



# Progress in Essential Oils

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## Asafoetida Oil and Extract

Oleo-gum-resins are naturally occurring mixtures of an essential oil, gum and a resin. One of the most well-known oleo-gum-resins is asafoetida. Asafoetida is a well-known condiment and source of traditional medicine, mainly in Afghanistan, India, Iran and Pakistan. The name asafoetida originates from the Persian word ‘aza,’ or ‘asa,’ (which means resin or mastic gum) and the Latin word ‘foetida’ (meaning “fetid, bad, stinking”). According to Shah and Zare (2013), it is also known as ‘devil’s dung.’

In addition to being a popular condiment in Afghanistan, India, Iran and Pakistan, particularly India, asafetida is reported to possess a wide range of biological properties (Sahebkar and Iranishi, 2010), which leads to its wide use in the above-listed countries in their traditional medicines (Iranshahy and Iranishahi, 2011, and Shah and Zare, 2014).

Asafoetida is an oleo-gum-resin obtained from the exudates of the roots of the Afghanistani, Indian and Iranian endemic plant members of several *Ferula* species. Although *Ferula assa-foetida* L. is the main source of asafoetida, other *Ferula* species such as *F. foetida* (Bunge) Regel, *F. rubricaulis*. Boiss., *F. alliacea* Boiss. and *F. narthex* Boiss. have been reported (Coppen, 1995) to be used as a source of asafoetida gum-oleo-resin.

Raghavan et al. (1974) reported that the origin of *F. alliacea* was Iran, *F. assa-foetida* was Iran and Afghanistan (although it is cultivated in a few border countries to a limited extent), *F. foetida* was southern Turkey, Iran and Afghanistan, *F. subricaulis* was Iran, and *F. narthex* was western Tibet, Indian and Pakistani Kashmir.

The majority of the Afghanistani production of *F. assa-foetida* oleo-gum-resin is found along the Iranian border in Herat Province, while the major

producing regions in Iran are located in the Kerman and Mashad areas. George (2012) noted that minor production of the oleo-gum-resin is found in Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan and Uzbekistan, and possibly Turkmenistan.

*Ferula assa-foetida* is a perennial, monoecious, herbaceous member of the Apiaceae that can grow to a height of 2–3 m, with a circular mass of 30–40 cm. It possesses 10-cm-thick flowering stems (panicles) that possess large compound pubescent umbels that contain 20–25 whitish-yellow inflorescent umbelettes that, when pollinated, yield 1-cm-long 8-mm-broad, winged reddish brown fruit (seeds) that contain a milky juice. Although all parts of the plant possess the distinctive pungent fetid smell, the asafoetida oleo-gum-resin is obtained by tapping the large, thick, pulpy taproot that can be 12.5–15 cm in diameter at its crown (Shah and Zare, 2013).

Just prior to flowering (March and April in Iran), the soil is cleaned away from the upper part of the tap root and the stem is removed close to the crown to facilitate the ease of tapping it to collect the milk. It is normal to protect the exudate with stones from the hot sun.

The tapping of the oleo-gum-resin from exposed *F. assa-foetida* taproot/rhizome generally takes place when the plants are flowering. A cut is made above the ground level and the soft exudate is collected every few days. Initially, the exudate is sticky and grey in color, while on drying it becomes hard and darkens to an amber color (Golmohammadi, 2013).

Once the exudate is collected, fresh slices are made on the taproot, from which further exudate is collected. This procedure is repeated for up to three months, after which exudation has ceased (Coppen 1995).

In India, asafoetida is available in three main forms: paste, tears and masses. The paste often contains extraneous matter. The tears are dull greyish-white, yellow or reddish-brown, rounded or flattened, and can be agglutinated, sticky or separate. The mass, which is the most commonly encountered form, consists of tears agglomerated into a mass that often contains roots and soil impurities (George, 2012).

Asafoetida is known as ‘hing’ if its origin is *F. assa-foetida* or hingra if its origin is *F. foetida*. The spice trade favors hing because it is richer in odor and is water-soluble, while hingra is oil-soluble (George, 2012). Shivashankar et al. (1972) reported that asafoetida hing and asafoetida hingra are two distinctly different products. Asafoetida hing can be of Iranian or Afghanistani (Pathani) origin. Iranian hing was reported to be available as Iranian-ras, Iranian Khada or XL, and Iranian numbers 1, 2, 3 and 4. Pathani hing was reported to be available as Nayachal, Hadda, Nayazamin, Galmin, Kabuli, Shabandi, Kawal, Charas, etc., according to its geographical origin.

