

# The Unlocking Potential of Tamarind Seed as a Natural Excipient in Pharmaceutical Formulation

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## ABSTRACT

**Background:** Tamarind seed polysaccharide (TSP) is an example of a natural polysaccharide that exhibits unique qualities that set it apart from synthetic excipients. TSP is a desirable excipient with the potential to be used in various applications. Tamarindus indica seeds naturally contain a polysaccharide called TSP, which has shown great promise in the pharmaceutical business lately. TSP is distinct due to its high swelling index, high drug retaining capacity, and high thermal stability, which are particularly important for various cutting-edge drug delivery methods. It also functions as a carrier for innovative drug delivery systems in oral, buccal, colon, ophthalmic systems, nanofabrication, and wound dressing. It also performs the functions of stabilizer, thickening, binder, release retardant, modifier, suspending agent, viscosity enhancer, and emulsifying agent.

**Objectives:** Through several quantitative and qualitative tests, the purpose of this study is to explore the existence of important phytochemical elements in the polysaccharides found in Tamarind seed. Standard procedures were used to check for alkaloids, flavonoids, phenolics, saponins, tannins, and terpenoids. Significant amounts of polysaccharides from Tamarind seeds were found in the results, and these compounds may have pharmacological benefits such as anti-inflammatory, antibacterial, and antioxidant properties. The variety of TSP applications is the main topic of this review. These results pave the door for more studies into the therapeutic applications of tamarind seed polysaccharides and advance our knowledge of the medicinal potential of these seed polysaccharides. They also give traditional uses of tamarind seed a scientific foundation. To investigate their modes of action and potential for therapeutic development, future research will concentrate on identifying and characterizing these molecules.

**Methods:** Several extraction techniques used to separate the polysaccharides from tamarind seeds are discussed in this paper. Its manufacturing yield is cost-effective because of the basic approaches used for its separation and characterization. Tamarind seed polysaccharides must

be examined and evaluated phytochemically to find the bioactive components that give them their medicinal qualities.

**Keywords:** Tamarind seed polysaccharides (TSP), Phytochemicals, Pharmaceutical excipient, Drug delivery system, Therapeutic application.

## INTRODUCTION

It is seldom feasible to formulate an active pharmacological component into the appropriate dose forms without including an excipient. Excipients play a crucial role in medical compounds, constituting a significant portion of therapeutic products. These are inactive compounds that are crucial to the formulation of a dosage form [1]. The additives are now used in innovative formulations to serve particular goals and, in certain situations, can directly or indirectly affect the amount and/or the rate of drug dissolution and absorption. (As shown in Fig.1.1) This is due to advancements in medication delivery technologies. The additives are very helpful in the development of modified-release systems for drug delivery and have been effectively used in the production of liquid, solid, and semi-solid dosage forms [2].



Fig.1.1. tamarind pods, which may serve as a natural excipient in pharmaceutical formulation.

According to the International Pharmaceutical Excipients Council of America (IPEC), excipients are any substance, apart from the active ingredient or prodrug, that has been suitably assessed for safety and is added to the drug formulation system to:

1. Facilitate the system processing while production,
2. Maintain, uphold, or improve patient compliance, bioavailability, or stability.
3. Help in the product authentication process.
4. Improve any additional feature concerning the medication product's general safety and efficacy or storage [3].

Pharmaceutical excipients might be synthetically produced or naturally occurring [1]. The primary classification of excipients in pharmaceutical products is based on their use and purpose: Disintegrants, lubricants, glidants, and binder-fillers-diluents. Sanding suspending agents, plasticizing agents, coloring agents, as well as film formers and agents Gum, printing inks, dispersion agents, flavors, sweeteners, antioxidant substances, and preservation solutions [4] Various plant-based medicinal excipients are available, including cellulose, acacia, gum, carrageenan, pectin, gelatin, agar, and gum [5]. Most studies on drug delivery systems now focus on natural gums, derived mostly from seeds or other plant components. These replace the commercially available synthetic excipients [6]. Naturally occurring gums and mucilage are examples of biocompatible, inexpensive, and readily accessible polymers favored over semi-synthetic and synthetically produced excipients because of their non-irritating nature, soothing effect, and lack of toxic effects [7].

