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Ethnopharmacological, Phytochemical and Pharmacological Review on *Tamarindus indica* L.

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Abstract
Tamarind (*Tamarindus indica*) commonly known as the Tentul tree indigenous to tropical Central Africa, grows up to a height of 20-30 m with a spreading crown. It is used in the treatment of several ailments as a home-based remedy either singly or in combination with other herbs. It has been traditionally used in the treatment of heart ailments, pain relief, diabetes, constipation, fever, jaundice, parasitic infestation, respiratory problems, laxative, aphrodisiac properties etc. The various phytoconstituents present in it include glycosides, saponin, tannin, fatty acids etc. Tamarind pulp shows the presence of arginine, histidine, methionine etc. The essential oil present in it includes limonene, geraniol, safrole, cinnamic acid etc. The through literature review has revealed the antimicrobial, antiparasitic, antifungal, antiviral, analgesic, anti-diabetic, Anti-inflammatory, Hepatoprotective activity of *Tamarindus indica* L. The present review article will instigate researchers to isolate important bioactive compounds which in turn will help in drug discovery from natural sources.

Keywords: *Tamarindus indica*, Epicatechin, tartaric acid, anti-diabetic, abdominal pain

Introduction
The exploration of Medicinal plants for therapeutic potential, coupled with sustainable practices contributes to a holistic approach to healthcare. Even today a considerable percentage of people relies on herbal remedies for their healthcare needs [1]. Each plant species contains a unique set of bioactive compounds that may have potential health benefits. Among various plants that exist, Tamarind (*Tamarindus indica*) an evergreen ornamental tree [2]. Mentioned in Charaka Samhita and Sushruta Samhita [3] is having potential health benefits.

Vernacular Names

Hindi	:	Imli, katare, Amli.
Tamil	:	Puli, Ambilam, Amilam.
Oriya	:	Teetuli, Tentuli.
Bengali	:	Tentul, tinturi, amli, Ambli, Nuli.
Assamese	:	Teteli.

Taxonomical Position

Kingdom	:	Plantae
Subkingdom	:	Tracheobionta
Class	:	Magnoliopsida
Order	:	Fabales
Family	:	Fabaceae
Genus	:	*Tamarindus*
Species	:	*indica*
Scientific name	:	*Tamarindus indica* [3].

Geographical Distribution
Tamarind is indigenous to tropical Central Africa. It grows naturally in Cameroon, Central Africa Republic, Chad, Ethiopia, Gambia, Guinea, Guinea-Bissau, Kenya, Mozambique, Madagascar, Mali, Niger, Nigeria, Senegal, Sudan, Tanzania, and Uganda. It was introduced in India, Ceylon, and Southeast Asia millennia ago from Africa [1, 4, 5]. In the Indian subcontinent, it is distributed in Northern, Southern and Central regions. [2, 6].

Countries in which this plant is mostly encountered includes Mexico, Costa Rica, Indonesia, Bangladesh, and Thailand [7].

Botanical Description

Tamarind tree grows up to a height of 20-30 m with a spreading crown up to 12 m in diameter with a good shady canopy, and seldom straight trunk [8, 9].The stems are grey, brown in color; short, stout, fissured, rough and scaly; Bark - brownish or dark grey, 15 cm in length [1-3, 10]; horizontally and longitudinally fissured [8, 9]; Leaves-15 cm in height, rachis slender cadcous, channeled; stipulus linear. Leaflets - Subset: 10-20 pairs; 8-30 by 5-8 mm, oblong; obtuse, glabrous reticulately veined [2, 10]. Flowers - Pinkish or pale yellow, Few flowered racemes at the end of the branchlets; pedicel 6-10 mm in length, long slender articulate below the calyx; glabrous, bracts concave, 6-8 mm. long, enclosing the buds. Fruits-4-20 cm long-scurfy brown; brittle, sausage-shaped pods; curved and compressed between the seeds and pithy green inside, when unripe, 1-10 seeds present in each pod. The fruit contains an acidic pulp, red pulp preferred for medicinal uses. Pulp from the unripe fruit is stated to be harmful. Seeds - 18 mm in long; dark brown or black and yield starch, Obovate-oblong, smooth, compressed with shallow oblong pit on each of the flat faces with hard and smooth Testa, irregular in shape; [1-3, 10]. Pods 7.5-20 cm in length, 2.5 cm in breadth, 1 cm in thickness, slightly curved, sub compressed and scurfy [2, 10].

