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Nutmeg and mace

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20.1 Introduction

Nutmeg and mace are two different parts of the same fruit of the nutmeg tree, *Myristica fragrans Houtt.* (Myristicaceae). The nutmeg tree is indigenous to the Banda islands in the Moluccas. The species of the genus Myristica are distributed from India and South-East Asia to North Australia and the Pacific Islands. Sinclair (1958) listed a total of 72 species distributed in these areas. The major nutmeg growing areas are Indonesia and Grenada (West Indies). It is also grown on a smaller scale in Sri Lanka, India, China, Malaysia, Western Sumatra, Zanzibar, Mauritius and the Solomon Islands.

Nutmeg belongs to a small primitive family Myristicaceae with about 18 genera and 300 species. Myristica is the most primitive genus of the family (Sinclair, 1958). Warming (1890) and Talbot (1902) opined that Myristicaceae is closely related to Lauraceae. But there is evidence from morphological and anatomical studies that Myristicacea is more closely related to Annonaceae and Canellaceae (Wilson and Maculans, 1967). At present Myristicaceae is considered as a member of Magnoliales or its taxonomical equivalents (Cronquist, 1981; Dahlgren, 1983).

Nutmeg is a conical tree reaching a height of 4 to 10 metres. The tree is dioecious with male and female flowers occurring on different trees. Nutmeg tree is obligatory cross pollinated and an ant mimicking flower beetle (*Formicomum braminus* – Anthridae) is an effective pollinator in South India (Armstrong and Drummond, 1986). The fruits are pendulous, broadly pyriform, yellow, smooth, 7–10 cm long, fleshy splitting open into two halves when ripe, showing the ovoid 2–3 cm long dark brown shining seed with hard seed coat, surrounded by a lanciate red aril attached to the base of the seed. The seed of nutmeg is large with ruminate endosperm and is considered as the most primitive among the flowering plants (Corner, 1976).

20.2 Production and chemical structure

Nutmeg and mace are the two major primary products of *Myristica fragrans* and are commercially considered as spice. Nutmeg is the dried kernel of the seed and mace is the dried aril surrounding the seed. Both the spices have similar flavour. However, nutmeg is reported to be slightly sweeter than mace and is more preferred in food. Besides nutmeg and mace a number of other products are commercially important. Oleoresins, nutmeg butter and essential oils are also derived from *M. fragrans* and they find varied uses in the food, medicine and perfume industries.

Nutmeg is produced in the tropical areas of Indonesia and the West Indies. World production of nutmeg is about 12 000 tons per year with an annual world demand of 9 000 tons. Production of mace is about 2 000 tons. Indonesia and Grenada dominate production and export both products with a world market share of 75% and 20% respectively. Other producing countries include India, Malaysia, Papua New Guinea, Sri Lanka and a few Caribbean Islands.

The East Indian islands of Siauw, Sangihe, Ternate, Ambon, Banda and Papua produce highly aromatic nutmeg, traded as East Indian nutmeg. Grenada produces the West Indian nutmeg which is milder in flavour and lighter in colour. International trade in nutmeg is either of the East Indian or the West Indian nutmeg, with a negligible quantity of wild 'Bombay' nutmeg imported by USA. The principal import markets are the European Community, the USA, Japan and India. Singapore and the Netherlands are the major re-exporters. USA is the biggest individual market for whole nutmegs. US importers prefer the East Indian type of deep brown, aromatic nutmeg and orange red mace in their whole form. Indonesia has traditionally been the principal supplier of nutmeg and mace to the US market, accounting for an average 65% of total US imports of nutmeg per year in terms of volume.