Polymers that comprise monosaccharides are called polysaccharides. Polysaccharides are easily altered chemically and biochemically to form a variety of polysaccharide variants because they have distinct derivative groups on their molecular chains [8]. Large molecular weight polymers known as polysaccharides have intricate, branching structures made up of many monosaccharidic residues connected by o-glycosidic bonds. These substances are gel-formic and hydrophilic. One common natural bio polysaccharide group that is readily available in natural sources, biodegradable, toxic-free, and less costly is plant polysaccharides [9]. The many polysaccharides that are utilized in pharmaceutical delivery applications include guar gum, gum made from xanthan, locust seed gum, and cellulose ethers [10]. Naturally occurring polysaccharides can be derived from a variety of sources, including plants (pectin and gums), microbes (dextran), animals (chitosan), and algae (alginate) [11]

Fig.1.2: representation of tamarind in both raw and powder form highlighting its natural source. Tamarind seed polysaccharide, a galactoxylan isolated from the tamarind kernel, (As shown in Fig.1.2) is one of the newly discovered biopolymers among other plant polysaccharides. It has been proven to have numerous promising uses in the food, cosmetic, and pharmaceutical industries. The *Tamarindus indica* seeds were used to isolate Tamarind Seed Polysaccharides (TSP) [9]. In recent times, tamarind seed polysaccharide has been employed in various forms of dosage as an effective medicinal excipient [9]. The elongated, shiny, orbicular to rhomboid seeds of tamarinds. They measure 3–10 cm by 1.3 cm. It is a dicotyledon. The firm seeds range in color from red to purple-brown. A membrane that resembles

seed chambers.  
dense. Every  
contains 320–700 g



parchment lines the  
Cocaledons are  
kilogram of fruit  
of seeds [12].



Fig.1.3. tamarind seed is a rich source of polysaccharides, phenols, and proteins.

The seed coat and kernel are the two basic components of tamarind seeds. (As shown in Fig.1.3). The majority of the seed mass, or around 28.6%, is made up of tannins and crude fiber in the seed coat. On the other hand, 65–73% non-starch polysaccharide, 15-20% protein, and 6-8% fat is present in the seed kernel. Tamarind seeds are highlighted in this composition as a polysaccharide-rich retention food with a substantial fat and protein content [13].

Division: Divided into the Kingdom Plantae, Class Dicotyledoneae, Division Angiospermae, and Order Fabales, family: Leguminosae/Fabaceae Claesalpiniaceae is the subfamily. Type: *Tamarindus* Type: *T. indica* [14]. Tamarind kernel powder is made from the white kernel that is extracted from tamarind seeds. Proteins, carbs, fiber, and fats abound in tamarind kernels [7].

## HISTORY

Imli represents the traditional name for tamarind. The Indian textile market saw the introduction of tamarind kernel powder as a starch alternative for cotton scaling. The TSP extraction and isolation procedure was initially developed in a lab setting and then refined there as well [8].

Most tropical nations, including those in Africa, the Caribbean, South America, and Southern Florida, employ tamarind as an ancient remedy. These nations include Bangladesh, India, Sudan, Nigeria, and Nigeria [14].

## ORIGIN

Tamarind has a millennium-long history, and it is thought to have originated in East Africa. Throughout trading channels, it crossed countries and arrived on the Indian continent, where it was incorporated into Ayurvedic treatment and Indian food. During the time of colonialism, it finally made its way to the Southeast Asian region, the Middle East, and the Americas [15].

Large evergreen trees, known as tamarinds, are widely grown in the waterless regions of Central and South Indian states, as well as in other Southeast Asian nations. They are also a major commercial crop [8].

