fabric dyeing where it provides insect repellency and an attractive aroma. Pan makers also use the powdered rhizome as an ingredient in their chewing tobaccos.

A limited amount of oil of *H. spicatum* rhizome oil is produced in India. An ethanolic extract of *H. spicatum* rhizomes was determined by Sharma et al. (1975) to contain cryptomeridiol.

Garg et al. (1977) used TLC and retention times on packed column GC to report that the oil of *H. spicatum* var. *acuminatum* contained:

T-7. Comparative percentage composition of the fresh rhizome oils of *Alpinia galanga* produced from plants grown in different environments

Compound	Oil 1	Oil 2	Compound	Oil 1	Oil 2
α-pinene	0.9	3.3	methyl carvacrol	0.1	0.8
camphene	2.8	3.9	bornyl acetate	2.7	0.8
β-pinene	0.7	9.3	δ-elemene	1.4	t
myrcene	0.8	t	α-terpinyl acetate	1.1	0.2
α-phellandrene	t	1.2	α-copaene	0.6	-
p-cymene	0.6	t	methyl (E)-cinnamate	-	2.5
limonene	3.4	0.5	β-cedrene	0.5	-
1,8-cineole	6.1	42.3	β-caryophyllene	0.2	0.4
(Z)-β-ocimene	t	0.9	(Z)-β-farnesene	0.2	t
(E)-β-ocimene	0.7	0.3	α-humulene	0.2	0.4
γ-terpinene	0.5	0.4	(E)-β-farnesene	0.6	0.3
cis-sabinene hydrate	-	8.8	germacrene D	1.2	0.9
terpinolene	0.3	t	α-muurolene	0.6	t
linalool	0.5	0.4	δ-cadinene	0.9	t
camphor	0.7	3.2	(E)-nerolidol	-	1.0
borneol	1.7	t	caryophyllene oxide	0.2	t
terpinen-4-ol	0.5	0.6	viridiflorol	4.5	1.0
α-terpineol	0.8	5.5	guaiol	0.2	0.1
myrtenol	-	0.1	α-cadinol	2.3	3.3
α-fenchyl acetate	54.3	t	bulnesol	2.3	t
methyl thymol	1.2	0.2			

t = trace (<0.1%)
Oil 1: Produced from subtropical-grown rhizomes
Oil 2: Produced from sub-temperate grown rhizomes

α-pinene (1.4%)
β-pinene (1.4%)
p-cymene (0.5%)
1,8-cineole (56.3%)
terpinolene (0.2%)
linalool (6.8%)
borneol (0.3%)
α-terpineol (1.6%)
β-caryophyllene (0.1%)
γ-cadinene (0.7%)

They also reported that camphor, linalyl acetate, α-humulene and eugenyl acetate were trace components of this oil.

Dixit (1977, cited in Bottini et al., 1987) reported that the rhizome oil of *H. spicatum* contained:

α-pinene (1.4%)
β-pinene (1.4%)
limonene (1.3%)
1,8-cineole (37.2%)
β-phellandrene (4.5%)
p-cymene (5.0%)
linalool (18.0%)
β-caryophyllene (24.1%)
elemol (4.2%)
caryophyllene oxide (0.5%)

Nigam et al. (1979, cited in Bottini et al., 1987) found that the main components of the rhizome oil of *H. spicatum* were:

α-pinene (1.8%)
β-pinene (4.5%)
limonene (17.0%)
1,8-cineole (27.1%)
β-phellandrene (7.0%)
p-cymene (9.6%)
linalool (16.6%)
α-terpineol (6.5%)
β-terpineol* (1.8%)
β-caryophyllene (3.5%)