20.2.1 Nutmeg

Fruits are harvested when they split open on ripening. The split fruits are either plucked from the tree with a hook bill or are collected soon after they drop onto the ground. Nutmeg is dried in large trays by various procedures. The unshelled nutmegs are dried in the sun until the seeds inside rattle on shaking. Normally nutmeg dries in about a week. The seed cover is removed by breaking the hard seed coat mechanically. Nutmeg is usually packed in double layered linen, jute, sisal or polythene bags. If other packing materials are used, care must be taken to avoid materials which might lead to 'sweating' and mould development. Packaging should be such that the maximum weight loss is 10%. Spices must be dried thoroughly prior to shipment. They can then be transported in conventional vessels. Powdered nutmeg is prepared by grinding at ambient temperature. Since during traditional grinding, most of the volatile oil escapes and quality deteriotes, chill conditioning and cryogenic grinding are alternative methods followed at present (McKee and Harden, 1991). The myristicin fraction of the volatile oil together with elemicin is responsible for the hallucinogenic property of the seed.

20.2.2 Mace

Mace is detached from the nut carefully soon after harvest, washed, flattened by hand or between boards and then sun dried until they become brittle. Hot air ovens can be used

Table 20.1 Composition of nutmeg and mace (%)

Composition	Nutmeg	Mace
Moisture	40.00	40.00
Volatile oil	11.00	15.30
Non-volatile ether extract	33.60	21.98
Starch	30.20	44.05
Sugars		
Glucose	0.10	0.17
Fructose	0.07	0.10
Total reducing sugars	0.17	0.27
Sucrose	0.72	0.39
Total sugars	0.89	0.65
Protein	7.16	9.91
Crude fibre	11.70	3.93
Total ash	2.57	1.56
Ash insoluble in HCl	0.20	0.15
Polyphenols		
Total tannins	2.50	–
True tannins	1.00	–

Source: Gopalakrishnan (1992).

for drying and the colour retention is much better than sun dried mace. Dried mace is graded and packed. The fixed oil content of mace ranges from 20 to 35%. The general composition of nutmeg and mace are given in Table 20.1.

20.2.3 Nutmeg oil and mace oil

The essential oil from nutmeg is steam distilled usually from substandard nutmeg and nutmeg oil ranges from 5 to 15% of the seed weight. The essential oil is highly sensitive to light and temperature and yields a colourless, pale yellow or pale green oil with a characteristic odour of nutmeg. The oil is soluble in alcohol and insoluble in water. The essential oil of East Indian nutmeg and West Indian nutmeg differ in their flavour and odour characteristics. The East Indian nutmeg oil is considered superior to the West Indian nutmeg oil, having a better aroma and a higher amount of phenyl propanoid ethers (Masada, 1976) and terpenes (Lewis, 1984). The physico-chemical properties of the two oils are reported to be different (Table 20.2). East Indian nutmeg oil is also reported to

Table 20.2 Specifications of British Standards Institutions for nutmeg oil

Specification	East Indian Oil	West Indian Oil
Colour	BS 2999/37:1971 Colourless to yellow	BS 2999/38: 1971 Colourless to pale yellow
Apparent density (mass per ml) at 20ºC	0.885 to 0.915	0.860 to 0.880
Optical rotation at 20ºC	8.0º to 25.0º	25.0º to 45.0º
Refractive index at 20ºC	1.4750 to 1.4880	1.4720 to 1.4760
Solubility in ethanol (90 per cent (v/v) at 20ºC)	3.0 volumes	4.0 volumes

Source: Purseglove *et al.* (1981).

Table 20.3 Composition of nutmeg oils of different geographical origins (%)

