17 Star Anise

B. Chempakam and S. Balaji

17.1. Introduction

Star anise (*Illicium verum* Hook) is a spice that closely resembles anise in flavour, obtained from the star-shaped pericarp. It is native to southern China and northern Vietnam and is grown almost exclusively in southern China, Indochina and Japan. The spice was first introduced into Europe in the 17th century. The oil, produced by a process of steam distillation, is substituted for European aniseed (*Pimpinella anisum* L.) in commercial drinks (Morton, 2004). The fruit is star-shaped and consists of 8–13 carpels joined centrally and is a well-known spice used in Vietnamese cuisine (Loi and Thu, 1970). It is so named from the stellate form of its fruit. The essential oil of star anise fruits is used in the confectionary trade to flavour liquorice and other candies and in the baking trade to flavour cakes, cookies and biscuits. It has a volatile oil content of 2.5–3.5% in the fresh fruit and 8–9% in the dried material. The fixed oil content is about 20% (Heath, 1981). This small tree, belonging to the family *Iliciaceae* which grows in the evergreen forests of southern China and the mountainous regions of Indochina, is cultivated in the Vietnamese province of Lang Son and in the mountainous regions of Eastern Laos.

Japanese star anise (*I. anisatum*), a similar tree, is not edible because it is highly toxic. Cases of illness, including serious neurological effects such as seizures, which are reported after using star anise tea, may be the result of using this species (Biessels *et al.*, 2002). It is similar to *I. verum*, but its fruit is smaller and with a weaker odour, which is said to be more similar to cardamom than to anise. While it is poisonous, and therefore unsuitable for internal use, the Chinese use the fruits to treat some skin problems (Lai *et al.*, 1997).

Vietnam produces more than 2000 t of star anise seeds per annum. About 1600 t of seeds are exported to Cuba, China and the Soviet Union. In addition, 200–250 t of essential oil are shipped to France and Czechoslovakia. In China, which is the largest supplier of star anise to the world market, Vietnamese star anise is blended and then exported to France. In France, it is used as a raw material in the production of alcoholic beverages (FAO, 1993).

17.2. Botany and Uses

Botany

The plant belongs to the genus of the family *Illiciaceae*, order *Illiciales*, subclass *Magnoliidae*, class *Magnoliopsida*. It is a small to medium-sized evergreen tree reaching up to 8 m (26 ft) in height. The trees have evergreen, aromatic leaves and bisexual flowers. The leaves are lanceolate and the axillary flowers are yellow, the female portion of the flower consists of 7–15 carpels (Rosengarten, 1969). The fruits are star-shaped, reddish-brown, consisting of 6–8 carpels arranged in a whorl. Each carpel is 10 mm long, boat-shaped, hard and wrinkled, containing a seed. The seeds are brown, compressed, ovoid, smooth, shiny and brittle.

They are harvested before they ripen, then sun dried. Star anise, as the name suggests, is star-shaped, radiating between five and ten pointed boat-shaped sections, about eight on average. These hard sections are seedpods. Tough-skinned and rust-coloured, they measure up to 3 cm (1.25 in) long. The fruit is picked before it ripens and is then dried (Lust, 1984; Stuart, 1987). The tree is propagated by seed and cultivated mainly in China and Japan for export and home markets.

Uses

The stars are available whole, or ground to a red-brown powder. The bulk of the oil in commerce is obtained from the star anise fruit in China. Apart from its use in sweetmeats and confectionery, it contributes to meat and poultry dishes, combining especially well with pork and duck. It is also one of the ingredients used to make the broth for the Vietnamese noodle soup called *phở*.

Star anise is an ingredient of the traditional five-spice powder of Chinese cooking. Chinese stocks and soups very often contain the spice. In the West, star anise is added in fruit compotes and jams and in the manufacture of anise-flavoured liqueurs, the best known being anisette. It is an ingredient of the mixture known as 'Chinese Five Spices' (Morton, 2004). The water-soluble extract of *I. anisatum* promotes hair growth and may be a useful additive in hair growth products (Sakaguchi *et al.*, 2004). Star anise is also used in different Indian curry powders for making meat preparations.

17.3. General Composition

The seeds contain some volatile oil, resin and a large amount of fixed oil (Meisner, 1818). The fruit (without the seeds) contains volatile oil, resin, fat, tannin, pectin and mucilage. The volatile oil (*oil of star-anise*) amounts to about 4–5% and is almost identical with *oil of anise* (from *P. Anisum*, Linné). Star-anise oil from Chinese fruit has a specific gravity at 15°C (59°F) of 0.980–0.990 and its known constituents are anethol, phellandrene, safrol and hydro-quinone-ethyl-ether (Flückiger, 1879). Poisonous *sikimin* has been detected in the fruit (Eykmann, 1881), while Schlegel (1885) found a crystalline principle of a pronounced odour of musk. He also found *saponin* in the watery extract.

The closely related Japanese star anise, *I. anisatum*, is highly toxic. It contains a poisonous sesquiterpene lactone, called anisatin, causing severe inflammation of the kidneys, urinary tract and digestive organs, as well as affecting the nervous system (Lederer *et al.*, 2006). It contains anisatin, shikimin and sikimitoxin, which cause severe inflammation of the kidneys, urinary tract and digestive organs. Other compounds present in this toxic species of *Illicium* are safrole and eugenol, which are not present in *I. verum* and are used to identify its adulteration.

Anisatin and its derivates are suspected of acting as strong GABA antagonists. It is impossible to recognize Chinese and Japanese star anise in its dried or processed form by its appearance only, due to morphological similarities between the species. There are cases of product recalls when products containing star anise were found to be contaminated by Japanese anise (Biessels *et al.*, 2002; Johanns *et al.*, 2002; Vandenberghe *et al.*, 2003; Lee *et al.*, 2003b; Ize-Ludlow *et al.*, 2004).