Asafoetida oleo-gum-resins were reported by Guzman and Siemonsma (1999) to contain resin (30%), gum (25–50%) and an essential oil (6–9%), whereas Singhal and Kulkani (1997) noted that it comprised resin (40–64%), gum (25%), an essential oil (10–17%) and ash (1.5–10%).

Nataraj and Gundakalle (2010) obtained market samples of asafoetida from four different Indian markets: Belagaum (B), Mumbai (M), Pune (P) and Mysore (Y). The samples were dry, hard, irregular, large or small, light brown, strongly pungent masses (B); irregular mixtures of yellowish-brown soft and sticky, strongly pungent and acrid tears (M); dry, hard, square, large

or small, white and less pungent masses (P); and dry, long, irregular-sized, reddish-brown, strongly pungent masses (Y). The samples (B), (M), (P) and (Y) were found to possess oil contents of 4.99%, 6.90%, 3.9% and 5.0%, respectively.

George (2012) reported that the average annual imports and exports of asafoetida from India between 2005 and 2010 were a 66 metric tonnes and 452 mt., respectively. In its natural habitat, *F. assa-foetida* is normally found growing in desert plains at altitudes of 600–1200 m (Golmohammadi, 2013).

The gum fraction of asafoetida oleo-gum-resin mainly comprises glucose and polysaccharides such as arabinose, galactose, rhamnose, glucuronic acid and 4-O-methyl glucuronic acid (George, 2012). The resin fraction is more complex as it contains notanol, asaresinotannol A and B (Singhal and Kulkarni, 1997), either in the free state or in the partially combined form with ferulic acid [3-(4-hydroxy-3-methoxyphenyl-2-propenoic acid)] and umbelliferone (7-hydroxycoumarin) in the free or combined state with ferulic acid (Parimal et al., 2011). The resin fraction contains mainly ferulic acid esters (60%), free ferulic acid (1.3%) (George, 2012), farnesiferol A, B and C (Caglioti et al., 1958, 1959), foetidin, assafoetidin (Buddrus et al., 1985), ferocolicin (Bunerji et al., 1988) as a disulfide, and coumarin A (Appendino et al. 1994) and coumarin B (Kajimoto et al. 1989). A more detailed discussion of the non-volatile constituents that have been identified in *F. assa-foetida* can be found in the review by Iranshahi and Iranshahi (2011).

In the United States, asafoetida oil, fluid extract and oleo-gum-resin have been granted GRAS status. Most of the commercially available asafoetida powder is a mixture of rice flour, gum arabic and about 30% asafoetida oleo-gum-resin.

A survey of the recent literature reveals that asafoetida oil has been reviewed before (Lawrence, 1981, 1985 and 2003).

Khajeh et al. (2005) compared the composition of supercritical fluid CO<sub>2</sub> extracts of dried *F. assa-foetida* plants with that of a hydrodistilled oil. The composition of the extracts and oil as determined by GC-FID and GC/MS is shown in **T-1**.

A hardened oleo-gum-resin of asafoetida that was purchased in Italy was macerated with methanol at room temperature for seven days. After filtration and removal of the methanol in a rotary film evaporator at 50°C, the dried extract was dissolved in dimethyl sulfoxide and analyzed using GC-FID and GC/MS by Angelini et al. (2009). The constituents characterized in this methanol extract were as follows:

1-propenyl sec-butyl disulfide<sup>a</sup> (19.5%)  
4-vinylguaiaicol (17.4%)  
ferulic acid (11.2%)  
β-pinene (6.2%)  
acetaldehyde diethyl acetal<sup>b</sup> (5.1%)  
α-pinene (3.1%)  
guaiaol (2.1%)

vanillin (1.2%)  
elemol (1.1%)  
β-caryophyllene (0.9%)  
α-humulene (0.8%)  
farnesyl acetate\* (0.6%)  
(Z)-β-ocimene (0.6%)  
sativene (0.6%)  
methyl chavicol (0.5%)  
trans-pinocarvyl acetate (0.5%)  
(E)-β-ocimene (0.5%)  
aristolene (0.5%)  
β-eudesmol (0.5%)  
farnesol\* (0.3%)  
bis (sec-butyl) disulfide (0.2%)  
limonene (0.2%)  
α-terpineol (0.2%)  
pinocarveol<sup>c</sup> (0.2%)  
1-propyl sec-butyl disulfide (0.2%)  
α-fenchyl alcohol (0.1%)  
myrcene (0.1%)

**T-1. Comparative percentage composition of the volatiles of a number of supercritical fluid CO<sub>2</sub> extracts of *Ferula assa-foetida* plants and its hydrodistilled oil of supercritical fluid CO<sub>2</sub> extracts of *Ferula assa-foetida* plants and its hydrodistilled oil**

