Active Chemicals and Uses of Tamarindus Indica: a Review

Dr. Madhusudan Bera[1]
[1]*Assistant Professor, Department of Chemistry, Government General Degree College, Dantan-II*

***Abstract*—Tamarindus indica is conventionally used in the treatment of a wide range of conditions, including diarrhea, abdominal pain, wound healing, snake bites, inflammation, colds, helminth infections, and fever. In addition, it exhibits potential antimicrobial, antidiabetic, and anti-inflammatory activities, as well as effects on satiety regulation, suggesting a possible role in the prevention and management of obesity and other chronic diseases. These therapeutic effects are likely attributed to the presence of various polyphenols and bioactive compounds such as *n*-hexaoxane, eicosanoid acid, β-sitosterol, octacosanyl ferulate, 21-oxobehenic acid, pinitol, and proanthocyanidins. Different parts of the plant—including the leaves, seeds, bark, pulp, and flowers—contain these compounds, offering multiple health benefits and potential applications in the pharmaceutical industry.**

***Index Terms*—Tamarindus indica, antimicrobial, antidiabetic, wound healing, anticancer.**

1 INTRODUCTION:

The use of medicinal plants for treating various human diseases is a practice rooted in ancient traditions. Tamarindus indica Linn also known as Ingraji chinch (Marathi), Kodukka Puli (Tamil) tentul (Bengali), Teteli (Assamese), Imli (Hindi), Tamarind (English) is a tropical evergreen tree native to Africa and Southern Asia. Various parts of this tree including its seeds, roots, leaves, bark, and fruits—have been widely used in traditional medicine in both India and Africa [1]. India is a major global producer of tamarind, with an estimated annual output of 162.15 thousand metric tons, primarily from Maharashtra, Karnataka, and Tamil Nadu. Amid rapid transformations in the global food industry, India's tamarind exports are expected to surge in 2024–25, driven by rising international demand and expanding culinary applications [2]. Tamarind is primarily available in two varieties: sweet and sour. Sweet tamarind is harvested when ripe and consumed directly, while sour tamarind is typically processed into a variety of value-added products [3]. Differerent parts of tamarind tree consist of a number of carbohydrates, proteins, fats, essential amino acids, phytochemicals, tannins, vitamins and minerals. Tamarind also has phenolic compounds such as catechin, epicatechin, procyanidin B2, and other constituents like tartaric acid, mucilage, pectin, arabinose, xylose, galactose, glucose, uronic acid, and triterpenes. These bioactive components of tamarind have a variety of biological functions like anti-inflammatory, analgesic, anti-pyretic, antibacterial, hypolipidemic, anti-diabetic, hepatoprotective, anti-ulcerogenic, antioxidant etc [4-8]. The present study aims to evaluate the chemical composition and various health benefits of Tamarindus indica.

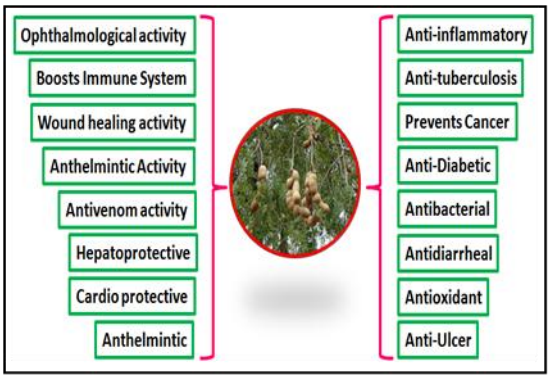

Fig. Uses of Tamarind.

2. CHEMICAL COMPOSITION:

Different parts of Tamarindus indica including the Leaves, stems, flowers, fruits and seeds have been extensively used in pharmaceutical industry owing to presence of valuable bioactive components.

2.1 Leaves:
Tamarind leaves contain a variety of compounds, including protein, lipids, fiber, and essential vitamins such as thiamine, riboflavin, niacin, pipecolic acid, citric acid, nicotinic acid, 1-malic acid, ascorbic acid, and β-carotene. It contains 13 essential oils, among which limonene, benzoate, and benzyl are the most prominent, followed by pentadecanol and hexadecanol [9-10].

2.2 Stem bark:
It is rich in carbohydrates, tannins, saponins, and flavonoids. [11].

2.3 Root bark:
Root bark of tamarind containsn-hexacosane, eicosanoic acid, β-sitosterol, pinitol, octacosanylferulate, 21-oxobehenic acid, apigenin, vitexin [12].

