Tamarind (Tamarindus indica)

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Tamarind (*Tamarindus indica*)

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Abstract

Tamarindus indica is recognized highly around the world for its nutritional and high health promotion values. In the recent past, antioxidants from natural sources and their roles in prevention and treatment of various ailments have been extensively studied. Wide distributions of polyphenol and flavonoid compounds in *Tamarindus indica* are believed to be responsible for its high antioxidant activity. Phenolic compounds present in tamarind are beneficial for cardiovascular health and immunological health and have specific roles in anti-microbial and anticancer activities. The flavonoids present in different parts of tamarind are known to exhibit defence mechanism as an anti-inflammatory, antidiabetic and antihyperlipidemic agent for the treatment of several human health hazards. Although a huge amount of data is available in the literature concerning the antioxidant properties of *Tamarindus indica*, this chapter is an attempt to compile all those information in a single platform to aid the future direction of this research area.

Keywords

Tamarind · Health benefits · Antioxidants · Polyphenol · Fruit pulp · Flavonoids

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16.1 Botanical Name, Common Name

Botanical name: *Tamarindus indica* Linn
Common name: Teteli (Assamese), Imli (Hindi), Tamarind (English)

16.2 Introduction

Tamarindus indica L. is one of the chief leguminous plant species of Fabaceae family. Almost each and every part of this plant has some use in medicinal, nutritional, economic, or environmental context. Therefore, it is regarded as a multipurpose tree. Although it is capable of tolerating a dry condition of 5–6 months long duration, but it has a very minimal amount of chance in surviving at stumpy temperature (Pereira et al. 2011). The diverse varieties of tamarind can be further divided into two distinct types—acidic variety and sweet acidic variety. The former variety easily develops under warm and sunny locations and therefore is most common. The latter, which is a sweet-type variety, is more sensitive to fluctuations in temperature and so not readily available. Tamarind has a great demand towards its fruits that are either consumed as fresh raw material or processed. The mouth-watering sweet acidic taste of tamarind pulp is due to balanced combination of tartaric acid and reducing sugar content. Pulp has various utilities such as seasoning, flavour confections, curries, chutneys, sauces, juice, infusion, brine, or beverage. Seeds of tamarind are the by-products of various industries that use tamarind pulp as their raw material. An occurrence of an elevated amount of chemicals such as tannins as well as various dyeing substances in the testa makes the entire seed unpleasant for direct consumption (Kumar and Bhattacharya 2008). Therefore, seeds are first soaked and boiled in water before consumption. A well-known product known as tamarind kernel powder or TKP is the foremost industrial product of tamarind seed industry. TKP has various utilizations such as a raw material in the jute and paper industries, initial sizing material of the fabric and textile industry (Kumar and Bhattacharya 2008). Jellose, which is a polysaccharide isolated from its seed, is utilized as a stabilizer in cheese as well as mayonnaise and ice cream and in the manufacturing of pharmaceutical product. In some developing countries, tamarind seeds can serve as a substitute protein source to lessen malnutrition problems. Flowers and leaves can be eaten fresh, cooked in a variety of dishes, or can be prepared into curries, salads and soups. So, basically this plant has huge potential in eradicating many problems associated with human health and that's why a compiled review of the work done on this plant is an extremely necessary step for providing a direction to the future researchers.

16.2.1 Origin and History

Various authors have anticipated different geographical areas for the origin of tamarind like Far East or Africa (Coates-Palgrave 1988) or Ethiopia (Troup 1921). But the fact is that tamarind is aboriginal to Africa and exotic to Central America and the Asian subcontinent. However 'Tamarind' word itself is a Persian word derived from 'tamar-i-hind' meaning 'date of India'. Moreover, the presence of tamarind is indicated in the historic Indian Brahma Samhita scriptures way before between 1200 and 200 BC (El-Siddig 2006). Therefore many natural scientists including Morton and Dowling (1987) thought it to have been originated from India. The dispersal of tamarind to Asia is thought to have occurred in the first millennium BC. Later, the development of cultivation techniques for tamarind was acknowledged in the country of Egypt by 400 BC. It is believed that Arab and Persian merchants brought tamarind to South East Asia from India.

16.2.2 Production

Among Asian countries, India and Thailand are the leading tamarind producers followed by Indonesia, Sri Lanka, Bangladesh and Thailand. Apart from that, Mexico and Costa Rica are the prime producers of Tamarind in America. Although in Africa tamarind has its wide uses among the local people but no commercial productions have been reported so far. Trivial producers in Africa are Zambia, Kenya, Senegal, Tanzania and Gambia (El-Siddig 2006). An interesting observation can lead us to the fact that India is the only country in the world to produce tamarind as fruit of commercial crop. Within the country, tamarind is abundantly cultivated in Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Odisha, Karnataka, Kerala, Bihar and West Bengal. India recorded a yield of 188,278 tonnes of tamarind in the year 2007–2008 and 193,873 tonnes in the year 2008–2009 (Rao and Mathew 2012). Tamil Nadu accounted for the largest volume of tamarind production in the year 2018, followed by Kerala and Maharashtra. About 5.5 million tonnes of Tamarind fruit have been marketed widely within India and about 70,000 tonnes have been exported annually. India exported 97,000 tonnes of fresh and dried tamarind worth Rs. 14 crores to West Asia, Europe and America during 1996–1997. For the purpose of marketing, salt has been replaced by sugar to ensure its preservation and preparation. This sweet pulp is exported to countries such as the USA and Europe to be used in confectionery. After India, Thailand holds the second position as a leading tamarind producer with a record of 140 thousand tonnes production margin (Yaacob and Subhadrabandhu 1995). Production and export of tamarind from other Asian countries take place at much lesser scale as compared to Thailand and India. Out of the total world production of tamarind, sour variety is most widespread comprising 95%. Thailand is considered as the world's biggest producer of sweet tamarind.

