Tamarindus indica: Extent of explored potential

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Submitted: 14-05-2010

ABSTRACT

Tamarindus is a monotypic genus and belongs to the subfamily Caesalpinioideae of the family Leguminosae (Fabaceae), *Tamarindus indica* L., commonly known as *Tamarind* tree is one of the most important multipurpose tropical fruit tree species in the Indian subcontinent. 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. *T.indica* is used as traditional medicine in India, Africa, Pakistan, Bangladesh, Nigeria,and most of the tropical countries. It is used traditionally in abdominal pain, diarrhea and dysentery, helminthes infections, wound healing, malaria and fever, constipation, inflammation, cell cytotoxicity, gonorrhea, and eye diseases. It has numerous chemical values and is rich in phytochemicals, and hence the plant is reported to possess antidiabetic activity, antimicrobial activity, antivenomic activity, antioxidant activity, antimalarial activity, hepatoprotective activity, antiasthmatic activity, laxative activity, and anti-hyperlipidemic activity. Every part of the plant from root to leaf tips is useful for human needs. Thus the aim of the present review is to describe its morphology, and explore the phytochemical constituents, commercial utilization of the parts of the plant, and medicinal and pharmacologic activities so that *T. indica*'s potential as multipurpose tree species can be understood.

Key words: Antidiabetic, antioxidant, antimicrobial, antiinflammatory, hepatoprotective, *Tamarindus indica*

INTRODUCTION

Medicinal plants are the back bone of Traditional medicine.[1] Traditionally, the use of plant preparation as sources of drug are based on the experience and superstitions passed from generation to generation, virtually by the word of mouth.[2] Research on medicinal plant has increased recently all over the world. Medicinal plants have been used in various systems, as they have potential against numerous diseases. The movement of Tamarind to Asia must have taken place in the first millennium BC. Cultivation of Tamarind in Egypt by 400 BC has been documented and it was mentioned in the Indian Brahmasamhita Scriptures between 1200and 200 BC. About 370-287 BC, Theophrastus wrote on plants and two descriptions refer to Tamarind, his sources were probably from East Africa.

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Access this article online

Quick Response Code:

Website: www.phcogrev.com

DOI: 10.4103/0973-7847.79102

Taxonomical classification

Kingdom	Plantae
Phylum	Spermatophyte
Class	Angiosperm
Sub class	Dicotyledone
Family	Leguminosae
Subfamily	Caesalpiniaceae
Genus	*Tamarindus*
Species	*indica*

Plant description and morphology

Tamarindus indica [Figure 1] is of moderate to large in size, evergreen tree, up to 24 m in height and 7m in girth. The latest morphologic and molecular analyses and continued study will clarify the exact positioning of *Tamarindus* in relation to its putatively related genera.[3-7] It is a large evergreen tree with an exceptionally beautiful spreading crown, and is cultivated throughout almost the whole country, except in the Himalayas and western dry regions.[8] Leaves alternate, compound, with 10-18 pairs of opposite leaflets; leaflets narrowly oblong, 12-32×3-11 mm, petiole and rachis finely haired, midrib and net veining more or less conspicuous on both surface. Flowers attractive pale yellow or pinkish, in small, lax spikes about 2.5 cm in width. Flower buds completely enclosed by 2 bracteoles, which fall very early; sepals 4, petals 5, the upper 3 well developed, the lower 2