2.4 Flower:
Tamarind flowers contain a diverse range of phytochemicals, including carbohydrates, alkaloids, terpenoids, glycosides, saponins, tannins, and flavonoids [13].

2.5 Fruits:
Tamarind fruit primarily contains tartaric acid (3-10%), along with other organic acids like acetic acid, citric acid, formic acid, malic acid, succinic acid and different amino acids (alanine, leucine, phenylalanine, proline, serine). It also contains various sugars, pectin, tannins, fiber, cellulose, some pyrazines (trans-2- hexenal), and some thiazoles (2-ethylthiazole, 2- methyl thiazole) and and terpenes (limonene, geraniol) [14-17].

2.6 Seeds:
It is a great Source of protein and starch, sulfur amino acids and phenolic antioxidants like Monosaccharides (Arabinose, glucose), Polysaccharides [Cellulose, chitinase, galactose, mucilage, pectin, uronicacid, xylose], Campesterol, β-amyrin, β-sitosterol, lipids with fatty oils, total protein (15%) [palmitic acid, oleic acid, linoleic acid, eicosanoic acid, albuminoid. amyloids, phytohemaglutinins], and some keto acids. Oligomeric procyanidins, Bufadienolide (Scilliphraside 3-O-β-D glucopyranosyl (1-2)-L-rhamnopyranoside), and Cardenolide (Uzarigenin-3-O-β-D-xylopyranosyl (1-2)-α-L rhamnopyranoside) [16-18]

3. MEDICINAL ACTIVITIES:

Tamarindus indica is known for its various pharmacological activities, owing to the presence of bioactive compounds in its fruits, seeds, and other parts. Some of the key pharmacological activities of tamarind include:

3.1 Antioxidant activity
Fruits, leaves and seeds of tamarind are natural sources of antioxidants due to presence of vitamin C, flavonoids, carotenes, and vitamin B complex and polyphenols. Tamarind can scavenge free radicals, inhibit lipid peroxidation and formation of TBARS. Antioxidant activity is typically associated with the presence of phenolic compounds, which possess common structural features enabling them to act as reducing agents, hydrogen donors, and singlet oxygen scavengers, among other mechanisms. At the cellular level, various antioxidant compounds can neutralize or eliminate free radicals, thereby protecting cell structures from damage [19-20].

3.2 Antidiabetic activity:
It exhibits potent antidiabetic activity, particularly in the form of aqueous and ethanolic extracts of its fruit pulp, seeds and leaves. These extracts reduce blood sugar levels by the slowdown of the absorption of glucose into the bloodstream, improve insulin sensitivity, and protect against oxidative stress in diabetic models [21-23].

3.3 Antimicrobial activity:
The ethanolic extract of *Tamarindus indica* demonstrated a broad spectrum of in vitro antibacterial activity against multi-drug-resistant (MDR) Gram-positive and Gram-negative bacterial isolates. It also exhibited synergistic effects when combined with standard antibiotics such as imipenem, amikacin, and ofloxacin, leading to a reduction in their minimum inhibitory concentrations (MICs). Mechanistic studies revealed that the extract disrupted bacterial cell membrane permeability, as indicated by potassium and nucleic acid leakage, ultimately causing cell lysis and death. Furthermore, the bioactive compounds showed strong binding

affinity to *Staphylococcus aureus* protease and *Pseudomonas aeruginosa* elastase, supporting the extract's ant virulence potential [24].

3.4 Anti-inflammatory activity:

It shows anti-inflammatory properties, with research showing that extracts from its root and stem bark can help reduce inflammation. These effects are believed to be due to its bioactive compounds, such as alkaloids, flavonoids, and tannins. The extracts of Tamarindus indica can inhibit the production of inflammatory molecules like cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), and 5-lipoxygenase., neutralizing free radicals and protecting cells from oxidative stress and stabilize red blood cell membranes, preventing damage and reducing inflammation associated with tissue injury [25-26].

3.5 Analgesic activity:

Tamarindus indica (tamarind) exhibits notable analgesic activity, making it effective in pain relief. Research indicates that extracts, especially from the stem bark and leaves, can reduce pain in animal models. This analgesic effect is believed to stem from the plant's anti-inflammatory properties and its ability to inhibit biochemical mediators of pain, such as cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), and 5-lipoxygenase. Additionally, tamarind extracts may activate the opioidergic system, contributing to pain relief at both peripheral and central levels. The presence of phytochemicals like flavonoids, saponins, alkaloids, and steroids likely underpins these effects. Tamarind has also been traditionally used to manage pain, inflammation, and related ailments in various medicinal systems [27-29].

