# 20 Tamarind

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## 20.1. Introduction

The tamarind, *Tamarindus indica* L. (family Leguminosae), is a widely distributed tree spice which is also grown as a shade tree on highways. It is one of the most important multi-purpose tree species in the Indian subcontinent. It is a large evergreen tree with an exceptionally beautiful spreading crown and is cultivated throughout almost the whole country, except in the Himalayas. It is cultivated in more than 53 countries in the world.

Tamarind is thought to have originated in Madagascar (Von Maydell, 1986; Hockin, 1993). The tree grows wild throughout the Sudan and was introduced into and adopted in India so long ago that it has often been reported as also being indigenous there. The tamarind fruit was at first thought to be produced by an Indian palm, as the name tamarind comes from a Persian word *Tamar-I-hind*, meaning date of India. Its name *amlika* in Sanskrit indicates its ancient presence in the country (Mishra, 1997). In Myanmar, it is reported as one of the commonest village trees in the dry zone (Troup, 1921). The fruit was well known to the ancient Egyptians and to the Greeks in the 4th century BC. It is now cultivated throughout semi-arid Africa and South Asia, where it has become naturalized in several regions. The tree has long been naturalized in the East Indies and the islands of the Pacific. The tamarind was introduced into tropical America, Bermuda, the Bahamas and the West Indies certainly much earlier. It has been planted extensively in Bangladesh, India, Myanmar, Malaysia, Sri Lanka, Thailand and several African, Australian, Central American and South American countries. The fruit became known in Europe during the Middle Ages (http://www.hort.purdue.edu/newcrop/morton/tamarind.html). Commercial plantations are reported in Belize, Central American countries and in north Brazil (Sharma and Bhardwaj, 1997). In all tropical and near-tropical areas, including South Florida, it is grown as a shade and fruit tree, along roadsides and in backyards and parks. India has 61,700 ha of cultivated tamarind and produces 179,310 t (Premaja and Manojkumar, 2007).

## 20.2. Botany and Uses

### Botany

Tamarind is an evergreen, moderate to large tree, growing up to 24 m in height and 7 m in girth. The most useful part is the pod, but all the tree parts are used in one way or another. The tree is highly wind-resistant, with strong, supple branches, drooping at the ends, and has a dark grey, rough, fissured bark. The flowers are borne in small racemes, very small, five-petalled, yellow coloured with orange or red streaks. The flower buds are distinctly pink. The sepals, four in number, shed when the flower opens. The pods are 7.5–20 cm long, 2.5 cm broad and 1 cm thick, more or less constricted between the seeds, slightly curved, brownish-ash coloured and scurfy. There are three to 12 seeds in each pod contained in loculi, enveloped by a tough, leathery parchment-like membrane, called the endocarp. Outside the endocarp is the light-brownish, red, sweetish acidic, edible pulp, traversed by a number of branched, ligneous strands. The outermost covering of the pod is fragile and easily separable. The pods begin to ripen from February to April. At first, the pods are tender-skinned with green, highly acid flesh and soft, whitish, underdeveloped seeds. As they mature, the pods fill out somewhat and the juicy, acidulous pulp turns brown or reddish-brown. Thereafter, the skin becomes a brittle, easily cracked shell and the pulp dehydrates naturally to a sticky paste enclosed by a few coarse strands of fibre extending lengthwise from the stalk (http://www.hort.purdue.edu/newcrop/morton/tamarind.html; http://www.uni-graz.at/~katzer/engl/Tama_ind.html).

## Uses

All parts of the tamarind tree are useful in one way or another. Tamarind is valued mostly for its fruit and pulp, which is used for a wide variety of domestic and industrial purposes (Kulkarni *et al.*, 1993), in particular to prepare juice, jam, syrup and sweets. Tamarind juice concentrate (TJC) is a convenient product due to the ease with which it can be dissolved and reconstituted in warm water. The specific heat of TJC increases with temperature and the glass transition temperature of the product is −70.74°C (Ahmed *et al.*, 2007). Tamarind intake appears to have an additional beneficial effect on the mobilization of deposited fluoride from bone, by enhancing urinary excretion of fluoride (Khandare *et al.*, 2004). It can also be eaten raw and is used in southern India to induce an acidic flavour to curries. The combinations of acidulants such as tamarind and antioxidant spices improves the retention of $\beta$-carotene during cooking (Gayathri *et al.*, 2004). Tamarind extract can be used as a replacement for citric acid, phosphoric acid and other acids that are added to soft drinks. Beverages containing tamarind extract have an improved shelf life due to higher pH and also yield a flavour profile equivalent to or better than beverages sweetened with aspartame (Zablocki and Perore, 1996).

