Progress in Essential Oils

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Styrax Oil

Styrax, which is sometimes referred to as storax, is the balsamic oleoresin obtained from trees belonging to the *Liquidambar* genus. There are two major sources of styrax; one is obtained from *L. orientalis* Mill. (so-called Asian styrax or Levant storax originating from Asia Minor), while the other is obtained from *L. styraciflua* L. (known as American styrax originating from Central America, mainly Guatemala and Honduras). *Liquidambar orientalis* exists in var. *orientalis* and var. *integriloba* forms. An oleoresin can also be obtained from *L. formosana* H., which occurs in Southeast Asia (China, Vietnam, etc.). According to Coppen (1995), this material is used locally and does not enter world trade.

To obtain the styrax oleoresin, the bark of the styrax tree is notched with a spoon-shaped sharp cutting instrument around a quarter of the diameter of the tree with an incision that is ca. 3–4 inches long (Igolen 1973). The bast of the trunk is also scraped to induce the flow of oleoresin, which takes 2–3 weeks before the initial balsam can be collected in a cuplike receptacle similar to that used in latex collection from rubber trees. The collection of balsam is done monthly and is found in the sapwood of the tree. The balsam is cleaned by washing with boiling water, removed in fluid form and allowed to become a semi-solid mass before shipping. Igolen (1973) reported that at one time 100–120 tonnes of Asian styrax were produced in Turkey; however, by the mid-1970s this amount had dropped to 60–70 tonnes. By 1990, this amount had dropped to ca. 15 tonnes annually (Tanker et al. 1993). Furthermore, it was noted by Tanker et al. that the production of the styrax balsam is under strict state control in Turkey, with the majority of it originating from the forests near Koycegiz and Mamaris.

Guenther (1943) reported that upon steam distillation of Asian styrax balsam, an oil in 0.5% yield could be produced. However, if superheated steam was used, the yield increased to 1.0% (Guenther 1952).

The oil of Asian styrax was reported (Guenther 1952) to contain cinnamic acid, cinnamyl cinnamate (occasionally known as styracine), 3-phenylpropyl cinnamate, ethyl cinnamate, benzyl cinnamate, styrene and vanillin. Guenther (1952) also reported that American styrax oil contained styrene, cinnamic acid, cinnamyl alcohol, 2-phenylpropyl alcohol, 3-phenylpropyl cinnamate, cinnamyl cinnamate and vanillin.

Huneck (1963) isolated oleanonic acid and 3-epi-oleanonic acid (triterpene acids) from the balsam of *L. orientalis*.

Igolen (1973) also reported that styrene, cinnamic alcohol, 3-phenylpropyl alcohol, 3-phenylpropyl cinnamate, cinnamyl cinnamate, cinnamic acid and vanillin were components of the oleoresin of *L. orientalis*.

Analysis of styrax oil by Boelens et al. (1981) revealed that it contained benzaldehyde, cinnamaldehyde, acetophenone, benzoic acid, cinnamic acid, 3-phenylpropionic acid, ethyl benzoate, benzyl benzoate, ethyl cinnamate, 3-phenylpropyl cinnamate, 4-ethylphenol and 4-vinylphenol.

Analysis of a sample of styrax (*L. orientalis*) by Hafizoglu (1982) using GC revealed that the main components of this sample were as follows:

styrene (0.5%)
3-phenylpropyl alcohol (0.5%)
cinnamyl alcohol (2.0%)
cinnamic acid (4.0%)
3-phenylpropyl cinnamate (7.5%)
cinnamyl cinnamate (21.0%)

The authors noted that the other approximately 60% were nonvolatile components of high molecular weight.

Maurer and Hanser (1988) characterized the presence of isobutyl cinnamate, isoamyl cinnamate and linalyl cinnamate in styrax oil.