17.4. Chemistry

Chinese star anise is an evergreen bush of the magnolia order grown in Vietnam and southern China. The ripe, strongly anise-smelling fruits open up in a star. They are used as a spice and for the production of star anise oil by steam distillation. Star anise oil is a colourless to pale yellow liquid which solidifies on cooling.

Volatiles

Physical properties

Table 17.1 presents the physical properties of the star anise essential oil. The colour of the steam distilled oil samples was greenish-yellow and that of oils from liquid CO_2 extraction was yellow. This can also be seen by the difference between the average dominant wavelength for liquid CO_2 extraction and that for steam distillation.

The specific gravity of steam-distilled oil was a little higher than that of the oil from liquid CO_2 extraction. The specific gravities of the samples from the two methods were similar to the standard values of anise essential oil reported by the FCC (Food Chemicals Codex), as cited by Heath (1981). The refractive indices, as well as the optical rotation of the oils from steam distillation and those from liquid CO_2 were not significantly different. All values of optical rotation were of *levo* orientation.

Chemical composition

The essential oil, which ranges from 2.5 to 5.0%, includes the following chemical compounds: α-pinene, camphene, β-pinene, linalool, *cis*-anethole, *trans*-anethole, safrole, anisaldehyde and acetoanisole. The chemical structures of these compounds are given in Fig. 17.1. The oil is of medium viscosity and will solidify at low temperatures and may

need to be hand-warmed before use. The oil is extracted by steam distillation from the dried ripe fruit and seeds (WHO and Institute of Materia Medica, 1990).

The main component (80–90%) is (*E*)-anethole. Star anise oil, and (*E*)-anethole isolated from it, is used in anise liqueur (Anisette, Sambuca) and anise brandy (Pernod, Ouzo, Raki, Arak), liquorice sweets, toothpaste, etc. It has almost completely replaced the original anise seed oil, obtained from the umbellifer *P. anisum*. Shikimic acid (Wang *et al.*, 2001), used in the production of the antiviral drug Tamiflu® (Roche), is extracted from the fruits of Chinese star anise and related species (Rahway, 1989).

Star anise contains primarily anethole and fatty oil. Essential oil of star anise has a sweetish, burning flavour and a highly aromatic odour. It is located primarily in the woody shell and, to a lesser extent, in the seed. An elevated moisture content and excessively high temperature create a risk of self-heating.

Zhou *et al.* (2005) determined anethole composition quantitatively by GC in the fruit of *I. verum* from various places in the Guangxi province. The average recovery rate and the RSD were 102.31% and 1.78%, respectively. The content of anethole in the fruit of *I. verum* from various places was more than 4.5%.

Table 17.1. Physical properties, extraction yield and anethole content of star anise essential oil.

Characters	Steam distillation	Liquid CO2 extraction
Extraction yield (% r.m.)	10.2	11.2
Anethole content in essential oil (%)	92.2	89
Total anethole content (% r.m.)	9.4	10.0
Physical properties		
Colour	Greenish-yellow	Yellow
Dominant wavelength	571.8 nm	575.2 nm
Specific gravity	0.9873 (25,125)	0.9859 (25/25)
Refractive index	1.5553 (25°C)	1.5517 (25°C)
Optical rotation	0.3167 (20°C)	0.3333 (20°C)

Source: Tuan and Hanantileke (1997).