16.2.3 Botanical Description

Tamarind is a hefty, evergreen, or semi-evergreen tree of 12–14 m high with a thick trunk up to 1.5–2 m across and up to 8 m in circumference. Leaves are alternate and even pinnate, 5–12.5 cm long, shortly petioled and petiole glabrous or puberulent. Leaflets are subsessile, 10–12 paired, closely set on the rachis, oblong, obtuse, glabrous and reticulately veined. Flowers are few, borne in racemes at the ends of branches, the lateral flowers are dropping. Flowers bisexual, irregular with a pedicel (5–10 mm) are connected at the apex. Bracts are early caduceus and ovate oblong. There are two small bracteoles, boat-shaped and reddish. Calyx (8–15 mm long) with a very constricted turbinate tube with four unequal sepals, imbricate, ovate and membranous in nature. Corolla of five petals with two anterior and three upper; the upper petals are more or less longer than the sepals while the anterior petals are found as bristle embedded in the basal portion of the staminal tube Out of all the seven stamens, three are fertile and rest four are sterile. Anthers are reddish brown in colour, oblong in nature, transverse and dehisce longitudinally. The position of ovary is superior to other floral parts with few to numerous ovules, stalked. The fruits are pods, 5–16 cm long and 2 cm broad, oblong, curved or straight, compressed. The outer epicarp of pod exhibits a brown or light grey colour and scaly. The pulp inside is soft and blackish brown in colour. Each of the pod contains up to 3–12 obovate, oblong mature seeds. Seeds are hard, and colour varies from slightly reddish to purplish brown, exalbuminous with thick cotyledons.

16.3 Antioxidant Properties of *Tamarindus indica*

Antioxidants are the substances that inhibit the oxidation process of the targets even at low concentration and thus acting as body's endogenous defence system against free radicals. These antioxidants can be grouped into two broad categories—natural and synthetic antioxidants. According to some researches in the recent past, the use of synthetic antioxidants has shown their unwanted side effects, so extensive use of such materials may cause potential health risk in the near future (Kaur and Kapoor 2001). Therefore, nowadays people are more interested towards natural antioxidants rather than synthetic products. Natural antioxidants primarily include polyphenols that present in almost every portion of the plants such as barks, fruits, leaves, nuts, roots and seeds. Flavonoids (a subclass of polyphenol) are second most important natural antioxidants (Lu et al. 2011). Vitamins, for instance, vitamin C (ascorbic acid) and vitamin E (Tocopherol), carotenoids are furthermore known to have antioxidant potentials. *Tamarindus indica* is known to have remarkable antioxidant property. Different parts of tamarind such as fruit pulp, pericarp, seed and leaves are natural sources of antioxidants that can be an alternative to synthetic antioxidants. Different antioxidant compound identified from various parts of tamarind along with the antioxidants present in their products are described below.

16.3.1 Seed

Tamarind is an admirable supply of natural antioxidants such as phenolic compounds and flavonoids. Polyphenols are the most noteworthy compounds responsible for antioxidant properties of plant raw material (Buck Up and Samappito 2011). Tsuda et al. (1994) reported four phenolic compounds from seeds of tamarind, which are 2-hydroxy-3′, 4′dihydroxyacetophenone, methyl 3,4-hidydroxybenzoate, epicatechin and 3,4-dihydrophenyl acetate. Furthermore, they have reported that these extracts exhibited antioxidant activities by plummeting lipid peroxidation in vitro. Later on, Lakhe et al. (2017) confirmed the antioxidant property of tamarind seed extract through peroxide value and Kreis test. Caffeic acid is the most important compound in seed extract responsible for its antioxidant properties protecting cells against lipid peroxidation (Razali et al. 2015). Methanolic extracts obtained from tamarind seed coat have the potential to restore activity of antioxidants of enzymatic origin such as catalase of carbon tetrachloride (CCl_4)-induced oxidative damage in albino rats in vitro and superoxide dismutase (Sandesh et al. 2014). They suggested that these products could be used as health supplement, nutraceutics as well as food preservative. Because of the occurrence of flavonoids, phenols and tannins, the extracts from seed coat possess a number of activities such as lipid peroxidation, diminution, antimicrobial, antihyperlipidemic, antidiabetic, antityrosinase, collagen stimulating, anti-inflammatory (Soradech et al. 2016). Not only the raw seed coats but also the phenolic substances from the dry heated seed coats are potent antioxidant source (Siddhuraju 2007). Even the tamarind seed husk has high content of phenolic compounds and antioxidant activities as reported by many researchers (Povichit et al. 2010; Sinchaiyakit et al. 2011).

16.3.2 Pericarp

The outermost layer, that is, exocarp is variously known as skin, pericarp, peel, or husk of a fruit. Polyphenolic profile of methanolic extract of tamarind pericarp mostly contains proanthocyanidins (73.4%) such as (þ)-catechin, taxifolin, procyanidin trimer, luteolin, epicatechin, naringenin of total phenols, procyanidin B_2, apigenin, eriodictyol and tetramer, pentamer and hexamers of procyanidin as a whole (Sudjaroen et al. 2005). Pumthong (1999) also found extracts of tamarind pericarp to be dominated mainly by polymeric tannins and oligomeric procyanidins.