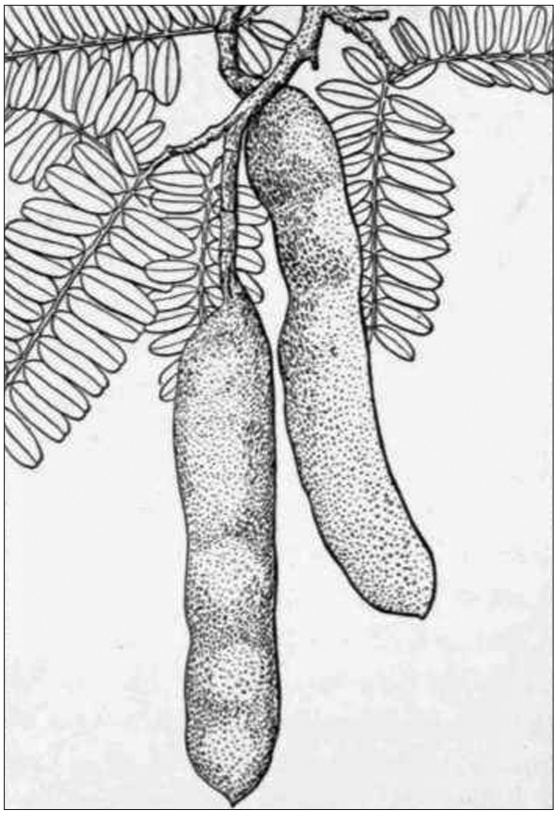

Figure 1: *Tamarindus indica*

minute. Fruit is a pod, indehiscent, subcylindrical, 10-18 ×4 cm, straight or curved, velvety, rusty-brown; the shell of the pod is brittle and the seeds are embedded in a sticky edible pulp. Seeds are 3-10, approximately 1.6 cm long, irregularly shaped, and testa hard, shiny, and smooth.

Vernacular names

In India, Tamarind is known by a wide variety of vernacular names: Tetuli (Assamese); Amli, Nuli, Textili Tentul (Bengali); Amali, Ambali (Gujarati); Ambli, Amli, Imli, (Hindi); Puli (Malayalam); Amli, Chinch, Chitz (Marathi); Koya, Tentuli (Oriya); Imli (Punjabi); Chinta (Telugu).[9]

T. indica is used as a Traditional medicine in India, Sudan, Nigeria, Bangladesh, and most of the tropical countries. Contrary to pharmaceuticals, it is often freely and readily available. [10-16] Almost all parts of the tree find some use or the other in food, chemical, pharmaceutical, and textile industries, and as fodder, timber, and fuel.[17,18] Commercial plantations are reported in Central American countries and in north Brazil.[19] Large segments of human population and animals in the developing countries suffer from protein malnutrition. *T. indica* is rich in nutrients and plays an important role in human nutrition, mainly in the developing countries. [20, 21] *T. indica* contains high levels of crude protein. *T. indica* also contains a high level of protein with many essential amino acids, which help to build strong and efficient muscles *T. indica* is also high in carbohydrate, which provides energy, and is rich in minerals, such potassium,

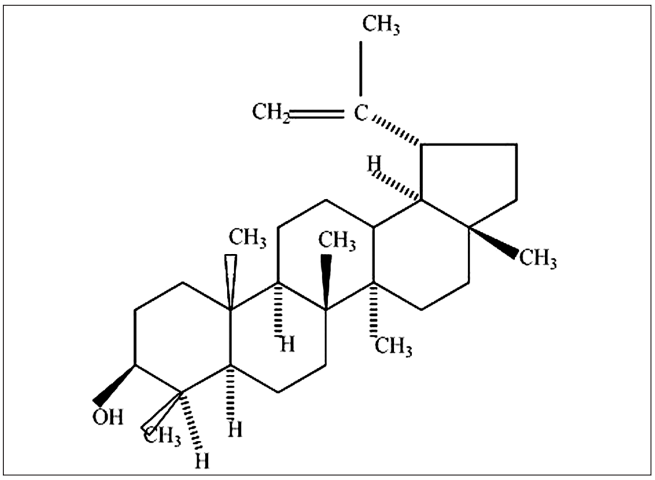

Figure 2: Lupeol

phosphorus, calcium, and magnesium. *T. indica* can also provide smaller amounts of iron and vitamin A. The whole plant of Tamarind is uesd extensively for medicinal and industrial purpose, hence it is very beneficial to the human being. [22]