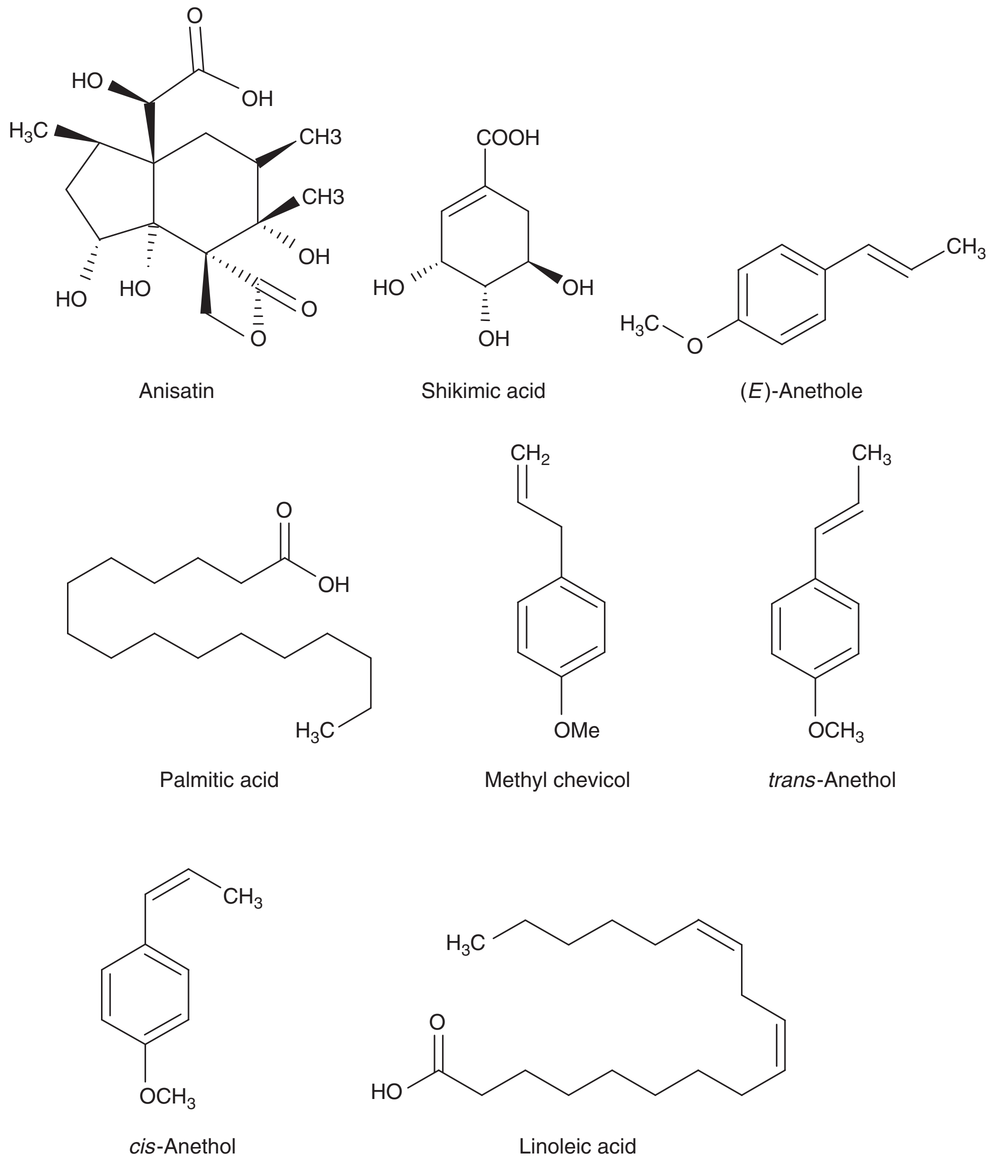

Fig. 17.1. Components of essential oil from star anise (*I. verum*).

Extraction techniques

The essential oil from star anise fruits traditionally is extracted by steam distillation. These processes are not expensive but can induce thermal degradation, hydrolysis and water solubilization of some fragrance constituents (Reverchon, 1997).

In recent years, extraction of oils from plant materials with liquid and supercritical CO_2 has drawn increasing attention from researchers in the food and other industries (Stahl and Gerard, 1985; Rizvi *et al.*, 1986). The composition of star anise essential oil isolated by supercritical extraction is qualitatively similar to the composition of hydrodistilled anise oil reported in the literature (Cu, 1986; Cu *et al.*, 1990). From a quantitative point of view, essential oil obtained by supercritical extraction contains a higher percentage of anethole with respect to hydrodistilled oil (Table 17.1). Indeed, the percentage of this antioxidant compound ranged from 71.6 to 85.9% in the hydrodistilled oil against 94.2% found in the supercritical extract (Tuan and Hanantileke, 1997).

Star anise volatile oils can also be isolated by supercritical CO_2 extraction coupled to a fractional separation technique. Gas chromatography-mass spectrometry analysis of the various fractions obtained in different extraction and fractionation conditions allowed the identification of the best operating conditions for the isolation of essential oil. A good extraction performance was obtained operating at 90 bar and 50°C (for 630 min) for both treated materials. Optimum fractionation was achieved in both cases by operating at 90 bar and −10°C in the first separator and at 15 bar and 10°C in the second (Della Porta *et al.*, 1998).

Results of detailed GC-MS analysis of these two fractions are reported in Table 17.2 (volatile oil column and waxes column). The Kovats index for each compound identified is also reported in the same table. Anise waxes were formed mainly by *n*-pentacosane (35.7%), *n*-heneicosane (25.8%), *n*-tricosane (10.3%), *n*-docosane (9.0%) and *n*-tetracosane (6.2%). Volatile oil contained 94.2% of anethole (*cis* and *trans*). In the oil, estragole (1.4%), limonene (1.7%), linalool (0.3%), two terpineol isomers (0.3%) and linalyl acetate (0.3%) were also present. Caryophyllene (0.5%) and *trans*-bergamotene (0.7%) were the main compounds among sesquiterpenes.

A relatively simple apparatus was described by Lucchesi *et al.* (2004) for extracting essential oils from aromatic plant material by atmospheric solvent-free microwave extraction (SFME) without the addition of any solvent or water. The essential oils from spices like star anise extracted by SFME for 30 min and 1 h were similar to those obtained by conventional hydrodistillation (HD) for (respectively) 4 and 8 h.

Another extraction technique for volatile oil by online coupled packed capillary high performance liquid chromatography-capillary gas chromatography (micro-HPLC-CGC) yielded new compounds that were not found nor separated before by conventional capillary gas chromatography-mass spectrometry method (Wang *et al.*, 2004).

Composition

The GC-MS pattern of fruit volatile oil of star anise (*I. verum* Hook) shows the presence of 25 components, which account for 99.9% of the total amount (Padmashree *et al.*, 2007). The major components are *trans*-anethole (93.9%), estragole (1.05%) and limonene (1.05%) (Table 17.3). Fifteen components are identified from its acetone

extract, accounting for 80.27% of the total amount. *trans*-Anethole (51.81%) is found as a major component, along with linoleic acid (11.6%), 1-(4-methoxyphenyl)-prop-2-one (6.71%), foeniculin (5.29%) and palmitic acid (1.47%).

Phenylpropanoids

Two new phenylpropanoid glucosides and an alkyl glucoside from the fruits of *I. verum* were isolated and their chemical structures were elucidated on the basis of spectroscopic studies (Lee *et al.*, (2003a,b). The two racemic mixtures of phenylpropanoids [1-(4′-methoxyphenyl)-(1*R*, 2*S* and 1*S*, 2*R*)-propanediol and 1-(4′-methoxyphenyl)-(1*R*, 2*R* and 1*S*, 2*S*)-propanediol] were isolated, along with two known phenylpropanoids.

Sesquiterpenes

A summary of the different sesquiterpenes isolated from the extracts of various plant parts of star anise is shown in Table 17.4.