The pulp, when mixed with seawater, cleans silver, copper and brass. The leaves are eaten by cattle and goats and furnish fodder for silkworms, *Anaphe* sp. in India and *Hypsoides vuilletii* in West Africa. Tamarind leaves and flowers are useful as mordants in dyeing. Tamarind seeds yield amber oil, useful as an illuminant and as a varnish, especially preferred for painting dolls and idols. The powder made from tamarind kernels has been adopted by the Indian textile industry as 300% more efficient and more economical than cornstarch for sizing and finishing cotton, jute and spun viscose, as well as having other technical advantages. It is commonly used for dressing homemade blankets. Other industrial uses include employment in the colour printing of textiles, paper sizing, leather treating, etc. Tamarind seed husk is a natural source of tannin that can be used beneficially to manipulate rumen fermentation (Bhatta *et al.*, 2001). At low concentration, this tannin has a beneficial effect on the performance of crossbred lactating cows (Bhatta *et al.*, 2000).

The heartwood is highly prized for furniture, panelling, wheels, axles, gears for mills, ploughs, planking for the sides of boats, wells, mallets, knife and tool handles, rice pounders, mortars and pestles. Tamarind twigs are sometimes used as ‘chewsticks’ and the bark of the tree as a masticatory, alone or in place of lime with betelnut. The bark is often employed in tanning hides and in dyeing, and is burnt to make ink. The lac produced by the lac insect parasitizing on a tamarind tree may be harvested and sold as stick-lac for the production of lacquers and varnish.

## 20.3. General Composition

The tamarind fruit (pod) has mainly pulp and seeds. The seeds are covered by a thin parchment, membrane-like structure. The pulp constitutes 30–50% of ripe fruit (Purseglove, 1987; Shankaracharya, 1998). The shell and fibre account for 11–30% and the seed constitutes around 25–40% (Chapman, 1984). The fruit pulp (both ripe and dried) contains mainly tartaric acid, reducing sugars, pectin, tannin, fibre and cellulose. The general composition of tamarind fruits is given in Table 20.1.

Both pulp and seed are a good source of potassium, calcium and phosphorus. The kernel and testa are very rich in potassium, sodium, zinc and iron. The whole seed has 13–27% protein, 4.5–16% fat, 11–25% total sugars and 50–57% carbohydrates. The pulp is considered a promising source of tartaric acid, alcohol (12%) and pectin (21–22%). The red pulp of some types contains the pigment, chrysanthemin. The seeds contain approximately 63% starch, 14–18% albuminoids and 4.5–6.5% of a semi-drying oil. The seed kernel also has similar fat and protein contents, while the carbohydrate content is slightly higher (65–72%). The testa is rich in fibre, e.g. ~ 21% (Ishola *et al*., 1990; Bhattacharya *et al*., 1993). The mineral composition of tamarind is given in Table 20.2.

The tender leaves and flowers also show high calcium and phosphorus content. The leaves have 16–18% carbohydrates. Thiamine, riboflavin and niacin were also detected in both leaves and flowers. Table

**Table 20.1.** Composition of tamarind fruits.

| Constituent | Content |
|---|---|
| Moisture (%) | 15–30 (62.5–69.2) |
| Proteins (%) | 2.00–8.79 (1.4–3.3) |
| Fat/oil/crude lipid (%) | 0.50–2.53 (0.27–0.81) |
| Carbohydrates, total (%) | 56.70–70.70 |
| Fibre, crude (%) | 2.20–18.30 |
| Tartaric acid, total (%) | 8.00–18.00 (8.40–12.40) |
| Reducing sugars (%) | 25.00–45.00 |
| Total ash (%) | 2.10–2.90 (1.20–1.72) |
| Pectin (%) | 2.00–4.00 |
| Cellulose (%) | 19.40 (1.80–3.20) |
| Albuminoids (%) | 3.00–4.00 |
| Total available carbohydrates (%) | 41.77 |
| Alcohol-insoluble solids (%) | 22.70 |
| Water-insoluble solids (%) | 22.70 |
| Non-reducing sugars (%) | 16.52 |
| Total sugars (%) | 41.20 (21.40–30.85) |
| Starch (%) | 5.70 |
| Tannin (mg) | 600.00 |
| Ascorbic acid a (mg) | 3.00–9.00 |
| β-carotene equivalent (μg) | 10.00–60.00 |
| Thiamine (mg) | 0.18–0.22 |
| Riboflavin (mg) | 0.07–0.09 |
| Niacin (mg) | 0.60 |
| pH | (3.15) |
| Pentoses (%) | (4.20–4.80) |
| Sucrose (%) | (0.10–0.80) |

*Note*: The values given in the parantheses are for ripe fruit.
*Source*: Meillon (1974); Duke (1981); Ishola *et al*. (1990).