Source component	Grenada	St. Vincent	Malay seedlings	Papua	Indonesia	Penang	Singapore (1)	Singapore (2)
α-pinene	10.6	12.6	12.8	21.3	18.0	19.9	21.2	19.2
Camphene	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4
β-pinene	7.8	12.1	9.3	14.3	9.7	17.7	12.7	11.0
Sabinene	50.7	49.6	44.1	30.0	27.0	36.3	17.8	15.4
Myrcene	2.5	2.8	2.9	2.4	2.2	2.5	2.6	2.3
α-phellandrene	0.4	0.6	0.6	0.5	0.5	0.4	1.0	0.7
α-terpinene	0.8	1.9	1.8	1.1	2.0	0.8	4.0	2.5
Limonene	3.1	3.3	3.1	2.7	2.7	2.8	3.6	3.4
1,8-cineole	2.5	2.3	2.1	1.9	1.8	1.5	3.2	2.7
γ-terpinene	1.9	3.1	2.8	1.9	3.3	1.3	6.8	4.1
p-cymene	3.2	0.7	0.8	0.5	0.7	0.3	1.8	2.7
Terpinolene	1.7	1.2	1.2	1.1	1.1	0.6	2.1	2.6
trans-sabinene hydrate	0.8	0.3	0.5	0.1	0.6	0.2	0.3	0.5
Copaene	0.3	*	*	0.2	0.3	*	0.2	0.2
Linalool	0.9	0.4	0.2	1.0	0.3	0.2	0.8	0.9
cis-sabinene hydrate	0.7	0.2	0.4	0.2	0.6	0.2	0.2	0.4
cis-p-menth-2-en-ol	0.4	0.1	0.1	0.3	0.5	0.1	0.3	0.3
Terpinen-4-ol	6.1	3.5	6.0	3.9	7.3	2.0	9.3	10.9
cis-piperitol	0.5	0.4	0.4	0.6	0.4	0.3	0.5	0.3
Safrole	0.2	0.1	0.8	1.5	2.1	0.6	1.9	3.2
Methyl eugenol	0.2	0.1	0.5	0.2	1.2	0.6	0.6	*
Eugenol	0.2	*	0.3	0.1	0.7	0.3	*	*
Elemicin	1.4	1.3	1.7	0.4	0.5	4.6	0.3	0.3
Myristicin	0.5	0.8	4.1	10.4	13.5	3.3	6.3	12.4

* Traces detected
Source: Lewis (1984).

have a higher concentration of myristicin (up to 13.5%), than West Indian nutmeg oil (less than 1%) (Table 20.3)

Mace oil is obtained by steam distillation of dried aril and yields 4 to 17% oil. It is a clear red or amber dark red liquid with characteristic odour and flavour. Mace oil is more expensive than nutmeg oil. Leaves also yield oil (0.34–0.65%), chemically similar to nutmeg oil, but its flavour and odour are inferior to both mace and nutmeg oil.

Extraction of essential oil can be carried out by different methods. However, mace oil extracted using liquid and dense carbon dioxide was superior in quality and flavour compared with the steam distilled oil (Naik *et al.*, 1988). Essential oil has got several compounds, most of which are invaluable to industries. Because of its aroma, the essential oil is used as a natural flavouring extract in cosmetic industries. In addition to its use in cosmetic industries, nutmeg is also used in the pharmaceutical industry. The pharmacological properties of nutmeg are attributed to the compounds found in the essential oil. The first report on nutmeg constituents was by Frederick Power and Henry Salway (Power and Salway, 1907, 1908). Numerous compounds have been isolated from nutmeg and mace. The yield and quality of the oil depends on the geographical location (Table 20.3), grades and the distillation process involved. The major constituents of both nutmeg and mace oil are monoterpene hydrocarbons, together with smaller amounts of oxygenated monoterpenes and aromatic ethers (Purseglove *et al*., 1981).

Major constituents of the monoterpene hydrocarbons are pinene and sabinene and the major aromatic ether constituent is myristicin. Aromatic ethers, myristicin, safrole and elemicin determine the flavour and medicinal properties to a great extent. A recent GC analysis of the oils of nutmeg and mace showed 33 constituents in nutmeg oil and 51 in mace oil. Both the oils are qualitatively similar in composition, differing only in their quantity. Nutmeg oil consists of 76.8% monoterpenes, 12.1% oxygenated monoterpenes and 9.8% phenyl propanoid ether whereas mace oil contains 51.2% monoterpenes, 30.3% oxygenated monoterpenes and 18.8% phenyl propanoid ethers (Table 20.4) (Mallavarapu and Ramesh, 1998), and the composition varies with the geographical location (Baldry *et al*., 1976; Masada, 1976; Lawrence, 1981; Kumar *et al*., 1985; Gopalakrishnan, 1992). The Indonesian nutmeg contained 2% myristicin compared with 0.13% in *M. argentea*. No myristicin was reported in *M. muelleri*. The safrole content, a suspected carcinogen, was 0.13, 0.51 and 0.245 in *M. fragrans*, *M. argentea* and *M. muelleri*, respectively (Archer, 1988). The myristicin fraction together with the elemicin is responsible for the hallucinogenic properties of nutmeg seed. The composition of essential oil changes on prolonged storage. The structure of some of the compounds are given in Fig. 20.1.

