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REVIEW ARTICLE

A Critical Incredulous Appraisal of Traditional Uses, Phytochemistry and Pharmacological Aspects of Tamarind (*Tamarindus indica* L.)

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ABSTRACT

Tamarind (Tamarindus indica, Fabaceae), a tropical arboreal podded fruit found in Africa and Asia is highly valued for its pulp. Tamarind fruit pulp has a sweet acidic taste due to a combination of high contents of tartaric acid and reducing sugars. The various constituents of the pulp include pectin, protein, fiber and cellulosic materials. The proximate composition of the tamarind pulp depends on locality. The pulp is widely used for domestic and industrial purposes, and also claims some medical uses. Seeds are gaining importance as an alternative source of proteins, and are besides rich in some essential minerals. Seed pectin can form gels over a wide pH range. Tamarind leaves are a fair source of vitamin C and α-carotene; mineral content is high, particularly P, K, Ca and Mg. Anti-oxidant, anti-inflammatory, anti-microbial and anti-fungal activity has been documented from several plant parts. Tamarind is also extensively used in traditional medicine. Antibacterial, antiviral as well as antifungal properties in addition to its coagulation potentials, tamarind seed and other parts of the plant showed a promising step in water treatment and purification and a potential solution to current problem in developing countries. It was used and tested as antimicrobial agent against some bacteria that are present in unpurified water sample and was found to be valuable. Tamarind seed powder has the capability of reducing turbidity in unpurified or raw water. This paper reports brief information of tamarind fruit, composition of tamarind pulp and its tradition uses.

Keywords: *Mineral content, Tartaric acid, Coagulation, Fermifuge, Laxative, Fluorosis, Antioxidant, Chitosan, TKP*

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INTRODUCTION

Tamarind (*Tamarindus indica* L.) is one of the most widespread trees of the Indian subcontinent. It is a large evergreen tree with an exceptionally beautiful spreading crown, and is cultivated throughout the whole of India, except in the Himalayas and western dry regions. Tamarind plant grows up to 40-80 meters depending on soil condition and environment factors associated with the weather condition. Full-grown tamarind pod or mature pods when cracked open have brownish-black colored fruit containing hard black seed. Almost all parts of the tree find a use in the food, chemical, pharmaceutical or textile industries, or as fodder, timber and fuel [1].

The tamarind pods are collected by simply shaking the branches of the tree. These pods typically contain 3-12 seeds, which have irregular shapes and are either flattened or rhomboid. In India, there are primarily two varieties of tamarind: the red variety and the common brown variety (Fig. 1 & 2). The pulp of the red tamarind is less acidic in taste, whereas the pulp of the brown variety has a more acidic or sour taste. The brown variety's pulp contains a higher proportion of free acids compared to the red variety. The red variety's pulp gets its color from the anthocyanin pigment called chrysanthemin, while the brown variety's pulp gets its brown color from leucocyanidin. The tamarind tree is a versatile tree, with almost every part of it serving some nutritional or medicinal purpose. However, the most valuable and commonly used part is the fruit, which provides acidic pulp. This pulp contains tartaric acid, reducing sugars, pectin, protein, fiber, and cellulosic materials [2-9].

Fig. 1 & 2 Red & Common Brown

Fig. 3: Tamarind Kernel Powder

Varieties of Tamarind

Tamarind constitutes pulp, seeds, shell and fibres. The various constituents of the pulp include tartaric acid, reducing sugars, pectin, protein, fiber and cellulosic materials. The proximate composition of the tamarind pulp depends on locality. The pulp is widely used for domestic and industrial purposes, and also claims some medical uses. The pods are allowed to ripen on the tree until the outer shell is dry and could be easily separated from the pulp without adherence. A typical fruit/pod contains about 55% pulp, 34% seeds, and 11% shell and fibres. Tamarind pulp also claims some medical uses and is regarded as a digestive, carminative, laxative, expectorant and blood tonic. The pulp has been found to possess hypolipidemic activity. Tamarind intake helps in delaying the progression of flourisis in humans by enhancing the urinary excretion of fluorine. Vitamin B content is quite high; carotene and vitamin C contents are low. Presence of tannins and other dyeing matters in the seed testa make the whole seed unsuitable for consumption, but they become edible after soaking and boiling in water. Tamarind kernel powder (Fig. 3) is an important sizing material in textile, paper and jute industries [10-15].