**Table 20.2.** Mineral composition of tamarind (mg/kg).

| Mineral | Pulp | Seed | Kernel | Testa |
|---|---|---|---|---|
| Calcium | 81–466 | 9.3–786.0 | 120 | 100 |
| Phosphorus | 86–190 | 68.4–165.0 | – | – |
| Magnesium | 72.03 | 17.5–118.3 | 180 | 120 |
| Potassium | 62–570 | 272.8–610.0 | 1020 | 240 |
| Sodium | 3.0–76.7 | 19.2–28.8 | 210 | 240 |
| Copper | 21.83 | 1.6–19.0 | – | – |
| Iron | 1.3–10.9 | 6.5 | 80 | 80 |
| Zinc | 1.06 | 2.8 | 100 | 120 |
| Nickel | 0.52 | – | – | – |

*Source*: Marangoni *et al*. (1988); Ishola *et al*. (1990); Bhattacharya *et al*. (1993).

**Table 20.3.** Composition of tender leaves and flowers of tamarind.

| Constituent | Tender leaves | Flowers |
|---|---|---|
| Moisture (%) | 70.5–78.0 | 80.0 |
| Protein (%) | 4.0–5.8 | 2.8 |
| Fat/oil (%) | 1.2–2.1 | 1.5 |
| Fibre (%) | 1.9–3.0 | 1.5 |
| Carbohydrates (total) (%) | 16.0–18.0 | |
| Ash/minerals (%) | 1.0–1.5 | 0.7 |
| Calcium (mg) | 101–250 | 35.5 |
| Magnesium (mg) | 71.0 | |
| Phosphorus (mg) | 140.0 | 45.6 |
| Iron (mg) | 2.0–5.2 | 1.5 |
| Thiamine (mg) | 0.1–0.2 | 0.07 |
| Riboflavin (mg) | 0.1–0.2 | 0.14 |
| Niacin (mg) | 1.5–4.1 | 1.14 |
| Vitamin C (mg) | 3.0–6.0 | 13.80 |
| Carotenes (mg) | | 0.31 |

*Source*: Lewis and Neelakantan (1964); Duke (1981).

20.3 gives the composition of the tender leaves and flowers.

Among fatty acids, linoleic acid was the major constituent (nearly 50%), followed by oleic (~ 24%) and palmitic acids (~ 15%). Table 20.4 gives the fatty acid composition of the seed oil of tamarind. Among sterols, betasitosterol constituted 66–72%, followed by campesterol (16–19%) and stigmasterol (Andriamanantena *et al.*, 1983).

Tamarind kernel powder has around 15% dietary fibre and 14% crude protein. Crude lipid is around 8%, 4.5% ash and has a calorific value of 1511 kj/100 g dry matter. Total protein fractionation revealed that 100 g of seed flour yields around 7 g protein, of which albumins and globulins each constituted ~ 2.5 g, prolamines 0.7 g and glutelins 1.3 g.

**Table 20.4.** Fatty acid composition of seed oil (%).

| Fatty acid | Content |
|---|---|
| Lauric acid (C12:0) | NP |
| Myristic acid (C14:0) | NP |
| Palmitic acid (C16:0) | 14.67 |
| Stearic acid (C18:0) | 5.27 |
| Oleic acid (C18:1) | 23.67 |
| Linoleic acid (C18:2) | 49.13 |
| Linolenic acid (C18:3) | 2.23 |
| Behenic acid (C22:0) | 5.03 |

NP = not present.
*Source*: Pugalenthi *et al.* (2004).

## 20.4. Chemistry

### Volatiles

Analysis of the volatile compounds of tamarind revealed the presence of more than 80 compounds. Aromatic and furan derivatives were dominant. The major constituents were 2-phenyl acetaldehyde (25.4% of total volatiles), which has a fruity and honey-like odour, 2-furfural (20.7%), having a caramel-like flavour, followed by hexadecanoic acid (18.1%) and limonene, which has a citrus flavour. A list of the volatile compounds detected in tamarind is given in Table 20.5.

The composition of volatile constituents in tamarind varies with climate and also between varieties. Grollier *et al.* (1998) reported that the main flavour compound of the tamarind pulp was 2-acetylfuran. An analysis of the volatile constituents of the fruit pulp of tamarinds grown in Malaysia indicated the presence of 66 compounds; furan derivatives and carboxylic acids were dominant, accounting for 44.4 and 33.3% of the total volatiles, respectively. The major components were furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenylacetaldehyde (7.5%) (Wong *et al.*, 1998). Sagrero *et al.* (1994) identified 16 volatile compounds from the fruit pulp of tamarind collected from Australia through GC and GC-MS and reported that aromadendrene was the major constituent in the oil, corresponding to 90% of the flavour constituents. Structures of some of the volatile components are given in Fig. 20.1.

#### *Composition of the leaf oil of* Tamarindus indica *L.*

The major constituents of the leaf oil of tamarind are linalool anthranilate, benzyl benzoate and limonene. α-Pinene, β-pinene, nerol, etc., were noticed in minor quantity. The components are listed in Table 20.6.