Acar and Anil (1991) used GC/MS to analyze the neutral and acidic fractions of a steam distillate of L. orientalis balsam. The components that were identified were α-pinene, β-pinene, myrcene, camphene, limonene, 1,8-cineole, p-cymene, terpinolene, linalool, terpinen-4-ol, α-terpineol, dihydrocoumarone*, cinnamaldehyde, methyl (E)-cinnamate, an ethylphenol isomer, an allylphenol isomer*, epoxycinnamyl cinnamate*, propyl cinnamate, 1-benzoyl-3-phenylpropyne*, 3-phenylpropionic acid, benzoic acid, palmitic acid and linoleic acid. The compounds that have an asterisk in the above list require corroboration before their

natural occurrence in styrax oil can be confirmed.

Tanker et al. (1993) determined that a steam-distilled oil of styrax of Turkish origin contained styrene, benzaldehyde, benzyl alcohol, 3-propyl alcohol, cinnamyl alcohol, cinnamaldehyde, vanillin, ethyl cinnamate, benzyl cinnamate, 3-phenylpropyl cinnamate and cinnamyl cinnamate.

Chalchat et al. (1994) analyzed a fraction (40%) of Honduras styrax balsam gum using GC and GC/MS. The components identified in this fraction were as follows:

styrene (1.8%)
tricyclene (0.7%)
phenol (0.1%)
β-pinene (0.2%)
acetophenone (0.2%)
3-ethylphenol (1.1%)
3-phenylpropyl alcohol (3.1%)
cinnamyl alcohol (4.1%)
phenylpropionic acid (0.1%)
α-cubebene (0.2%)
methyl cinnamate (0.1%)
1-(4-hydroxyphenyl)-ethanone (0.1%)
β-caryophyllene (1.8%)
cinnamyl acetate (0.1%)
ethyl cinnamate (0.2%)
cinnamic acid (4.8%)
2-hydroxyphenylpropyl alcohol (0.1%)
4-(2-methylpropyl)-phenol (0.3%)
caryophyllene oxide (0.4%)
α-muurolol (1.1%)
benzyl 3-phenylpropionate (0.5%)
benzyl cinnamate (1.7%)
3-phenylpropyl 3-phenylpropionate (0.3%)
3-phenylpropyl cinnamate (32.3%)
cinnamyl cinnamate (38.0%)

Trace amounts (< 0.1%) of benzoic acid, phenylacetaldehyde and 3-phenyl-2-propenal were also characterized in the same oil. In addition, four pentadecenes (1.0%) were also determined to be constituents of this styrax fraction.

The composition of water-distilled oils of American (Honduras) and Asian (Turkey) styrax was the subject of analysis by Fernandez et al. (2005). The results of this comparative study are presented in **T-1**. Although the oil obtained from *L. formosana* is not an item of commerce it is included in this review for completeness.

Using both TLC and GC as the method of analysis, Ivanov et al. (1969) determined that the components found in steam-distilled oil of

Comparative percentage composition of the volatiles from Turkish and Honduras styrax gums **T-1**

Compound	Turkish	Honduras	Compound	Turkish	Honduras
ethylbenzene	0.1	0.5	chavicol	0.1	0.2
styrene	70.4	30.9	(E)-cinnamaldehyde	t	t
α-thujene	t	0.1	methyl phenylpropionate	–	t
benzaldehyde	t	0.6	(Z)-anethole	–	t
α-pinene	19.0	19.6	cinnamyl alcohol	0.3	0.9
camphene	0.7	0.6	3-phenylpropyl acetate	t	0.1
thuja-2,4(10)-diene	0.1	1.5	α-cubebene	t	2.1
β-pinene	4.3	4.1	α-longipinene	0.1	–
myrcene	0.4	t	α-ylangene	t	0.4
α-phellandrene	0.1	0.1	α-copaene	t	0.9
(E)-β-methylstyrene	0.2	0.8	α-cedrene	t	t
p-cymene	0.1	0.2	β-cedrene	t	0.3
limonene	1.2	0.5	cinnamyl acetate	t	t
acetophenone	0.2	3.2	isocaryophyllene	t	t
γ-terpinene	0.1	0.1	longifolene	0.1	0.9
dehydro-p-cymene	t	t	β-caryophyllene	0.2	20.2
terpinolene	0.1	0.1	ethyl cinnamate	t	t
allo-ocimene*	–	t	β-gurjunene	t	0.7
isoborneol	t	–	α-humulene	0.1	1.1
3-phenylpropanal	0.1	0.2	germacrene D	t	0.3
pinocarveol*	t	–	γ-muurolene	t	t
4-ethylpenol	0.2	1.7	α-muurolene	t	0.9
pinocamphone	t	–	calamenene*	t	0.3
ethylbenzoate	–	t	δ-cadinene	0.1	1.6
borneol	t	t	valencene	t	0.1
terpinen-4-ol	0.1	t	α-calacorene	t	0.1
α-terpineol	0.2	–	caryophyllene oxide	t	0.4
methyl chavicol	–	0.3	α-muurolol	t	0.2
myrtenol	t	0.1	benzyl cinnamate	t	0.1
verbenone	t	t	3-phenylpropyl cinnamate	0.2	0.4
3-phenylpropyl alcohol	0.2	1.4	cinnamyl cinnamate	0.4	0.2