During storage and transportation, oils should be protected from light and stored in tightly-packed containers at a temperature not exceeding 25ºC. Prolonged storage deteriorates the composition of the oil.

20.2.4 Nutmeg oleoresin

Nutmeg oleoresin is obtained by solvent extraction of spices. Oleoresins contain saturated volatile oil, fatty oil and other extractives soluble in the particular solvent employed. Nutmeg oleoresins, obtained by solvent extraction from the dried spice of nutmeg, are used in colouring and flavouring in the food industry. The spice oleoresin can be used in place of the dried spice. The commercial products exhibit a range in their essential oil and fixed oil content depending on the method of extraction and solvents employed. Nutmeg extracted with benzene yields 31 to 37% of oleoresins and with cold ethanol yields 18 to 26%. A higher fatty oil is obtained by hydrocarbon solvents while polar solvents like alcohol and acetone yield low fatty oils and resins. Commercial mace oleoresins are available with volatile oil content ranging from 10 to 55%. When extracted with petroleum ether, it yields 27 to 32% and contains 8.5–22% volatile oils, and after chilling the yield reduces to 10–13% (Naves, 1974). Oleoresins extracted with non-polar solvents are preferred in flavouring processed foods since they are more stable to heat, whereas the perfume industry prefers polar solvents since they are soluble in most perfume materials and do not deposit any fatty materials in the bottles or containers (Purseglove *et al*., 1981).

20.2.5 Nutmeg butter

The fixed oil of nutmeg is known as nutmeg butter. Nutmeg butter contains 25 to 40% fixed oil, which is obtained by expressing the crushed nuts or by extracting with solvents. Fixed oil is a semi solid, or reddish brown fat with both the aroma and taste of nutmeg. It is completely soluble in hot alcohol and sparingly soluble in cold alcohol. The fixed oil is freely soluble in ether or chloroform and is composed of trimyristin (84%), unsaponifiable constituents (9.8%), oleic acid (3.5%), resinous materials (2.3%), linolenic acid (0.6%) and formic, acetate and cerotic acids in traces. Trimyristicin is a