**Table 20.5.** Volatile compounds of tamarind (mg/kg).

| Compound | Content | Compound | Content |
|---|---|---|---|
| Acetaldehyde | < 0.01 | γ-Terpinene | 0.01 |
| Ethanol | < 0.01 | Acetophenone | < 0.01 |
| Diacetyl | < 0.01 | Methylbenzoate | 0.02 |
| Ethyl acetate | 0.08 | *cis*-Linalool oxide | 0.01 |
| Isovaleraldehyde | 0.09 | 4-Methylbenaldehyde | 0.02 |
| 2-Methylbutanal | 0.03 | Terpinolene | < 0.01 |
| 1-Penten-3-ol | < 0.01 | *trans*-Linalool oxide | < 0.01 |
| 2-Ethylfuran | 0.01 | α-Dimethylstyrene | < 0.01 |
| Isoamyl alcohol | 0.01 | Nonanal | 0.02 |
| 2-Methylbutanol | < 0.01 | 2-Phenylethanol | 0.02 |
| 1-Methyl-1H-pyrrole | 0.03 | 4-Methylacetophenone | < 0.01 |
| 1*H*-Pyrrole | 0.02 | (*E*,*Z*)-2,6-Nonadienal | < 0.01 |
| Pyrrolidine | < 0.01 | 2-Methylacetophenone | < 0.01 |
| Toluene | 0.01 | Terpinen-4-ol | < 0.01 |
| 3-Methyl-2-butenol | < 0.01 | Octanoic acid | < 0.01 |
| Hexanal | 0.02 | Al-terpineol | 0.02 |
| 1-Ethyl-1h-pyrrole | < 0.01 | Methyl salicylate | 0.03 |
| 2-Furfural | 0.62 | Safranal | < 0.01 |
| (*E*)-2-Hexenal | 0.01 | Al-ionene | 0.02 |
| Ethylbenzene | 0.02 | 2,3-Dihydrobenzofuran | < 0.01 |
| *p*-Xylene | 0.13 | 2-Phenylethyl butyrate | < 0.01 |
| *o*-Xylene | 0.04 | (*E*)-2-Decenal | 0.02 |
| Heptanal | < 0.01 | Vitispirane | 0.02 |
| Methional | 0.01 | (*E*)-Anethole | < 0.01 |
| 2-Acetylfuran | < 0.01 | 1*H*-Indole | 0.04 |
| α-Pinene | < 0.01 | Methyl decanoate | < 0.01 |
| Propylbenzene | < 0.01 | Eugenol | < 0.01 |
| Benzaldehyde | 0.03 | (*E*)-2-Undecenal | < 0.01 |
| 5-Methylfurfural | 0.01 | Decanoic acid | < 0.01 |
| β-Pinene | < 0.01 | Al-cedrene | 0.01 |
| 6-Methyl-5-hepten-2-one | < 0.01 | Geranyl acetone | < 0.01 |
| Sabinene | < 0.01 | Dodecanoic acid | 0.02 |
| Octanal | < 0.01 | Tetradecanoic acid | 0.06 |
| α-Phellandrene | < 0.01 | Methyl hexadecanoate | < 0.01 |
| (*E*,*E*)-2,4-Heptadienal | 0.01 | Hexadecanoic acid | 0.54 |
| α-Terpinene | < 0.01 | Ethyl linoleate | 0.02 |
| 1,2,4-Trimethylbenzene | < 0.01 | Octadecanoic acid | 0.02 |
| *p*-Cymene | 0.01 | 2-Butoxyethanol acetate | 0.02 |
| 1,8-Cineole | < 0.01 | Cyclohexyl acetate | < 0.01 |
| Benzyl alcohol | < 0.01 | Limonene | 0.15 |
| 2-Phenylacetaldehyde | 0.76 | | |

*Source*: Pino *et al.* (2004).

### Non-volatiles

Tamarind has tartaric acid as its major organic acid component. Many polyphenols are found in the coat of the tamarind fruit. Tamarind kernel powder (TKP) has a xyloglucan, which has a variety of uses. TKP, a crude extract of tamarind seeds, has been used as a replacement for starch in cotton sizing and as a wet-end additive in the paper industry, where it replaces starch and galactomannans (Glicksman, 1986). Refined tamarind seed polysaccharide is used as a thickening, stabilizing and gelling agent in the food industry, particularly in Japan where it is a permitted food additive (Glicksman, 1986; Gidley *et al.*, 1991).