Traditional Uses

In traditional practice, the pulp is applied on inflammations, is used in a gargle for sore throat and, mixed with salt, as a cream for rheumatism. It is, further, administered to alleviate sunstroke, The pulp is said to aid the restoration of sensation in cases of paralysis. In Colombia, an ointment made of tamarind pulp, butter, and other ingredients is used to rid domestic animals of vermin. Tamarind fruits were well-known in Europe for their medicinal properties, having been introduced by Arab traders from India. The pulp has been reported in several pharmacopoeias, such as the British and American [16]. The powdered seeds are made into a paste for drawing boils and, with or without cumin seeds and palm sugar, are prescribed for chronic diarrhoea and dysentery. The seed coat, too, is astringent, and is also specified for the latter disorders. An infusion of the roots is believed to have curative value in chest complaints and is an ingredient in prescriptions for leprosy. Leaves and Flowers Tamarind leaves and flowers, dried or boiled, are used as poultices for swollen joints, sprains and boils. The latter are usually applied after grinding leaves and flowers into pow-der whereby they are used in lotions or infusions. Lotions and extracts made from them are used in treating conjunctivitis, as antiseptics, as vermifuges, treatments for dysentery, jaundice, erysipelas and haemorrhoids, and various other ailments. The leaves, mixed with salt and water, are used to treat throat infections, coughs, fever, intestinal worms, urinary troubles and liver ailments. Leaves and pulp act as a cholagogue, laxative and are often used in treating liver 'congestion', constipation and haemorrhoids. Bark The bark of the tamarind tree is regarded as an effective astringent, tonic and febrifuge. It is used as a tonic and in lotions or poultices to relieve sores, ulcers, boils and rashes. Fried with salt and pulverized to an ash, it is given as a remedy for indigestion and colic. A decoction is used in cases of gingivitis, asthma and eye inflammations. Lotions and poultices made from the bark are applied on open sores and caterpillar rashes [17-25]. The bark of the tree should be peeled off if needed for medicinal purposes during the time when the tree is not flowering or when the flowering season ends. The pulp is applied on inflammations and is also used in a gargle for sore throat. The pulp is said to aid the restoration of sensation in cases of paralysis [26].

Culinary Uses

Tamarind is a multipurpose fruit with a characteristic sweet and sore taste used in various foods preparation around the world, this appetizing pod-like fruit is dietary power house with an large quantity of health benefit. Tamarind is a multipurpose plant. The pulp of the fruit has been used as a spice in Asian cuisine, especially in the southern part of India, for a long time. Leaves and flowers can be eaten as vegetables, and are prepared in a variety of dishes. Due to its pleasant acidic taste and rich aroma, the pulp is widely used for domestic and industrial purposes. The pulp is used for seasoning, to flavor confections, curries and sauces and is used as a substitute for chemical acidulants in the preparation of certain beverages [27].

Tamarind pulp can be processed into number of products including tamarind juice, concentrate, powder, pickles and paste. The brown soft tissue of the fruit is juicy with characteristics acidic, and has a sweet-tangy taste. They are used to make curries, salads, stews and soups. The sticky, edible tamarind pulp is a common ingredient in culinary preparations such as, sugary candies, curries, chutneys, sauces, ice cream and squashes. Dehusked tamarind seeds have been found to be a rich source of pectin, the jelly-forming constituent of many fruits, vegetables, seeds, etc. Undercooked tamarind is fit for human consumption; it has an extraordinary sore taste. Aside from being in world cuisine, tamarind fruit is tremendously popular because of its perceived medicinal benefits. Commercial tamarind-based drinks are available from many countries [28].

Phytochemistry and Pharmacological Aspects

Tamarind is reported to have amino acids, fatty acids, and minerals. Differences in composition found in the literature are perhaps due to differences in genetic variation or strains, stages of maturity at which the plant parts were harvested, growing conditions [29]. Tamarind pulp typically contains 20.6% water, 3.1% protein, 0.4% fat, 70.8% carbohydrate, 3.0% fiber and 2.1% ash, consequently the pulp has small water content and a high protein quantity, carbohydrate and mineral. On the other hand, the proximate composition of the tamarind fruit depends on locality of cultivation. Antimicrobial Properties of Tamarind

Tamarind fruit and seed are reported to have certain level of anti-fungal and antibacterial properties. An agar diffusion assay method, extract from tamarind flowers showed anti-bacterial activity against four different bacteria tested (*Staphylococcus aureus, Bacillus subtilis, Escherichia coli* and *Pseudomonas aeroginosa*). Tamarind leaves poses a strong invitro anti-bacterial activity common gram positive and gram-negative bacterium that were tested. Anti-fungal Activity Plant extracts from tamarind fruit appeared to be promising as fungicidal agent against cultures of *Aspergillus niger* and *Candida albicans* [30].