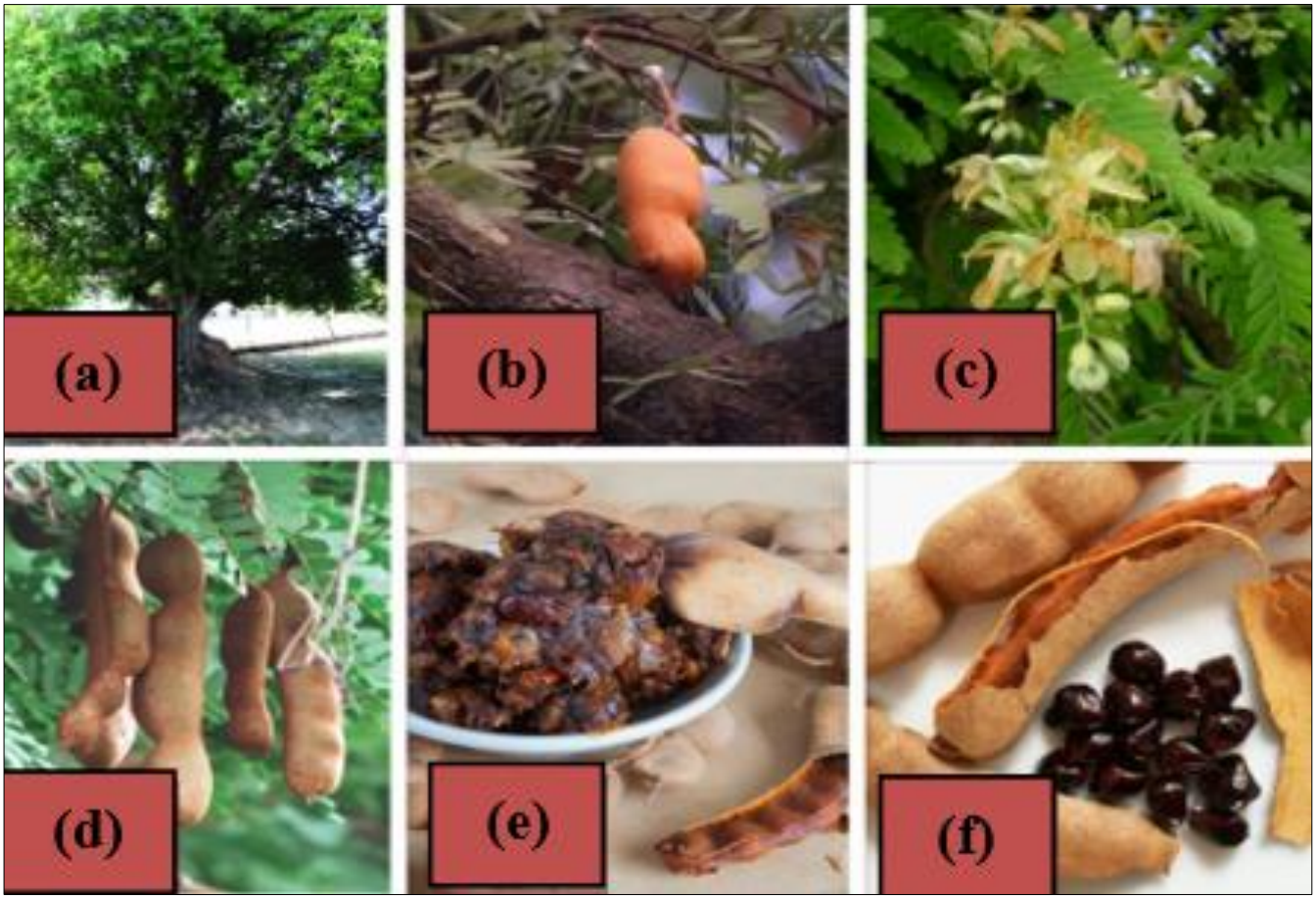

Fig 1: (a) *Tamarindus indica* tree (b) Stem bark of *T. indica*. (c) Leaflets, leaf and flowers of *T. indica*. (d) *T. indica* fruits. (e) Rusty-brown pulp of *T. indica.* (f) Irregularly shaped, shiny, and smooth seeds of *T. indica*