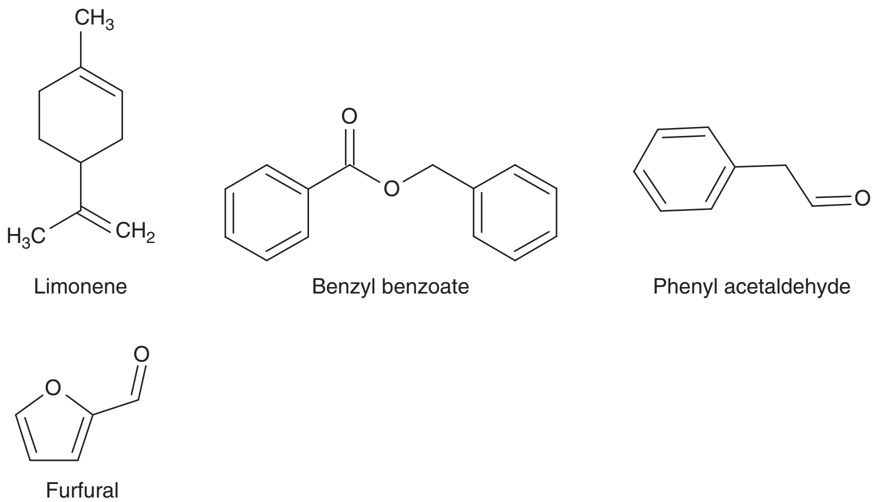


**Fig. 20.1.** Structures of major volatile compounds of tamarind.

*Composition of tamarind kernel powder*

Tamarind kernel powder, on fractionation, affords a homogeneous polysaccharide composed of D-glucose, D-xylose, D-galactose and L-arabinose in the molar ratios of 8:4:2:1 (Srivastava and Singh, 1967). The polysaccharide is composed of (1 → 4)-$\beta$-D-glucan backbone substituted with side-chains of $\alpha$-D-xylopyranose and $\beta$-D-galactopyranosyl (1 → 2)-$\alpha$-D-xylopyranose linked (1 → 6) to glucose residues. The glucose, xylose and galactose units are present in the ratio of 2.8:2.25:1.0 (Glicksman, 1986; Gidley *et al.*, 1991).

**Table 20.6.** Leaf oil components of tamarind (%).

| Compound | Content |
|---|---|
| (*E*)-2-Hexanal | 1.7 |
| α-pinene | 1.0 |
| β-pinene | 1.4 |
| *p*-Cymene | 0.6 |
| Limonene | 24.4 |
| (*E*)-*b*-Ocimene | t |
| Linalool | 1.0 |
| Linalool anthranilate | 4.7 |
| Al-terpineol | 0.7 |
| Nerol | 1.0 |
| Benzyl benzoate | 40.6 |
| Pentadecanol | 8.2 |
| Hexadecanol | 12.4 |

t = trace.
*Source*: Pino *et al.* (2002).

## Extraction and isolation techniques of tamarind xyloglucans and polyphenols

The major polyphenolic compounds of tamarind pericarp were extracted using organic solvents and the metabolites were isolated by semi-preparative high-performance liquid chromatography. Their structures were elucidated by liquid chromatography–electrospray-ionization-mass spectrometry (LC–ESI-MS), nano-electrospray-ionization mass spectrometry (ESI-MS) and, where possible, by gas chromatography-mass spectrometry (GC-MS) and $^1$H and $^{13}$C NMR (Sudjaroen *et al.*, 2005). Solvent extraction experiments showed that ethanol had a higher selectivity than ethyl acetate for extraction of (–)-epicatechin; yields of (–)-epicatechin using ethanol were about 150 mg/100 g. The antioxidant mixture extracted from sweet Thai tamarind seedcoat using solvent extraction with ethanol was found to be the most active in terms of peroxide value (Luengthanaphol *et al.*, 2004).

Several oligosaccharide fragments, ranging from two to nine contiguous residues, have been isolated from purified tamarind xyloglucan using enzymatic digestion and partial acid hydrolysis. Structures were determined using matrix-assisted laser adsorption ionization-time of flight (MALDI-TOF) mass spectrometry, gas chromatography (GC), gas chromatography-mass spectrometry (GC-MS) and Dionex high-pH anion exchange–high performance liquid chromatography (HPAE–HPLC) (Marry *et al.*, 2003).

The profile (%) of polyphenolics in tamarind pericarp was dominated by proanthcyanidins in various forms, such as (+)-catechin, procyanidin $B_2$, (–)-epicatechin (9.4), procyanidin trimer (11.3), procyanidin tetramer (22.2), procyanidin pentamer (11.6) and procyanidin hexamer (12.8), along with taxifolin (7.4), apigenin (2.0), eriodictyol (6.9), luteolin (5.0) and naringenin (1.4) of total phenols, respectively. Tamarind seeds comprised procyanidins only, represented (%) mainly by oligomeric procyanidin tetramer (30.2), procyanidin hexamer (23.8), procyanidin trimer (18.1), procyanidin pentamer (17.6), with lower amounts of procyanidin $B_2$ (5.5) and (–)-epicatechin (Sudjaroen *et al.*, 2005).