Compound	SCF volatiles*	Oil
α-pinene	1.2–2.0	5.9
β-pinene	0.9–1.5	5.0
myrcene	0.9–1.4	0.8
α-phellandrene	0.6–0.9	0.7
1,4-cineole	0–0.8	1.4
p-cymene	0–0.5	0.7
limonene + β-phellandrene	1.4–2.2	2.0
(Z)-β-ocimene	2.9–4.1	1.3
(E)-β-ocimene	0–6.1	2.6
1-propyl-sec-butyl disulfide	0–0.7	0.6
(Z)-1-propenyl-sec-butyl disulfide	4.9–5.4	8.7
(E)-1-propenyl-sec-butyl disulfide	50.3–59.4	40.0
bis (1-methyl propyl) disulfide	1.2–1.4	0.8
bis (1-methyl-1-propenyl) disulfide	1.9–2.4	3.4
(E)-anethole	0–1.9	–
β-caryophyllene	–	1.4
bis (1-methyl-thio) propyl disulfide	2.5–3.6	–
α-humulene	0–1.0	1.0
γ-gurjunene	0–1.1	1.9
germacrene D	0–2.1	–
viridiflorene	0–3.1	0.5
cuparene	–	1.0
γ-cadinene	–	0.8
(Z)-γ-bisabolene	0–1.0	–
δ-cadinene	–	1.5
(E)-γ-bisabolene	0–1.4	–
germacrene B	7.7–11.7	7.8
10-epi-γ-eudesmol	–	1.7
γ-eudesmol	–	0.6
hinesol	–	0.9

\*Supercritical fluid CO<sub>2</sub> volatiles

2,3,4-trimethylthiophene (0.1%)  
 isovaleric acid (0.1%)  
 camphene (0.1%)

<sup>a</sup>correct isomer not identified; <sup>b</sup>probably the (Z)-isomer; <sup>c</sup>probably the dimethyl acetal; <sup>d</sup>probably the *trans*-form

Trace amounts of  $\alpha$ -fenchene and camphene were also characterized in this methanol extract.

Dehpour et al. (2009) collected the above-ground aerial parts of *F. assa-foetida* from the sari forest (Iran). After air-drying and chopping, the materials were subjected to 3-hr hydrodistillation. The oil was analyzed by GC/MS only; however, as it appears that most of the constituents were misidentified, the composition will not be included in this review

The roots of *F. assa-foetida* were collected from Gonabad (Khorasan Razavi Province) and Tabas (Yazd Province) at two elevations (1150 m and 690 m, respectively) in Iran by Mirzaei and Hasanloo (2009). After air-drying, the root samples were powdered and separately hydrodistilled for 3 hr to produce oils from Gonabad and Tabas samples in 0.8% and 1.6%, respectively. The two oils were subjected to GC-FID and GC/MS analysis, the results of which are presented in **T-2**.

Sahebkar and Iranishi (2011) reported that the main components (>2.0%) they identified in the oleo-gum-resin of *F. assa-foetida* of Iranian origin were  $\alpha$ -pinene,  $\beta$ -pinene, (E)-1-propenyl sec-butyl disulfide, (Z)-1-propenyl sec-butyl disulfide and 1-methylthiolpropyl-(E)-1-propenyl disulfide.

Kanini et al. (2011) collected the aerial parts of *F. assa-foetida* from Babini (Kerman, Iran). After air-drying, the herbage was subjected to hydrodistillation for 4 hr. The oil was analyzed using GC-FID and GC/MS to reveal that it possessed the following composition:

$\alpha$ -pinene (11.3%)  
 $\beta$ -pinene (6.1%)  
 myrcene (0.2%)  
 $\alpha$ -phellandrene (0.5%)  
 p-cymene (0.7%)  
 limonene (2.2%)  
 $\beta$ -phellandrene (0.1%)  
 (Z)- $\beta$ -ocimene (2.8%)  
 terpinolene (< 0.1%)  
 (Z)-1-propenyl-sec-butyl disulfide (9.1%)  
 (E)-1-propenyl-sec-butyl disulfide (32.8%)  
 bis (1-methylpropyl) disulfide (3.4%)

isocaryophyllene (2.1%)  
 $\alpha$ -humulene (1.0%)  
 $\gamma$ -gurjunene (0.6%)  
 cuparene (0.1%)  
 $\delta$ -cadinene (2.7%)  
 germacrene B (5.1%)  
 10-epi- $\gamma$ -eudesmol (0.1%)