Ethnopharmacological Information

Tamarindus indica is used in the treatment of several ailments as a home-based remedy either singly or in combination with other herbs. Various parts of this plants such as seeds, root, leaves, bark and fruits have rich nutritional value and broad usage area in traditional system of medicine [2, 7, 11]. It has been traditionally used in the treatment of heart ailments, pain relief, diabetes, constipation, fever, jaundice, various infections, healing wound, parasitic infestation, respiratory problems, laxative, aphrodisiac properties [4, 5] and antidote for poisoning [3].

The inhabitants of Florida consume the young twigs by soaking them in water for 24 h for purgative action, to treat abdominal pain and in the treatment of vesical schistosomiasis (Helminth infections). Decoction of the bark is used for excessive menstruation mainly in West India [12]. In Nigeria, decoction of Bark is used as astringent, wound and Diarrhoea, One cup of root decoction is taken twice a day for Epilepsy in Africa. The bark is boiled in water and used along with *Trichilia America* to enhance the emetico-cathartic properties in the treatment of leprosy. Large quantity of 'tamarind' infusion is usually drunk by the woman before sexual intercourse, Mixture of 'tamarind' with pepper and honey in water, called Konkori Badji is used as a Contraceptive in ancient Africa and America. Millets along with tamarind and ground seeds of *Jatropha curcas* or with *Trichilia emetic* is used in the treatment of gonorrhea. The ash of bark is used for urinary discharge, gonorrhea and healing ulcers. Decoction of Bark of *Tamarindus ind*ica along with *Mangifera indica* is used to treat Malaria. One tablespoon of sugared decoction of ground tamarind stem bark and *Capsicum frutescens* fruit pericarps is used to treat Dysuria pain.

Infusion of fresh Leaves are taken thrice daily for hypotension, diabetes and hepatitis in India. In Asian regions,

decoction of the leaves is used to reduce inflammatory conditions, tumors, ring worm, diseases of blood, small pox, ophthalmia, and other eye diseases and can also be used to wash during conditions occurring due to snake and insect bites. Leaf boiled with water, cooled and given as a drink to sheep and goats to treat complications during delivery. Leaf is pounded and used as Earache by East Indian people. Decoction of Leaf Bud is used for cleaning eyes. Fruits of *T. indica* are used as an antipyretic while the mixture of fruits and leaves are used in the treatment of malaria by the people of Britain, West Indies and Egypt [4, 5]. Fruit soaked in water is orally consumed to treat Microbial infection diseases including STD's. Fruit pulp mixed with water and sugar is used to treat cold. Milk production can be increased in lactating mothers by eating Kunu (a kind of porridge) prepared with fruit of tamarind and *Ximenia Americana* or drink a macerate of tamarind fruit in water. Fruits macerated in water can be used to relieve labor pain during Pregnancy. In America, Unripe fruit are used as astringent, and cure "vata;" Ripe fruit are used as appetizer, laxative, heating, tonic to the heart, anthelmintic and cure 'vata' and 'kappa'; heals wound and fracture. Its anti-inflammatory property eases out joint pain, consumption of ½ a teaspoon of roasted tamarind seeds powder twice a day with water helps in boosting joint lubrication which soothes pain. Tamarind seed is powdered and used to cure all teeth related problems; clean nicotine stuck to teeth. The powder of the tamarind seeds is also consumed for treating high blood pressure and heart disease. The inhabitants of Asian countries use this seed powder for its abundant dietary fiber which helps to reduce cholesterol. This is a fantastic natural appetizer and aids in digestion and is also useful for treating stomatitis and easing constipation. Diarrhea and dysentery are well treated by the tamarind seed's crimson outer shell. Xyloglucan works well as a fruit pectin alternative and can therefore be used as a treatment for colitis, diarrhoea and dysentery. Colon cancer can be prevented and treated using sticky tamarind seed juice. In India, Seed is used for scorpion sting, [13]. The powder of seeds is made into a paste and tied over a boil to extract the pus. The seeds are also mixed with cumin seeds and palm sugar in chronic diarrhea and dysentery. In Mexico, the seed coat is a valuable remedy in diarrhea and dysentery [13, 14]. Bile production can be increased by the juice obtained from seeds and thus used to treat indigestion. Aerial parts are crushed, soaked in water and given orally to the cattle for Infertility. Twigs are sometimes used by the tribal people as 'chew-stick.' In south India the Decoction of fresh plant parts (Bark & Leaf) along with potash is used as skin cleanser, blood tonic and Jaundice. In India, Leaf / Bark mixed with water and pepper is consumed for Sorcery. The pulp had been official in old British, American, and other pharmacopeias. In British Pharmacopeia it was used as laxative and refrigerant and in the preparation of confection of senna, a leguminous herb [15]. Generally, the pulp is made into a big ball or kept in gunny bags for years. The old pulp is preferred in medicine. The pulp is boiled with water and sweetened and is used as refrigerant, carminative, and laxative and much prescribed in febrile affliction in Panama. In South India, Pulp is used as a major ingredient in juices and other drinks for seasoning, in prepared foods, for flavoring confections, curries and sauces. The ripe pulp is an effective laxative in habitual constipation in Jamaica. The ripe pulp is an effective laxative in habitual constipation in Jamaica [14].