16.3.3 Fruit Pulp

The pulp constitutes most part (25–50%) of the mature fruit of tamarind, the fibre and shell constitute 10–30% and the seed constitutes about 25–45% (El-Siddig et al. 1999). Fruit pulp of *Tamarindus indica* is a rich source of phytonutrients, including phenolic compounds that have the potential to act like proper dietary antioxidants. It is a prosperous resource of polyphenols such as flavan-3-ols (epicatechin and catechin), flavonoids (vitexin, iso-vitexin), procyanidin, triterpenes (orientin, iso-orientin) and vitamins (B3, E and C) (Narina et al. 2019). When flesh of tamarind was compared with other fruits such as avocado, jackfruit, mango and longan, it showed the highest phenolic content (Soong and Barlow 2004). Moreover, fruit extract obtained from tamarind boosts up and triggers the antioxidant defence coordination of the body. Raw extract of pulp, when administered on model animals in laboratory, largely enhanced the efficiency of certain enzymatic antioxidants such as superoxide dismutase and glutathione peroxidase (Lim et al. 2013; Martinello et al. 2006). Fruit pulp extract of tamarind caused 50% lowering in the initial level of serum total cholesterol, 73% lowering of non-high-density lipoprotein (non-HDL) cholesterol, 60% triglyceride reduction and an enhancement up to 61% in case of high-density lipoprotein level during an in vitro experiment performed on hypercholesterolemic hamster. The experiment showed free radical scavenging activity of the obtained extract as proved by 2–2-diphenyl-1-picrylhydrazyl (DPPH), low lipid peroxidation in serum, and radical superoxide assays (Martinello et al. 2006). Fruit pulp is a rich source of organic acids. Among all the chemical constituents of tamarind, tartaric acid is most abundant. The acidic taste of tamarind is due to the existence of high concentration of tartaric acid in various parts (El-Siddig et al. 1999). Other organic acids comprise succinic acid, malic acid, formic acid, oxalic acid, acetic acid and citric acid (Katsayal et al. 2019).

16.3.4 Leaf

Antioxidant activities of tamarind leaf have been highlighted by many researchers (Mbaye et al. 2017; Selvi et al. 2011). Flavonoids and tannins are the main constituent of tamarind leaf (De Caluwé et al. 2010). Methanolic extracts of leaf show 80% phenol, 60–70% flavonoids and 50% tannin content (Selvi et al. 2011). These abundant polyphenolic constituents are responsible for the antioxidative activities of its leaves. HPLC-UV spectroscopy analysis of leaf extracts identified six flavonoids derivatives—Luteolin 7-o-glycosides, luteolin, apigenin, isorientin, orientin, vitexin and one polyphenol derivative derivative—caffeic acid (Escalona-Arranz et al. 2010). Gas chromatography-mass spectrometry (GC-MS) analysis of leaf extracts also showed the presence of sterols and phenolic compounds. Those compounds are limonene, naringin, caryophyllene, p-cymene and ß-sitosterol (Escalona-Arranz et al. 2010). Limonene and naringin are the two well-known phenolic compounds in citrus fruits having antioxidant activities (Bacanli et al. 2015). ß-Sitosterol is a naturally occurring sterol molecule mostly found in legumes, cereals, plant oil, seed and nuts. It has potential to inhibit the growth of specific type of tumour cell in vitro. ß-Sitosterol was seen to prevent lipid peroxidation and restore the activity of nonenzymatic antioxidants to normal function in a DMH (1,2-dimethylhydrazine)-mediated colon carcinogenesis in Wistar rats (Baskar et al. 2012). Glycosides are also known to have antioxidant potential. A good figure of glycosides such as isoorientin, isovitexin, vitexin and orientin have been extracted from the leaves of tamarind (Bhatia et al. 1966). Leaves of tamarind are known to be a very rich source of ascorbic acid or vitamin C (El-Siddig 2006).

16.3.5 Juice Concentrate

Tamarind juice is a wealthy supply of antioxidant that boosts up body's immune system. It is a very rich resource for ascorbic acid, which acts as a blood purifier. Regular consumption of juice extracts of *Tamarindus indica* prevents the body from oxidative damage. It has the inherent capacity to prevent the entire process of oxidation of cholesterol, thus preventing them by adhering to the walls of arteries and finally jamming them in the process. This will, in turn, lessen the threat of high cholesterol level and coronary heart disease (Maheshwari et al. 2014). The approximate composition of juice concentrate as reported by Central Food Technological Research Institute, that is, CFTRI is enumerated later:

Invert sugars 50%
Total tartaric acid 13%
Moisture content 30%
Protein 3%
Pectin 2%
Cellulosic material 2%

16.3.6 Antioxidant Properties of Products Obtained From *Tamarindus indica*

Tamarind kernel powder (TKP) is the final product of tamarind seed industry. TKP is incorporated during preparation of baked products such as cake and biscuits in order to improve nutritional content and increase shelf life. TKP-incorporated baked products showed increased shelf life that might be due to its potent antioxidant properties (Chakraborty et al. 2016). Pectin is a very much naturally occurring polysaccharide in the plant body. It is extensively engaged as stabilizing emulsifying and gelling agent (Koubala et al. 2008). Pectin isolated from tamarind pulp is known to exhibit antioxidant potential. Its antioxidant activity is higher than or similar to tamarind seed, pulp, or seed coat (Sharma et al. 2015). Rodriguez Amado et al. (2016) formulated and standardized a new tablet from tamarind leaf. They evaluated antioxidant and hepatoprotective potential of the formulation on a Sprague Dawley rats intoxicated with CCl_4. They found that redox balance of all enzymatic antioxidants remained normal and lipid peroxidation is inhibited in the experimental groups treated with tablets. Xyloglucan is a natural polysaccharide obtained from tamarind seed kernel. This polysaccharide has a range of applications in areas like medicine industry, textile industry and food and drug delivery technology (Mishra and Malhotra 2009). Xyloglucan exhibits strong antioxidant, antimutagenic and anticarcinogenic activity along with gallic acid (Hirun et al. 2015). Tril et al.

Table 16.1 Various antioxidant compounds isolated from different parts of *Tamarindus indica*

Various parts	Compounds	References
Seed	2-Hydroxy-3′,4′dihydroxyacetophenone, methyl 3, 4-hidydroxybenzoate, 3,4-dihydrophenyl acetate, epicatechin, and caffeic acid	Tsuda et al. (1994), Razali et al. (2015).
Pericarp	Naringenin, taxifolin, (þ)-catechin, luteolin, eriodictyol, epicatechin, apigenin, procyanidin B_2, and trimers-tetramers-pentamers-hexamers of procyanidin.	Sudjaroen et al. (2005)
Fruit pulp	Catechin, epicatechin, vitexin, iso-vitexin, procyanidin, orientin, iso-orientin, vitamins (B_3, E, C), formic acid, oxalic acid, acetic acid, malic acid, tartaric acid, succinic acid, and citric acid	Narina et al. (2019), Katsayal et al. (2019).
Leaves	Luteolin 7-o-glycosides, luteolin, apigenin, isorientin, orientin, vitexin, caffeic acid, limonene, naringin, Caryophyllene, p-cymene, ß-sitosterol, vitexin, isovitexin, orientin, isoorientin and vitamin C	Escalona-Arranz et al. (2010), Bhatia et al. (1966), El-Siddig (2006).