3.6 Hepatoprotective Activity:

It has demonstrated significant hepatoprotective potential. Studies indicate that its extracts and bioactive compounds can protect the liver from damage caused by toxic agents such as paracetamol, cadmium, and aluminum chloride. This protective effect is largely attributed to its antioxidant and anti-inflammatory properties. Tamarind contains antioxidants like ascorbic acid (vitamin C) and β-carotene, which help neutralize free radicals and mitigate oxidative stress in liver tissues. It has also been shown to inhibit lipid peroxidation, a process that compromises cell membrane integrity and contributes to liver damage. Furthermore, tamarind extracts can reduce pro-inflammatory cytokines such as TNF-α and lower serum levels of liver enzymes like ALT, AST, and ALP—key indicators of liver injury. Research has also demonstrated hepatoprotective effects of tamarind polysaccharides, particularly against thioacetamide-induced liver damage in animal models, including Wistar rat pups exposed prenatally to aluminum chloride [30-32].

3.7 Antivenom activity:

In Indian traditional medicine, various plants have been extensively used as remedies for snake bites. Studies have investigated the effect of Tamarindus indica (tamarind) seed extract on both the pharmacological and enzymatic activities induced by Daboia russelii (formerly *Vipera russelli*) venom. Tamarind seed extract was found to inhibit several venom enzymes in a dose-dependent manner, including phospholipase A_2 (PLA_2), proteases, hyaluronidase, L-amino acid oxidase, and 5-nucleotidase. These hydrolytic enzymes are primarily responsible for the early toxic effects of envenomation, such as local tissue damage, inflammation, and hypotension. Moreover, the extract neutralized venom-induced degradation of the β-chain of human fibrinogen and prevented indirect hemolysis. Importantly, animals treated with tamarind seed extract 10 minutes after venom injection were protected from venom-induced toxicity. Due to its ability to inhibit key hydrolytic enzymes and counteract pharmacological effects of snake venom, T. indica seed extract shows potential as an adjunct or alternative to antivenom serum therapy. Additionally, it may serve as a valuable natural source of enzyme inhibitors targeting PLA_2, metalloproteinases, serine proteases, hyaluronidases, and 5-nucleotidases—enzymes implicated in a range of human and animal pathophysiological conditions [33-34].

3.8 Weight reducing Activity:

Tamarindus indica (tamarind) may support weight loss through multiple mechanisms, including appetite regulation, metabolic enhancement, and inhibition of fat accumulation. Rich in dietary fiber, tamarind promotes satiety and helps reduce cravings, which

can lead to lower calorie intake. One of its active compounds, hydroxycitric acid (HCA), is believed to inhibit the enzyme ATP-citrate lyase, which plays a role in converting carbohydrates into fat—thereby potentially reducing fat storage. Additionally, tamarind may help boost metabolism, supporting fat burning. Its digestive benefits, including relief from bloating and constipation, further contribute to a healthier weight management process. Tamarind also acts as a natural detoxifier, aiding in the elimination of toxins and promoting overall health, which can indirectly support weight loss efforts [35-37].

3.9 Wound healing activity:

Tamarind is used for the treatment of wounds in Indian system of medicine. Tamarindus indica cork and seed *masi* have demonstrated potent wound-healing activity in an excision wound model. Among the two, the cork *masi* exhibited significantly greater wound-healing efficacy compared to the seed *masi* [38].

3.10 Anti-diarrheal & Anti- dysentery activity:

Tamarindus indica (tamarind) has a long history of traditional use as an antidiarrheal and ant dysenteric agent. Its therapeutic potential lies in its ability to reduce diarrheal episodes and manage dysentery—a severe form of diarrhea characterized by the presence of mucus or blood. In traditional medicine, tamarind pulp combined with lemon has been used to treat diarrhea, while the root has been specifically employed for dysentery. Scientific studies have supported these traditional practices, with ethanolic extracts from tamarind seeds demonstrating significant antidiarrheal activity in animal models. Phytochemical analyses have revealed the presence of tannins and flavonoids in tamarind, compounds known for their astringent and antimicrobial properties, which may contribute to its effectiveness in treating gastrointestinal disorders. Overall, these findings affirm tamarind's traditional use in managing diarrhea and dysentery [39].