Due to tamarind's rich nutrient and chemical composition as reported in many studies, it could be adopted as a less expensive alternate protein source that can alleviate protein malnutrition among traditional people living in developing countries [16, 17]. Tamarind pulps are a major source of sugars, vitamin C, minerals which exhibits high antioxidant capacity [18].

Photochemical Information

Phytochemical study on Tamarindus indica indicates the presence of Cardiac glycosides, phenolic compounds, tartaric acid, mucilage, fatty acid, Pectin, triterpenoids and steroids.

Joshi *et al.*, 2023 [3] reported the presence of octacosanyl ferulate in ethyl acetate fraction, tannins, saponins, glycosides, peroxidase and lipids were reported to be present in concentrated ethanolic bark extract, invert sugar, citric acid, pipecolic acid, nicotinic acid, 1-malic acid, volatile oils (geraniol, limonene), lupanone, lupeol, orientin, isoorientin, vitamin B2 & B3, vitamin C, vitexin, isovitexin were reported in Pet. Ether & benzene fruit pulp extract and the presence of Phlorotannins, apple acid, grape acid, succinic acid, citric acid in ethyl acetate leaf extract, β-amylin, compesterol, β-sitosterol and seven hydrocarbons were present in unsaponifiable tissue of *T. indica* seed oil where the Mucilage, arabinose, xylose, galactose pectin, glucose and uranic acid was also found.

Mehathaz *et al.*, 2020 [2] reported the presence of 13 elements among which limonene and benzyl benzoate in ethyl acetate extract were in abundance; n-hexacosane, eicosanoic acid, β-sinosterol, (+)-pinitol were reported to be present in Pet. Ether & benzene fraction; volatile furan derivatives (44.4%) and carboxylic acid (33.3%) were found in concentrated ethanolic extract of fruit pulp; fatty acids like palmitic acid, oleic acid, linoleic acid, and eicosanoid acid was extracted from seeds ethanolic extract.

Shah NC, 2014 reported the presence of some essential oils like terpenes (limonene, geraniol), phenylpropanoids (safrole, cinnamic acid, ethyl cinnamate), methyl salicylate, pyrazine, and alkyl thiazoles [1] in concentrated ethanolic in leaf and fruit extract which was fractionated with pet. Ether and benzene.

Bhadoriya *et al.*, 2012 reported presence of triterpene, pectin, mucilage, xylose, arabinose, beta alanine, proline, phenylalanine, leucine, potassium, 1-malicacid, tannin, glycosides in ethyl acetate fruit extract [1, 3, 5].