#### *Properties of TKP*

TKP is one of the cheapest gums available, but it has an unpleasant odour, dull colour and a presence of water insolubles. Low solubility in cold water and fast biodegradability are some other characteristics. Humidification and compression of the composite material prepared from the tamarind seed gum and the cellulosic-rich sisal plant fibre increased its adhesive strength. This material has potential industrial applications, such as in false roofing and room partitioning (Veluraja *et al.*, 1997). A number of chemical modifications of tamarind seed polysaccharide have been described, including acetyl (Rao and Beri, 1955), hydroxyalkyl (Schiavio and Maderno, 1958; Shimohiro *et al.*, 1983) and carboxymethyl (Shimohiro *et al.*, 1983; Omya and Tabuchi, 1985) derivatives. Carboxymethylation of tamarind kernel powder increased its solubility in cold water and the stability of its paste to microorganisms (Goyal *et al.*, 2006). The functional, as well as the nutritional, properties of the meal and concentrate from tamarind kernels (raw and roasted) revealed that the *in vitro* digestibility was 71.3; the kernel protein was rich in lysine, glutamic acid, aspartic acid, glycine and leucine, but deficient in sulphur-containing amino acids (Bhattacharya *et al.*, 1994).

Tamarind xyloglucan imparted more viscous, liquid-like rheological properties and heat stability to the gelatinized tapioca starch/xyloglucan mixtures (Pongsawatmanit *et al.*, 2006). Tamarind seed powder can also be used for the production of tannase under solid-state fermentation (SSF) using *Aspergillus niger* ATCC 16620 (Sabu *et al.*, 2005). The tamarind foam mats prepared from the binary combinations of the foaming agents ovalbumin, mesquite gum and a low-molecular weight, surface-active blend yielded foams that exhibited longer drainage mean times, higher yield stress, apparent plastic viscosity, critical drying time, instantaneous elastic modulus and a shorter onset of the critical drying time to yield tamarind powders with better sensory flavour perception (Carter *et al.*, 2001).

## 20.5. Medicinal and Pharmacological Uses

Tamarind has many medicinal uses. It is reported to have the following medicinal properties:

- Digestive
- Hepatic tonic
- Anti-inflammatory
- Corneal wound healing
- Antioxidant
- Other medicinal uses.

### Digestive

Due to its medicinal value, tamarind is used as an Ayurvedic medicine for gastric and/or digestion problems. Tamarind pulp alone, or in combination with limejuice, honey, milk, dates, spices or camphor, is used as a digestive, even for elephants (Morton, 1987).

### Hepatic tonic

The flowers are used to cure jaundice and bleeding piles (Brown, 1954; de Padua *et al.*, 1978). Tamarind pulp alone, or in combination with limejuice, honey, milk, dates, spices or camphor, is used as a remedy for biliousness and bile disorders and as an antiscorbutic (Morton, 1987).

### Anti-inflammatory

Tamarind leaves and flowers, dried or boiled, are used as poultices for swollen joints, sprains and boils (http://www.kingtutshop.com/Egyptian-Herb/Tamarind.htm). The pulp is used as an anti-inflammatory agent and as a gargle for sore throats. Lotions and extracts made from the leaves are used in treating conjunctivitis and are also used as antiseptics (Morton, 1987). Lotions and poultices from the bark are applied on open sores and caterpillar rashes. The powdered seed paste/seedcoat is also used to cure boils (http://www.haryana-online.com/Flora/imli.htm). The bark is used as a tonic or in poultices to treat ulcers, wounds, boils, sores and rashes in eastern Sudan and also in the Philippines (Dalziel, 1937). The bark of the tree is regarded as an effective astringent, tonic and febrifuge.

### Corneal wound healing

Bacterial keratitis is a serious infectious ocular disease requiring prompt treatment to prevent frequent and severe visual disabilities. The tamarind seed polysaccharide (TSP) appears to be a promising candidate as a vehicle for the topical treatment of bacterial keratitis. TSP prolongs the precorneal residence times of antibiotics and enhances drug accumulation in the cornea, probably by reducing the washout of topically administered drugs (Ghelardi *et al.*, 2004). The ability of the TSP to promote corneal wound healing may depend on its influence on the integrin recognition system (Burgalassi *et al.*, 2000a). It can be a potentially useful adjuvant for ophthalmic delivery systems (Burgalassi *et al.*, 2000b). Timolol in association with TSP has a prolonged duration of action and is suitable for ocular administration in cases of elevated intraocular pressure (D'Amico *et al.*, 1999).