Three neurotropic sesquiterpenoids, veranisatins A, B and C, were isolated from star anise (*I. verum* Hook. fil., *Illiciaceae*) (Nakamura *et al.*, 1996). A dichloromethane extract of *I. tsangii* yielded murolane sesquiterpenes and menthane monoterpenes (Ngo *et al.*, 1999).

Sy and Brown (1998) isolated prezizaane sesquiterpene angustisepalin from the aerial parts of *I. angustisepalum*. Angustisepalin is formally the 10-benzoyl ester of neomajucin, previously reported from *I. majus*.

Table 17.2. Area percentages of the compounds found in the star anise extracts.

Compounds	SFE oil (%)[a]	Waxes (%)[a]	HP (%)[a]
α-Thujene	tr	–	–
α-Pinene	0.09	–	–
β-Pinene	0.03	–	–
Myrcene	0.04	–	–
α-Phellandrene	0.02	–	–
3-Carene	0.09	–	–
α-Terpinene	0.01	–	–
para-Cymene	0.04	–	–
Limonene	1.74	–	–
cis-Ocimene	tr	–	–
γ-Terpinene	0.06	–	–
Terpinolene	0.02	–	–
Linalool	0.31	–	–
4-Terpineol	0.20	–	–
α-Terpineol	0.09	–	–
Estragole	1.45	–	–
cis-Anethole	0.15	–	–
trans-Anethole	94.05	–	60.53
Lynalyl acetate	0.11	–	–
α-Cubebene	0.21	–	–
β-Elemene	0.01	–	–
Caryophyllene	0.53	–	0.36
α-*trans*-Bergamotene	0.72	–	0.53
α-Humulene	0.02	–	–
β-*cis*-Farnesene	0.01	–	–
δ-Cadinene	–	–	0.11
Spathulenol	–	–	0.15
$C_{12}H_{15}N_3O_2$	–	–	0.87
Torreyol	–	–	0.07
α-Cadinol	–	–	0.46
$C_{16}H_{14}O$	–	–	2.56
trans-cis-Farnesol	–	–	2.11
$C_{15}H_{26}O$	–	–	1.97
$C_{15}H_{20}O_3$	–	–	2.23
Palmitic acid	–	0.72	0.33
Methyl palmitate	–	1.37	0.80
$C_{20}H_{28}O$	–	–	0.53
Methyl linoleate	–	–	0.54
n-Heneicosane	–	25.85	3.15
Methyl heneicosane	–	3.44	–
n-Docosane	–	9.03	7.10
n-Tricosane	–	10.35	7.37
n-Tetracosane	–	6.22	4.27
n-Pentacosane	–	35.71	1.70
n-Hexacosane	–	2.18	1.92
n-Heptacosane	–	1.73	0.34
n-Octacosane	–	0.64	tr
n-Nonacosane	–	2.77	tr

Note: [a]Percentages are expressed as gas chromatograph areas without any correction factor.
tr = Percentages lower than 0.01; – = not detectable.
SFE oil column: compounds recovered in the second separator.
Waxes column: compounds recovered in the first separator (90 bar and 50°C for 510 min).
HP column: composition of the extract (300 bar and 50°C for 180 min) recovered in the second separator on a previously treated matter.
Source: Della Porta *et al*. (1998).

Table 17.3. Flavour profile of star-anise volatile oil.

Name of compound	Identity	Peak %
α-Pinene	KI,MS	0.12 ± 0.020
β-Pinene	KI,MS	0.03 ± 0.020
Myrcene	KI,MS	0.02 ± 0.003
α-Phellandrene	KI,MS	0.04 ± 0.001
3-Carene	KI,MS	0.15 ± 0.020
α-Terpinene	KI,MS	0.02 ± 0.001
p-Cymene	KI,MS	0.05 ± 0.003
Limonene	KI,MS	1.05 ± 0.040
trans-Ocimene	KI,MS	0.09 ± 0.010
cis-β-Ocimene	KI,MS	0.01 ± 0.001
γ-Terpinene	KI,MS	0.04 ± 0.001
Terpinolene	KI,MS	0.03 ± 0.003
Linalool	KI,MS	0.29 ± 0.020
γ-Terpineol	KI,MS	0.12 ± 0.030
4-Terpineol	KI,MS	0.09 ± 0.020
α-Terpineol	KI,MS	0.08 ± 0.010
Estragole	KI,MS	1.05 ± 0.120
cis-Anethole	KI,MS	0.14 ± 0.020
trans-Anethole	KI,MS	93.9 ± 1.560
α-Cubebene	KI,MS	0.10 ± 0.010
β-Clemene	KI,MS	0.01 ± 0.001
Caryophyllene	KI,MS	0.10 ± 0.010
Bergamotene	KI,MS	0.01 ± 0.002
Δ-Cardinene	KI,MS	0.04 ± 0.002
α-Cadinol	KI,MS	0.02 ± 0.001

Source: Padmashree *et al.* (2007).

Three novel seco-prezizaane sesquiterpenes were isolated from leaves of *I. parviflorum* (swamp star anise, yellow star anise), a species occurring endemically in Central Florida. The compound cycloparvifloralone possesses a hitherto unknown ring system with a cage-like acetal/hemiketal structure. Lactones (cycloparviflorolide) and parviflorolide, which were obtained as an inseparable mixture, coexist in hemiketal/keto equilibrium. It could be shown that a 4,7-hemiketal occurs in an analogous fashion to pseudoanisatin, a known constituent of other *Illicium* species. From the fruits of *I. floridanum* the novel ortholactone was also isolated (Schmidt, 1999).