The tamarind fruit consists mainly of pulp and seeds. The fruit, both ripe and dry, contains mainly tartaric acid, reducing sugars, pectin, tannin, fibre and cellulose. The whole seeds also contain protein, fat, sugars and carbohydrates. Both pulp and seeds are good sources of potassium, calcium and phosphorous and contain other minerals like sodium, zinc and iron [31, 34] .

The pulp constitutes 30–50 % of the ripe fruit , the shell and fibre account for 11–30 % and the seed about 25–40 % . The dried tamarind pulp of commerce contains 8–18 % tartaric acid (2, 3-dihydroxy butanedioic acid–$C_4H_6O_6$, a dihydroxy carboxylic acid) and 25–45 % reducing sugars, of which 70 % is glucose and 30 % fructose. The tender fruits contain most of the tartaric acid in free form (up to 16 %). The sweetness of ripe tamarind fruit is, however, outweighed by tartaric acid (Fig. 4) which has an intensively acidic taste. The tartaric acid and the sugar contents reportedly vary from place to place [32, 33].

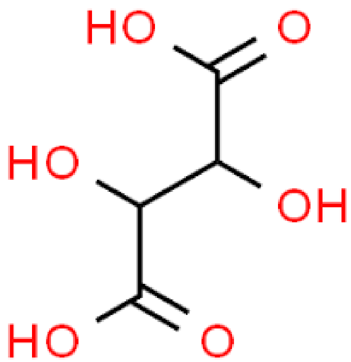
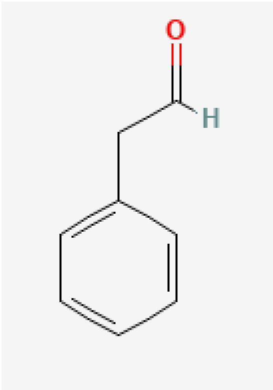


Fig. 4 Structure of Tartaric Acid

Tamarind contains other organic acids, such as oxalic acid, succinic acid, citric acid and quinic acid. The ascorbic acid content in tamarind is reportedly very low and varies from 2–20 mg/100 g. Free amino acids, such as proline, serine, β-alanine, phenylalanine and leucine, were identified in the pulp. Tamarind pulp is rich in minerals such as potassium (62–570 mg/100 g); phosphorus (86–190 mg/100 g); and calcium (81–466 mg/100 g), and iron (1.3–10.9 mg/100 g). It also excels in riboflavin and is a good source of thiamin and niacin, but is poor in vitamin A and vitamin C [35] .

The most outstanding characteristic of the tamarind fruit is that it is one of the most acidic of all fruits, because of its tartaric acid content which imparts the sour taste and outweighs the high total sugar content. Several pyrazines and thiazoles were also found in tamarind. Non-volatile flavour components in the pulp have been identified and analyzed by using high-performance liquid chromatography. It has been reported that major components of the volatiles were 2-phenyl acetaldehyde (Fig. 5) with a fruity and honey-like odour, a caramel-like flavour and hexadecanoic acid (Fig. 6) and limonene (Fig. 7) having a citrus flavour. Volatile components of tamarind fruits were isolated by simultaneous steam distillation/solvent extraction as well [36].