In contrast to the oil of *F. assa-foetida*, the aerial parts of *F. foetida* were collected by Kanani et al. (2011) from Sabzevar (Khorasan, Iran), air-dried and subjected to hydrodistillation for 4 hr. The constituents characterized in this oil using GC-FID and GC/MS were as follows:

$\alpha$ -pinene (3.4%)  
 dimethyl trisulfide (0.1%)  
 $\beta$ -pinene (0.8%)  
 myrcene (0.9%)  
 $\delta$ -3-carene (< 0.1%)  
 p-cymene (0.2%)

limonene (0.7%)  
 $\gamma$ -terpinene (0.1%)  
 2,5-diethylthiophene (27.5%)  
 2,3,4-trimethylthiophene (49.0%)  
 $\beta$ -caryophyllene (0.5%)  
 3,6-dimethoxy-2-ethyl-benzaldehyde (3.7%)  
 $\alpha$ -humulene (0.2%)  
 elemicin (8.1%)  
 valeraldehyde propyleneglycol acetal<sup>†</sup> (2.1%)

<sup>†</sup>identity requires corroboration

Fruit of *F. assa-foetida* were collected from plants growing on Mount Telesm (Kermanshah Province, Iran), air-dried, and subjected by Bahrami et al. (2012) to simultaneous distillation and extraction for 3 hr using a modified Likens-Nickerson apparatus. Analysis of the oil using GC/MS and retention indices only revealed that it possessed the following composition:

**T-2. Comparative percentage composition of the root oils of two origins of *Ferula assa-foetida***

Compound	Gonabad oil	Tabas oil
(Z)-1-propenyl methyl disulfide	0.3	—
(E)-1-propenyl methyl disulfide	0.2	0.2
propyl sec-butyl disulfide	0.3	0.4
(Z)-1-propenyl sec-butyl disulfide	12.4	9.2
(E)-1-propenyl sec-butyl disulfide	30.7	18.8
bis (1-methyl propyl) disulfide	0.5	1.3
bis (1-methylthio) ethyl disulfide	0.1	—
$\alpha$ -elemene	—	0.5
methyl (1-methylthio) ethyl disulfide	0.4	—
tetradecane	—	0.5
2,2-bis (methylthio) propane	0.5	0.3
bis (1-methylthio) propyl disulfide	5.8	3.2
methyl (1-methylthio) propyl disulfide	10.9	4.3
$\gamma$ -gurjunene	0.3	—
2-methyl 2-methylthiopropional	1.4	2.5
$\beta$ -selinene	—	0.3
pentadecane	0.3	0.8
methyl pentyl tetrasulphide	2.4	3.1
$\delta$ -cadinene	0.5	—
(Z)-asarone	—	0.9
germacrene B	0.8	0.7
guaial	2.6	4.6
hexadecane	—	0.2
carotol	0.3	1.1
$\alpha$ -eudesmol	1.5	2.5
10-epi- $\gamma$ -eudesmol	12.7	18.7
guaia-6, 9-diene	0.3	0.6
aristolene	—	0.8
hinesol	2.9	4.5
agrospirol	2.8	5.1
7-epi- $\alpha$ -eudesmol	4.8	8.2
guaial acetate	2.8	—

$\alpha$ -pinene (1.7%)  
 camphene (0.2%)  
 sabinene (1.0%)  
 myrcene +  $\beta$ -pinene (0.6%)  
 $\alpha$ -phellandrene (0.5%)  
 p-cymene (0.2%)  
 limonene (0.9%)

(Z)- $\beta$ -ocimene (0.5%)  
 (E)- $\beta$ -ocimene (0.5%)  
 l-propyl sec-butyl disulfide (0.5%)  
 (Z)-l-propenyl sec-butyl disulfide (5.9%)  
 (E)-l-propenyl sec-butyl disulfide (1.1%)  
 bis (1-methyl propyl)disulfide (0.5%)  
 $\alpha$ -copaene (0.7%)