17.5. Medicinal and Pharmacological Properties

Star anise essential oil, *I. verum*, is often used as a substitute for anise seed oil in perfumery because it shares similar chemistry. It is used in aromatherapy to help relieve coughing, colic, cramping, hiccups and indigestion. It should be used in moderation to avoid skin irritation (Rosengarten, 1969; Lust, 1974; Stuart, 1987).

Like anise, star anise has been assigned the following pharmacological properties:

- Carminative
- Stomachic
- Stimulant and diuretic
- Antirheumatic
- Antimicrobial

Table 17.4. Sesquiterpenes isolated from the extracts of various plant parts of star anise.

Pericarp of *I. merrillianum* (Huang *et al.*, 2002, 2004)	Barks of *I. difengi* (Huang *et al.*, 1997)	Pericarp of *I. minwanense* (Yokoyama *et al.*, 2002, 2003)	Fruits of *I. floridanum* ELLIS (Schmidt *et al.*, 2001)
3-Deoxypseudoanisatin 2β-hydroxy-3,6-dedioxypseudoanisatin 8-α-hydroxy-10-deoxycyclomerrillianolide 10-β-hydroxypseudoanisatin 10-β-hydroxy cyclopseudoanisatin 1,6-dihydroxy-3-deoxyminwanensin 8-deoxy merrilliortho-lactone	3 β-*O*-acetyl-mangiferolic acid, mangiferonic acid, mangiferolic acid butulinic acid	(1*S*)- and (1*R*)-minwanenone, 1-α-hydroxy-6-deoxypseudoanisatin, (2*S*)-hydroxy-6-deoxypseudoanisatin, 3-oxopseudoanisatin, (3*S*, 6*R*)-4, 7-epoxy-6-deoxypseudoanisatin, 7-*O*-methylpseudomajucin and (+)-8,11,13,15-abietatetraene)	debenzoyl-7-deoxo-1-α, 7-α-dihydroxytashironin, debenzoyl-7-deoxo-7 α-hydroxytashironin, debenzoyl-7-deoxo-7 α-hydroxy-3-oxotashironin (1–3)

- Chemopreventive
- Insecticidal
- Antiflu drug.

Antimicrobial property

The spice has got potent antimicrobial properties. Chemical studies indicate that a major portion of this antimicrobial property is due to anethole, present in the dried fruit. Studies with isolated anethole (compared with standard anethole) indicated that it was effective against bacteria, yeast and fungal strains (De *et al*., 2002). The recent findings of Singh *et al.* (2006) showed that the volatile oil inhibited the growth of *Fusarium moniliforme* completely at 6 μl dose. In the case of extract, 50% mycelial zone inhibition was obtained for *Penicillium citrinum* and *P. viridicatum*. Moreover, the volatile oil was found to be effective for controlling the growth of *F. moniliforme* and *Aspergillus niger*, whereas the extract has been found to be highly effective for *A. flavus*. The extract has shown better activity for *Staphylococcus aureus* and *Bacillus cereus* in comparison with volatile oil and commercial bactericide, i.e. Ampicillin. However, volatile oil has shown better activity for *Salmonella aeruginosa* and *B. subtilis*.

Phenylpropanoid glucosides from the fruits are preventive agents against sepsis (Lee *et al*., 2003b). Anethol extract from star anise seeds inhibits fungal growth (Hitokoto *et al*., 1980). It is also effective against dermatitis and the oil does not give cross-reactions and pseudo cross-sensitivity (Rudzki and Grzywa, 1976).

Antioxidant activity

The extract has shown excellent activity for the inhibition of primary and secondary oxidation products in rapeseed oil and could be considered as a natural antioxidant, which may be used for the chemoprevention of diseases occurring due to oxidative deterioration (Anon., 1992). The antioxidant activity is due to the high percentage of anethole, which is more than 80% (Padmashree *et al*., 2007). The antioxidant activity of star anise oil is due to the high percentage of anethole (more than 80%).

Chemopreventive property

Phenylpropanoids and phytoquinoids isolated from *Illicium* plants showed inhibitory activities against Epstein-Barr virus early antigen (EBV-EA), even at 1 × 10 mol ratio, and the inhibitory activity of their compounds was found to be more than that of β-carotene (Itoigawa *et al*., 2004). Two phenylpropanoids having prenyl group, 4-allyl-2-methoxy-6-(3-methyl-2-butenyl) phenol and 4-allyl-2, 6-dimethoxy-3-(3-methyl-2-butenyl) phenol, showed more potent activities as antitumour promoters. The presence of a prenyl moiety in the phenylpropanoids plays an important role in antitumour-promoting activity. Hence, the prenylated phenylpropanoids might be valuable as potential cancer chemopreventive agents.

Insecticidal property

Thirteen seco-prezizaane terpenoids isolated from star anise species (*I. floridanum*, *I. parviflorum* and *I. verum*) were found to possess insecticidal activity (Kuriyama *et al*., 2002). Anisatin and pseudoanisatin exhibited moderate insecticidal activity against German cockroaches (*Blattella germanica* L.). The insecticidal activities of phenylpropene, (*E*)-anethole, derived from the fruit of star anise, *I. verum*, were examined by Chang and Ahn (2002) against adults of *B. germanica*. As naturally occurring insect-control agents, the *I. verum* fruit-derived materials could be useful for managing populations of *B. germanica*. Insecticidal properties were also observed in non-polar crude extracts of star anise against eggs, larvae and adults of *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch (Ho *et al*., 1995).

Antiflu drug

Star anise is the industrial source of shikimic acid, a primary ingredient used to create the antiflu drug, Tamiflu (Goodman, 2005). Tamiflu is regarded as the most promising drug to mitigate the severity of the bird flu H5N1 strain of virus. Currently, Tamiflu is the only drug available which may reduce the severity of bird flu (also known as avian flu).