(2014) evaluated various physicochemical, antioxidant and antimicrobial properties of rich fibre powder extracted from the tamarind pulp. Authors urged that fibre powder can be utilized during food processing as a natural preservative due to the presence of natural antioxidants (phenols and flavonoids) and antimicrobial compounds in it (Table 16.1).

16.4 Antioxidant-Mediated Biological Activities of *T. indica* and Its Mechanism of Action

Free radicals are the short-lived reactive molecules possessing unpaired electrons. Depending upon its site of production and concentration, these reactive molecules may react with cellular proteins and macromolecules and modify several cellular proteins, lipids, DNA and cellular signal transduction pathway. Both enzymatic and nonenzymatic antioxidants have different mechanism of action towards these free radicals. The working mechanism of enzymatic antioxidants includes breakdown and removal of free radicals while nonenzymatic antioxidants perform its action by directly breaking the free radical chain reactions. All natural antioxidants fall under the category of nonenzymatic antioxidants. Natural antioxidant compounds have loads of positive biological effects towards health promotion. Antioxidant-mediated biological role of tamarind includes antinematodal, anticancer, antimicrobial, molluscicidal, antifungal, antidiabetic, cytotoxic, antiviral and anti-inflammatory (Katsayal et al. 2019). Atawodi and Mubarak (2015) from their experiment reported an in vivo hepatoprotective and nephroprotective effect of different parts of tamarind attributed to its antioxidant potential. Fruit pulp extract of tamarind caused lowering in the level of non-HDL cholesterol, serum total cholesterol and triglyceride, again, an increase in high-density lipoprotein levels during an in vitro experiment performed on hypercholesterolemic hamster representative of its potential in minimizing the threat of atherosclerosis in humans (Martinello et al. 2006). Antioxidant-mediated ameliorative effect of seeds of the extracts of *Tamarindus indica* on chemically induced nephrotoxicity and renal cell carcinoma has been well explained by Vargas-Olvera et al. (2012). Various polyphenolic compounds in the seed extract have antioxidant enzyme induction as well as cancer signalling pathway blockage properties. Studies have shown that intake of antioxidants from natural sources has advantageous effect on cardiovascular system. Fruit extract of tamarind exhibits hypocholesterolemic and antioxidant properties. It increases the expression of low-density lipoprotein (LDL) receptor gene, ABCG5 and Apo-A1, and decreases the expression of microsomal triglyceride protein (MTP) coding gene and 3-hydroxy-3-methylglutaryl-CoA (HMG-CoA) reductase in the liver. In this way it prevents triglyceride accumulation in liver by increasing cholesterol excretion and intake of LDL-cholesterol from tangential tissues and lowering cholesterol biosynthesis. It prevents atherosclerosis by preventing LDL-cholesterol oxidative damage (Lim et al. 2013). Epicatechin, a flavonoid compound present in seed and fruit of tamarind, shows hypolipidemic effect by lowering triglyceride level (Landi Librandi et al. 2007). The antioxidant activity is mostly associated with the presence of a diverse group of phenolic compounds. In Tamarind, phenols are the most dominantly found natural antioxidant. These compounds act as hydrogen donors or metal ion chelators by inhibiting the oxidation of low-density lipoprotein (LDL). Phenolic compounds inactivate free radicals by transferring hydrogen molecules from its hydroxyl groups. It maintains a shielding role against various neurodegenerative diseases such as cancers and cardiovascular disease (Menezes et al. 2016). Alpha-tocopherol (vitamin E) is a potential lipid-soluble antioxidant found in the fruit of tamarind. It functions by chain breaking during reactive species mediated membrane lipid peroxidation. Tocopherol reacts with lipid peroxyl radical and forms a stable product tocopheroxyl radical that is inadequately reactive to initiate membrane lipid peroxidation by its own (Nimse and Pal 2015). Ascorbic acid (vitamin C), a hydrosoluble antioxidant mainly present in fruit pulp, is another free radical scavenger. It acts by giving away an electron to the lipid radical itself changing to ascorbate radical and thereby terminating the lipid peroxidation. The resultant ascorbate radical is feebly reactive and changes to ascorbate by reductase-dependent nicotinamide adenine dinucleotide (NADH) or nicotinamide adenine dinucleotide phosphate (NADPH). Alternatively ascorbate radical can undergo pH-dependent disproportionate reaction forming one molecule of dehydroascorbate and one molecule of ascorbate. The former does not have antioxidant property and hence it is transformed back to ascorbate by accepting two more electrons. Flavonoids are another group of compounds known for its antioxidative property. Free radical can be interfered by flavonoids through different mechanisms. One way out is the direct scavenging of free radicals in which flavonoids tend to stabilize the reactive species by reacting with them and thus making them less reactive. Radicals are made inactive because of highly reactive hydroxyl group of flavonoids. Second mechanism includes nitric oxide (NO) scavenging. Although a minimal production of NO is significant for maintaining proper dilation of blood vessel, overinduction can cause oxidative damage. At high concentration, NO tends to react with the free radicals yielding the highly destructive peroxynitrite. Peroxynitrite oxidizes LDLs; as a consequence it causes irreversible damage to the cell membrane. Flavonoids have the potential to scavenge these free radicals, resulting in less damage (Nimse and Pal 2015) (Table 16.2).