$\beta$ -elemene (0.3%)  
 $\alpha$ -cubebene (0.5%)  
 isocaryophyllene (0.6%)  
 $\alpha$ -gurjunene (6.2%)  
 bis (1-methylthio) propyl disulfide (1.1%)  
 $\beta$ -gurjunene (0.5%)  
 (Z)-l-propenyl propyl trisulfide (1.0%)  
 (E)-l-propenyl trisulfide (0.3%)  
 $\alpha$ -humulene (1.2%)  
 $\alpha$ -acoradiene (0.3%)  
 germacrene D (3.1%)  
 $\beta$ -acoradiene (0.3%)  
 $\gamma$ -gurjunene (0.7%)  
 $\beta$ -selinene (1.3%)  
 $\alpha$ -selinene (0.9%)  
 cadina-1,4-diene (1.1%)  
 cuparene (0.4%)  
 $\beta$ -bisabolene (1.1%)  
 $\gamma$ -cadinene (3.4%)  
 methyl pentyl tetrasulfide (0.5%)  
 $\delta$ -cadinene (4.8%)  
 calamenene\* (2.2%)  
 (E)- $\gamma$ -bisabolene (0.6%)  
 $\alpha$ -cadinene (0.3%)  
 elemol (0.5%)  
 germacrene B (11.0%)  
 $\alpha$ -amorphene (0.3%)  
 $\beta$ -humulene (0.9%)  
 longipinene epoxide (0.8%)  
 guaial (2.7%)  
 5-epi-7-epi- $\alpha$ -eudesmol (4.9%)  
 $\gamma$ -eudesmol (1.1%)  
 T-cadinol (23.2%)  
 $\beta$ -eudesmol (1.9%)

\*correct isomer not identified

**T-3. Comparative percentage composition between two seed oils of *Ferula assa-foetida* from different Iranian locations**

Compound	Location 1 oil	Location 2 oil
2,5-dimethyl thiophene	0.1	t
(Z)-1-propenyl methyl disulfide	0.3	0.1
$\alpha$ -thujene	0.4	0.4
(E)-1-propenyl methyl disulfide	0.3	0.2
bornylene	0.1	—
$\beta$ -pinene	0.7	0.2
myrcene	0.2	0.3
methyl sec-butyl disulfide	0.2	0.3
limonene	0.4	0.3
(Z)- $\beta$ -ocimene	0.2	—
terpinolene	—	0.2
dipropyl disulfide	—	0.2
(Z)-1-propenyl sec-butyl disulfide	23.9	23.0
(E)-1-propenyl sec-butyl disulfide	18.8	25.5
bis (1-methyl propyl) disulfide	1.3	2.3
$\alpha$ -fenchyl acetate	0.4	0.1
syclohexyl sec-butyl disulfide	0.3	0.6
linalyl acetate	0.2	0.2
sabinyl acetate*	0.4	t
$\alpha$ -longipinene	1.9	0.7
neryl acetate	0.5	—
isolekene	0.2	0.7
methyl (1-methylthio) ethyl disulfide	1.0	0.5
$\alpha$ -gurjunene	0.2	0.5
bis (1-methylthio) propyl disulfide	19.4	11.0
$\alpha$ -guaiene	0.7	—
$\alpha$ -humulene	0.5	0.6
ar-curcumene	0.3	0.9
$\beta$ -selinene	1.1	0.2
cuparene	0.4	0.7
$\delta$ -cadinene	0.2	0.4
germaarene B	1.3	3.2
ledol	0.6	0.5
globulol	1.0	0.1
guaial	1.9	1.9
carotol	—	0.7
viridiflorol	0.7	1.4
$\gamma$ -eudesmol	2.0	0.3
hinesol	0.4	2.5
agarospirol	1.7	4.0
cubenol	1.5	0.1
bulnesol	6.7	4.3
$\alpha$ -bisabolol	3.1	1.6
guaial acetate	1.2	2.3
farnesyl acetate*	0.6	0.5

\*correct isomer not identified; t = trace (< 0.1%); location 1 = Kohsorkh Kashmac; location 2 = Yazd

Mizraei and Hasanloo (2012) collected seeds of *F. assa-foetida* from two locations in Iran that were 420 km apart. One collection was from Kohsorkh Kashmac (Khorassan Razavi Province), and the other from Yazd (Yazd Province). Both locations were at elevations greater than 1,200 m. Oils were separately produced from each of the collections in 2.85% and 2.3% yield, respectively, by using hydrodistillation for 3 hr. Each oil was analyzed by GC-FID and GC/MS, and a summary of the results can be seen in **T-3**.

The bitter oleo-gum-resin (B) of *F. assa-foetida* was collected from Larestan (Fars, Iran), the sweet oleo-gum-resin (S) was collected from Yazd (Iran) and a third sample (I) was purchased from a market in Bangalore (India). Each sample was subjected to hydrodistillation for 3 hr to yield 4.75% oil (B), 3.41% oil (S) and 3.13% oil (I). The results of the analyses of the three oils as determined by GC-FID and GC/MS by Kameli et al. (2012) can be seen in **T-4**. Trace amounts (<0.05%) of sabinene,  $\alpha$ -phellandrene,



$\delta$ -3-carene, p-cymene, terpinolene, (E,E)-allo-ocimene and another allo-ocimene isomer, and tetradecane were found in the bitter asafoetida oil, neryl acetate,  $\alpha$ -elemene and  $\beta$ -eudesmol were found in the sweet asafoetida oil, and  $\alpha$ -phellandrene and p-cymene were found in the Indian asafoetida oil.