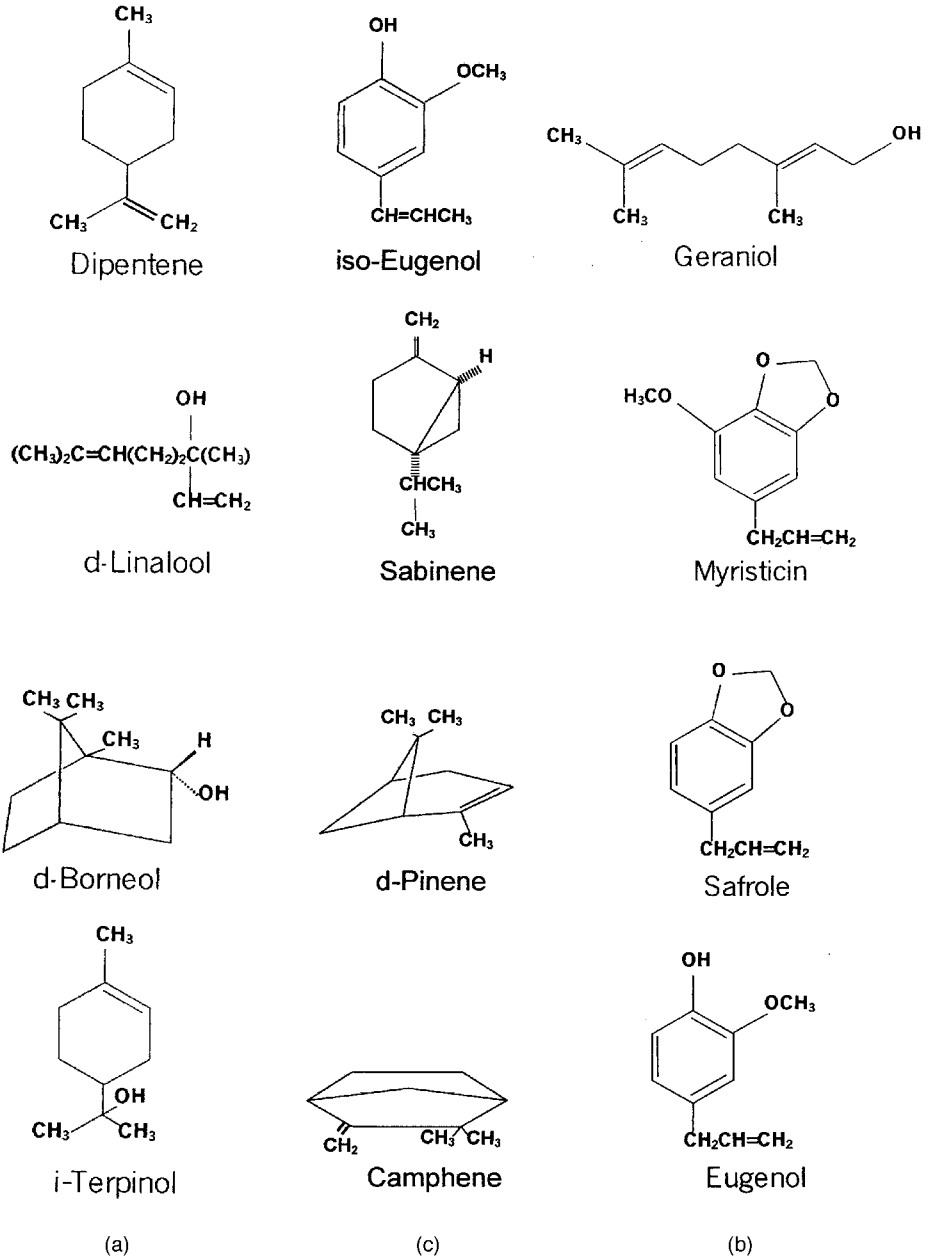

Fig. 20.1 Chemical structures.

triglyceride of myristic acid and is volatile to yellowish grey solid. Reports say that the best nutmeg butter is imported from the East Indies. The fixed oils are also used in perfumes and medicines. In medicines, it is used for external application for sprains and rheumatism.

20.3 Main uses and functional properties

20.3.1 Food

Nutmeg, mace, their oleoresins and essential oils are used in the food and beverage industries. Although whole nutmeg is available, ground nutmeg is more popular. The spice in the ground form is mainly used in the food processing industry. In South-East Asia, China and India, both the spices are used sparingly.

Nutmeg is a standard seasoning in many Dutch dishes. Nutmeg and its oleoresin are used in the preparation of meat products, soups, sauces, baked foods, confectioneries, puddings, seasoning of meat and vegetables, to flavour milk dishes and punches. The fleshy outer cover of the fruit is crystallized or pickled or made into jellies.

Mace is sold either as whole or as ground spice and is used in savory dishes. Mace is used to flavour milk-based sauces and processed meats like sausages. Soups, pickles and ketchup, pickles and chutneys are also seasoned with mace. Because of its aroma, the essential oil is used as a natural flavouring extract and is employed for flavouring food products and liquors. Nutmeg oil and mace oil are used mainly in flavouring soft drinks, canned foods and meat products.