Chemical constituents of T. indica

Phytochemical investigation carried out on *T. indica* revealed the presence of many active constituents, such as phenolic compounds, cardiac glycosides,[23] L-(-)mallic acid,[14] tartaric acid, the mucilage and pectin, arabinose, xylose, galactose, glucose, and uronic acid.[24,25] The ethanolic extract of *T. indica* showed presence of fatty acids and various essential elements like arsenic, calcium, cadmium, copper, iron, sodium, manganese, magnesium, potassium, phosphorus, lead, and zinc.[26]

The pulp contains organic acids, such as tartaric acid, acetic acid, citric acid, formic acid, malic acid, and succinic acid; amino acids; invert sugar (25-30%); pectin; protein; fat; some pyrazines (trans-2-hexenal); and some thiazoles (2-ethylthiazole, 2-methylthiazole) as fragrant; and the seed polysaccharides are found with a main chain consisting of β-1,4-connected glucose molecules together with xylose (alpha-1,6) and galactose; total protein; lipids with fatty oils; and some keto acids.[27] In the leaves of the plant, two triterpenes, lupanone and lupeol [Figure 2] were found.[28]

The leaf oil contains 13 components among which linonene and benzyl benzoate were most predominant.[29] Phytochemical investigation of the root bark of *T. indica* showed the presence of *n*-hexacosane, eicosanoic acid, b-sitosterol, octacosanyl ferulate, 21-oxobehenic acid, and (+)-pinitol. The presence of the bioactive compound (+)-pinitol in this plant is being reported for the first time.[30] The volatile constituents of the fruit pulp were furan derivatives (44.4%) and carboxylic acid (33.3%) of the total volatiles.[31] The major fatty acids of seeds were palmitic acid, oleic acid, linoleic acid, and eicosanoic acid. The unsaponifiable matter from the seed oil of *T. indica* showed presence of β-amyrin, compesterol, β-sitosterol and seven hydrocarbons.

The aerial parts of this plant have demonstrated the presence

of tartaric acid, acetic acid, and succinic acid, gum, pectin, sugar, tannins, alkaloid, flavonoids, sesquiterpenes, and glycosides.[32-35] *T. indica* seeds and pericarp contain phenolic antioxidants.

The profile of polyphenolics in Tamarind pericarp was dominated by proanthocyanidins in various forms, such as apigenin [Figure 3], catechin [Figure 4], procyanidin B2, epicatechin [Figure 5], procyanidin dimer [Figure 6a], procyanidin trimer [Figure 6b], along with taxifolin [Figure 7], eriodictyol [Figure 8], naringenin [Figure 9], of total phenols, respectively. The content of Tamarind seeds comprised only procyanidins, represented mainly by oligomeric procyanidin tetramer, procyanidin hexamer, and procyanidin pentamer with lower amounts of procyanidin B2 epicatechin.[36]

Uses of various parts of *T. indica*

Fruit pulp

Tamarind is valued mostly for its fruit, especially the pulp, which is used for a wide variety of domestic and industrial purposes.[37] The acidic pulp is used as a favorite ingredient in culinary preparations, such as curries, chutneys, sauces, ice cream, and sherbet in countries where the tree grows naturally,[38-40] In India, the pulp is also eaten raw and sweetened with sugar.[41] Tamarind pulp is also used to make sweet meats mixed with sugar called Tamarind balls.[42] Tamarind pulp is used as a raw material for the manufacture of several industrial products, such as Tamarind Juice Concentrate, Tamarind Pulp Powder, tartaric acid, pectin, tartarates, and alcohol.[43,44]

Seed

Tamarind seed is a by-product of the commercial utilization of the fruit, the seed comprises the seed coat or testa (20-30%) and the kernel or endosperm (70-75%).[45, 46] However, it has several uses. It is commercially available as a food additive for improving the viscosity and texture of processed foods.[47] The name "jellose" has been suggested for the seed polysaccharide as it describes both its jelly forming properties and the carbohydrate character.[48,49] It has been recommended for use as a stabilizer in ice-cream, mayonnaise, and cheese and as an ingredient or agent in a number of pharmaceutical products, and the seed oil is said to be palatable and of culinary quality.[50] The oil is used for making varnish to paint idols,[51,52] and light lamps.[53,54]