### Antioxidant

Methanol and aqueous acetone extracts of dry-heated tamarind seedcoat sample showed hydroxyl radical scavenging activity, as well as exhibiting good antioxidant activity against the linoleic acid emulsion system, and the values were lower and higher than the synthetic antioxdiant, BHA, and ascorbic acid, respectively (Siddhuraju, 2006). The seeds showed a much higher antioxidant activity and phenolic content than the edible portions (Soong and Barlow, 2004). Treatment of hypercholesterolaemic hamsters with the *T. indica* fruit pulp extract led to a decrease in the levels of serum total cholesterol, non-HDL cholesterol and triglyceride and to an increase of high-density lipoprotein (HDL) cholesterol levels. It also led to decreased lipid peroxidation in serum and improved the efficiency of the antioxidant defence system, indicating the potential of tamarind extracts in diminishing the risk of atherosclerosis development in humans (Martinello *et al.*, 2006). Tamarind may be an important source of cancer chemopreventive natural products in tropical regions (Sudjaroen *et al.*, 2005). Tamarind xyloglucans were immunoprotective at low picogram doses. The tamarind xyloglucans also blocked UV-activated phosphorylation of SAPK/JNK protein (Strickland *et al.*, 1999).

### Other medicinal uses

Tamarind preparations are recognized universally as refrigerants in fevers and as laxatives and carminatives (Morton, 1987). The laxative properties of the pulp and the diuretic properties of the leaf sap have been confirmed by modern medicinal science (Bueso, 1980). In South-east Asia, the fruit is prescribed to counteract the ill effects of overdoses of false chaulmoogra, *Hydnocarpus anthelmintica* Pierre, given in leprosy. The pulp is said to aid the restoration of sensation in cases of paralysis (Morton, 1987). In Colombia, an ointment made of tamarind pulp, butter and other ingredients is used to cure domestic animals of vermin. The pulp is mixed with salt, as a liniment for rheumatism (Morton, 1987). It is also administered to alleviate sunstroke, *Datura* poisoning and alcoholic intoxication (Benthal, 1933; Dalziel, 1937; Eggeling and Dale, 1951; Chaturvedi, 1985), etc. It is reported to aid in the care of malarial fever also (Timyan and Bwa, 1996). In Mauritius, the Creoles mix salt with the pulp and use it as a liniment for rheumatism and make a decoction of the bark for asthma (http://www.kingtutshop.com/Egyptian-Herb/Tamarind.htm). Lotions and extracts made from tamarind preparations are used in treating dysentry, jaundice, erysipelas, haemorrhoids and various other ailments (Morton, 1987).

Tamarind leaves, seeds and fruits are also used in traditional Indian medicine (Jayaweera, 1981). The fruit shells are burnt and reduced to an alkaline ash, which enters into medicinal formulae. Powdered seeds/seedcoat, with or without cumin seeds and palm sugar, are prescribed for chronic diarrhoea and dysentery. Root infusion is used to cure chest complaints and is an ingredient in prescriptions for leprosy (http://www.haryana-online.com/Flora/imli.htm). The leaves and roots contain the glycosides, vitexin, isovitexin, orientin and isoorientin. Tamarind root bark is used for abortion. The root bark is ground into a powder, mixed with hot water and administered 3 days prior to an abortion and for the prevention of pregnancies (Lakshmanan and Narayanan, 1994). A decoction of the bark is used in cases of gingivitis, asthma and eye inflammation. The bark yields the alkaloid, hordenine. The bark has also been used to recover loss of sensation due to paralysis and to heal urinary discharges and gonorrhoea. Bark is also one of the ingredients of *Abayalavana*, used to cure enlarged spleen in India. In South India, tamarind-pepper rasam is also considered an effective home remedy for a cold.

## 20.6. Quality Specifications

There are quality specifications to be followed for seedless tamarind and dry tamarind, as well as tamarind concentrate, a product resulting from the concentration of hot water extract of soluble solids of tamarind pulp under vacuum, which is marketed by private agencies. Seeds are removed from the matured fruit, pressed and sold as tamarind pulp. This pulp generally is devoid of rind, seed and fibre. Seed content should not exceed 10% for average, 7% for fair, 5% for good or 3% for special-quality tamarind pulps. As per Agmark grades, a higher moisture content of up to 20% is allowed for pulp. Agmark specifications for seedless tamarind vary from Special to Grade C.

Special, Grade A and Grade B are awarded to dry tamarind under Agmark rules based on the percentage of rind, fibre, moisture and insect damage. For tamarind seed, there are only two grades, e.g. Special and Grade A (Table 20.7). Quality specifications are listed for undecorticated and decorticated tamarind seeds, as well as tamarind powder.

### Prescription for requirement, methods of sampling and test for tamarind concentrate

Tamarind concentrate shall be obtained by hot water extraction of clean tamarind pulp, with subsequent concentration under vacuum. The tamarind fruits shall be mature, sound, fresh and shall be free from insect and fungal attack or any other blemish which affects quality. There should not be any added colouring or flavouring agents.