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

L. formosana balsam were α-pinene, β-pinene, p-cymene, δ-3-carene, limonene, ethyl cinnamate, cinnamyl cinnamate, bornyl acetate, linalyl acetate, cinnamaldehyde, pulegone, methyl cinnamate, carvone, fenchone, camphor, geraniol, vanillin, 3-phenylpropyl alcohol, cinnamyl alcohol and α-terpineol. As these components were not spectroscopically confirmed as components of *L. formosana* oil, the study must be considered preliminary and the identifications tentative.

Leaf oils: An oil produced from the fresh leaves of *L. styraciflua* was found (Taltje and Bos 1979) to contain vitispirane, valeranone and valarenal as components.

In a follow-up paper, Taltje et al. (1980) characterized (E,E)-2,4-octadienal, α-thujene, α-pinene, camphene, sabinene, β-pinene, myrcene, α-phellandrene, 1,4-cineole, α-terpinene, p-cymene, β-phellandrene, 1,8-cineole, limonene, (E)-β-ocimene, *cis*-sabinene hydrate, γ-terpinene, p-cymene, a linalool oxide isomer, terpinolene, linalool, *trans*-sabinene hydrate, α-fenchyl alcohol, perillene, terpinen-1-ol, a β-terpineol isomer, 2,5-dimethyl-3-vinylhexa 1,5-dien-5-ol, borneol, terpinen-4-ol, p-cymen-8-ol, α-terpineol, *cis*-piperitol, *trans*-piperitol, vitispirane, α-copaene, β-caryophyllene, β-cubebene, α-humulene, allo-aromadendrene, germacrene D, δ-cadinene, α-muurolol, valeranone, valerenal, and anthracene in the same leaf oil of *L. styraciflua*. In addition, the authors also identified dibutyl phthalate in the oil. Obviously this non-naturally occurring constituent was a plasticizer that was leached from some plastic the leaves had come in contact with prior to oil isolation.

Wyllie and Brophy (1989) analyzed a lab-distilled oil from leaves obtained from a single sweet gum tree growing in Sydney (Australia). The components found in this leaf oil were as follows:

α-thujene (1.2%)
α-pinene (18.0%)
camphene (0.2%)
β-pinene (1.4%)
sabinene (12.8%)
myrcene (0.5%)
α-phellandrene (0.9%)
α-terpinene (6.4%)
limonene (1.2%)
β-phellandrene (2.3%)
γ-terpinene (8.9%)
p-cymene (2.9%)
terpinolene (2.1%)
β-bourbonene (0.2%)
vitispirane (0.4%)
terpinen-4-ol (30.1%)
β-caryophyllene (1.3%)
allo-aromadendrene (0.2%)
α-humulene (1.1%)
α-terpineol (3.0%)
germacrene D (1.4%)
δ-cadinene (0.6%)
γ-cadinene (0.4%)
T-cadinol (0.3%)
α-cadinol (0.1%)

Trace amounts (< 0.1%) of α-copaene, *trans*-p-menth-2-en-1-ol, *cis*-p-menth-2-en-1-ol, α-muurolene, a calamenene isomer, p-cymen-8-ol, a calacorene isomer, cubenol, T-muurolol and α-muurolol were also characterized in this oil.