The leaves of *F. assa-foetida* collected during its flowering period from some cultivated plants growing in Khorramabad (Lorestan Province, Iran) were subjected to hydrodistillation for 4 hr to yield 0.38% oil. Analysis of this leaf oil by Ahmadvand et al. (2013) using GC-FID and GC/MS revealed that the main constituents of the oil were:

eremophilene (31.3%)  
 $\delta$ -cadinene (22.1%)  
 longiborneol (12.1%)  
 dehydro-aromadendrene (4.0%)  
 isolekene (4.0%)  
 $\gamma$ -gurjunene (3.9%)  
 $\alpha$ -guaiene (3.5%)  
 $\alpha$ -pinene (1.5%)  
 ledene oxide (1.0%)  
 $\beta$ -caryophyllene (1.0%)  
 $\alpha$ -gurjunene (1.0%)  
 $\beta$ -pinene (0.2%)

Kavoosi and Rowshan (2013) performed collection of *F. assa-foetida* oleo-gum-resin by the incision method from the crown of the plant at three times (June 15, 30 and July 15). The colors of the oleo-gum-resin from the different collections were brown (June 15), red (June 30) and gray-blond (July 15). Each of the air-drying collections was separately dissolved in water and hydrodistilled to yield an oil that was analyzed by a combination of GC-FID and GC/MS. The results of the analyses are shown in T-5. Examination of these results really shows the importance of the exudate collection date on the oil composition.

L. Caglioti, H. Naef, D. Arigoni and O. Jeger, *Zur Kenntnis der Sesquiterpene und azulene. 126. Mitteilung Über die Inhaltsstoffe der asafoetida I. Farnesiferol A*. *Helv. Chim. Acta*, **41**, 2278–2292 (1958).

L. Caglioti, H. Naef, D. Arigoni and O. Jeger, *Zur Kenntnis der Sesquiterpene und azulene. 127 Mitteilung Über die Inhaltsstoffe der asafoetida II. Farnesiferol B and C*. *Helv. Chim. Acta*, **42**, 2557–2570 (1959).

S. Shivashankar, M.L. Shankaranarayana and C.P. Natarajan, *Asafoetida-varieties, chemical composition, standard and uses*. *Indian Food Pack*, **26**(2), 36–44 (1972).

B. Raghavan, K.O. Abraham, M.L. Shankaranarayana, L.V.L. Sastry and C. P. Natarajan, *Asafoetida II. Chemical composition and physico-chemical properties*. *Flav. Indust.*, **5**, 179–181 (1974).

B.M. Lawrence, *Asafoetida oil*. In: *Progress in essential oils*. *Perfum. Flavor.*, **6**(1), 38, 43 (1981); **10**(1), 43 (1985); **28**(1), 78–81 (2008).

J. Buddrus, H. Bauer, E. Abu-Mustafa, A. Khattab, S. Mishaal, E.A.M. El-Khrisy and M. Lischeid, *Foetidin, a sesquiterpenoid coumadin from Ferula assa-foetida*. *Phytochemistry*, **24**, 869–870 (1985).

A. Banerji, B. Mallick, A. Chatterjee, H. Budzikiewicz and M. Breuer, *Asafoetidin and ferocolicin, two sesquiterpenoid coumarins from Ferula assafoetida Regel*. *Tet. Lett.*, **29**, 1557–1560 (1988).

T. Kajimoto, K. Yahiro and T. Nohara, *Sesquiterpenoid and disulphide derivatives from Ferula assafoetida*. *Phytochemistry*, **28**, 1761–1763 (1989).

G. Appendino, S. Tagliapetra, G.M. Nano and J. Jakupovic, *Sesquiterpene coumarin ethers from asafoetida*. *Phytochemistry*, **35**, 183–186 (1994).

J.J.W. Coppen, *Asafoetida and Galbanum*. In: *Gums, resins and latexes of plant origin*. p 108–111, FAO, UN. Rome (1995).

R.S. Singhal and P.R. Kulkarni, *Handbook of Indices of Food Quality and Authenticity*. p. 395, Woodhead Publishing, Cambridge, UK (1997).

C.C. de Guzman and J.E. Siemonsma, *Plant Resources of South-East-Asia. No 13, Spices*.