## PHYSICAL PROPERTIES OF TAMARIND SEED

Table 1.1 outlines four key parameters of a sample, detailing its texture, color, taste, and odor. The texture is described as smooth, sticky, and moist, while the color is brownish-red. The taste of the sample is both acidic and sweet, and its odor is typically sour. These characteristics provide a sensory profile of the sample.[16]

| Sr. No | Parameters | Characters                |
|--------|------------|---------------------------|
| 1.     | Texture    | Smooth, sticky, and moist |
| 2.     | Color      | brownish-red              |
| 3.     | Taste      | Acidic and sweet          |
| 4.     | Odour      | Typically, sour           |

Table 1.1

The polysaccharides found in tamarind seed was soluble in heated water but unusable in cold water and organic solvents. Additionally, it was shown that the polysaccharides derived from tamarind seed had excellent flow characteristics. The pH value of 6.1 indicated that the drug could be administered as prescribed without causing any side effects [17].

## CHEMICAL COMPOSITION

The components of tamarind seeds include:

Proteins (18-20%), Polysaccharides (35-55%), and raw tamarind bean 6-10% fat, 7-18% fiber, 3-7.10% fat, free sugars, inorganic salts, 4-10% moisture, and 1-3% ash. Tamarind Kernal Powder is a blend of 55-65 % galactoxyloglucan polysaccharide [7].

Chemical compositions of tamarind seed:

The table1.2 presents the chemical composition of tamarind seeds, including data for the whole seed, seed kernel, and testa. It includes percentages for moisture, protein, fat/oils, crude fiber, carbohydrates, and ash. [12].

| CONSTITUENTS | WHOLE SEED (%) | SEED KERNAL (%) | TESTA (%) |
|--------------|----------------|-----------------|-----------|
| Moisture     | 9.4 -11.3      | 11.4 – 22.7     | 11.0      |
| Protein      | 13.3 - 26.9    | 15.0 – 20.9     | -         |
| Fat/oils     | 4.5 – 16.2     | 3.9 – 16.2      | -         |
| Crude fiber  | 7.4 – 8.8      | 2.5 – 8.2       | 21.6      |
| Carbohydrate | 50.0 – 57.0    | 65.1 – 72.2     | -         |
| Ash          | 2.4 – 4.2      | -               | -         |