16.5 Health Benefits

Tamarind products are frequently used as health remedies right the way through Asian subcontinent, Africa and the America since time immemorial (El-Siddig 2006). The entire tree has tremendous medicinal importance that has been utilized in traditional African medicine and Indian Ayurvedic medicine (Jayaweera 1981; Parrotta 1990). Tamarind fruit is used as a blood tonic, digestive aid, expectorant, laxative and carminative (Komutarin et al. 2004). The laxative characteristic of the pulp is due to the presence of high amounts of tartaric acids, malic acid and potassium acid tartrate (Irvine 1961). The pulp unaided or in amalgamation with spices or camphor, milk, lime juice, dates and honey is used as carminative and during digestive disorders. It is also used as a remedy for bile disorders, febrile conditions and biliousness. Tamarind is also utilized for the handling of mild malarial fever (Timyan 1996). The fruits have molluscicidal, anti-bacterial and anti-fungal properties as well (Guerin and Reveillere 1984; Ray and Majumdar 1976). Antibacterial effect is due to the presence of a compound called lupeol (Al-Fatimi et al. 2007). Tamarindienal, a compound isolated from the fruit, exhibits antifungal activity (Imbabi et al. 1992; Imbabi and Abu-Al-Futuh 1992). Anti-inflammatory properties of tamarind pulp have also been well reported (Rimbau et al. 1999). Tamarind pulp extract is used to cure malarial fever and alleviate sunstroke. Pulp is used to treat skin infection and intestinal ailments. Moreover, juice extracted from pulp is used as a gargle to take care of sore throats.

Tamarind seeds are known for its antidiabetic properties (Maiti et al. 2004; Rama Rao 1975). Seeds are used in the treatment of bladder stones, ulcers and dysentery (Rama Rao 1975). Antiobesity effect of seed is due to the presence of procyanidin (Kumar and Bhattacharya 2008). The glucosyl transferase inhibitor, which is a compound obtained from seed husks, was reported to exhibit antidental caries effect in a report claimed by Tamura et al. (1996). It is also used against snake bite in India. Antivenom nature of tamarind has been studied and found that the seed extracts possess potential to inhibit protease, 5′-nucleotidase phospholipase, hyaluronidase and l-amino acid oxidase enzyme activities of venom in dosage-dependent mode (Ushanandini et al. 2006).

The boiled or dried flowers and leaves of tamarind are used as poultices for swollen joints, boils and sprains. Extracts and lotions prepared from leaves and flowers are used in treating jaundice, dysentery, haemorrhoids, erysipelas and as antiseptics, vermifuges and conjunctivitis. During coughs, urinary troubles, liver

Table 16.2 Antioxidant-mediated biological activities of *Tamarindus indica*

Compound name	Various parts	Biological effect	References
Methyl 3,4-dihydroxybenzoate	Seed coat	Anticancer, spasmolytic,	Kuru (2014), Tsuda et al. (1994)
3,4-dihydroxyphenyl acetate	Seed coat	Antimicrobial, spasmolytic	Tsuda et al. (1994), Kuru (2014)
Vitamin C	Fruit pulp	Antioxidant, immune stimulant	Kuru (2014), Meena et al. (2018), De Caluwé et al. (2010)
2-hydroxy-3′, 4′-dihydroxyacetophenone	Seed coat	Anticancer, spasmolytic	Escalona-Arranz et al. (2010), Tsuda et al. (1994), Kuru (2014)
Catechin	Pulp	Antioxidant	Kuru (2014), Bhadoriya et al. (2011)
Taxifolin	Pericarp, pulp	Antioxidant	Bhadoriya et al. (2011)
Succinic acid	Pulp	Antioxidant	Bhadoriya et al. (2011)
Apigenin	Pulp	Antioxidant, anti-inflammatory	Bhadoriya et al. (2011)
Tannins	Pulp	Antimicrobial, Antiulcers	Kuru (2014), Meena et al. (2018), Gupta et al. (2014)
Tartaric acid	Leaves, pulp	Antioxidant, antimicrobial, laxative	Meena et al. (2018), Adeniyi et al. (2017)
Terpenoids	Pulp	Anti-inflammatory, antimicrobial	Iskandar et al. (2017), Gupta et al. (2014)
Procyanidin B_2, dimer, trimer	Pulp, leaves, pericarp	Anticancer, antiulcers	Bhadoriya et al. (2011), Kuru (2014)
Orientin	Leaves	Antioxidant	Meena et al. (2018)
Isoorientin	Leaves	Antioxidant	Meena et al. (2018)
Oxalic acid	Leaves	Antioxidant, anticoagulant, allelochemical,	Meena et al. (2018)
Vitexin	Leaves	Antioxidant	Meena et al. (2018)
Isovitexin	Leaves	Antioxidant	Meena et al. (2018)
Naringenin	Leaves	Antioxidant	Meena et al. (2018)
Citric acid	Leaves, pulp	Antioxidant, anti-inflammatory	Sairah et al. (2014), Meena et al. (2018), Bhadoriya et al. (2011)
Malic acid	Pulp, leaves	Antioxidant, laxative,	Sairah et al. (2014), Bhadoriya et al. (2011), Meena et al. (2018)
Epicatechin	Pulp, seed, pericarp	Anticancer, antioxidant, antiulcer,	Tsuda et al. (1994), Kuru (2014), Adeniyi et al. (2017), Bhadoriya et al. (2011)

Source: Katsayal et al. (2019)