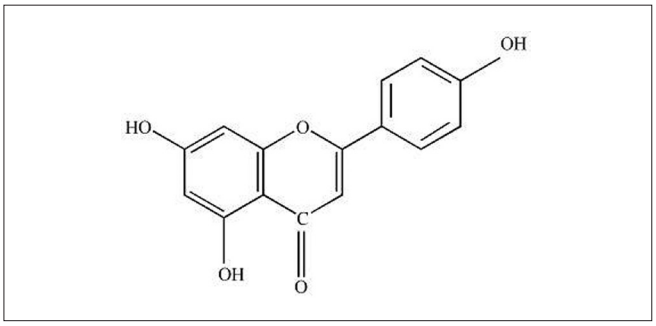

Figure 3: Apigenin

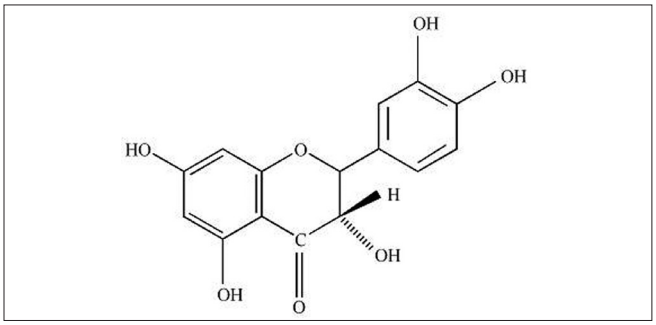

Figure 5: Epicatechin

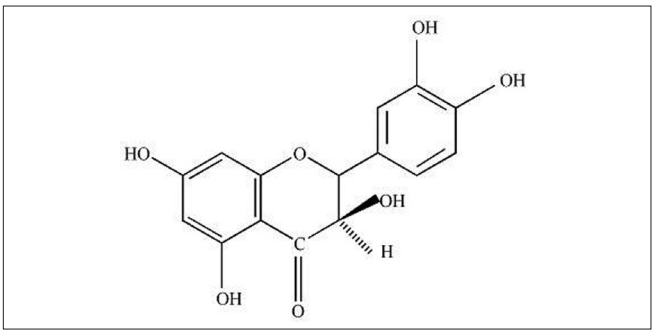

Figure 4: Catechin

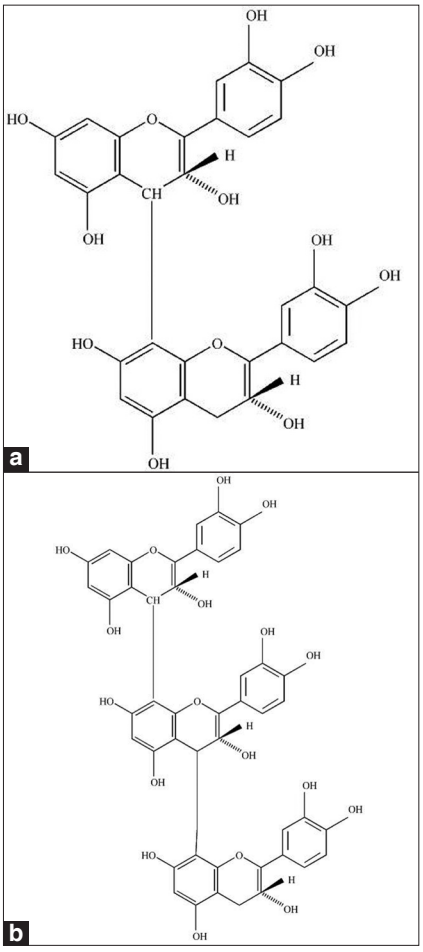

Figure 6: (a) Procyanidin dimer (b) Procyanidin trimer

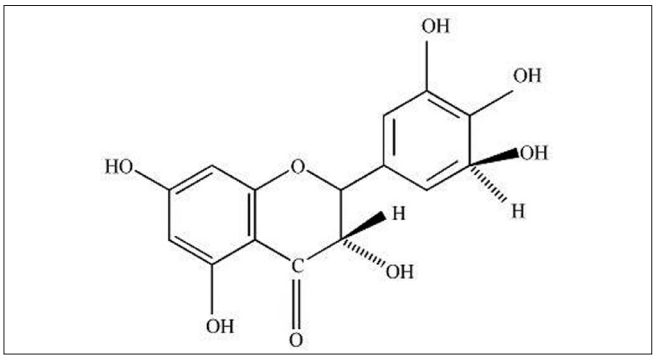

Figure 7: Taxifolin

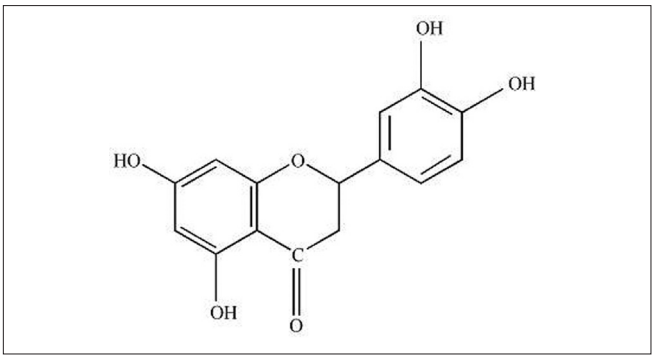

Figure 8: Eriodictin

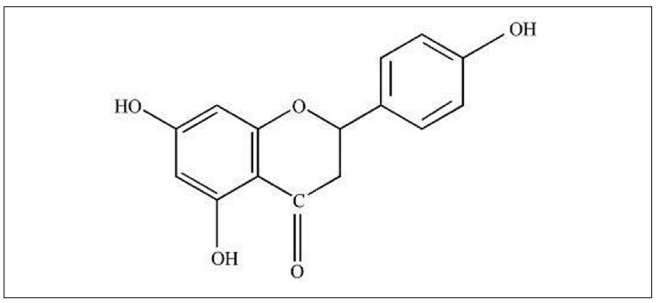

Figure 9: Naringenin

Flowers and leaves

The leaves, flowers, and immature pods of Tamarind are also edible. The leaves and flowers are used to make curries, salads, stews, and soups in many countries, especially in times of scarcity.[55] These are used in some Thai food recipes because of their sourness and specific aroma.[45] Children in Gambia mix the acid leaves with gum from fig trees to make a chewing gum.[56] The leaves and flowers are also useful as a mordant in dyeing. A yellow dye derived from the leaves colors wool red and turns indigo dyed silk to green.[52,54] Mature leaves are used as a bleaching agent in the preparation of young leaves of "buri" (*Corypha alata*) for hat making in the Philippines.[57]

Wood