It shall be manufactured under hygienic conditions, light to dark brown in colour, and the flavour should be characteristic of tamarind fruit. No burnt flavour should be present. It shall be free from harmless extraneous vegetable materials (fibre and rind common to tamarind, and stems up to

**Table 20.7.** Agmark specifications for tamarind seedless, dry tamarind and tamarind seed.

| Character/grade | Special | A | B | C |
|---|---|---|---|---|
| *Tamarind seedless (%/weight max.)* | | | | |
| Moisture | 15 | 17 | 20 | 20 |
| Seed content | 5 | 10 | 15 | 20 |
| Foreign matter (organic) | 4 | 6 | 8 | 10 |
| Foreign matter (inorganic) | 1 | 1.5 | 2 | 2 |
| *Dry tamarind (%/weight max.)* | | | | |
| Seed content | 35 | 40 | 45 | – |
| Fibre | 6 | 8 | 10 | – |
| Rind | 3 | 4 | 6 | – |
| Insect damage | 2 | 3 | 5 | – |
| Moisture | 15 | 20 | 25 | – |
| *Tamarind seed (%/weight max.)* | | | | |
| Extraneous matter | 1 | 2 | – | – |
| Damaged and discoloured | 2 | 5 | – | – |
| Weight/l | 900 | 800 | – | – |
| Moisture | 9 | 10 | – | – |

*Source*: Saideswara Rao and Mary Mathew (2001).

10 mm in length and sepal bracts aggregating an area of 5 $cm^2$, pits (a whole pit (stone) or one half seed of the tamarind fruit) and pit fragments (piece of tamarind seed less than the equivalent of one half pit and which weighs at least 5 mg). It should be free from living insects, moulds, insect fragments and rodent contamination visible to the naked eye.

## Packing

Tamarind preparations shall be packed in tin plate or glass containers which should be sealed appropriately. The tin plate container shall be lacquered with acid-resistant lacquer. Each container should be labelled with the name of the material, name and address of the manufacturer, net mass of the contents of the container in grams, date of manufacture, list of additives and manufacturer's licence number. Requirements for tamarind concentrate and limits of heavy metals are given in Table 20.8.

## Patents

A general patents search revealed as many as 161 web pages for green tamarind, 77 for tamarind powder, 53 for tamarind pulp, 51 for tamarind paste, 35 for tamarind juice

**Table 20.8.** Requirements for tamarind concentrate and limits for heavy metals (as per IS 5955:1993).

| Tamarind concentrate | Requirement |
|---|---|
| *Characteristics* | |
| Headspace of the can in mm, max. | 6 |
| Microbiological requirements | To satisfy the test |
| Moisture,% by mass, max. | 15 |
| Total soluble solids, % by mass, min. | 65 |
| Total insoluble pulp, % by mass, max. | 2 |
| Total tartaric acid, %, min. | 9 |
| Acid insoluble ash (on dry basis), % by mass, max. | 0.5 |
| Total reducing sugar, % by mass, max. | 35 |
| *Limits for heavy metals* | |
| Arsenic, ppm, max. | 1.0 |
| Lead, ppm, max. | 2.5 |
| Copper, ppm, max. | 30 |
| Zinc, ppm, max. | 50 |
| Tin, ppm, max. | 250 |

concentrate, 26 for tamarind jam, 21 for tamarind kernel powder, 15 for tamarind pickles and three for tamarind chutney (http://www.scopus.com/scopus/home.url).

As many as 15 Indian patents for tamarind were filed from 1995 to 2004. Patent areas included process of tamarind paste and concentrate; tamarind pickles and tamarind garlic chutney preparations; preparation of Indian traditional tokku-like product from green tamarind; preparation of tamarind extract in the form of paste/jam; improved process of the production of tamarind powder; preparation of carboxy methyl tamarind kernel powder for printing polyester fabrics; recovery of potassium bitartarate; pectin sugar fruit acids by by-products from tamarind pulp; process of extraction of polysaccharides from tamarind seed kernel; recovery of tartaric acid from tamarind pulp; and a method of improving jute yarn sizing by the application of modified tamarind kernel powder (http://www.indianpatents.org.in/db/test).

## 20.7. Conclusion

Tamarind is rich in calcium, potassium, zinc and iron. The major flavour compounds in tamarind are furfural and phenyl acetaldehyde. Benzyl benzoate, linalool anthranilate and limonene are the major leaf oil components. Quality specifications are available for a few tamarind products, but a large number of tamarind products are emerging and there is scope for developing quality specifications for other products as well. Tamarind is used traditionally as an astringent, an anti-inflammatory and anti-diuretic agent, a liniment for rheumatism, a laxative, a carminative and a digestive agent. Scientific basis for such claims is lacking and hence warrants detailed investigation.

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