Duru et al. (2002) compared the composition of the steam-distilled oil of the leaves of *L. orientalis* var. *orientalis* and *L. orientalis* var. *integrifolia* obtained from Fethiye and Milas (Turkey), respectively. The oil compositions can be found in **T-2**. The authors also found trace amounts of camphene, isomenthol, nerol, β-caryophyllene, aromadendrene and allo-aromadendrene in both oils. *cis*-Myrtanol and an isomer of farnesyl acetate were found in the oil of *L. orientalis* var. *integrifolia*, while decane and an isomer of humulene epoxide were characterized in the oil of *L. orientalis* var. *orientalis*.

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Comparative percentage composition of *Liquidambar orientalis* var. *orientalis* and *L. orientalis* var. *integrifolia* leaf oils **T-2**

Compound	var. *orientalis* oil	var. *integrifolia* oil
α-pinene	4.1	3.6
sabinene	11.0	9.4
β-pinene	1.7	1.7
α-phellandrene	0.7	t
α-terpinene	1.1	t
p-cymene	0.5	0.5
limonene	0.8	t
β-phellandrene	2.2	t
γ-terpinene	6.3	2.1
octanol	–	0.2
terpinolene	0.9	t
terpinen-4-yl acetate	1.4	1.4
nonanol	–	1.4
menthol	1.9	1.9
terpinen-4-ol	22.0	20.0
α-terpineol	25.0	28.0
myrtenol	–	3.2
trans-piperitol	–	0.7
trans-carveol	0.5	t
cis-carveol	–	5.2
viridiflorene	1.7	2.4
trans-carvyl acetate	4.2	3.3
α-longipinene	0.7	t
β-gurjunene	1.1	–
germacrene D	5.9	5.3
α-farnesene*	1.0	1.4
δ-cadinene	2.9	4.2
spathulenol	0.5	0.2
caryophyllene oxide	0.5	2.5
globulol	–	0.2
T-cadinol	0.2	0.3
farnesol*	0.6	0.6

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

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Galbanum Oil

Mihara et al. (1990) used lanthanide shift reagents to determine that the enantiomeric distribution of 2-methoxy-3-(1-methylpropyl)-pyrazine in galbanum oil was 100% (S)-(+). Furthermore, the authors determined that the odor thresholds of the (S)-(+)-, (R)-(-)- and racemic forms were 0.01 ppb and 0.04 ppb, respectively.

Using both flame photometric (FPD) and atomic emission GC detectors (AED) Fellous et al. (1993) examined the sulfur compounds found in galbanum oil and an acetonic resinoid. Through the use of both detectors, S-isopropyl 3-methyl-2-butenthioate, S-sec-butyl 3-methyl-2-butenthioate, S-sec-amyl 3-methyl-2-butenthioate, S-isopropyl thiotiglate, S-sec-butyl thiotiglate, S-sec-amyl thiotiglate, S-sec-butyl 2-methyl-2-penten-thioate, S-sec-butyl 2-methyl-2-hexen-thioate, S-sec-butyl 3-methylbutanthioate, S-isopropyl benzothioate and S-sec-butyl benzothioate were identified as constituents of galbanum oil. Sec-butyl 1-propenyl disulphide was only identified in the acetonic resinoid along with the other sulfur-containing thioesters. The structures of these compounds can be seen in **F-1**.

According to an ISO draft document (1996), the main constituents of galbanum oil were reported to be as follows:

α-pinene (7.0–21.0%)
β-pinene (45.0–65.0%)
sabinene (0.3–2.0%)
δ-3-carene (2.5–16.0%)
myrcene (2.5–3.5%)
(E,Z)-1,3,5-undecatriene (0.4–1.5%)

In addition, the ratio of (E,Z)-1,3,5-undecatriene to (E,E)-1,3,5-undecatriene was reported to be 2.0 to 5.5.