Table 1.2

## CHEMICAL STRUCTURE

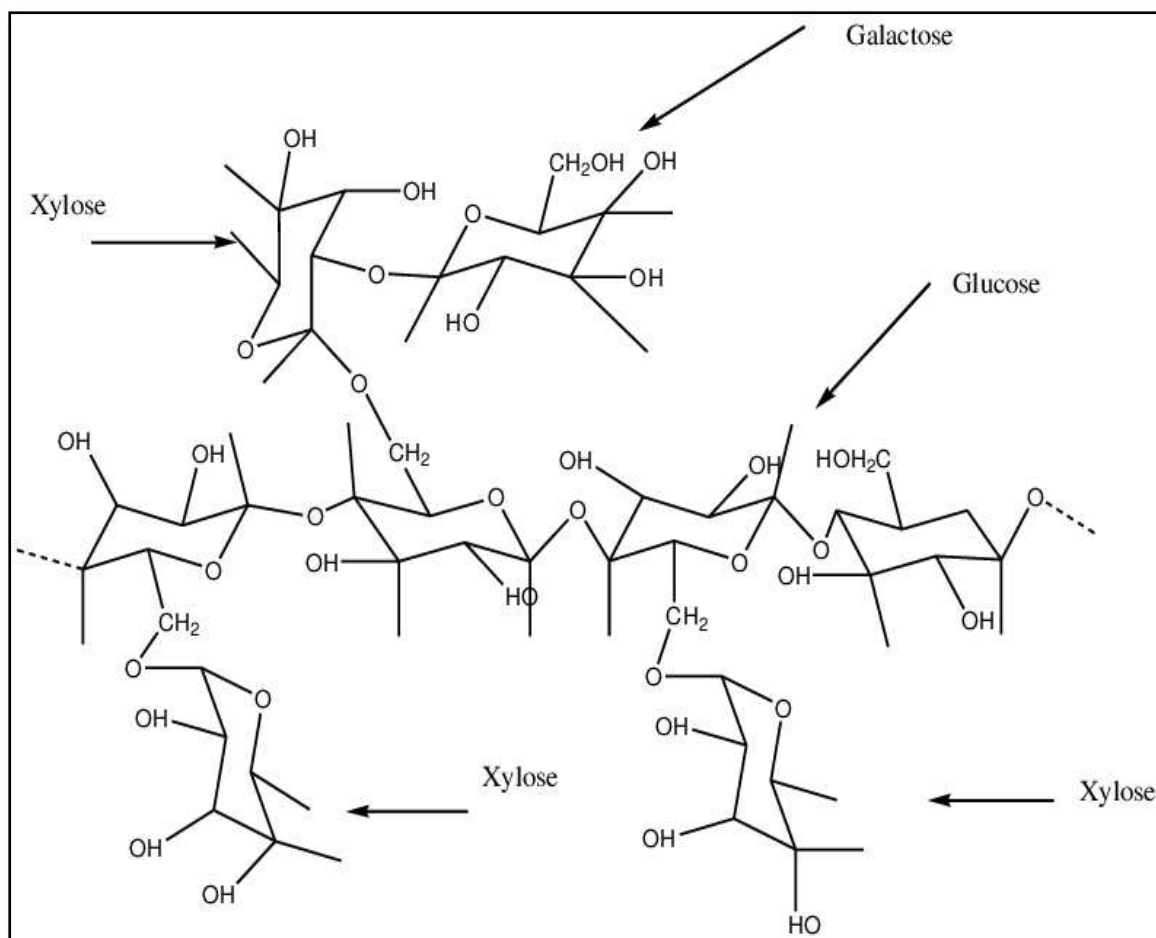


Fig.1.4. structural representation of polysaccharides comprising xylose, galactose, and glucose units, demonstrating the arrangement of sugar monomers in the polymer.

#### ISOLATION OF TAMARIND SEED POLYSACCHARIDE

##### METHOD 1

The white portion of the tamarind seeds is obtained by removing their coat. Ground tamarind seeds into a coarse to fine powder, which was then soaked in freshly distilled water for twenty-four hours. TSG release gum and TSG isolation using a muslin cloth. After the gum's marc is removed, an equal amount of 100% ethyl alcohol is then added, causing a precipitate to form that must be filtered off. Once the substance is gum-free, the procedure for isolation is ongoing. At 40°C, the decoupled gums are then dried in a hot air oven. After that, the dried gum was powdered and kept at room temperature in sealed containers [8].