17.6. International Specifications, Desirable Limits

Packaging and storage

Star anise is harvested and shipped all year round. It is packaged in, among other things, bast bales (50 kg) and bags (40 kg).

Conditions for storage

TEMPERATURE Favourable travel temperature range: 5–25°C. Star anise should be transported in areas which exhibit the lowest temperatures during the voyage and are dry. In any event, storage beneath the weather deck or, in the case of shipping, in containers in the uppermost layer on deck, must be avoided as the deck or container is strongly heated by the intense tropical sun and, at temperatures of > 25°C, essential oils may be lost.

HUMIDITY/MOISTURE Star anise should be stored away from goods which are sensitive to moisture/humidity or release moisture (e.g. copra).

Designation	Humidity/water content
Relative humidity	60–70%
Water content	8–12%
Maximum equilibrium moisture content	65%

VENTILATION Star anise requires particular temperature, humidity/moisture and possibly ventilation conditions. In order to avoid formation of mould, the storage space should be cool, dry and, most particularly, easy to ventilate.

Recommended ventilation conditions: air exchange rate: 6 changes/h (airing).

MECHANICAL INFLUENCES

1. Star anise easily becomes fragile and must therefore be handled with appropriate care.
2. Breakage may amount to as much as 25%.
3. With bagged cargo, point loads applied, for example, by hooks may result in damage (tears) to the bags, and thus in loss of volume. Plate or bag hooks, which, due to their shape, distribute the load and reduce the risk of damage, should thus be used.

Adulteration and its identification

Chinese star anise (*I. verum* Hook, F.) is a well-known spice used in the treatment of infant colic. Japanese star anise (*I. anisatum* L.), however, has been documented to have both neurologic and gastrointestinal toxicities.

A methodological approach for an effective and reliable quality control of Chinese star anise (*I. verum* Hook. F.) was developed and validated by Lederer *et al.* (2006). A combined method of TLC and HPLC-MS/MS was used for differentiation of various *Illicium* species, especially Chinese and Japanese star anise. Species can be distinguished by their TLC flavonoid pattern. A sensitive and selective HPLC/ESI-MS/MS method was developed for the detection and quantification of lower admixtures of *I. anisatum* and of further toxic *Illicium* species at a low concentration range using the sesquiterpene lactone anisatin as a marker. This assay includes a solid-phase extraction clean-up procedure with a high recovery (> 90%).

Star anise herbal tea may be adulterated with *I. anisatum* Linn. A short and rapid method using microscopy and gas chromatography (GC) was developed to detect *I.anisatum* Linn., an adulterant in the powdered mixture of *I. verum*. Anatomical differences in the epicarp cells of *I. verum* and *I. anisatum* fruits can be defined clearly under fluorescent microscopy and scanning electron microscopy. A GC method can also be used for quick identification of possible *I. anisatum* adulteration with *I. verum* (Joshi *et al*., 2005).

17.7. Conclusion

Star anise belongs to a family of spices with a rich history. In addition to its traditional uses, it has multiple applications in botany, chemistry, pharmacology and therapy. The spice is back in the region as an ingredient of the drug to fight bird flu. It is also the primary source of shikimic acid used to produce oseltamivir phosphate, sold under the brand name, Tamiflu. Thus, it has become a major weapon against global influenza. Although only limited human-to-human transmission has been confirmed, scientists fear a worldwide pandemic could erupt if the virus mutates to a highly pathogenic form that humans can pass efficiently among themselves. Now scientists are finding faster, cheaper ways to produce more of the only drug proven capable of combating avian flu. Tamiflu (oseltamivir phosphate) reduces flu mortality by inhibiting the virus from spreading.

Moreover, star anise contains bioactive compounds possessing insecticidal properties, which can be exploited for evolving natural grain protectants. More attention also has to be focused on the antimicrobial, antioxidant and chemopreventive properties of the spice.

References

Anon. (1992) Les agents antioxygenes. *Pour la Science* 179, 10–12.

Biessels, G.J., Vermeij, F.H. and Leijten, F.S. (2002) Epileptic seizure after a cup of tea: intoxication with Japanese star anise. *Ned Tijdschr Geneeskd* 146(17), 813–816.

Carolyn Heal and Michael Allsop (1983) *Cooking With Spices*, David & Charles, Vermont.

Chang, K.S. and Ahn, Y.J. (2002) Fumigant activity of (*E*)-anethole identified in *Illicium verum* fruit against *Blattella germanica*. *Pest Management Science* 58(2), 161–166.

Cu, J.Q. (1986) The kingdom of essential oil. In: Lawrence, B.M., Mookherjee, B.D. and Willis, B.J. (eds) *Flavour and Fragrances: A World Perspective*, Proceedings of the 10th International Congress of Essential Oils, Washington, DC, 16–20 November. Elsevier, Amsterdam.

Cu, J.Q., Perineau, F. and Goepfert, G. (1990) GC/MS analysis of star anise oil. *Journal of Essential Oil Research* 2, 91–92.

De, M., De, A.K., Sen, P. and Banerjee, A.B. (2002) Antimicrobial properties of star anise (*Illicium verum* Hook f). *Phototherapeutic Research* 16(1), 94–95.

Della Porta, G., Taddeo, R., D'Urso, E. and Reverchon, E. (1998) Isolation of clove bud and star anise essential oil by supercritical CO_2 extraction. *Lebensmittel –Wissenschaft und Technologie* 31, 454–460.

Eykman, J.F. (1881) Isolation of Shikimin from star anise. *Pharmacology Journal and Transactions* 11, 1046.

FAO (1993) Beer, J.H. de (ed.) *Non-wood Forest Products in Indochina – Focus: Vietnam*. FAO document repository.