Tamarind wood has many uses, including making furniture, wheels, mallets, rice pounders, mortars, pestles, ploughs, well construction, tent pegs, canoes, side planks for boats, cart shafts and axles, and naves of wheels, toys, oil presses, sugar presses, printing blocks, tools and tool handles, turnery, and so on.[58,59] In North America, Tamarind wood has been traded under the name of "Madeira mahogany" [60] It is valued for making gunpowder.[42,60,61] The ash is used to remove hair from animal hides.[38,54,62] and can be mixed with fruit pulp for cleansing and brightening brass and copper vessels.

Seed testa and bark

The seed testa contains 23% tannin, in leather tanning tests, Tamarind tannin gives harsh and highly colored leather, which could be used for heavy soles, suitcases, and others. The seed husk has also been found to be an effective fish poison.[63,64] Bark tannins are used in the preparation of ink and for fixing dyes.[65]

Tamarind kernel powder

Tamarind Kernel Powder (TKP) produced from the seeds is another commercial product and is often reported in commercial digests.[66] The TKP will become rancid and brown if stored inadequately and the storage ability and color will be better if it is defatted.[67] In India, TKP is used as a source of carbohydrate as the adhesive or binding agent in paper and textile sizing, and weaving and making jute products,[46,52]as well as textile printing.[68]

