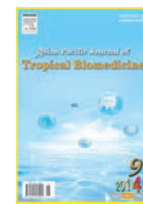


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Tamarindus indica and its health related effects

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PEER REVIEW

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Comments

This is a valuable review providing comprehensive information on the medicinal utilization of *T. indica*. Further investigation on the antioxidant and anti-inflammatory properties of this plants is needed.

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ABSTRACT

Tamarindus [*Tamarindus indica* L. (*T. indica*)], belongs to the family Leguminosae (Fabaceae), commonly known as Tamarind tree, is one of the fruit tree species that is used as traditional medicine. The aim of this article is to review the current literature on health related effect of *T. indica*. Literature review about this plant was conducted between 2003 and 2014 through Pubmed and Google. The keywords Tamarind, *T. indica* were used for search. Only the health related articles selected. Tamarind tree is found especially in the Indian subcontinent, Africa, Pakistan, Bangladesh, Nigeria and most of the tropical countries. It is preferred to be used for abdominal pain, diarrhea and dysentery, some bacterial infections and parasitic infestations, wound healing, constipation and inflammation. It is a rich source of most of the essential amino acids and phytochemicals, and hence the plant is reported to possess antidiabetic, antimicrobial, antivenom, antioxidant, antimalarial, cardioprotective, hepatoprotective, antiasthmatic, laxative and anti-hyperlipidemic activity. *T. indica* has ameliorative effects on many diseases. It can also be preferred as a nutritious support for malnourished patients as it is cheap and easy to access. Those effects should be clarified with further research.

KEYWORDS

Tamarind, Antioxidant, Phytochemicals, Nutrition, Tryptophan

1. Introduction

Traditional medicine, on the contrary of pharmacotherapy, can be easily accessible and ready to use especially in tropical countries, so it has an important role in first line approach. For example, in Burkina Faso, 90% of people prefer to use traditional medicine[1]. Plants are the basic elements of traditional medicine and preferred as a treatment choice in an increasing amount[2].

Tamarindus indica (*T. indica*) is evergreen tree that can reach 24 m height and 7 m girth that has pale yellow

and pink flowers[2]. It needs dry climate so the region it is commonly seen extends Africa to Senegal in west, Sudan and Ethiopia in east, Mozambique and Madagascar in south[1]. It is also thought that the plant came to India from Africa[1,2]. Thailand, Bangladesh, Indonesia in Asia; Mexico, Costa Rica in America are some of the countries in which this plant is mostly encountered[3].

Every part of *T. indica* plant (root, body, fruit, leaves) not only has rich nutritional value and broad usage area in medicine but also has industrial and economic importance. Tamarind can be the most acidic and sweet fruit according

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to its growing season[3]. According to World Health Organization report, tamarind fruit is an ideal source of all essential amino acids except tryptophan (82%)[4]. Its seeds also have similar properties so it becomes an important, accessible protein source especially in countries where protein malnutrition is a common problem.

According to phytochemical analysis results, *T. indica* contains phenolic compounds like catenin, procyanidin B2, epicatechin, tartaric acid, mucilage, pectin, arabinose, xylose, galactose, glucose, uronic acid and triterpen[5]. The nutritional values of *T. indica* raw fruit are given in Table 1[6].

Table 1

Nutritional value per 100 g of Tamarind (*T. indica*). (Source: USDA National Nutrient data base).

Principle	Nutrient value	Percentage of RDA
Energy	239.00 Kcal	12%
Carbohydrates	62.50 g	40%
Protein	2.80 g	5%
Total tat	0.60 g	3%
Cholesterol	0 mg	0%
Dietary fiber	5.10 g	13%
Vitamins		
Folates	14.000 µg	3.5%
Niacin	1.938 mg	12.0%
Pantothenic acid	0.143 mg	3.0%
Pyridoxine	0.066 mg	5.0%
Thiamin	0.428 mg	36.0%
Vitamin A	30.000 IU	1.0%
Vitamin C	3.500 mg	6.0%
Vitamin E	0.100 mg	<1.0%
Vitamin K	2.800 µg	2.0%
Electrolytes		
Sodium	28 mg	2%
Potassium	628 mg	13%
Minerals		
Calcium	74.00 mg	7.0%
Copper	0.86 mg	9.5%
Iron	2.80 mg	35.0%
Magnesium	92.00 mg	23.0%
Phosphorus	113.00 mg	16.0%
Selenium	1.30 µg	2.0%
Zinc	0.10 mg	1.0%
Phyto-nutrients		
Carotene-β	18 µg	–
Crypto-xanthin-β	0 µg	–
Lutein-zeaxanthin	0 µg	–

In most of the African countries, it is also a popular beverage[7]. In traditional medicine, it is used in wound healing, abdominal pain, diarrhea, dysentery, parasitic infestation, fever, malaria and respiratory problems. It is also commonly used in tropical countries because of its laxative and aphrodisiac properties[1,2].