Bhadoriya *et al.*, 2011 reported the presence of benzyl benzoate (40.6%), cinnamates, serine, catenin, procyanidin, epicatechin, Tartaric acid, glucose, uronic acid, galactose in hydroalcoholic leaf extract [1, 3, 5], tartaric acid (20%), pectin (2.8%), invert sugar in [1, 3, 5] in concentrated ethanolic fruit pulp extract fractionated with pet. ether, benzene; A new bufadienolide (Scilliroside 3-O-β -D glucopyranosyl-(1-2)-Lrhamnopyranoside), cardioid (uzarigenin-3-O-β-D xylopyranosyl (1-2)-α -L rhamnopyranoside) were identified from the ethanolic extract obtained from seed [1, 3, 5].

Tamarind pulp shows the presence of arginine, histidine, methionine, calcium, phosphorus, iron, thiamine, and riboflavin and a good source of niacin. Ascorbic acid content is low except in the peel of young green fruits [1].

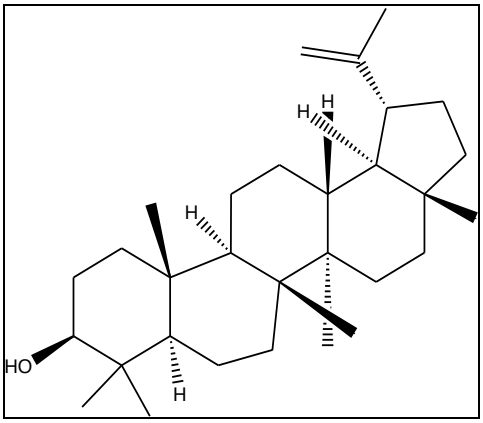

Fig 2: Structure of Lupeol

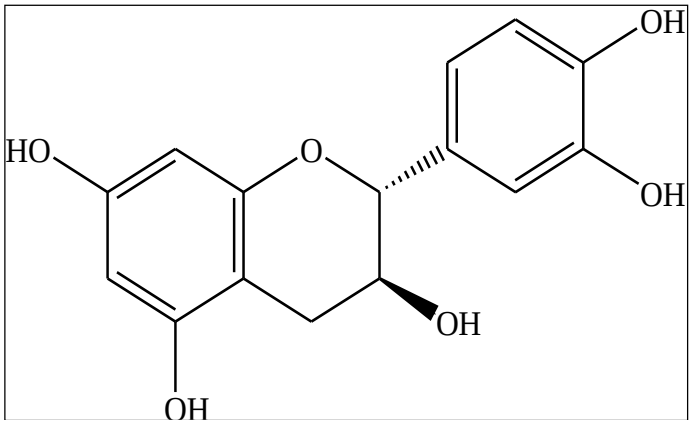

Fig 3: Structure Apigenin

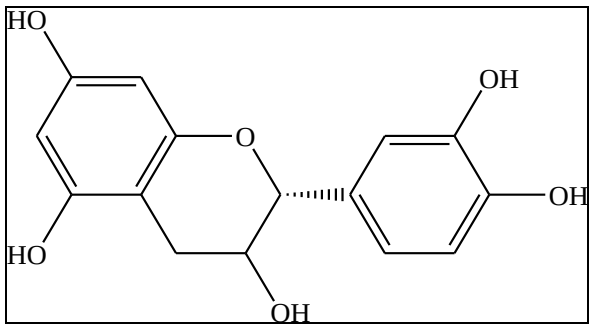

Fig 4: Structure Catechin

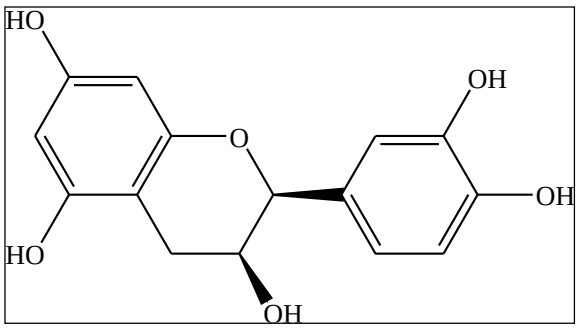

Fig 5: Structure Epicatechin

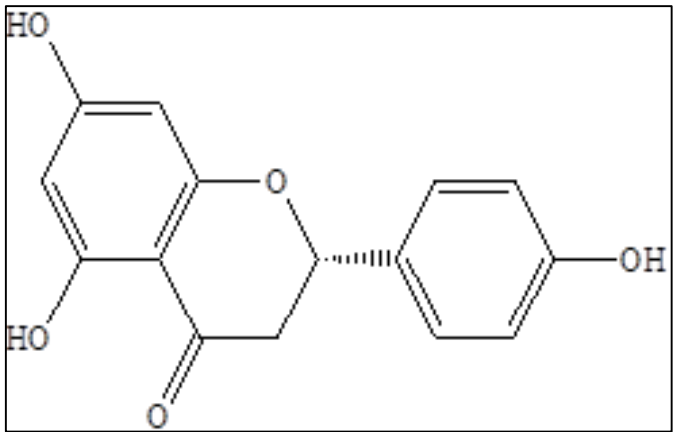

Fig 6: Structure Naringenin

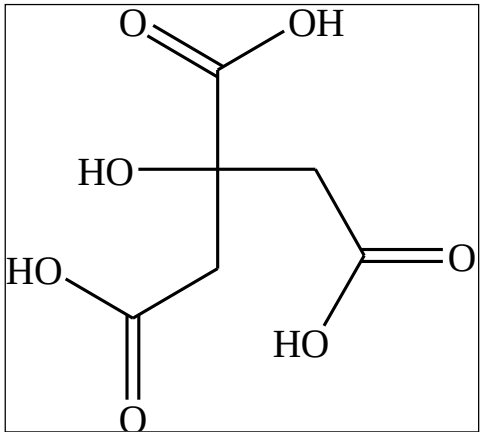

Fig 7: Structure Citric Acid

Pharmacological Information

Antidiabetic activity: Maiti *et al.*, 2004 [19] reported significant ant diabetic activity in STZ-induced diabetic rat by gavage at a dose of 80 mg/kg/day body weight in hydroalcoholic and aqueous extract of *Tamarindus indica* seeds which showed a significant diminution of fasting blood sugar level after 7 days [19].