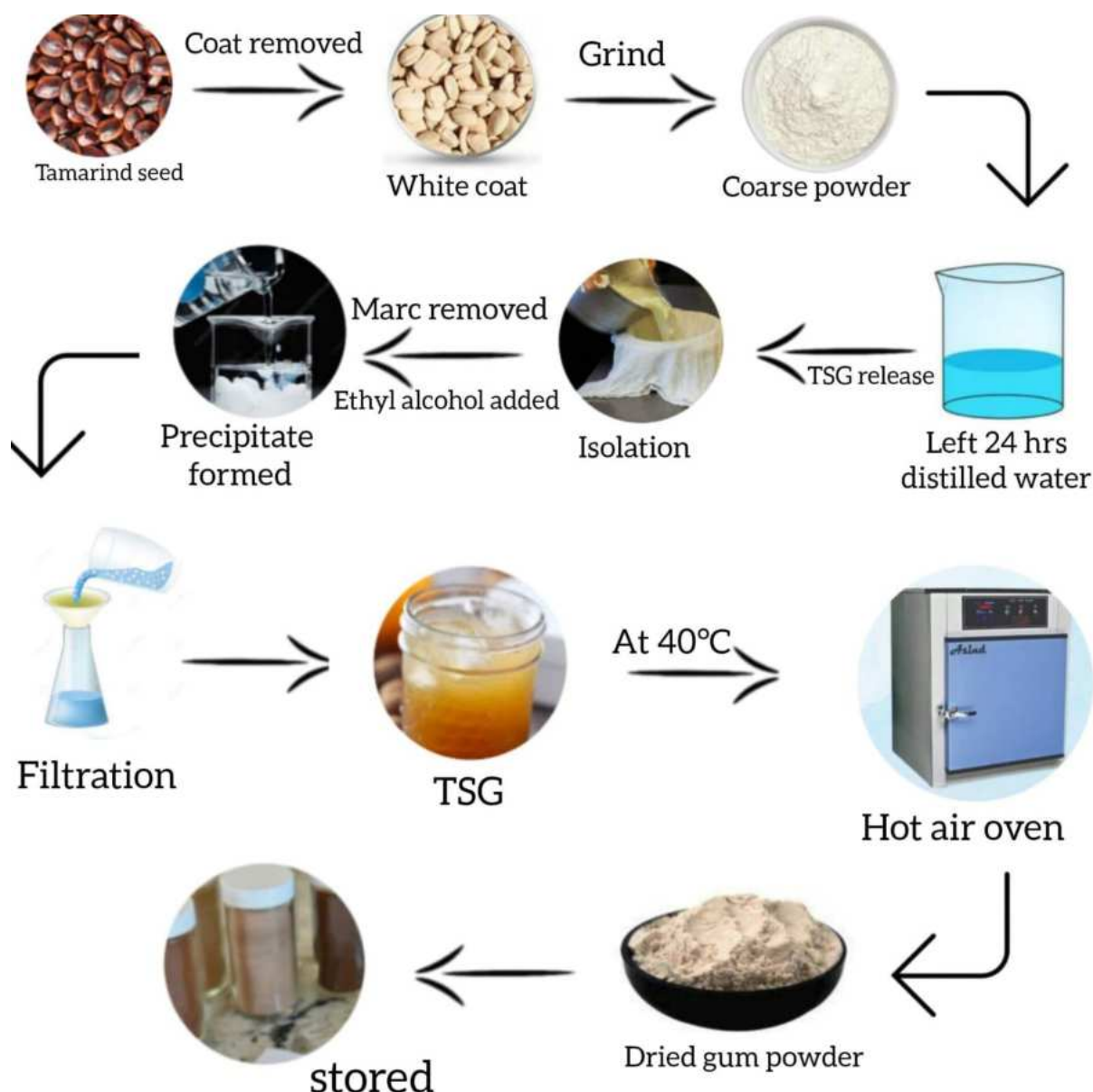


Fig.1.5 shows an image flowchart detailing the process of extracting tamarind seed gum (TSG).

#### METHOD 2

For two hours, the crushed *Tamarindus indica* seeds were submerged in water, cooked for one hour, and then allowed to settle to release the gum into the liquid. To extract marc from the filtrate, the seeds were collected and compressed in a muslin bag. The gum was then precipitated by adding an equivalent amount of acetone to the filtrate. The process of filtration was utilized to separate the gum. The marc was not thrown away; instead, it was subjected to a series of extractions using progressively less extracting solvent—water—as the number of extractions increased. Once the material was gum-free, the isolation process was maintained. The gum that had separated was dried at 400 degrees Celsius in a hot air oven.

[10].