For this review article, literature review was conducted between March 1978 and September 2013 through Pubmed and Google. Tamarind and *T. indica* were used as keywords and only the health related 51 articles considered in this review.

2. Health related effects of *T. indica*

2.1. Gastrointestinal system and related disorders

2.1.1. Laxative

T. indica fruit is used as a laxative in traditional medicine because of its high malic acid, tartaric acid and potassium content[1,2].

2.1.2. Abdominal pain, diarrhea and dysentery

There are various reasons of abdominal pain. Mostly encountered reasons are diarrhea and constipation. For diarrhea *T. indica* leaves, for constipation *T. indica* fruit, for abdominal pain soft parts of bark and root can be used[1,2].

2.1.3. Peptic ulcer

Peptic ulcer (mucosal damage deeper than 0.5 centimeters) is painful gastrointestinal damage in stomach and duodenum. It has been shown that *T. indica* seed extract has dose dependent protective effect on ulcer models induced by ibuprofen, alcohol and pylorus ligation. It is a possible new ulcer treatment[8]. The protective effect of *T. indica* seed comes from its polyphenolic compounds, mainly procyanidin, epicatechin and polymeric tannins. These compounds have anti oxidant effect and protective role against free radicals. Tannins also prevent the ulcer development via causing protein accumulation and vasoconstriction[8].

2.1.4. Spasmolytic effect

Tamarind fruit content cause smooth muscle relaxation via calcium channel blockage. It also explains the usage of *T. indica* in diarrhea treatment[9].

2.2. Cancer

Ameliorative effect of *T. indica* seed extract has been shown in chemical induced acute nephrotoxicity and renal cell carcinoma. This effect can be explained by antioxidant effect. Although oxidative damage is strongly associated with cancer; polyphenol compounds [2-hydroxy-dihydroxyacetophenone, methyl 3,4-dihydroxybenzoate, 3,4-dihydroxyphenylacetate, (-)-epicatechin, tannin, anthocyanidine and oligomeric proantocyanidins] in *T. indica* seed extract has antioxidant enzyme induction properties and cancer related signal pathway blockage effect[10].

2.3. Antimicrobial, antiparasitic, antifungal, antiviral, antinematodal features

Increasing antibiotic resistance among bacteria and toxic effects of antibiotics cause seeking of new effective agents. Medicinal plants are preferred by people because of their easy tolerability. *T. indica* is a potential antimicrobial agent[11].

T. indica extract has antibacterial properties against *Burkholderia pseudomallei*, *Klebsiella pneumoniae*, *Salmonella paratyphi*, *Bacillus subtilis*, *Salmonella typhi*,

Escherichia coli and *Staphylococcus aureus*[1–3,12–14]. Antibacterial effect of this plant is linked with its lupeol content[12].

T. indica bark extract showed 25% chemical inhibitory effect on *Salmonella typhi*. In the phytohemagglutinin presence or absence, it shows lymphoproliferative effect. It is commonly used for so many infectious state including malaria and it stimulates the immune system and act on parasitemia[15]. Tannin was also found in *T. indica* that its antiparasitic effect via binding the free proteins in the gastrointestinal canal of the parasite or glycoproteins found outside the parasite and cause the death of it. Studies done by bark and leaf extract of *T. indica* showed its effectiveness and they suggested the usage as an antiparasitic agent[16]. Fruits of *T. indica* are used as an antipyretic and leaves of it used in malaria treatment[1,2]. Potential antifungal effect of *T. indica* fruit also has been shown against *Aspergillus niger* and *Candida albicans*[3]. It has been reported that *T. indica* plant extract has antiviral properties against watermelon mosaic virus, cow pea mosaic virus and tobacco mosaic virus and antinematodal properties against *Bursaphelenchus xylophilus* and molluscicidal properties (due to saponin content) against *Bulinus truncatus*[3].

2.4. Anti-inflammatory effect

Anti-inflammatory effects of leaves, seeds and other parts of *T. indica* has been shown but this effect is not as strong as acetylsalicylic acid[17–19]. Analgesic effect also has been shown in mechanic, chemical and thermal pain models[19]. It stabilizes the red blood cell membrane and prevents the damage. Additionally it shows anti-inflammatory effect and inhibits the release of PG and NO (diclofenac like effect)[5].

When lysosomal damage occurs, phospholipase A2 appears and stimulates the production of inflammatory agents via hydrolysis of phospholipids. Prevention of cell damage causes cytoplasm content preservation and decreases inflammatory response. Polyphenols and flavonoid content of *T. indica* associated with anti-inflammatory and antinociceptive effects[5].