3.11 Immunomodulatory activity:

Tamarind, particularly its seeds, exhibits immunomodulatory properties, meaning it can influence the body's immune system. Polysaccharides extracted from tamarind seeds have been found to enhance phagocytosis—the process by which immune cells engulf pathogens—while also inhibiting leukocyte migration and cell proliferation. These actions indicate tamarind's potential role in regulating immune responses. Specifically, purified tamarind seed polysaccharides increase the activity of phagocytic cells, aiding in the clearance of pathogens and cellular debris. Inhibiting leukocyte migration, a key factor in inflammation, may help control excessive immune reactions. Additionally, tamarind's polysaccharides have been shown to suppress the proliferation of certain cells, possibly including cancerous or overactive immune cells. Tamarind is also rich in antioxidants such as flavonoids, tannins, polyphenols, and anthocyanins, which protect against damage caused by free radicals. Together, these immunomodulatory and antioxidant properties suggest tamarind's potential in managing various immune-related conditions [40].

3.12 Anti-emetic activity:

Tamarind (*Tamarindus indica*) has demonstrated anti-emetic activity, meaning it may help alleviate nausea and vomiting. Research shows that leaf extracts—particularly methanolic and butanolic forms—can be as effective as standard anti-emetic drugs like chlorpromazine. These findings are supported by traditional medicine, where tamarind has long been used to treat nausea, vomiting, and various digestive issues, including pregnancy-related nausea. Although the precise mechanisms are still under investigation, it is believed that certain compounds in tamarind help regulate the nervous system and digestive processes, contributing to its anti-emetic effects. Studies using animal models have confirmed the potential of tamarind leaf extracts to significantly reduce symptoms of nausea and vomiting, with effects comparable to pharmaceutical treatments [41-42].

3.13 Anti-cancer activity:

Despite significant advancements in diagnostic techniques and therapeutic strategies, cancer remains one of the most pressing global health challenges. Conventional anticancer treatments are often associated with severe side effects, prompting a growing interest in plant-based alternatives that may offer comparable efficacy with fewer adverse effects. Tamarind (*Tamarindus indica L.*) extracts have demonstrated notable antitumor properties. Studies

evaluating the cytotoxic effects of ethanolic and methanolic extracts from tamarind seed and pulp on cancer cell lines—A549 (lung cancer), HepG2 (liver cancer), and RAW 264.7 (macrophage cell line)—have shown promising results. These extracts significantly inhibited cancer cell proliferation, with the methanolic seed extract (MeOH_S) exhibiting the most potent cytotoxic activity. At a concentration of 4 μg/mL, MeOH_S reduced A549 cell viability to 86% ($p < 0.01$). Notably, treatment with higher concentrations (16 μg/mL and 256 μg/mL) led to a dominant multinucleated cell morphology rather than classical apoptotic features, suggesting that mitotic catastrophe followed by autophagy may be the primary mechanism of cell death. These findings highlight MeOH_S as a potential antineoplastic agent with a distinct mode of action. S. Rao et. al. reported the anti-ovarian and cervical cancer potential of tamarindus indica leaf ethanol crude extract [43-44].

3.14 Ophthalmological activity:

Tamarind, particularly its seed-derived polysaccharide (TSP), has demonstrated promising benefits for ophthalmic health, especially in the management of dry eye and as a vehicle for ophthalmic drug delivery. TSP functions as a natural thickening and mucoadhesive agent, contributing to improved tear film stability and prolonged drug retention on the ocular surface. Clinical formulations containing TSP (0.5% and 1%) have been shown to provide symptom relief for dry eye that is comparable to, or in some cases exceeds, that of hyaluronic acid, according to a study published in *BMC Ophthalmology*. TSP enhances ocular drug delivery by increasing the residence time of drugs on the corneal surface and improving their penetration. Additionally, tamarind extracts may offer protection against age-related ocular diseases. Some studies have indicated potential anti-cataract activity, suggesting that tamarind compounds may slow cataract progression. Tamarind seeds and their extracts are also rich in antioxidants, which help protect the eyes from oxidative stress and may reduce the risk of conditions such as macular degeneration [45-47].

3.15 Laxative properties:

Tamarind possesses natural laxative properties, primarily due to its high fiber content and the presence of organic acids such as malic and tartaric acids. These components aid digestion, alleviate bloating, and promote regular bowel movements, helping to relieve constipation [48-49].