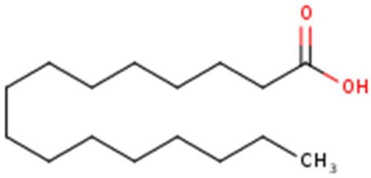


Fig. 5 Structure of 2-phenyl acetaldehyde Fig. 6 Structure of Hexa decanoic Acid

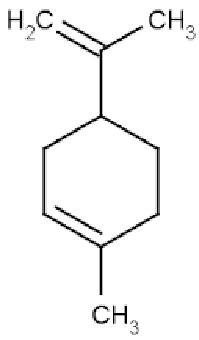


Fig. 7 Structure of Limonene

Unlike the pulp, tamarind seed is rich in protein (13–20 %) and oil (4.5–16.2 %). The seed coat is rich in fibre (20 %) and tannins (20 %) [Fig. 8] as well. Whole tamarind seed has been found to contain 131.3 g/kg crude protein, 67.1 g/kg crude fibre, 48.2 g/kg crude fat, 56.2 g/kg tannins and trypsin inhibitor activity (TIA) of 10.8, with most of the carbohydrate in the form of sugars. The trypsin inhibitor activity is higher in the pulp than in the seed, but both are heat labile. In one report it has been found that the seeds contain 63 % starch and 4.5–6.5 % of semi-drying oil [37].

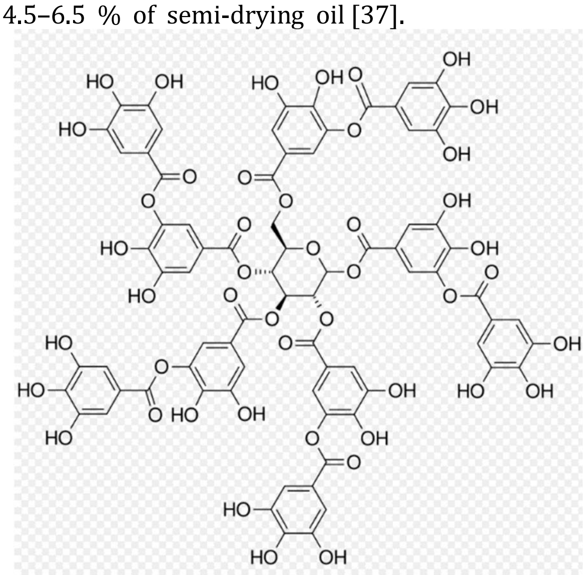


Fig. 8 A typical Structure of Tannin

Seed also contains 47 mg/100 g of phytic acid, which has minimal effect on its nutritive value. It also contains 14–18 % albuminoid tannins [38].

It has been opined that tamarind seeds are potential sources of food or food ingredients. The chemical composition and nutritive value of tamarind seeds and kernels was determined by several workers ..

Among fatty acids, linoleic acid, oleic acid and palmitic acid were the major constituents [39]. The percentage of the constituents varies from sample to sample with tartaric acid ranging from 8-18%, reducing sugars 25-45%, pectin 2-3.5% and protein 2-3%.8 Besides being a rich source of sugars, tamarind pulp is an excellent source of B-vitamins and exhibit high antioxidant capacity that appear to be associated with a high phenolic content. The fruit pulp is a good source of minerals especially potassium, calcium, phosphorous magnesium and sodium. Nevertheless, the proximate composition of the tamarind pulp depends on locality. The major volatile constituents of tamarind pulp include furan derivatives (44.4%) and carboxylic acids (38.2%), the components of which are furfural (38.2%), palmitic acid (14.8%), oleic acid (8.1%) and phenyl acetaldehyde (7.5%). The most abundant volatile constituent of tamarind is 2-acetyl-furan, coupled with traces of furfural and 5-methylfurfural, which form the total aroma of tamarind pulp. Tartaric acid is the major acid present in tamarind pulp which gives the pulp acidic taste. Tamarind pulp also contains malic, succcinic, citric and quinic acid. Nevertheless, the proximate composition of the tamarind pulp depends on locality. The functional properties of tamarind, such as nitrogen solubility index, water-absorption capacity, emulsifying capacity, foaming capacity and foam stability has also been studied by several researchers. TSP (Tamarind seed polysaccharide) [Fig. 9] is the purified product as well as major component of tamarind kernel powder (TKP) [Fig. 10]. It has been reported that TSP had different specifications to TKP. There have been numerous publications in the past 25–30 years concerning the primary structure of TSP [40-44] .