Medicinal and pharmacologic properties

Antimicrobial activity

T. indica has a broad spectrum of antibacterial activity. The methanolic leaf extract of *T. indica* was assessed for antibacterial activity against *Burkholderia pseudomallei*, and its name *in vitro* inhibitory potential suggests further animal studies to understand the role of *T. indica* in treating melioidosis.[69] Methanol and acetone extracts of *T. indica* have showed significant antimicrobial activity against *Klebsiella pneumoniae* the antibacterial activity was done by agar disk diffusion method. The activity was compared with standard antimicrobials *Amikacin and Piperacillin*.[70] The antimicrobial activity of the concentrated extracts (aqueous, ethonolic, acetone extract) were evaluated by determination of the diameter of zone of inhibition against both gram-negative and gram-positive bacteria and fungi using the paper disk diffusion method. These have potent antimicrobial activity against *Salmonella paratyphi*, *Bacillus subtilis*, *Salmonella typhi*, and *Staphylococcus aureus*.[71] Other studies have suggested that *T. indica* has shown potential antimicrobial activity; and that petroleum ether, water, ethanol extract of *T. indica* ripe fruit were evaluated for possible antibacterial activity against gram-positive and gram-negative species,[72] methonolic and aqueous extract of 30 medicinal plants and *T. indica* flower have shown anti-microbial activity.[73] The methanolic extracts of 14 species showed antibacterial activities during this preliminary screening. The result showed that the extract from *T. indica* possesses strong *in vitro* antibacterial activity against the bacteria tested.[74]

Antioxidant properties

The seed and pericarp of *T. indica* contain phenolic antioxidant compound.[36] Soxhlet methanolic extract of *T. indica* may be an important source of cancer chemopreventive. All extracts of *T. indica* exhibited good antioxidant activity (64.5–71.7%) against the linoleic acid emulsion system and the values were

lower and higher than the synthetic antioxidant, butylated hydroxyl anisole and ascorbic acid.[75] Thai *Tamarind* seed coat using solvent extraction with ethanol was found to be the most active in terms of peroxide value.[76] Ethanolic extract of fruit pulp of *T. indica* showed significant antioxidant and hypolipidemic activity in hypercholesterolemic hamsters,[77] Antioxidant activity of ethanolic extract of seed coat of *T. indica* by DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging method using ascorbic acid as a standard. This activity of *T. indica* extract may be attributed to its free radical-scavenging ability.[78] Ethanol extract prepared from the seed coat of *T. indica* exhibited antioxidant activity as measured by the thiocyanate and thiobarbituric method.[79] Ethyl acetate extracts prepared from the seed coat also had strong antioxidant activity. This was confirmed by some authors.[76] *T. indica* seed coat, a byproduct of the Tamarind gum industry, could be used as a safe and low-cost source of antioxidant, although other herbals may be more effective.[80]

Laxative properties

The fruit of *T. indica* is used traditionally as a laxative, due to the presence of high amounts of malic and tartaric acids and potassium acid.[62] Children in Madagascar are given whole Tamarind fruits for breakfast to overcome constipation. The laxative can be taken in the form of a sweetmeat, called Bengal by the Wolof people of Senegal, prepared from the unripe fruit of Tamarind and sometimes mixed with lime juice or honey.[38] In Bamako, Mali, drinks are prepared from the pulp[81] and in Burkina Faso, the fruits are crushed and soaked for half a day in water with a little salt before consumption.[82] Tamarind use as a laxative refers to the use of its fruit, and also the use of a macerate of its leaves with potash has been reported in northern Nigeria.[83]

Abdominal pain

Abdominal pain is not a specific disorder but a complaint, which refers to a painful abdomen and which may have a wide variety of causes, including constipation or diarrhea. Soaked fruits are also eaten by rural Fulani in Nigeria, to relieve constipation.[84] When *T. indica* leaves are used, it is more difficult to assess what may have caused the abdominal pain. In East Africa this could be due to diarrhea,[85-87] whereas in West Africa, although atypical, leaves have been known to be laxative[83] and macerated fresh bark of the young twigs was used both as a purgative and to relieve abdominal pain.[88] Roots, prepared as an extract, are used in the treatment of stomach ache or painful abdomen, mainly in East Africa,[87,89] and also in Burkina Faso it is used in abdominal pain and related complaints.[16] In Benin, the fresh bark of young stems is macerated for 24 h and taken orally as a purgative or for abdominal pain.[88]