Using retention indices on a polar column and GC/MS as the methods of analysis, Moyler and Clery (1997) determined that an oil of galbanum possessed the following composition:

tricyclene (2.3%)
α-pinene (9.6%)
camphene (0.2%)
β-pinene (53.7%)
sabinene (1.4%)
δ-3-carene (13.1%)
myrcene (2.9%)
limonene (1.8%)
(Z)-β-ocimene (2.3%)
(E)-β-ocimene (1.3%)
terpinolene (0.5%)
(E,Z)-1,3,5-undecatriene (0.5%)
(E,E)-1,3,5-undecatriene (0.2%)

The authors also noted that the oil contained an additional 98 components (10.2% of the oil), although none were identified.

Sadraei et al. (2001) examined the spasmolytic activity of the oil and various extracts of galbanum oleo-gum resin ex *Ferula gummosa* Boiss. (syn. *F. galbaniflua* Boiss. et Buhse). As part of this study, the authors also examined the composition of the oil and extracts. They found that the oil contained:

α-pinene (13.0%)
β-pinene (2.0%)
myrcene (10.0%)
δ-3-carene (9.0%)
limonene (14.0%)
γ-terpinene (6.0%)
terpinolene (10.0%)
linalool (9.0%)
butyl isovalerate (3.0%)
phellandral (5.0%)
α-campholenal (1.0%)
hexyl isovalerate (2.0%)
3,3-dimethylbutyric acid (1.5%)

An ether extract of the same batch of oleo-gum resin was determined to contain:

α-pinene (34%)
β-pinene (62%)
δ-3-carene (4%)

These analyses and those not reported for a pet ether extract and methanolic extract are suspect. They are mainly included in this review for completeness.

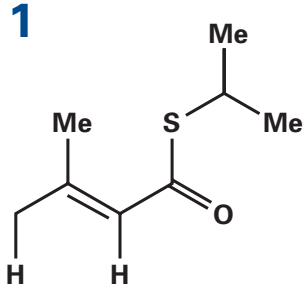
An oil produced in Iran from the oleo-gum resin of *F. gummosa* was found by Ghannadi and Amree (2002) to possess the following composition:

α-thujene (0.8%)
α-pinene (5.7%)
camphene (0.3%)
β-pinene (58.8%)
myrcene (4.6%)
α-phellandrene (0.6%)
δ-3-carene (12.1%)
p-cymene (0.1%)
limonene (4.0%)

Sulfur compounds found in galbanum oil and an acetonic resinoid using both flame photometric (FPD) and atomic emission GC detectors (AED)

F-1

1



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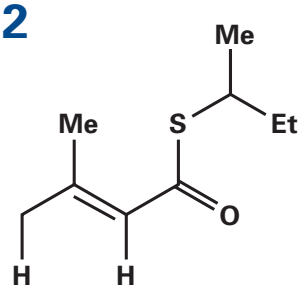

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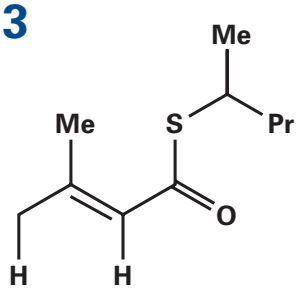

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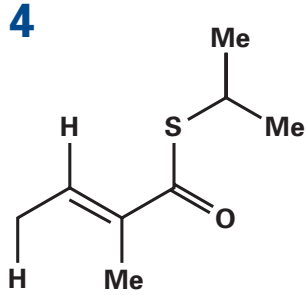

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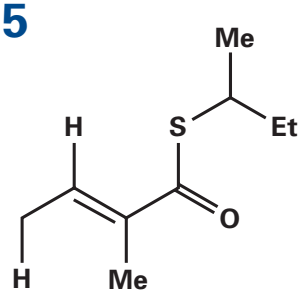