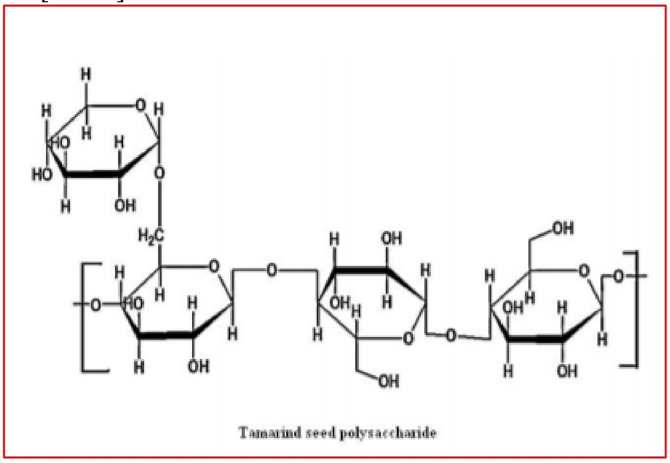


Fig. 9 Structure of Tamarind Seed Polysaccharide

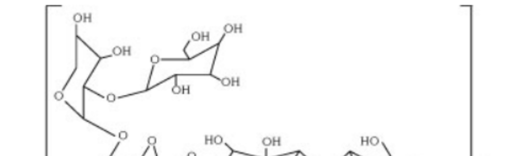


Fig. 10 Structure Tamarind Kernrl Powder

TKP is a polymer with an average molecular weight of 52 350 and a monomer containing 3 sugars, glucose, galactose, and xylose in a molar ratio of 3:1:2.. The polymer consists of a cellulose-type spine, which carries xylose and galactoxylose substituents. About 80% of the glucose residues are substituted by a 1+6 linked xylose units, which themselves are partially substituted by 1-2 galactose residues [45].

Usage of Tamarind for Water Purification

About one billion peoples across the globe lack safe drinking water and more than and as such six million people (of which two million are children) die from diarrhea every year due to water related infectious diseases. Natural plants with antibacterial activity have special preference over chemicals; this is because bacteria developed resistance with chemicals with time. Therefore, more scientific approach could be developed and used to exploit the vast potentials in locally available natural coagulant to treat our water particularly in the rural areas where the water bodies are subjected to numerous pollutants such as herbicides, insecticides and many other chemicals used for agriculture and industrial processes and hence where the government presence is virtually negligible [46].

Turbidity and impurities in water is caused by suspended matter in the form of clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, zooplankton, phytoplankton and other microorganisms. Turbid water has muddy or cloudy appearance and it is humanly unappealing. The turbidity increases as dirt becomes stronger. The history of the use of natural coagulant for the elimination of turbidity is long. Naturally friendly organic polymers have been adopted for over the past 2000 years in most part of India, some part of Africa and China as effective coagulants and coagulant aids in water containing high turbidities [8]. They may be synthesized parts of plant such as plant seeds, leaves, and roots. Natural coagulants have bright future and are concerned by many researchers because of their plentiful source, costless, environmentally friendly or harmless as of natural food source, multifunction, and biodegradable nature by most microorganisms in water purification. A wide range of wastewater management techniques having some associated merits and disadvantages are widespread. Most commonly wastewater treatments involve biological treatment such as nitrification, denitrification and phosphorus elimination, physiochemical treatment such as adsorption [3, 2].

In view of the above mentioned catastrophic health condition, there is need to reconsider the utilization of natural water purification methods by selected plants with purification potentials such as coagulation, antimicrobial as well as detoxification capabilities. The coagulants and antimicrobial agents used for wastewater treatment, some of them are harmful to human body and are very expensive and hence not affordable by common man Several natural polymeric coagulant (Chitosan) were used in the management of chemical oxygen demand (COD) and colour in a soap and detergent industrial wastewater. The outcome of the analysis obtained revealed that chitosan was exceptionally efficient in treating the wastewater. Also, they were able to accomplish maximum COD and colour reductions of 83% and 90% respectively [23]. Efficiency of four different natural coagulants namely: *T.foenum-graecum*, *Moringa oleifera, Cicer arietinum* and Dolichos lablab to eliminate COD and turbidity from industrial wastewater. At the best possible dosage and pH, the turbidity removal efficiencies of *M.oleifera*, Dolichos lablab, *T.foenum-graecum* and *Cicer arietinum* were found to be 61.60%, 71.74%, 58.20% and 78.33% respectively while COD cutback efficiencies of these coagulation agents were estimated to be 65.0%, 75%, 62.5% and 83%, respectively. Based on the results obtained from the work, it was concluded that, among the coagulants considered in the work, Cicer arietinum was the most effective in treating dairy wastewater. Analysis on the coagulation efficiency of common bean extract in treatment of different distillery wastewaters was found to be the best achieved efficiencies of organic matter removal where 68.8% for juice extraction of wastewater at pH of 8.50 with coagulant dose of 5 ml/l, and 60% for molasses wastewater at the original pH of this spillage (5.40) with the same dose. They accomplished that natural coagulants obtained from common bean could be used effectively for organic matter removal from extraction juice wastewater [47, 12, 36].