Wound healing

T. indica is often cited in the literature concerning the treatment of cuts, wounds, and abscesses. *T. indica*, bark or leaves are most commonly used, is applied externally on the spot, either as a decoction or as a powder or poultice, alone or in combination with other species.[13, 88, 90, 91] In the medicinal plant market in Dakar, Tamarind bark is mostly sold for wound healing purposes,[92] occasionally other Tamarind plant parts are found in wound healing medicine, such as the fruit,[93] the pod husks,[13] or the gum.[91] A decoction of *T. indica* leaves is one of the most important agents to clean wounds caused by Guinea worm infections.[94]

Malaria and fever

Fruits of Tamarind are known as a febrifuge in Madagascar;[95] in Ghana, malaria is treated with *Tamarind* leaves,[96] and the fruit pulp is used as a febrifuge and laxative.[13]

Antidiabetic activity

An aqueous extract from *T. indica* seeds had a potent antidiabetogenic activity in Streptozotocin-induced diabetic male rats. The aqueous extract of *T. indica* seeds was given to mild diabetic and severe diabetic rats, and hyperglycemia was significantly reduced, measured by fasting blood glucose levels.[97] Similarly, hyperlipidemia was found to be reduced, measured by different contents of cholesterol. This rat model may shed some light on the basis of ancient herbal therapy in India.[98]

Effect on cardiovascular system and blood

In Bangladesh, fruits of *T. indica* were evaluated for their effects on the lipid profile, systolic and diastolic blood pressure, and the body weight of humans.[99] In hypercholesterolemic hamsters, the effect of the crude extract from the pulp was investigated on lipid serum levels and atherosclerotic lesions. Tamarind extract has a high potential in diminishing the risk of atherosclerosis in humans.[77] Another experimental study on hamsters has shown that the hydroalcoholic extract of Tamarind pulp influenced the mediator system of inflammation.[100]

Antivenom activities

In the Indian traditional medicine, various plants have been used widely as a remedy against snake bite. In a study, the effect of *T. indica* seed extract was investigated for its pharmacologic and enzymatic activity. Tamarind seed extract inhibited phospholipase A, protease, hyaluronidase, L-amino acid oxidase, and 5'-nucleotidase enzyme activities of venom in a dose dependent manner.[73] The extract of *T. indica* neutralized the degradation of the β-chain of the human fibrinogen and the indirect hemolysis caused by the venom. The extract prolonged the clotting time moderately, and myotoxic effects, such as edema and hemorrhage, induced by the venom were neutralized significantly when different doses of the extract were administered, hence *T. indica* extract is an alternative for the serum therapy.[101]

Effect on cellular system

T. indica has shown to have an effect on the cellular system. The methonolic extract of *T. indica* fruit L-(-)-Di-n-butyl maleate was isolated and it exhibited a pronounced cytotoxicity against sea urchin embryo cells. In comparing structure-activity experiments could be exerted, that this toxicity is connected with the special

structure of the chemical. Only L-(-)-Di-n-pentyl maleate was a stronger inhibitor.[14] In the descending colon of Swiss albino mice, the fruit pulp caused a greater rate of cell proliferations than in the ascending part, when they were fed a diet of the pulp, compared with the negative controls.[102] A polysaccharide isolated and purified from *T. indica* showed immunomodulatory properties like phagocytic enhancement and inhibition of leukocyte migration during cell proliferation.[103] Phenolic flavonoids from the seed coat extract showed inhibitory effect on nitric oxide production. In a murine macrophage-like cell line RAW 264.7 and in mouse peritoneal macrophages the extract significantly attenuated the nitric oxide production with 68%, in a concentration dependent manner.[104] Trypanosomiasis is one of the major obstacles to livestock production in Africa. Its eradication and control is principally based on chemotherapy and chemoprophylaxis. The *in vitro* trypanocidal activity of 13 medicinal plants used by local herdsmen in Northern Nigeria for the treatment of trypanosomiasis was investigated. [105]