2.5. Antioxidant properties

Antioxidant properties of *T. indica* seed and leaves has been shown in many studies[2,3,20]. Not only phenolic properties (tannins) of raw seeds but also heat dried seeds has antioxidant properties[21].

Phenol rich food and beverages like red wine, grape seed, green tea and tamarind have hypolipidemic, anti-atherosclerotic, antioxidant, anti-inflammatory and immunomodulatory effect. *T. indica* fruit is rich in organic acid, pectin, vitamin, mineral content, polyphenol and flavonoid content. Rich polyphenol content exists in seed and fruit and they show regulatory effect on neutrophils[22].

2.6. Anti-diabetic effect

Diabetes mellitus type 1 and type 2 are caused by damage due to chronic inflammation of pancreatic β -cell island.

It causes abnormal insulin release, effects insulin receptor and post receptor events and ends with liver, kidney, eye damage. *T. indica* seed extract shows pancreatic β -cell island protective effect with its anti-inflammatory properties, blood glucose regulation, and reversal of damage to pancreatic tissue. These effects are caused by increase in pancreatic intracellular Ca^{2+} level (insulin like effect) and plasma insulin activity rather than decrease in glucose absorption. It also affects GLUT-2, GLUT-4, SREBP-1c (it increases mRNA concentration in liver) at target tissue[2,3,23–28]. Blood glucose level decrease effect of *T. indica* seed extract caused by pancreatic β -cell renewal and increase in glucose entrance to muscle and adipose tissue cells via increase in insulin secretion and inhibition of hepatic gluconeogenesis[25]. With the aid of these effects, polyphenol rich *T. indica* seed and extract can be used as nutritional support and can be combined with hypoglycemic agents[25].

Hyperinsulinemia and insulin resistance in fructose fed animals, decreases dehydroepiandrosterone and high density lipoprotein (HDL) levels and increases total cholesterol, very low density lipoprotein, low density lipoprotein (LDL), triglyceride levels. *T. indica* seed extract regulates insulin effect and shows ameliorative effect on metabolic syndrome[26]. In the literature, only one case reported with hyperglycemia after taking pill that contains tamarind plant extract but the content of this pill is not really known[29].

2.7. Effects on cardiovascular system

T. indica fruit is rich in polyphenol and flavonoid. It shows moderate antioxidant effect. Epidemiological studies have shown that flavonoid intake from fruits and vegetables have beneficial effect on cardiovascular health[30]. *T. indica* fruit shows hypocholesterolemic and antioxidant properties via increasing Apo-A1, ABCG5 and LDL receptor gene expression in liver, and decreasing HMG-CoA reductase and inhibition of MTP gene expression. It increases cholesterol excretion, decreases cholesterol biosynthesis, increases LDL-cholesterol intake from peripheral tissues and prevents triglyceride accumulation in liver. It also prevents LDL-cholesterol oxidative damage, the main risk factor of atherosclerosis[30]. Martinello *et al.* showed that *T. indica* fruit extract decreased serum total cholesterol (50%), LDL (73%) and triglyceride (60%) and increased HDL (61%). In high cholesterol diet group, it activates antioxidant defence mechanism and prevents aortic atherosclerosis[31,32].

T. indica seed shows antioxidant effect via its flavonoid, tannin, polyphenol, anthocyanin and oligomeric proanthocyanidin content. Polysaccharides isolated from *T. indica* seed show the immunomodulatory effect via increasing phagocytosis, inhibiting leukocyte migration and decreases cell proliferation[33]. Triglyceride decreasing effect is associated with epicatechin content of the extract. This compound increases total fatty acid, neutral and acidic sterols excreted via feces and shows its hypolipidemic effect in this way[33].

Tamarind seed and fruit are suggested as a nutritional support in patients with high blood cholesterol levels[30–33].

2.8. Liver protective effect

Alcohol and other chemicals, environmental, biologic toxins and many other factors are related with liver diseases that are important public health problem. Apoptosis (programmed cell death) is the main mechanism in most of the liver diseases. In acute alcohol induced liver toxicity *T. indica* leaves showed anti-apoptotic and liver protective effect. It causes membrane stabilization and decreases glutathione consumption. Additionally, it prevents CASP-3 activation and DNA fragmentation and causes histopathologic amelioration^[2,6].

2.9. Weight control effect

Obesity is the result of increased fat content of body, adipocyte hyperplasia and hypertrophy, and macrophage infiltration in adipose tissue. Many pharmacological agents have been tried, however very little of them could be used safely and most of them has many side effects. In western type fed animal model, *T. indica* fruit extract showed weight reduction and hypolipidemic properties^[34]. It is thought that it shows its effect with increasing dopaminergic transmission, regulating lipid metabolism, decreasing plasma leptin level. Flavonoids and polyphenols could be responsible for weight reduction. On the behalf of weight reductive effect, it shows serum cholesterol and LDL reductive and HDL increasing effect^[34,35]. Increased calorie and fat intake causes increase in blood lipids and hepatosteatosis. Daily *T. indica* fruit extract consumption shows reversal of hepatosteatosis^[35].