20.3.2 Functional properties and toxicity

Both nutmeg and mace are used in the pharmaceutical industries. Powdered nutmeg is rarely administered alone but it enters into the composition of numerous medicines as aromatic adjuncts. The use of essential oils in aromatherapy is gaining importance. The main constituents of nutmeg and mace, myristicin, elemicin and isoelimicin when presented in aroma form, act as stress relievers. In Japan, many companies diffuse such aromas through air ventilation systems to improve the work environment as well as the quality of air.

It is more commonly used in Oriental than in Western medicine. Medicinally it is known for its stimulative and carminative properties. The seeds are carminative, stomachic, astringent, deodorant, narcotic, aphrodisiac and useful in flatulence, nausea, and vomiting. The antioxidant properties of nutmeg have been discussed by various authorities (Madsen and Bertelsen, 1995; Lagouri and Boskou, 1995).

Oil of nutmeg is useful in the treatment of inflammation of the bladder and urinary tract, halitosis, dyspepsia, flatulence, impotence, insomnia and skin diseases. It is also used externally as a stimulant and the ointment as a counterirritant. Essential oil has got several compounds, most of which are valuable in industry. Most of the pharmacological properties of nutmeg are attributed to the compounds found in the essential oil. Mace oil possesses almost identical physiological and organoleptic properties as nutmeg oil. Nutmeg butter is a mild external stimulant used in the form of ointments, hair lotions and plaster, and used against rheumatism, paralysis and sprains.

Both nutmeg and mace contain the active ingredient myristicin which possesses narcotic properties. Nutmeg butter contains elemicin and myristicin which are also narcotic and cause psychotropic effects. Ingestion in large quantities produces narcosis, delirium, drowsiness, epileptic convulsions and even death. It also causes temporary constipation and difficulty in urination and increased fat deposition in liver. Powdered nutmeg is used occasionally as a hallucinogenic drug, but such use is dangerous as excessive dose of mace has a narcotic effect and symptoms of delirium and epileptic convulsions appear after 1–6 hours of consumption.

20.3.3 Perfume and other uses

Nutmeg oil is used in cosmetics, men's perfume and toiletries due to its aromatic properties. Mace oil possesses almost identical physico-chemical and organoleptic properties as nutmeg oil. Mace oil is also used to a limited extent in perfumes and soaps.

The myristicin component which imparts the hallucinogenic properties is also reported to be an effective insecticide. The lignin type of constituents in the nut are anticarcinogenic. Camphene present in the oil is used in the manufacture of camphor and related compounds and has strong antibacterial, antifungal and insecticidal properties. Pinene of the essential oil of nutmeg is used to make camphor, solvents, plasticizers, perfume bases and synthetic pine oil. Dipentene is used in the manufacture of resins and is used as wetting and dispersing agent. Myristic acid is used in the preparation of soaps, liquid detergents, shampoos, shaving creams, perfumes, plastics, in compounding rubber, paints and greases, in the synthesis of esters for flavours and perfumes and as a component of food grade additives. Resorcinols (malabaricone and malabaricone C) isolated from the mace exhibited strong antibacterial and antifungal activities against *Staphylococcus aureus* and *Candid* (Orabi *et al.*, 1991). Larvicidal properties are also reported in mace, the larvicidal principle in mace was identified as diarylnonanoid, malabaricone C against second stage larvae of *Toxocara canis* (Nakamura *et al*., 1988).

20.4 Quality issues

Nutmeg and mace are classified by origin (East Indian nutmeg and West Indian nutmeg) and grade. Good quality has to be maintained for trade of nutmeg and mace. Whole nutmegs are grouped under three broad quality classifications:

- *Sound*: Nutmegs which are used mainly for grinding and to a lesser extent for oleoresin extraction.
- *Substandard*: Nutmegs which are used for grinding, oleoresin extraction and essential oil distillation.
- *Distilling*: Poor quality nutmegs used for essential oil distillation.