Hepatoprotective and antiasthmatic activity

Some experimental studies have predicted that *T. indica* shows antiasthmatic and hepatoprotective effect. The methanolic extract of leaves of *T. indica* Linn, exhibited significant antihistaminic, adaptogenic, and mast cell stabilizing activity in laboratory animals. [106] Protective effect of *T. indica* Linn. (Caesalpiniaceae) was evaluated by injecting the rats with paracetamol. The aqueous extracts of different parts of *T. indica*, such as fruits, leaves (350 mg/kg p.o.), and unroasted seeds (700 mg/kg p.o.) were administered and a significant hepatoregenerative effect was observed for the aqueous extracts of Tamarind leaves, fruits, and unroasted seeds as judged from the parameters studied.[107]

Antiinflammatory and analgesic activity

T. indica bark is used in the treatment of pain traditionally, and the present work was undertaken to prove this scientifically by using suitable animal screening models, such as hot plate test and acetic acid induced writing test at the dose of 50 mg/kg, i.p. Petroleum ether extract showed significant increase in reaction time as compared with other extracts. Preliminary phytochemicals test showed presence of sterols and triterpenes in the extract; hence these compounds might be responsible for analgesic activity.[108] Leaf juice with ginger is used in the treatment of bronchitis,[82] and the bark dried and pounded and added to water for the treatment of eye inflammation.[62]

Effect on enzyme

Proteinase inhibitors with high inhibitory activities against human *neutrophil elastase* were found in seeds of the Tamarind tree *(T. indica)*. A *serine proteinase* inhibitor denoted PG50 was purified using ammonium sulfate and acetone precipitation activity showed that PG50 preferentially affected *elastase* release by platelet activating factor stimuli and this may indicate selective inhibition on platelet activating factor (PAF) receptors.[109] Other bioinsecticidal studies included both *in vivo* and *in vitro* studies. In an *in vitro* investigation about insect digestive enzymes from different orders of Coleoptera and Diptera, a proteinaceous inhibitor from *T. indica* seeds (TTI) showed remarkable activity. In an *in vivo* bioinsecticidal assay, larvae were fed TTI-incorporated artificial diets. The concentration of TTI added to cause 50% mortality (LD_{50}) was 3.2%.The addition of 4% TTI caused a mortality of approximately 34%.[110] *Neuramidase* from *Clostridium chauwoei* (jakari strain) was reduced in its activity in a dose dependent manner by a partially purified methanolic extract from the plant *T. indica*.[111]

Helminthes infections (parasitic worms)

Tamarind leaves are used in the extraction of Guinea worms, and afterward in the treatment of wounds, left by the parasite.[94,112] macerate of the seeds is used as vermifuge,[113] and also the fruits are used for this purpose. An extract of the leaves and the root is used to treat ankylostomiasis (hookworm) in some parts of Tanzania.[85]

Diarrhea and dysentery

Tamarind is also used for treating diarrhea and dysentery. Dysentery is a type of diarrhea containing mucus or blood, usually caused by an infection of the intestine. When diarrhea is not treated properly, the patient has risks of dehydration and death. The Tamarind pulp with lemon is used to treat diarrhea,[82] and the root is used to treat dysentery.[87]

CONCLUSION

Tamarind is used as a functional food. From this a large number of chemical compounds were isolated and used extensively in pharmaceutical, textile industries, fodder. Tree trunk is used as timber. Its taste is sour, sweet, cool and astringent, due to its ingredients. Many parts of the Tamarind tree have been used in traditional medicines to treat diseases as well as symptoms. Considering the over all benefits of the plant, it can be advocated as a safe, highly important, medicinal plant for mankind.

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Source of Support: Nil, **Conflict of Interest:** None declared