#### T-4. Comparative percentage composition of the oils of a bitter, sweet and Indian sample of *Ferula assa-foetida* oleo-gum-resin

Compound	B-oil	S-oil	I-oil
$\alpha$ -pinene	8.2	t	0.1
camphene	0.1	—	—
$\beta$ -pinene	1.3	t	t
myrcene	0.4	—	t
methyl butyl disulfide	—	0.2	0.1
limonene	0.2	—	0.1
(Z)- $\beta$ -ocimene	6.1	—	0.1
(E)- $\beta$ -ocimene	1.3	—	0.2
1-propyl-sec-butyl disulfide	0.5	t	4.2
(Z)-1-propenyl-sec-butyl disulfide	19.3	18.7	19.7
(E)-1-propenyl-sec-butyl disulfide	15.7	30.5	25.7
bis (1-methyl propyl) disulfide	0.1	1.6	0.8
(E)-2-decenal	—	—	0.7
bornyl acetate	0.1	—	—
p-vinyl guaiacol	—	—	1.1
$\alpha$ -longipinene	—	0.1	—
$\beta$ -elemene	0.1	—	—
bis (1-methylthio) ethyl disulfide	—	0.3	—
isocaryophyllene	0.2	—	—
bis (1-methylthio) propyl disulfide	29.7	5.1	44.4
(Z)- $\beta$ -farnesene	—	—	0.3
(E)- $\beta$ -farnesene	—	—	0.3
$\alpha$ -humulene	0.9	—	—
cis-cadina-1-(6),4-diene	0.3	—	—
$\beta$ -selinene	0.6	—	0.2
4-epi-cis-dihydro agarofuran	3.1	—	—
$\beta$ -dihydro agarofuran	0.6	0.2	—
$\beta$ -bisabolene	—	—	1.0
$\beta$ -cadinene	0.2	—	0.2
elemol	0.1	—	—
1-(propyl thio)-propyl disulfide	—	22.7	—
tetrahydro-2-ethyl thiophene	—	7.1	0.7
5-epi-7-epi- $\alpha$ -eudesmol	0.3	0.3	—
10-epi- $\gamma$ -eudesmol	4.0	2.2	—
eremoligenol	0.6	0.3	—
valerianol	1.0	—	—
methyl t-butyl sulfide	—	3.9	—
guaiol acetate	0.2	—	—

B-oil: bitter asafoetida oil; S-oil: sweet asafoetida oil; I-oil: Indian asafoetida oil

p. 255, Backhuys Publishers, Leiden, The Netherlands (1999).

M. Khajeh, Y. Yamini, N. Bahranifar, F. Sefidkon and M. Reza Pirmoradei, *Comparison of essential oils compositions of Ferula assa-foetida obtained by supercritical carbon dioxide extraction and hydro-distillation methods*. Food chem., **91**, 639–644 (2005).

P. Angelini, R. Pagiotti, R. Venanzoni and B. Granetti, *Antifungal and allelopathic effects of Asafoetida against Trichoderma harzianum and Pleurotus spp.* Allelopoeth J., **23**, 357–368 (2009).

A.A. Dehpour, M.A. Ebrahimzadeh, N.S. Fazel and N.S. Mohammad, *Antioxidant activity of the Methanol extract of Ferula assafoetida and its essential oil composition*. Gragas Aceites, **60**, 405–412 (2009).

H.H. Mirzaei and T. Hasanloo, *Essential oil composition of root of Ferula assa-foetida from two Iranian localities (Gonabad and Tabas)*. Asian J. Chem., **21**, 6354–6358 (2009).

H.R. Nataraj and M.B. Gundakalle, *Coparative pharmacognostic and phytochemical study of different market samples of asafoetida (Ferula narthex Bioss)*. Internat J. Res. Ayuveda Pharmacy, **1**, 258–263 (2010).

A. Sahebkan and M. Iranshahi, *Volatile Constituents of the Genus Ferula (Apiaceae)*. A Review J. Essent oil Bear. Plants, **14**, 504–531 (2011).

M.R. Kanani, M.R. Rahiminejad, A. Sonboli, V. Mozaffarian, S.K. Osaloo and S.N. Ebrahimi, *Chemotaxonomic significance of the essential oils of 18 Ferula species (Apiaceae) from Iran*. Chem. Biodivers., **8**, 503–517 (2011).

M. Iranshahi and M. Iranshahi, *Traditional uses, phytochemistry and pharmacology of asa foetida (Ferula assa-foetida oleo-gum-resin)—A review*. J. Ethnopharmacol., **134**, 1–10 (2011).