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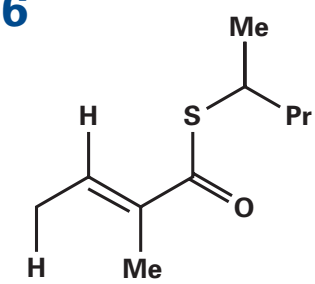

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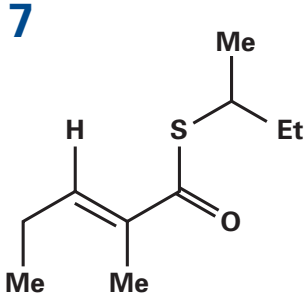

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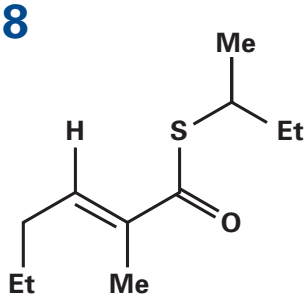

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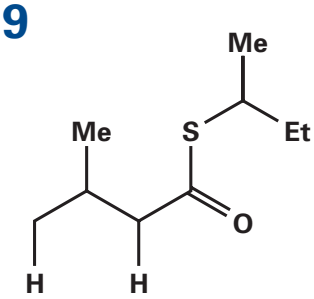

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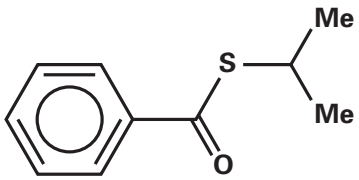

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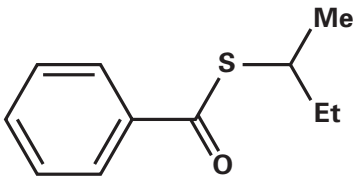

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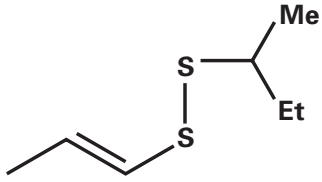

1 = S-isopropyl 3-methyl-2-butenthioate; **2** = S-sec-butyl 3-methyl-2-butenthioate; **3** = S-sec-amyl 3-methyl-2-butenthioate; **4** = S-isopropyl thiotiglate; **5** = S-sec-butyl thiotiglate; **6** = S-sec-amyl thiotiglate; **7** = S-sec-butyl 2-methyl-2-pententhioate; **8** = S-sec-butyl 2-methyl-2-hexenthioate; **9** = S-sec-butyl 3-methylbutanthioate; **10** = S-isopropyl benzothioate; **11** = S-sec-butyl benzothioate; **12** = sec-butyl 1-propenyl disulphide

(Z)-β-ocimene (1.2%)
(E)-β-ocimene (0.2%)
terpinolene (0.5%)
linalool (0.5%)
trans-verbenol (0.2%)
(E,Z)-undeca-1,3,5-triene (1.8%)
myrtenol (0.2%)
α-fenchyl acetate (0.1%)
α-terpinyl acetate (0.5%)
β-caryophyllene (0.1%)
γ-elemene (2.4%)
α-humulene (0.3%)
germacrene D (0.7%)
γ-cadinene (0.3%)
δ-cadinene (0.4%)
germacrene B (0.6%)
guaiol (0.5%)
β-eudesmol (0.1%)
bulnesol (0.2%)

Finally, Sayyah et al. (2001) analyzed an oil produced from the fruit of F. gummosa using both GC and GC/MS. The constituents characterized in this oil were as follows:

α-thujene (3.3%)
α-pinene (18.3%)
camphene (0.2%)
sabinene (3.1%)
β-pinene (50.1%)
α-phellandrene (0.3%)
δ-3-carene (6.7%)
allo-ocimene† (2.9%)
β-phellandrene (2.1%)
myrtenal (0.5%)
α-cubebene (0.4%)
α-elemene† (0.9%)
germacrene D (1.8%)
α-muurolene (0.8%)
δ-cadinene (1.2%)
β-sesquiphelladrene† (1.1%)

†incorrect identification based on GC elution order

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D.A. Moyler and R.A. Clery, *The aromatic resins: Their chemistry and uses.* In: *Flavours and Fragrances.* Edit., K.A.D. Swift, pp. 46–115, Royal Soc. Chem., Cambridge, UK (1997).