Table 16.3 Medicinal uses of different parts of *Tamarindus indica*

Disorder/medicinal use	Parts used	Reference
Laxative	Pulp, leaf, bark	Komutarin et al. (2004), Bhat et al. (1990), Havinga et al. (2010)
Abdominal pain	Leaf, root, bark	Havinga et al. (2010), Chhabra et al. (1987), Doughari (2006)
Wound healing	Leaf, bark	Fabiyi et al. (1993)
Diabetes	Seed	Maiti et al. (2004)
Hepatoprotective	Leaf, fruit, seed	Pimple et al. (2007)
Dysentery	Root, leaf	Bhadoriya et al. (2011), Chhabra et al. (1987)
Diarrhoea	Pulp	Bhadoriya et al. (2011)
Infertility	All arial parts	Alawa et al. (2002)
Malaria	Bark, fruit, leaf	Havinga et al. (2010)
Antivenom	Seed, leaf, root	Ushanandini et al. (2006)
Vertigo	Pulp	Havinga et al. (2010)
Anti-inflammatory	Pulp	Rimbau et al. (1999)
Mumps	Leaf	Havinga et al. (2010)
Fever	Pulp, bark, leaf	Havinga et al. (2010)
Ear ache	Leaf	Havinga et al. (2010)
Scurvy	Fruit pulp	Havinga et al. (2010)
Measles	Pods, leaves	Havinga et al. (2010)

ailments, fever, intestinal worms and throat infections, leaves are mixed with salt and water and consumed directly. Leaves and bark are mostly used to heal wounds when applied in the mode of a powder or decoction or as a poultice, separately or with other species. (Fabiyi et al. 1993). Bark of the tamarind tree is utilized as effective tonic, febrifuge and astringent. It is applied to relieve ulcers, sores, rushes and boils. Bark and leaves are used for wound healing, applied superficially on the spot, either in combination with other species, as a powder or poultice, alone or as a decoction (Table 16.3).

16.6 Conclusion

According to health experts, some synthetic antioxidants are carcinogenic so extensive use of such materials corresponds to health risk. Therefore nowadays people prefer more natural antioxidants over synthetic. Tamarind is one such easily available fruit that serves as a natural source of antioxidants. It has tremendous contribution towards traditional health care system and its tremendous potential can be used more extensively in developing modern-day drugs. Therefore, further investigations and research work should be carried out about its antioxidant and biochemical potential with the aid of modern techniques for finding out the enormous scope hidden within this majestic plant *Tamarindus indica*.

References

Adeniyi OV, Olaifa FE, Emikpe BO, Ogunbanwo ST (2017) Phytochemical components and antibacterial activity of Tamarindus indica Linn. Extracts against some pathogens. Biotechnol J Int 17(2):1–9

Alawa JP, Jokthan GE, Akut K (2002) Ethnoveterinary medical practice for ruminants in the subhumid zone of northern Nigeria. Prev Vet Med 54(1):79–90

Al-Fatimi M, Wurster M, Schröder G, Lindequist U (2007) Antioxidant, antimicrobial and cytotoxic activities of selected medicinal plants from Yemen. J Ethnopharmacol 111(3):657–666

Atawodi LL, Mubarak SE (2015) Hepatoprotective and nephroprotective effects of methanolic extract of different parts of *Tamarindus indica* Linn in rats following acute and chronic carbon tetrachloride intoxication. Annu Res Rev Biol 5(2):109–123

Bacanli M, Başaran AA, Başaran N (2015) The antioxidant and antigenotoxic properties of citrus phenolics limonene and naringin. Food Chem Toxicol 81:160–170

Baskar AA, Al Numair KS, Gabriel Paulraj M, Alsaif MA, Muamar MA, Ignacimuthu S (2012) β-sitosterol prevents lipid peroxidation and improves antioxidant status and histoarchitecture in rats with 1, 2-dimethylhydrazine-induced colon cancer. J Med Food 15(4):335–343

Bhadoriya SS, Ganeshpurkar A, Narwaria J, Rai G, Jain AP (2011) *Tamarindus indica*: extent of explored potential. Pharmacogn Rev 5(9):73

Bhat RB, Etejere EO, Oladipo VT (1990) Ethnobotanical studies from central. Nigeria Econ Bot 44 (3):382–390

Bhatia VK, Gupta SR, Seshadri TR (1966) C-glycosides of tamarind leaves. Phytochemistry 5 (1):177–181

Buck Up, Samappito (2011) Res J Med Plant 5(6):695–705

Chakraborty P, Chakraborty N, Bhattacharyya DK, Ghosh M (2016) Effect of tamarind kernel powder incorporation in property and quality aspects of biscuit, bread and cake making. Arch Appl Sci Res 8(1):30–39

Chhabra SC, Mahunnah BLA, Mshiu EN (1987) Plants used in traditional medicine in eastern Tanzania. I. Pteridophytes and angiosperms (Acanthaceae to Canellaceae). J Ethnopharmacol 21:253–277

Coates-Palgrave K (1988) Trees of Southern Africa-*Tamarindus indica*, vol 10. LCS Striuk Publishers, Cape Town, pp 278–279

De Caluwé E, Halamoud K, Van Damme P (2010) *Tamarindus indica* L.: a review of traditional uses, phytochemistry and pharmacology. Afrika Focus 23(1):53–83

Doughari JH (2006) Antimicrobial activity of *Tamarindus indica* Linn. Trop J Pharm Res 5 (2):597–603

El-Siddig K (2006) Tamarind: *Tamarindus Indica* L. Crops for the future. Southampton Centre for Underutilised Crops, Southampton

El-Siddig K, Ebert G, Lüdders P (1999) Tamarind (Tamarindus indica L.): a review on a multipurpose tree with promising future in the Sudan. Angew Bot 73(5–6):202–205

Escalona-Arranz JC, Pérez-Rosés R, Jiménez IL, Rodríguez-Amado J, Argota-Coello H, Cañizares-Lay J, Sierra-González G (2010) Chemical constituents of *Tamarindus indica* L. leaves. Rev Cuba Quím 22(3):65–71

Fabiyi JP, Kela SL, Tal KM, Istifanus WA (1993) Traditional therapy of dracunculiasis in the state of Bauchi-Nigeria. Dakar Med 38(2):193–195

Guerin JC, Reveillere HP (1984) Activité antifongique d'extraits vegetaux a usage therapeutique.1. Etude de 41 extracts sur 9 souches fonguques (Antifungal activity of plant extracts used in therapy). 1. Study of 41 plant extracts against 9 fungal species). Ann Pharm Fr 42(6):553–559 (English summary)

Gupta C, Prakash D, Gupta S (2014) Studies on the antimicrobial activity of tamarind (*Tamarindus indica)* and its potential as food bio-preservative. Int Food Res J 21(6):2437–2441