Hamidreza *et al.*, 2010 reported stereological study in streptozotocin-induced diabetic rats by gavage at the dose of 50, 100 and 200 mg/kg/day of aqueous extract of *Tamarindus indica* seeds (AETIS) from one week after induction of diabetes on pancreatic islets [20].

Sole SS, Srinivasan BP, 2012 reported that in male Wistar rats at different doses (120 and 240 mg/kg body weight) with streptozotocin-induced diabetes mellitus using aqueous extract of tamarind seeds which selectively increases glucose transporter-2, glucose transporter-4, and islets' intracellular calcium levels and stimulates β-cell proliferation resulting in improved glucose homeostasis.

Antimicrobial, antiparasitic, antifungal, antiviral, antinematodal activity: Nwodo *et al.*, 2011 [21] reported *in vitro* potential antimicrobial activity against Gram negative and positive strains (TiB subfractions) respectively, in crude ethanol extract of the stem bark of *Tamarindus indica* using agar well diffusion technique [21].

Djeussi *et al.*, 2013 reported antibacterial properties against *Burkholderia pseudomallei*, *Klebsiella pneumoniae*, *Salmonella paratyphi*, *Bacillus subtilis*, *Salmonella typhi*, *Escherichia coli* and *Staphylococcus aureus using T. indica* extract of leaf in dilution method [22-24].

Analgesic activity: Khalid *et al.*, 2010 [11] reported both central and peripherally acting analgesic property using aqueous fruit extract of *T. indica* extract (60-600 mg/kg) in male Wistar rats. It significantly ($p<0.05$) inhibited the writhing test in a dose-dependent manner with the percentage of analgesia recorded between 51.8 and 74.1%. In addition, the extract also significantly ($p<0.05$) increased the latency time in the hot plate test in a dose-dependent manner [25].