Farag, S.E. and Abo-Zeid, M. (1997) Degradation of the natural mutagenic compound safrole in spices by cooking and irradiation. *Nahrung* 41(6), 359–361.

Flückinger, F.A. (1879) *Pharmacographia: A History of the Principal Drugs of Vegetable Origin, Met with in Great Britain and British India*. Macmillan, London.

Goodman, P.S. (2005) Star Rises in Fight Against Bird Flu. Demand for a Chinese Fruit Skyrockets. *Washington Post Foreign Service* November 18, p. D01.

Heath, H.B. (1981) *Source Book of Flavours*. The AVI Publishing Company, Westport, Connecticut, pp. 221–222.

Hitokoto, H., Morozumi, S., Wauke, T., Sakai, S. and Kurata, H. (1980) Inhibitory effects of spices on growth and toxin production of toxigenic fungi. *Applied and Environmental Microbiology* 39(4), 818–822.

Ho, S.H., Ma, Y., Goh, P.M. and Sim, K.Y. (1995) Star anise, *Illicium verum* Hook f. as a potential grain protectant against *Ttibolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. *Postharvest Biology and Technology* 6, 341–347.

Huang, J.M., Nakade, K., Kondo, M., Yang, C.S. and Fukuyama, Y. (2002) Brine shrimp lethality test active constituents and new highly oxygenated seco-prezizaane-type sesquiterpenes from *Illicium merrillianum*. *Chemical and Pharmaceutical Bulletin* (Tokyo) 50(1), 133–136.

Huang, J.M., Yang, C.S., Zhao, R., Takahashi, H. and Fukuyama, Y. (2004) Seven novel seco-prezizaane-type sesquiterpenes from the pericarps of *Illicium merrillianum*. *Chemical and Pharmaceutical Bulletin* (Tokyo) 52(1), 104–107.

Huang, P., Nishi, M., Zheng, X.Z., Lai, M.X. and Naknishi, T. (1997) Triterpene acids from the barks of *Illicium difengpi*. *Yao Xue Xue Bao* 32(9), 704–707.

Itoigawa, M., Ito, C., Tokuda, H., Enjo, F., Nishino, H. and Furukawa, H. (2004) Cancer chemopreventive activity of phenylpropanoids and phytoquinoids from *Illicium* plants. *Cancer Letters* 214(2), 165–169.

Ize-Ludlow, D., Ragone, S., Bruck, S.I., Jeffrey, N., Bernstein, J.N., Duchowny, M. and Garcia Peña, B.M. (2004) Neurotoxicities in infants seen with the consumption of star anise tea. *Pediatrics* 114(5), e653–e656.

Johanns, E.S., van der Kolk, L.E., van Gemert, H.M., Sijben, A.E., Peters, P.W. and de Vries, I. (2002) An epidemic of epileptic seizures after consumption of herbal tea. *Ned Tijdschr Geneeskd* 146, 813 –816.

Joshi, V.C., Srinivas, P.V. and Khan, I.A. (2005) Rapid and easy identification of *Illicium verum* Hook. f. and its adulterant *Illicium anisatum* Linn. by fluorescent microscopy and gas chromatography. *Journal of Association of Official Analytical Chemists International* 88(3), 703–706.

Kuriyama, T., Schmidt, T.J., Okuyama, E. and Ozoe, Y. (2002) Structure–activity relationships of seco-prezizaane terpenoids in gamma-aminobutyric acid receptors of houseflies and rats. *Bioorganic and Medicinal Chemistry* 10(6), 1873–1881.

Lai, M., Yao, W., Yang, M., Huang, P., Liu, B. and Zheng, X. (1997) Studies on the pharmacognosy of Cortex Illicii and its adulterants. *Zhong Yao Cai* 20(12), 601–604.

Lederer, I., Schulzki, G., Gross, J. and Steffen, J.P. (2006) Combination of TLC and HPLC-MS/MS methods. Approach to a rational quality control of Chinese star anise. *Journal of Agricultural and Food Chemistry* 54, 1970–1974.

Lee, S.W., Li, G., Lee, K.S., Song, D.K. and Son, J.K. (2003a) A new phenylpropanoid glucoside from the fruits of *Illicium verum*. *Archives of Pharmacological Research* 26(8), 591–593.

Lee, S.W., Li, G., Lee, K.S., Jung, J.S., Xu, M.L., Seo, C.S., Chang, H.W., Kim, S.K., Song, D.K. and Son, J.K. (2003b) Preventive agents against sepsis and new phenylpropanoid glucosides from the fruits of *Illicium verum*. *Planta Medica* 69(9), 861–864.

Loi, D.T. and Thu, N.V. (1970) *Medicinal Trees and Pharmaceutical Material und Herbs in Vietnam*. Pharmacy College Publisher, Hanoi, pp. 209–211.

Lucchesi, M.E., Chemat, F. and Smadja, J. (2004) Solvent-free microwave extraction: an innovative tool for rapid extraction of essential oil from aromatic herbs and spices. *The Journal of Microwave Power and Electromagnetic Energy* 39(3–4), 135–139.

Lust, J. (1974) *The Herb Book*. Bantam Books, New York, pp. 344.

Meisner, W. (1818) Beitrag zur Geschichte des Chrom. *Annalen der Physik* 60(12), 366–394.

Minodier, P., Pommier, P., Moulene, E., Retornaz, K., Prost, N. and Deharo, L. (2003)

Morton, M. (2004) *Cupboard Love, A Dictionary of Culinary Curiosities*. Insomniac Press, Toronto, Canada.