Havinga RM, Hartl A, Putscher J, Prehsler S, Buchmann C, Vogl CR (2010) *Tamarindus indica* L. (Fabaceae): patterns of use in traditional African medicine. J Ethnopharmacol 127 (3):573–558

Hirun N, Sangfai T, Tantishaiyakul V (2015) Characterization of freeze-dried gallic acid/ xyloglucan. Drug Dev Ind Pharm 41(2):194–200

Imbabi ES, Abu-Al-Futuh IM (1992) Investigation of the molluscicidal activity of *Tamarindus indica* L. Int J Pharmacol 30(2):157–160

Imbabi ES, Ibrahim KE, Abulfutah IM, Hulbert P (1992) Chemical characterization of tamarind bitter principle. Fitoterapia 63(6):537–538

Irvine FR (1961) Woody plants of Ghana, Woody plants of Ghana, vol 40. Oxford University Press, London

Iskandar I, Setiawan F, Sasongko LD, Adnyana IK (2017) Six-month chronic toxicity study of tamarind pulp (*Tamarindus indica* L.) water extract. Sci Pharm 85(1):10

Jayaweera DMA (1981) Medicinal plants (Indigenous and Exotic) used in Ceylon. Part 111. Flacourtiaceae-Lytharaceae. A publication of the National Science Council of Sri Lanka, Ceylon, pp 244–246

Katsayal BS, Sallau AB, Muhammad A, Garba A (2019) Antioxidant potentials of *T. indica* and its environmental application: a mini review. Curr Biotechnol 8(2):96–103

Kaur C, Kapoor HC (2001) Antioxidants in fruits and vegetables–the millennium's health. Int J Food Sci Technol 36(7):703–725

Komutarin T, Azadi S, Butterworth L, Keil D, Chitsomboon B, Suttajit M, Meade BJ (2004) Extract of the seed coat of *Tamarindus indica* inhibits nitric oxide production by murine macrophages in vitro and in vivo. Food Chem Toxicol. Pergamon Press, Oxford, UK 42(4):649–658

Koubala BB, Mbome LI, Kansci G, Mbiapo FT, Crepeau MJ, Thibault JF, Ralet MC (2008) Physicochemical properties of pectins from ambarella peels (*Spondias cytherea*) obtained using different extraction conditions. Food Chem 106(3):1202–1207

Kumar CS, Bhattacharya S (2008) Tamarind seed: properties, processing and utilization. Crit Rev Food Sci Nutr 48(1):1–20

Kuru P (2014) *Tamarindus indica* and its health related effects. Asian Pac J Trop Biomed 4 (9):676–681

Lakhe P, Karikar M, Chopde M (2017) Tamarind seed–a potential antioxidant. Int J Res Biosci Agric Technol 5(2):1131–1133

Landi Librandi AP, Chrysóstomo TN, Azzolini AE, Recchia CG, Uyemura SA, de Assis-Pandochi AI (2007) Effect of the extract of the tamarind (*Tamarindus indica*) fruit on the complement system: studies in vitro and in hamsters submitted to a cholesterolenriched diet. Food Chem Toxicol 45(8):1487–1495

Lim CY, Mat Junit S, Abdulla MA, Abdul Aziz A (2013) In vivo biochemical and gene expression analyses of the antioxidant activities and hypocholesterolaemic properties of *Tamarindus indica* fruit pulp extract. PLoS One 8(7):e70058

Lu M, Yuan B, Zeng M, Chen J (2011) Antioxidant capacity and major phenolic compounds of spices commonly consumed in China. Food Res Int 44(2):530–536

Maheshwari RK, Lal Jat B, Khan S, Ranjee MM, Chaudhary U (2014) To demystify savory *Tamarindus indica* Linn. for healthcare. Int J Pharm Nat Med 2(2):173–179

Maiti R, Jana D, Das UK, Ghosh D (2004) Antidiabetic effect of aqueous extract of seed of *Tamarindus indica* in streptozotocin-induced diabetic rats. J Ethnopharmacol 92(1):85–91

Martinello F, Soares SM, Franco JJ, Santos ACD, Sugohara A, Garcia SB, Uyemura SA (2006) Hypolipemic and antioxidant activities from *Tamarindus indica* L. pulp fruit extract in hypercholesterolemic hamsters. Food Chem Toxicol 44(6):810–818

Mbaye AI, Gueye PM, Fall AD, Kane MO, Badji KD, Sarr A, Bassene E (2017) Antioxidative activity of *Tamarindus indica* L. extract and chemical fractions. Afr J Biochem Res 11(2):6–11

Meena SZ, Rahman MA, Bagga P, Mujahid M (2018) Hepatoprotective activity of *Tamarindus indica* Linn stem bark ethanolic extract against hepatic damage induced by co-administration of antitubercular drugs isoniazid and rifampicin in Sprague Dawley rats. J Basic Clin Physiol Pharmacol 30(1):131–137

Menezes APP, Trevisan SCC, Barbalho SM, Guiguer EL (2016) *Tamarindus indica* L. A plant with multiple medicinal purposes. J Pharmacogn Phytochem 5(3):50

Mishra A, Malhotra AV (2009) Tamarind xyloglucan: a polysaccharide with versatile application potential. J Mater Chem 19(45):8528–8536

Morton JF, Dowling CF (1987) Fruits of warm climates. JF Morton, Miami

Narina SS, Catanzaro C, Gilani AH (2019) Moringa and tamarind: potential drought-tolerant perennial crops. In: Handbook of plant and crop stress, 4th edn. CRC Press, Boca Raton, pp 813–831

Nimse SB, Pal D (2015) Free radicals, natural antioxidants, and their reaction mechanisms. RSC Adv 5(35):27986–28006

Parrotta JA (1990) *Tamarindus Indica* L., Tamarind: Leguminosae (Caesalpinioideae), Legume family. US Forest Service, Southern Forest Experiment Station, Institute of Tropical Forestry, Río Piedras