C.K. George, *Asafoetida*. In: *Handbook of Herbs and Spices*. 2nd Edn., Vol 2. Edit., K.V. Peter, p 151–165, Woodhead Publishing, Cambridge, UK (2012).

G. Bahrami, R. Soltani, S-E. Sajjadi, M-R. Kanani, R. Naderi, N. Ghiasvand and Y. Shokoohinia, *Essential oil composition of Ferula assa-foetida L. fruits from western Iran*. J. Rep. Pharmaceut. Sci., **2**(2), 1–8 (2012).

H.H. Mirzaei and T. Hasanloo, *Chemical composition of the essential oils of Ferula assa-foetida seeds from two Iranian ecotypes*. J. Essent. Oil Bear. Plants, **15**, 84–88 (2012)

Z. Kameli, A. Alizadeh and A. Aboutalebi, *Bitter and Sweet Ferula assa-foetida L. essential oil composition from Iran and its comparison with Ferula assa-foetida L. used in India*. Internat Res. J. Appl. Basic Sci., **3**, 919–923 (2012).


F. Golmohammadi, *Medicinal plant of Ferula assa-foetida and its cultivating, main characteristics and economical importance in South Khorasan province—east of Iran*. Tech. J. Engin. Appl. Sci., **3**, 2334–2346 (2013).

N.C. Shah and A. Zare, *Asafoetida (Heeng): The well known medicinal condiment of India and Iran*. Herbal Tech. Industry, **10**(4), 1–8 (2013).

H. Ahmadvand, H. Amiri, Z.D. Elmi and S. Bagheri, *Chemical composition and antioxidant properties of Ferula assa-foetida leaves essential oil*. Iran. J. Pharmacol. Therapeutics, **12**(2), 52–57 (2013).

G. Kavooosi and V. Rowshan, *Chemical composition, antioxidant and antimicrobial activities of essential oil obtained from Ferula assa-foetida oleo-gum-resin: Effect of collection time*. Food Chem, **138**, 2180–2187 (2013).

N.C. Shah and A. Zare, *Asafoetida (Heeng): The well known medicinal-condiment of India and Iran*. Scitech J., **1**(4), 30–36 (2014).

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## T-5. Comparative percentage composition of the oils of *Ferula assa-foetida* oleo-gum-resin collected at different times

Compound	1	2	3
α-pinene	4.4	10.8	21.4
camphene	0.2	0.1	t
β-pinene	4.2	10.3	47.1
myrcene	0.7	1.6	0.6
α-phellandrene	2.9	0.1	t
p-cymene	0.4	t	t
limonene	3.0	0.6	t
β-phellandrene	t	t	0.2
(Z)-β-ocimene	5.7	7.9	2.4
(E)-β-ocimene	2.5	3.0	1.4
allo-ocimene*	0.3	1.0	t
(E,E)-allo-ocimene	0.3	0.4	t
1-propyl-sec-butyl disulfide	0.3	0.3	0.1
(Z)-1-propenyl-sec-butyl disulfide	8.1	27.8	0.1
(E)-1-propenyl-sec-butyl disulfide	23.9	20.3	0.7
1,2-dithiolane	t	t	18.6
thionol	t	t	2.6
bis (1-methyl propyl) disulfide	0.7	0.6	0.1
bornyl acetate	0.2	0.1	t
trans-pinocarvyl acetate	0.1	0.8	t
p-vinyl guaiacol	0.9	0.2	t
β-cedrene	0.1	0.2	t
β-caryophyllene	0.2	0.1	t
β-ylangene	0.1	0.2	t
bis (1-methyl thio) propyl disulfide	0.1	1.5	t
β-gurjunene	0.4	0.8	t
α-guaiene	0.7	0.1	t
α-humulene	0.5	0.4	0.1
β-selinene	1.0	0.4	t
α-selinene	0.3	0.1	t
propyl nitrito†	t	t	3.7
β-dihydro agarofuran	4.1	1.8	t
β-bisabolene	0.1	0.1	t
γ-cadinene	0.1	0.3	t
δ-cadinene	0.3	0.6	t
α-himachalene	0.1	0.1	t
elemol	0.3	0.1	t
longipinene epoxide	t	t	0.8
guaial	3.1	0.1	t
5-epi-7-epi-α-eudesmol	2.1	0.6	t
10-epi-γ-eudesmol	15.1	5.3	t
γ-eudesmol	3.5	t	t
agarospirol	3.0	0.1	t
β-eudesmol	1.1	0.4	t
α-eudesmol	4.5	t	t

t = trace (< 0.1%); 1 = oil from exudate from three collection times, June 15; 2 = oil from exudate from three collection times, June 30; 3 = oil from exudate from three collection times, July 15