2.10. Effect on fluoride toxicity

Fluoride, especially found in drinking water can be harmful in a dose dependent manner. According to World Health Organization report, optimum fluoride level of drinking water is between 0.5–1.0 mg/L. Above this limit it causes fluoride toxicity^[36]. Fluoride toxicity is an important global health problem, in India approximately 66.62 million people are affected. Fluoride may also be found in foods but it is especially found in drinking water. Excess fluoride intake alters gene expression, cell cycle, cell proliferation, cell migration, and has negative effect on respiration, metabolism, ion exchange, changes in cellular level (*i.e.* secretion, endocytosis, apoptosis, necrosis). Oxidative stress, loss of antioxidant capacity may also cause metabolic problems^[37]. Extract obtained from *T. indica* leaves ameliorates fluoride toxicity effects via its antiperoxidant and antioxidant properties^[37].

Extract obtained from *T. indica* fruit decreases plasma fluoride concentration and ameliorates fluoride induced liver and kidney damage^[38]. And also it has been shown that after some procedures *T. indica* fruit can be used in effective drinking water cleaning from fluoride, nickel and lead^[39,40].

2.11. Other effects of *T. indica*

2.11.1. Skin

T. indica xyloglucan is suggested as a natural additive

compound in sun creams because it has been shown that it has immunoprotective and DNA protective effect from ultraviolet damage^[41].

2.11.2. Wound healing

Application of some mixtures obtained from leaves and bark of *T. indica* tree at the wound area was also reported^[1,2].

2.11.3. Eye

T. indica seed polysaccharide is used in eye drops to increase its effective time period because of its mucoadhesive properties. The mixture with hyaluronic acid is used in xerophthalmia and with the aid of timolol it decreases intraocular pressure. Studies reported the effect of it in corneal wound healing especially after surgical procedures^[3,42,43].

2.11.4. Asthma and cough

It has been reported that *T. indica* can be effective in allergic asthma and cough via antihistaminic, adaptogenic and mast cell stabilizing effects^[2].

2.11.5. Nerve repair

It has been shown that xyloglucan obtained from *T. indica* seed serves suitable media for degenerated nerves and aids nerve regeneration^[44].

2.11.6. Iron bioavailability

Tuntipopit et al.^[45] reported in their study that *T. indica*, on the contrary of other herbs and plants, increases iron bioavailability.

3. Toxicity, side effects and drug interactions

The 2-year follow-up study done by Iida et al.^[46] reported that there were no side effects in animals fed with *T. indica* seed extract in different doses. Heimbach et al.^[47] also reported that there were no change in blood biochemistry, urine analysis, liver function test, body weight in animals fed with *T. indica* seed polysaccharide for 28 d. In another study toxic effect is not reported, but increase in white blood cells and thrombocyte is observed^[2]. *T. indica* seed contain tannin and the other compounds that make the digestion difficult so it is suggested that to consume it after boiling or waiting inside water^[3]. And also in long term use because of its acidic content it can cause dental erosion^[48]. Ibuprofen and acetylsalicylic acid when consumed with *T. indica* can increase their bioavailability and increase the blood levels of them^[49,50].

4. Conclusions

T. indica is a cheap and easily available plant. It is a rich source of essential amino acids, phytochemicals and vitamins. In traditional medicine, it has so many well known health benefits. With the aid of modern techniques it could be used

in evidence based medicine in so many health conditions. There is a need of further investigation about this plant and its potential antioxidant and anti-inflammatory properties that can help in many of the diseases.

Conflict of interest statement

We declare that we have no conflict of interest.

Comments

Background

T. indica is used traditionally in many countries as around the world. The whole plant parts have rich nutritional value and wide usage in medicine. In traditional medicine it is used in wound healing, abdominal pain, diarrhea, dysentery, parasitic infestation, fever, malaria and respiratory problems.

Research frontiers

The aim of this review is to highlight various medicinal usages of *T. indica* including Spasmolytic effect, anticancer, antimicrobial, antiparasitic, antifungal, antiviral, antinematodal features effects, etc.

Related reports

There are lots of papers related to the medicinal use of this plants.

Applications

This work provides much information of the medicinal use of this plant, which could be of help for the future investigation of *T. indica*.

Peer review

This is a valuable review providing comprehensive information on the medicinal utilization of *T. indica*. Further investigation on the antioxidant and anti-inflammatory properties of this plants is needed.

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