Pereira PHF, Voorwald HCJ, Cioffi MOH, Mullinari DR, Da Luz SM, Da Silva MLCP (2011) Sugarcane bagasse pulping and bleaching: thermal and chemical characterization. Bioresources 6(3):2471–2482

Pimple BP, Kadam PV, Badgujar NS, Bafna AR, Patil MJ (2007) Protective effect of *Tamarindus indica* Linn against paracetamol-induced hepatotoxicity in rats. Indian J Pharm Sci 69(6):827

Povichit N, Phrutivorapongkul A, Suttajit M, Chaiyasut C, Leelapornpisid P (2010) Phenolic content and in vitro inhibitory effects on oxidation and protein glycation of some Thai medicinal plants. Pak J Pharm Sci 23(4):403–408

Pumthong G (1999) Antioxidative activity of polyphenolic compounds extracted from seed coat of *Tamarindus indica* Linn (Doctoral dissertation). Graduate School, Chiang Mai University, Chiang Mai

Rama Rao M (1975) Flowering plants of Travancore. Bishen Singh Mahendra Pal Singh, Dehra Dun

Rao YS, Mathew KM (2012) Tamarind. In: Handbook of herbs and spices. CSIR, New Delhi, pp 512–533

Ray PG, Majumdar SK (1976) Antimicrobial activity of some Indian plants. Econ Bot 30 (4):317–320

Razali N, Junit SM, Ariffin A, Ramli NSF, Aziz AA (2015) Polyphenols from the extract and fraction of *T. indica* seeds protected HepG2 cells against oxidative stress. BMC Complement Altern Med 15(1):438

Rimbau V, Cerdan C, Vila R, Iglesias J (1999) Antiinflammatory activity of some extracts from plants used in the traditional medicine of North-African countries. Phytother Res 13(2):128–132

Rodriguez Amado JR, Lafourcade Prada A, Escalona Arranz JC, Pérez Rosés R, Morris Quevedo H, Keita H, Tavares Carvalho JC (2016) Antioxidant and hepatoprotective activity of a new tablets formulation from *Tamarindus indica* L. Evid Based Complement Alternat Med 6(1):1743403

Sairah S, Zammurad IA, Muhammad I, Al-Haq AM (2014) The possible role of organic acids as allelochemicals in *Tamarindus indica* L. leaves. Acta Agric Scand 64(6):511–517

Sandesh P, Velu V, Singh RP (2014) Antioxidant activities of tamarind (*Tamarindus indica*) seed coat extracts using in vitro and in vivo models. J Food Sci Technol 51(9):1965–1973

Selvi A, Tamil, Shipra S, Krithiga G, Chandrasekaran B, Rose C (2011) Antioxidant and antimicrobial activity of leaves extract (*Tamarindus indica*) and it's phytochemical characterization. J Pharm Res 4(12):4435

Sharma R, Kamboj S, Khurana R, Singh G, Rana V (2015) Physicochemical and functional performance of pectin extracted by QbD approach from *Tamarindus indica* L. pulp. Carbohydr Polym 134:364–374

Siddhuraju P (2007) Antioxidant activity of polyphenolic compounds extracted from defatted raw and dry heated *Tamarindus indica* seed coat. LWT-Food Sci Technol 40(6):982–990

Sinchaiyakit P, Ezure, Sriprang S, Pongbangpho S, Povichit N, Suttajit M (2011) Tannins of tamarind seed husk: preparation, structural characterization, and antioxidant activities. Nat Prod Commun 6(6):829–834

Soong YY, Barlow PJ (2004) Antioxidant activity and phenolic content of selected fruit seeds. Food Chem 88(3):411–417

Soradech S, Petchtubtim I, Thongdon AJ, Muangman T (2016) Development of wax-incorporated emulsion gel beads for the encapsulation and intragastric floating delivery of the active antioxidant from *Tamarindus indica* L. Molecules 21(3):380–393

Sudjaroen Y, Haubner R, Würtele G, Hull WE, Erben G, Spiegelhalder B, Owen RW (2005) Isolation and structure elucidation of phenolic antioxidants from Tamarind (*Tamarindus indica* L.) seeds and pericarp. Food Chem Toxicol 43(11):1673–1682

Tamura K, Fuji A, Shidehara N (1996) Health beverage containing glucosyl transferase inhibitors for dental caries prevention. Japanese Patent 07,258,105

Timyan J (1996) Bwa yo: important trees of Haiti. South-East Consortium for International Development, Washington, DC

Tril U, Fernández-López J, Álvarez JÁP, Viuda-Martos M (2014) Chemical, physicochemical, technological, antibacterial and antioxidant properties of rich-fibre powder extract obtained from tamarind (*Tamarindus indica* L.). Ind Crop Prod 55:155–162

Troup RS (1921) The Silviculture of Indian trees Leguminosae (Caesalpinieae) to Verbenaceae. 7. *Tamarindus indica* L. Clarendon Press, Oxford, pp 263–363

Tsuda T, Watanabe M, Ohshima K, Yamamoto A, Kawakishi S, Osawa T (1994) Antioxidative components isolated from the seed of tamarind (*Tamarindus indica* L.). J Agric Food Chem 42 (12):2671–2674

Ushanandini S, Nagaraju S, Harish Kumar K, Vedavathi M, Machiah DK, Kemparaju K, Girish KS (2006) The anti-snake venom properties of *Tamarindus indica* (leguminosae) seed extract. Phytother Res 20(10):851–858

Vargas-Olvera CY, Sánchez-González DJ, Solano JD, Aguilar-Alonso FA, Montalvo-Muñoz F, Martínez-Martínez CM, Ibarra-Rubio ME (2012) Characterization of N-diethylnitrosamine-initiated and ferric nitrilotriacetate-promoted renal cell carcinoma experimental model and effect of a tamarind seed extract against acute nephrotoxicity and carcinogenesis. Mol Cell Biochem 369(1–2):105–117

Yaacob O, Subhadrabandhu S (1995) The production of economic fruits in South-East Asia. Oxford University Press, Oxford