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Clove Oils and Extracts

Raina et al. (2001) analyzed the leaf oil of clove growing on the Andaman Islands (India). The composition of this oil was determined to be as follows:

(E)-β-ocimene (0.03%)
linalool (0.08%)
terpinen-4-ol (0.03%)
nerol (0.79%)
eugenol (94.41%)
α-copaene (0.04%)
β-caryophyllene (2.91%)
α-humulene (0.36%)
(E,E)-α-farnesene (0.06%)
γ-cadinene (0.18%)
(E)-nerolidol (0.03%)
caryophyllene oxide (0.67%)
humulene epoxide II (0.07%)
T-cadinol (0.07%)
cadalene (0.18%)
hexadecyl acetate (0.09%)

A lab-produced supercritical CO_2 extract of clove buds obtained from a market in Cairo (Egypt) was analyzed by El-Ghorab and El-Massry (2003). Using GC/MS as their method of analysis, the extract was found to contain the following constituents:

2-heptanone (0.04%)
1,1-ethandiyl acetate‡ (0.01%)
ethyl benzoate (0.01%)
methyl salicylate (0.15%)
chavicol (0.46%)
eugenol (48.05%)
farnesene° (14.89%)
α-humulene (3.75%)
eugenyl acetate (24.26%)
geranyl butyrate (2.77%)
tetradecanal (0.15%)
benzyl benzoate (0.23%)

‡not a naturally occurring constituent; °correct isomer not identified

Commercial samples of clove bud and leaf oil were screened against *Pediculus capitis* (human head louse) by Yang et al. (2003). The main constituents of these oils can be seen in **T-3**.

Zachariah et al. (2005) examined 10 accessions of clove growing in an experimental farm in Peruvannamuzhi (Kerala, India) for the bud (B) and pedicel (P) (flower stalk) oil content and eugenol, eugenyl acetate and β-caryophyllene contents. The range of data obtained was as follows:

oil content: B = 12.9–18.5%; P = 3.0–7.7%
eugenol: B = 44.0–55.0%; P = 60.0–72.4%
eugenyl acetate: B = 12.0–18.7%; P = 15.1–20.2%
β-caryophyllene: B = 14.7–25.0%; β-caryophyllene was not found in the P oil

Srivastava et al. (2005) compared the composition of the clove bud oils produced in the laboratory by water distillation of buds of Indian and Madagascan origin. The similarities and differences between these two oils can be seen in **T-4**. In addition, the authors also examined a commercial sample of clove leaf oil from Madagascar. This oil composition was determined to be as follows:

methyl salicylate (0.1%)
carvone (0.1%)
chavicol (0.1%)
linalyl acetate (0.1%)
eugenol (82.0%)
isoeugenol* (0.1%)
β-caryophyllene (13.0%)
trans-α-bergamotene (0.4%)
α-humulene (1.5%)
eugenyl acetate (0.4%)
γ-cadinene (0.3%)
(E)-nerolidol (0.2%)
caryophyllene oxide (0.5%)
humulene epoxide II (0.1%)
T-cadinol (0.2%)
α-cadinol (0.1%)
heptadecane (0.2%)
butyl octanoate (0.1%)
myristic acid (0.1%)
isopropyl myristate (0.1%)
oleic acid (0.1%)

*correct isomer not identified

Kapoor et al. (2005) reported that a steam-distilled oil of clove buds that was analyzed by GC/MS contained:

formic acid† (6.6%)
myrtenone (49.1%)
pulegone (4.1%)

Percentage composition of the main constituents of clove leaf and bud oil **T-3**