From the work carried on the natural coagulant it has been observed that Tamarind, to the best of our knowledge, no researcher has used tamarind seed to produce a coagulant that can treat wastewater from a detergent industry. Tamarind as Agent of Fluoride Removal Fluoride is known to be a natural contaminant for ground water resource globally. High fluoride content in ground water has been reported from India, China, Sri Lanka, the West Indies, Nigeria, Mexico, north and South America. Ground water is one of the major sources of water and meets the needs of 60% of India's households. So the quality of ground water can potentially affect the lives of over 100 million households, rich and poor, urban dwellers and villagers alike. However, Tamarind seed has been found to be effective in treating detergent industrial wastewater. It is, therefore, recommended that local industries should consider using this material (tamarind) for wastewater treatment as an alternative to chemical coagulant because it is biological origin, cost affordable cheap and readily available. According to the WHO the maximum acceptable fluoride concentration in drinking is 1.5mg/ L. The conventional methods of removal of fluoride include ion exchange, reverse osmosis and adsorption.

The ion exchange and reverse osmosis are relatively expensive and in most cases not good for human consumption as most mineral that are beneficial are removed as well. Therefore, adsorption is the feasible method for removal of fluoride. Plant materials are reported to accumulate fluoride and hence application as fluoride removing agents has been suggested. Example of such biosorbents are tamarind seed. As many plants were utilized in one way or the other for water purification, tamarind seed is not an exception because of its vast phytochemical composition. Coagulation - flocculation of the sample of wastewater using the tamarind seed powder with optimum pH of 7.2, has a showed a capacity of COD removal of 97.01% and 24.86% respectively; the optimum mixing time was divided in to rapid and slow conducted at 3 and15 minutes respectively. The turbidity and COD removal of 97.78% and 43.50% were attained at the optimum dosage of 400 mg/L [2, 8, 43].

CONCLUSION

Virtually all components of *Tamarindus indica* L. (including wood, root, leaves, bark, and fruits) possess either nutritional or medicinal value, along with various industrial and commercial uses. Tamarind is a versatile and nutritious fruit that serves a wide range of purposes. The fruit pulp of tamarind is utilized for seasoning, as a food ingredient, to enhance the flavor of confections, curries, and sauces, and is a key element in juices and certain beverages. The sweet acidic taste of tamarind fruit pulp is attributed to its high levels of tartaric acid and reducing sugars. While the pulp is relatively low in protein and oil, it is rich in several amino acids. It contains high levels of Vitamin B, while carotene and Vitamin C contents are relatively low. Tamarind seeds are a by-product of the tamarind pulp industry. The presence of tannins and other dyeing substances in the seed coat renders the entire seed inedible, but they can be made suitable for consumption by soaking and boiling in water. Tamarind seeds are also utilized as raw materials in the production of polysaccharides, adhesives, and tannins. The seeds and kernels are rich in protein content, while the seed coat is abundant in fiber and tannins (anti-nutritional factors). Seeds are increasingly recognized as an alternative protein source and are a good source of fatty acids and essential minerals such as calcium, phosphorus, magnesium, and potassium. Tamarind leaves are a decent source of Vitamin C and beta-carotene, with high mineral content, particularly phosphorus, potassium, calcium, and magnesium. Various plant parts of tamarind have been documented to exhibit antioxidant, anti-inflammatory, antimicrobial, and antifungal properties. Tamarind is widely used in traditional medicine across different cultures for a variety of purposes. Its ability to eliminate fluoride from water sources, antimicrobial properties against organisms like *Staphylococcus aureus, Bacillus subtilis, Escherichia coli*, and *Pseudomonas aeruginosa*, as well as its coagulation potential, make it a promising agent that, if properly utilized, could offer a viable solution to the emerging challenge of water purification. Tamarind seed in some community is a kitchen waste and usually disposed as waste, it is environmentally friendly, cost affordable and without any harmful effect on human. In many parts of the developing world, people lack access to portable drinking particularly in the rural areas where such natural products are readily available.

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