* correct isomer not identified

Bottini et al. (1987) also analyzed an oil produced from fresh, finely chopped rhizomes of *H. spicatum* collected in Lariakanta (nr. Nainital, Uttarakhand, India). The constituents that were characterized in this oil were as follows:

monoterpene hydrocarbons[†] (5.9%)
1,8-cineole (27.9%)
linalool (4.4%)
terpinen-4-ol (0.7%)
α-terpineol (1.0%)
elemol (8.5%)
10-epi-γ-eudesmol (5.1%)
α-eudesmol (4.8%)
α-cadinol (5.3%)
β-eudesmol (12.6%)

[†] includes α-pinene, β-pinene and limonene

GC/MS analysis of a steam-distilled oil of the chopped and oven-dried (60°C) rhizomes of *H. spicatum* by Chowdhury et al. (2002) revealed that the oil contained the following components:

α-pinene (1.0%)
myrcene (2.5%)
δ-3-carene (0.9%)
limonene (0.6%)
p-cymene (1.0%)
1,8-cineole (4.0%)
fenchone (1.5%)
linalool (1.6%)
camphor (1.0%)
benzyl acetate (1.0%)
terpinen-4-ol (0.8%)
α-terpineol (1.6%)
linalyl acetate (0.4%)
eugenol (5.1%)
benzoic acid (0.3%)
β-patchoulene (2.8%)
(Z)-jasmone (0.3%)
longifolene (0.4%)
β-caryophyllene (0.4%)
α-humulene (0.3%)
hydrocinnamaldehyde (0.3%)
3-methylbenzaldehyde (0.4%)
elemol (17.7%)
p-methoxycinnamic acid (10.0%)
carveol* (0.7%)
cadinene* (1.7%)
eudesmol* (14.1%)
farnesol* (0.7%)
farnesol* (0.7%)

* correct isomer not identified

In addition, the authors reported that the following compounds such as: bicycle[5.2]non-1-ene, 1,5-cyclocadinene, 4-nonyn-1-ol, 4-methyl-1,3-cyclohexen-1-ol, bicycle[3.2.0]heptan-2-one, neocarvomenthone, 3-methyl-2-cyclohexen-1-one and cyclopentane carboxylic acid were also characterized. It is without question that the authors used a computer program to identify these components and it should be noted that all of them were incorrectly identified. It is also very noticeable that the normal major components namely 1,8-cineole and linalool were minor components of this oil. Perhaps the oven-drying process may have caused the loss of these constituents.

Sabulal et al. (2007) analyzed an oil produced from the fresh rhizomes of *Hedychium spicatum* var. *acuminatum* that were collected from a hill station in Thiruvananthapuram district (Kerala, India). The constituents characterized in this oil were:

camphene (0.3%)
sabinene (0.1%)
β-pinene (1.3%)
myrcene (0.1%)
α-phellandrene (0.1%)
δ-2-carene (0.1%)
α-terpinene (0.1%)
p-cymene (0.1%)
limonene (0.5%)
1,8-cineole (44.3%)
γ-terpinene (0.1%)
trans-linalool oxide[f] (0.2%)
cis-linalool oxide[f] (0.2%)
linalool (25.6%)
camphor (0.4%)
δ-terpineol (0.3%)
terpinen-4-ol (1.3%)
α-terpineol (1.9%)
β-caryophyllene (0.2%)
cis-α-bergamotene (0.7%)
α-humulene (0.3%)
allo-aromadendrene (0.1%)
epi-cubebol (0.2%)
α-muurolene (0.2%)
γ-cadinene (0.3%)
β-himachalene (0.1%)
δ-cadinene (0.9%)
hedycaryol (2.6%)
cis-sesquisabinene hydrate (0.7%)
(E)-nerolidol (0.3%)
spathulenol (0.6%)
caryophyllene oxide (0.5%)
1-epi-cubenol (0.5%)
eremoligenol (1.3%)
α-cadinol (2.3%)
β-eudesmol (2.2%)
α-eudesmol (2.3%)
T-muurolol (4.4%)
8-epi-β-bisabolol (0.5%)

[f] furanoid form

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