Anti-inflammatory activity: Sole *et al.*, 2013 reported that correlation involved between Antidiabetic and anti-inflammatory action of aqueous seed extract of *T. indica* in diabetic rats. The anti-inflammatory action of extract was significant on nitric oxide (NO) and tumor necrosis factor-α (TNF-α) in addition to a favorable effect on β-cell neogenesis and improved mRNA concentration of SREBP-1c [26].
Bhadoriya *et al.*, 2012 reported the anti-Inflammatory and Antinociceptive Activities of a Hydroethanolic Extract of *Tamarindus indica* leaves using carrageenan-induced rat paw oedema method which was determined by acetic acid-induced writhing, tail-flick, and the hot plate model, when administered orally at a dose of 500, 750, and 1000 mg/kg body weight [27].

Hepatoprotective activity: Mahesh K *et al.*, 2010 reported hepatoprotective activity using in Wister rats using *T. indica* flower ethanol extracts were shown to have a hepatoprotective role with isoniazid and rifampicin-induced hepatotoxicity [28].

Antipyretic activity: Izquierdo *et al.*, 2007 reported antipyretic activity was shown against bacterial pyrogen and pyrexia-induced polysaccharide treated with different oral doses (5-100 mg/kg) using *Tamarindus indica bark extract*. A significant dose-dependent reduction of the rectal temperature [29].

Anti-emetic activity: Khan R *et al.*, 2005 reported anti-emetic activity using methanolic and butanolic extract of *Tamarindus indica* leaves were possesses equivalent to that of marketed medicine product of Chlorpromazine [30] in male Wistar rats.

Peptic ulcer: Kalra *et al.*, 2011 reported the dose dependent protective effect on ulcer models induced by ibuprofen, alcohol and pylorus ligation at a Dose of 100 mg/kg & 200 mg/kg body weight of methanolic extract administered orally to rats of different groups. Ranitidine at a dose of 50 mg/kg was used as a standard drug for these gastric ulcer models [31].

Spasmolytic effect: Ali N and Shah S, 2010 reported Spasmolytic effect using tamarind fruit extract content at a dose concentration of 3.0 mg/ml which causes smooth muscle relaxation via calcium channel blockage [32].

Anticancer Activity: Vargas-Olvera *et al.*, 2012 reported the Ameliorative effect of *T. indica* seed extract in chemical induced acute nephrotoxicity and renal cell carcinoma [33].

Antioxidant Activity: Azman *et al.*, 2009 reported that *In-vitro* Antioxidant Activity and *Artemia salina* L. Lethality of Pulp and Seed of *Tamarindus indica* L. Extracts. In *Artemia salina* lethality test, tamarind pulp caused significant mortality of the crustacean larvae with LC50 in the range of 26-28 µL/mL. Tamarind seed were not toxic to *Artemia salina* since the LC50 of the extracts was higher than 1000 µL/mL [34]. Paula *et al.*, 2009 reported that hydroalcoholic tamarind fruit pulp extract, traditionally used in spices, food components and juices, is rich in polyphenols that have demonstrated anti-atherosclerotic, antioxidant and immunomodulatory activities. The modulator effect of a crude hydroalcoholic extract on some peripheral human neutrophil functions. Extract was a more effective inhibitor of the PMA-stimulated neutrophil function [IC50 (in microg/10(6) cells) =115.7+/-9.7 (LumCL) and 174.5+/-25.9 (LucCL)], than the OZ- [IC50=248.5+/-23.1 (LumCL) and 324.1+/-34.6 (LucCL)] or fMLP-stimulated cells [IC50=178.5+/-12.2 (LumCL)]. The extract also inhibited neutrophil NADPH oxidase activity (evaluated by O2 consumption), degranulation and elastase activity (evaluated by spectrophotometric methods) at concentrations higher than 200 microg/10(6) cells, without being toxic to the cells, under the conditions assessed [35].