3.16 Anti tuberculosis activity:

Tamarind (*Tamarindus indica*) has shown potential anti-tuberculosis activity, attributed to its rich phytochemical composition, including tannins, flavonoids, alkaloids, and polyphenols. Several studies have indicated that extracts from tamarind leaves, bark, and seeds exhibit inhibitory effects against *Mycobacterium tuberculosis*, the bacterium responsible for tuberculosis (TB). In vitro assays have demonstrated that methanolic and ethanolic extracts of tamarind possess bacteriostatic and bactericidal properties, which may interfere with the mycobacterial cell wall synthesis or metabolic processes. These effects are believed to result from the synergistic activity of bioactive compounds such as lupeol, catechin, and epicatechin. Additionally, tamarind's strong antioxidant and immune-boosting properties may support host defense mechanisms against TB infection. Although further clinical studies are needed to confirm its efficacy and safety, tamarind holds promise as a complementary or alternative approach in TB treatment strategies [50].

3.17 Antimicrobial activity:

Tamarind has demonstrated broad-spectrum antimicrobial activity, attributed to its rich phytochemical content, including flavonoids, tannins, alkaloids, phenols, and organic acids. Extracts from various parts of the plant—particularly the leaves, bark, seeds, and pulp—have shown effectiveness against a range of pathogenic microorganisms. Studies have revealed that tamarind extracts possess antibacterial properties against both Gram-positive bacteria (e.g., *Staphylococcus aureus*, *Bacillus subtilis*) and Gram-negative bacteria (e.g., *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*). Methanolic and ethanolic extracts have often exhibited the most potent antibacterial effects, likely due to their ability to extract high concentrations of active phytochemicals. In addition to antibacterial activity, tamarind also shows antifungal potential. Extracts have inhibited the growth of fungal pathogens such as *Candida albicans* and *Aspergillus niger*, suggesting tamarind's

usefulness in treating fungal infections. The antimicrobial effects are believed to stem from the disruption of microbial cell walls and membranes, inhibition of microbial enzymes, and interference with DNA replication. Tamarind's high acidity and antioxidant content may also contribute to its antimicrobial efficacy. Given its broad antimicrobial spectrum and low toxicity, tamarind holds promise as a natural alternative or adjunct to synthetic antimicrobial agents in treating infections [51-52].

3.18 Cardio protective activity:

Studies have demonstrated that tamarind pulp and seed extracts can significantly reduce serum cholesterol, low-density lipoprotein (LDL), and triglyceride levels while increasing high-density lipoprotein (HDL), thereby improving lipid profiles and reducing the risk of atherosclerosis. The high antioxidant content of tamarind helps neutralize free radicals, preventing oxidative damage to the heart and blood vessels. Moreover, its anti-inflammatory action may inhibit the progression of vascular inflammation and endothelial dysfunction, which are key contributors to cardiovascular disease. Animal studies have also shown that tamarind extracts can reduce blood pressure and protect cardiac tissue from ischemia-induced damage. These findings support the potential use of tamarind as a natural cardio protective agent, either alone or as a complementary therapy in cardiovascular disease management [53].

In addition, the pulp extracted from tamarind is commonly processed into tamarind paste or concentrate, serving as a key ingredient in a wide range of culinary applications. It is widely used in curries, sauces, soups, and marinades. Tamarind is also the base for refreshing beverages such as tamarind juice, tamarind tea, and *agua de tamarindo*, which is popular in several regions around the world. In Indian cuisine, tamarind chutney is a staple condiment, typically served with snacks like samosas and pakoras. Tamarind sauce is also featured prominently in Thai, Mexican, and Middle Eastern cuisines. Beyond savory dishes, tamarind is used to produce various sweet treats, including tamarind balls, tamarind candy, and tamarind-flavored lollipops. In the cosmetics industry, tamarind extract is incorporated into skincare products like facial masks and scrubs due to its reputed skin-rejuvenating and moisturizing properties. Additionally, tamarind seeds are a source of xyloglucan, a polysaccharide with industrial uses in textile printing, paper manufacturing, and the production of adhesives and explosives [54-55].

4. CONCLUSION:

This review highlights the chemical constituents and health benefits of Tamarindus indica (tamarind). Tamarind is a valuable source of carbohydrates, dietary fiber, proteins, and various bioactive compounds, contributing to its notable nutritional and therapeutic potential. Its major health-promoting properties include antidiabetic, antioxidant, antibacterial, cardioprotective, and antidiarrheal activities. Based on scientific findings, tamarind can be recommended as a safe and beneficial addition to the daily diet. Its regular consumption may support overall health and well-being, making it a promising natural remedy in preventive and integrative healthcare.

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