Nakamura, T., Okuyama, E., and Yamazaki, M. (1996) Neurotropic components from star anise (*Illicium verum* Hook fil.). *Chemical and Pharmaceutical Bulletin* (Tokyo) 44(10), 1908–1914.

Ngo, K.S., Wong, W.T. and Brown, G.D. (1999) Murolane sesquiterpenes from *Illicium tsangii*. *Journal of Natural Products* 62(4), 549–553.

Okuyama, E., Nakamura, T. and Yamazaki, M. (1993) Convulsants from star anise (*Illicium verum* Hook F.). *Chemical and Pharmaceutical Bulletin* (Tokyo) 41(9), 1670–1671.

Padmashree, A., Roopa, N., Semwal, A.D., Sharma, G.K., Agathian, G. and Bawa, A.S. (2007) Star-anise (*Illicium verum*) and black caraway (*Carum nigrum*) as natural antioxidants. *Food Chemistry* (in press).

Rahway, N.J. (1989) *The Merck Index*. Eleventh edition. Merck & Co., Inc.

Reverchon, E. (1997) Supercritical fluid extraction and fractionation of essential oils and related product. *Journal of Supercritical Fluids* 10, 1–37.

Reverchon, E. and Senatore, F. (1994) Supercritical carbon dioxide extraction of chamomile essential oil and its analysis by gas chromatography–mass spectrometry. *Journal of Agricultural and Food Chemistry* 42, 154–158.

Reverchon, E., Della Oorta, G. and Senatore, F. (1995) Supercritical CO2 extraction and fractionation of lavender essential oil and waxes. *Journal of Agricultural and Food Chemistry* 43, 1654–1658.

Rizvi, S.S.H., Benado, A.L., Zollweg, J.A. and Daniels, J.A. (1986) Supercritical fluid extraction operating principles and food applications. *Food Technology* (Chicago) 40(7), 57–64.
Rosengarten, F., Jr. (1969) *The Book of Spices*. Livingston Publishing Co., Wynnewood, Pennsylvania.
Rudzki, E. and Grzywa, Z. (1976) Sensitizing and irritating properties of star anise oil. *Contact Dermatitis* 2(6), 305–308.
Sakaguchi, I., Ishimoto, H., Matsuo, M., Ikeda, N., Minamino, M. and Kato, Y. (2004) The water-soluble extract of *Illicium anisatum* stimulates mouse vibrissae follicles in organ culture. *Experimental Dermatology* 13(8), 499–504.
Schlegel, C.E. (1885) The fruit of *Illicium anisatum*, Loureiro. *The American Journal of Pharmacy* 57, 426.
Schmidt, T.J. (1999) Novel seco-prezizaane sesquiterpenes from North American *Illicium* species. *Journal of Natural Products* 62(5), 684–687.
Schmidt, T.J., Muller, E. and Fronczek, F.R. (2001) New allo-cedrane type sesquiterpene hemiketals and further sesquiterpene lactones from fruits of *Illicium floridanum*. *Journal of Natural Products* 64(4), 411–414.
Singh, G., Maurya, Sumitra, deLampasona, M.P., Catalan and Cesar (2006) Chemical constituents, antimicrobial investigations and antioxidative potential of volatile oil and acetone extract of star anise fruits. *Journal of the Science of Food and Agriculture* 86(1), 111–121.
Stahl, E. and Gerard, D. (1985) Solubility behaviour and fractionation of essential oils in dense carbon dioxide. *Perfume Flavor* 10, 29–37.
Stuart and Malcolm (1987) *The Encyclopedia of Herbs and Herbalism*. MacDonald and Company, Turin, Italy.
Sy, L.K. and Brown, G.D. (1998) A prezizaane sesquiterpene from *Illicium angustisepalum*. *Phytochemistry* 49(6), 1715–1717.
Tuan, D.Q. and Ilangantileke, S.G. (1997) Liquid CO_2 extraction of essential oil from star anise fruits (*Illicium verum* H.). *Journal of Food Engineering* 311, 47–57.
Vandenberghe, N., Pittion-Vouyouvitch, S., Flesch, F., Wagner, M. and Godet, E. (2003) An inaugural generalized tonic-clonic convulsive crisis following ingestion of Japanese star anise. *Presse Medicale* 11 32(1), 27–28.
Wang, X.Q., Guo, Y.J. and Yang, C.S. (2001) Determination of shikimic acid in fruit of *Illiciaceae* plants by HPLC with diode-array detection. *Zhongguo Zhong Yao Za Zhi* 26(7), 447–449.
Wang, X., Wang, H., Ma, J., Xu, Y. and Guan, Y. (2004) Analysis of volatile oil in *Illicium verum* fruit by on-line coupled packed capillary liquid chromatography/capillary gas chromatography. *Se Pu* 22(2), 101–105.
WHO (Manila), Institute of Materia Medica (1990) *Medicinal Plants in Vietnam*. WHO Regional Publications, Western Pacific Series No. 3, Hanoi, Manila, pp. 211–212.
Yokoyama, R., Huang, J.M., Yang, C.S. and Fukuyama, Y. (2002) New seco-prezizaane-type sesquiterpenes, jiadifenin with neurotrophic activity and 1,2-dehydroneomajucin from *Illicium jiadifengpi*. *Journal of Natural Products* 65(4), 527–531.
Yokoyama, R., Huang, J.M., Hosoda, A., Kino, K., Yang, C.S. and Fukuyama, Y. (2003) Seco-prezizaane-type sesquiterpenes and an abietane-type diterpene from *Illicium minwanense*. *Journal of Natural Products* 66(6), 799–803.
Zhou, J., Lu, G., Zhong, X. and Wen, H. (2005) Quantitative determination of anethole in the fruit of *Illicium verum* from various places of Guangxi province. *Zhong Yao Cai* 28(2), 106–107.