Hypocholesterolemia and antioxidant properties: Lim *et al.*, 2013 reported that *in vitro* study assessed by the 2, 2-diphenyl-1-picrylhydrazyl (DPPH) demonstrated that *T. indica* fruit pulp had significant amount of phenolic (244.9±10.1 mg GAE/extract) and flavonoid (93.9±2.6 mg RE/g extract) content and possessed antioxidant activities in hypercholesterolemic hamsters [36].
Chong *et al.*, 2012 reported that methanol extract of *T. indica* fruit pulp altered the expression of lipid-associated genes including ABCG5 and APOAI in HepG2 cells [37].
Librandi *et al.*, 2007 reported that hydroalcoholic extract of the tamarind (*Tamarindus indica*) fruit *in vitro* and in hamsters submitted to a cholesterol-enriched diet [38].
Jindal *et al.*, 2011 reported that hypolipidemic and weight reducing activity of the ethanolic extract of *Tamarindus indica* fruit pulp in cafeteria diet- and sulpiride-induced obese rats [39].

Weight control effect: Azman *et al.*, 2012 reported the Antiobesity effect in aqueous extract of *Tamarindus indica* L. pulp in high-fat diet-induced obese rats at 50 mg/kg, 25 mg/kg and 5 mg/kg body weight [40].

Effect on fluoride toxicity: Suganthi N &Srinivasan K, 2011 reported the kinetic studies which showed good correlation for a pseudo-second-order kinetic model. Column studies were conducted in 2.5cm diameter columns. The applicability of Phosphorylated Tamarind Nut Carbon (PTNC) for wastewaters containing Ni (II) and Pb (II) was evaluated. The effects of contact time, pH and carbon dose were studied in batch experiments at 30˚C. The mechanism of adsorption of metals on PTNC was found to follow ion exchange process predominantly and was supported by Fourier Transform Infrared Spectroscopy (FTIR). The metal removal was also confirmed by SEM studies [41].

Effect on skin: Strickland *et al.*, 2004 reported that *T. indica* xyloglucan is suggested as a natural additive compound in sun creams because of its immune and DNA protective effect from ultraviolet damage [42].

Effect on Eye: Uccello-Barretta *et al.*, 2013 reported the utilization of mixtures of tamarind-seed polysaccharide (TSP) and hyaluronic acid (HA), as artificial tears for ophthalmic applications in the eye dry syndrome, using NMR spectroscopy [43].
Burgalassi *et al.*, 2011 reported the *In-vitro* toxicity and *in vivo* investigations on rabbits for management of corneal wound healing Arabinogalactan as active compound lesions treated with an experimental 5.0% Arabinogalactan solution was studied and compared with those obtained applying solutions of hyaluronic acid and tamarind seed polysaccharide- the study was carried out by light and transmission electron microscopy [44].

Effect on Nerve repair: Victoria *et al.*, 2011 reported that xyloglucan obtained from *T. indica* seed serves suitable media for degenerated nerves and aids nerve regeneration [45].

Iron bioavailability: Zeder *et al.*, 2009 reported that *T. indica* increases iron bioavailability where all tested spices and herbs contained from 0.5 to 33 mg polyphenol per meal and were potent inhibitors of iron availability (20-90%), reducing iron availability in a dose-dependent manner--with the exception of tamarind, which at 11 mg polyphenol per meal enhanced iron availability [46].

Toxicity, side effects and drug interactions: Heimbach *et al.*, 2013 also reported that there was no change in blood biochemistry, urine analysis, liver function test, body weight in animals fed with *T. indica* seed polysaccharide for 28 days using 40 male and 40 female rats received diets containing 0, 40, 000, 80, 000, or 120, 000 ppm tamarind seed polysaccharide [47].

Conclusion

Tamarindus indica L. have been known since ancient times for its nutritive and medicinal values for the prevention and treatment of various diseases. The thorough investigation of this plant through the present study reveals the presence of various secondary metabolites like cardiac glycosides, triterpenoids, tannins, steroids, flavonoids, etc. It is well known that different pharmacological activities attributed by plant are mainly due to the various phytoconstituents present in the plant. Ethnomedicinal information ensures the various traditional uses of the plant which are highly encouraging to the future researchers to prove their medicinal value scientifically. Therefore, there is a scope to find out the possible pharmacological activities including discovery of new bioactive molecules as well as establish the importance of tamarind as a super food and hence may find several applications as an important neutraceutical.

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