Compound	Leaf oil	Bud oil	Compound	Leaf oil	Bud oil
β-caryophyllene	15.6	7.3	eugenol	79.5	69.8
α-humulene	3.4	0.8	eugenyl acetate	–	20.9
methyl salicylate	–	0.2	chavicol	0.1	0.4
caryophyllene oxide	0.6	0.2			

Comparative percentage composition of clove bud oils of Indian and Madagascan origin **T-4**

Compound	Indian oil	Madagascan oil	Compound	Indian oil	Madagascan oil
octane	–	0.1	β-caryophyllene	19.5	7.2
α-pinene	–	0.1	*trans*-α-bergamotene	1.3	0.2
(E)-β-ocimene	–	t	α-humulene	1.9	0.8
methyl benzoate	–	t	allo-aromadendrene	0.3	0.1
linalool	0.1	t	germacrene D	0.1	–
m-methylacetophenone	t	0.1	eugenyl acetate	2.1	6.0
methyl salicylate	0.3	0.1	α-selinene	0.1	0.3
nerol	t	0.1	calamenene*	0.1	0.1
carvone	0.1	0.2	γ-cadinene	0.8	0.2
chavicol	t	0.1	δ-cadinene	0.2	–
linalyl acetate	t	0.1	(E)-nerolidol	0.1	0.4
(E)-anethole	t	–	caryophyllene oxide	0.4	0.3
eugenol	70.0	82.6	humulene epoxide I	–	0.1
butyl benzoate	1.3	–	humulene epoxide II	0.1	t
α-cubebene	–	t	cubenol	–	0.1
methyl eugenol	–	t	T-cadinol	0.1	0.1
α-ylangene	–	t	T-muurolol	–	t
isoeugenol*	0.8	0.1	α-cadinol	0.1	0.1
vanillin	t	–	heptadecane	–	0.1
α-copaene	0.1	0.1			

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

eugenol (27.1%)
β-caryophyllene (8.7%)
α-humulene (1.1%)
caryophyllene oxide (1.0%)
hexadecanoic acid (4.3%)

†unusual clove bud oil constituent

This reviewer does not know the structure of the so-called myrtenone. Also, clove bud oil is rich in eugenol and eugenyl acetate, not a terpenoid ketone.

Lopez et al. (2005) screened a number of oils against a series of food-borne bacterial and fungal strains. Among the oils screened was a commercial oil of clove; however, whether the oil was bud, stem or leaf was not described. Nevertheless, the authors reported that the headspace above the oil, as determined by Solid Phase Microextraction (SPME) with a polydimethylsiloxane phase, was found to possess the following composition:

methyl chavicol (0.2%)
thymol† (0.1%)
eugenol (82.0%)
β-caryophyllene (10.0%)
α-humulene (2.9%)
eugenyl acetate (0.5%)
δ-cadinene (0.4%)
cis-calamenene (0.3%)

†incorrect identification

A commercial sample of clove leaf oil obtained in Germany was analyzed by GC and GC/MS (Jirovetz et al. 2006). In addition to demonstrating scavenging activity (antioxidant effect) of the oil against 2,2-diphenyl-1-picrylhydracyl, it was determined to possess the following composition:

limonene (0.1%)
1,8-cineole (0.1%)
methyl salicylate (0.1%)
methyl chavicol (0.2%)
chavicol (0.1%)
eugenol (76.8%)
β-caryophyllene (17.4%)
(E)-isoeugenol (0.1%)
α-humulene (2.1%)
α-farnesene* (0.1%)
eugenyl acetate (1.2%)
caryophyllene alcohol (0.1%)
caryophyllene oxide (0.4%)
humulene epoxide* (0.1%)

*correct isomer not identified

Trace amounts (< 0.1%) of *cis*- and *trans*-limonene oxide, methyl eugenol, (Z)-isoeugenol, α-clovene, (Z)-methyl isoeugenol, (E)-methyl isoeugenol, (Z)-isoeugenyl acetate and (E)-isoeugenyl acetate were also found in this same oil.

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