In Indonesia, high quality of sound whole nutmeg are traded in grades which refer to their size in numbers of nutmeg per pound: 80s, 110s and 130s or 'ABCD' which is an assortment of various sizes. Substandard nutmegs are traded as 'sound, shrivelled', which in general have a higher volatile content than mature sound nutmegs and are used for grinding, oleoresin extraction and oil distillation, and 'BWP' (broken, wormy and punky) which are used mainly for grinding as volatile oil generally does not exceed 8%. Distilling grades of nutmeg are of poor quality: 'BIA' or 'ETEZ' with a volatile oil content of 8% to 10% and BSL or 'AZWI' which has less shell material and a volatile oil content of 12–13%.

In Grenada, sound nutmegs are sold as sound unassorted which corresponds to the Indonesian grade 'ABCD'. Substandard nutmegs are classified as floats and as defective, the latter is similar to the Indonesian BWP grade but considered of high quality. Distilling grades of nutmegs are primarily exported to the USA and consist of floats.

Mace is classified as whole pale mace, No. 1 broken mace, selected, unassorted or siftings (Indonesia) and as whole, broken blades or siftings (Grenada). The International Standards applicable for trade in spices of nutmeg and mace are ISO 6577:1990.

Though national standards are available for maintaining the quality (see Tables 20.2, 20.5, 20.6 and 20.7), the European traders prefer the ASTA cleanliness specifications

Table 20.5 American Spice Trade Association (ASTA) cleanliness specifications

Product	Insect (by count)	Excreta mammalian (mg/lb)	Excreta other (% wt)	Mould (% wt)	Insect infested (% wt)	Foreign matter (% wt)
Nutmeg (broken)	4	5	1.0	*	*	0.5
Nutmeg (whole)	4	0	0.0	*	*	0.0
Mace	4	3	1.0	2.0	1.0	0.5

* Not more than 5% by weight insect defiled and mould infected.
Source: Sivadasan and Kurup (1999).

Table 20.6 Defect Action Levels prescribed by US Food and Drug Administration for spices

Mace	
Insect filth and/or mould	Average of 3% or more pieces by weight are insect infested and/or mouldy
Mammalian excreta	Average of 3 mg or more of mammalian excreta per pound
Nutmeg (whole)	
Insect filth and/or mould	Average of 10% or more pieces by count are insect infested and/or mouldy

Source: Sivadasan and Kurup (1999).

(Table 20.5) as they are more strict than the National standards. The Quarantine System and Plant Protection Law and the Food Sanitation Act set the quality standard in Japan. Aflatoxin (The Netherlands, Japan) and salmonella (United Kingdom) are the common complaints on the imports of nutmeg. The presence of insects is a major complaint for US importers.

Adulteration is common in the nutmeg trade. The essential oil has often been extracted before they are marketed and such nuts can be detected by their light weight and are more subjected to insect attack. *M. fragrans* is adulterated with *M. argentea*, *M. malabarica* and *M. otaba* which can be identified by their poor quality. The mace from *M. argentea* is imported as Papuan nutmeg from Papua New Guinea, *M. malabarica* is traded as Bombay nutmeg from India and from *M. otaba* as *Otaba* nutmeg. Trade of wild nutmeg exists and they are marketed as long, female, Macassar, Papua, Guinea, or Norse nutmeg. All these have been traced to *M. argentea* of New Guinea from where they enter into the market as Macassar nutmegs. *M. malabarica*, *M. otaba* and *M. argentea* are devoid of any aroma of *M. fragrans*.

Table 20.7 Dutch regulations for cleanliness specifications

Product	Ash content (max. %)	Sand content (max. %)	Volatile oil (min. %)	Others
Nutmeg	3.5	0.5	4.0	NVEE * 5.0
Mace	3.5	0.5	4.0	NVEE * 4.0

* NVEE – Non-volatile ether extract
Source: Sivadasan and Kurup (1999).

20.5 References

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