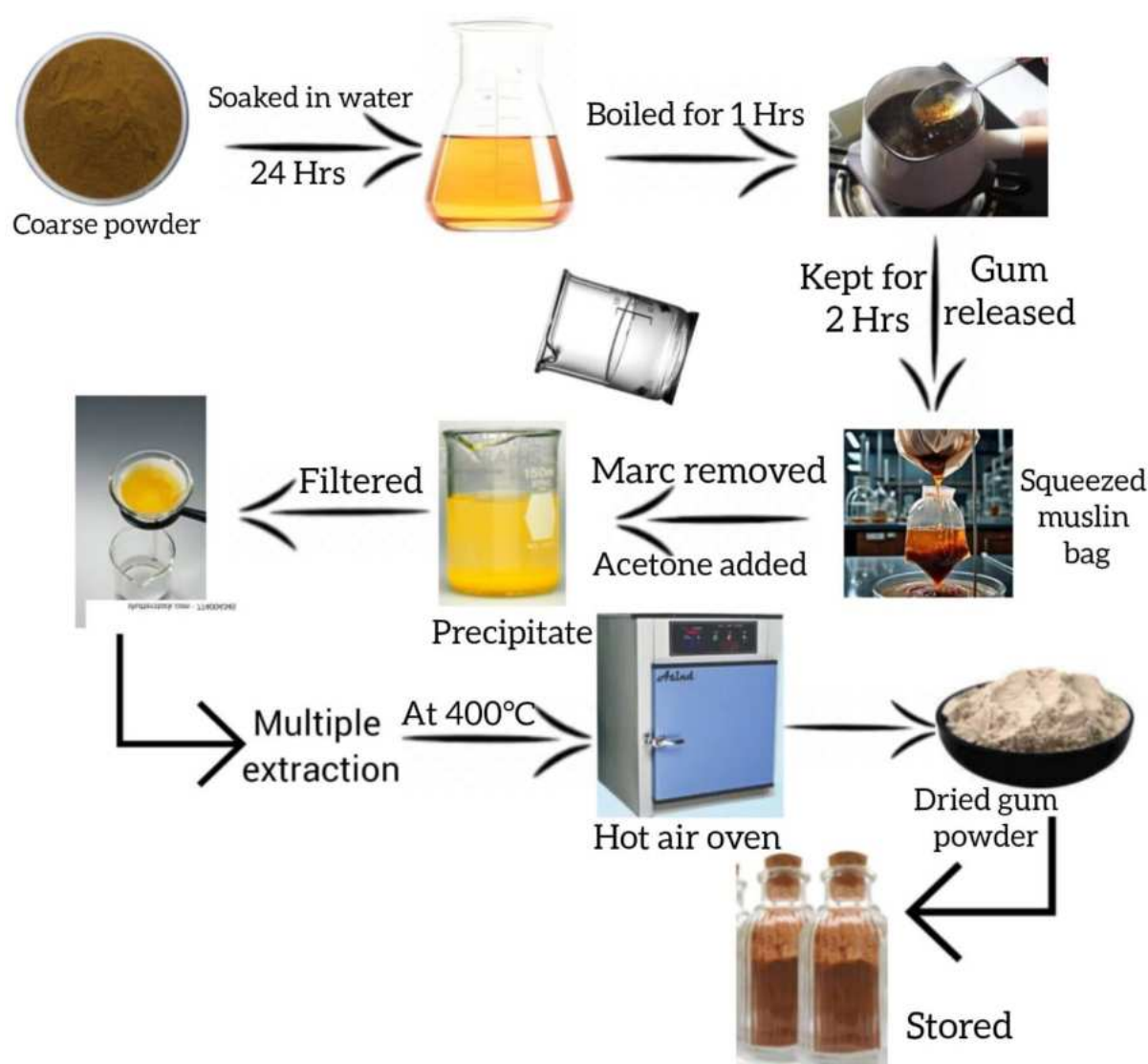


Fig.1.6 shows an image flowchart detailing the process of step-by-step extraction of tamarind seed gum

### METHOD 3

It has been said that the alcohol-insoluble portion of the tamarind seed coarse water extract, which makes up 60–65% of the husked kernel, is an abundant source of complex sugars. On an experiment scale, TSP was made in three batches using the techniques described by Rao et al. The mixture was made by adding 200 ml of cold distilled water to 20 g of tamarind kernel powder. 800 milliliters of steaming purified water were filled with the slurry. In a bath, the solution was brought to a boil for 20 minutes while being stirred. For the majority of the peptides and fibers to settle out, the resultant thin, transparent solution was left overnight.

After that, the mixture was placed in the centrifuge for 20 minutes at 5000 rpm. After being separated, the supernatant was continuously stirred and added to twice as much absolute alcohol. The item was sandwiched in felt. Following a wash with petroleum ether, diethyl ether, and 100% ethanol, the precipitate was vacuum-dried at 50 to 60 degrees Celsius. Granules with varying particle sizes were obtained by grinding and sieving the dried material. Tablets with an average particle size ranging between 150 and 75 microns were prepared [18].

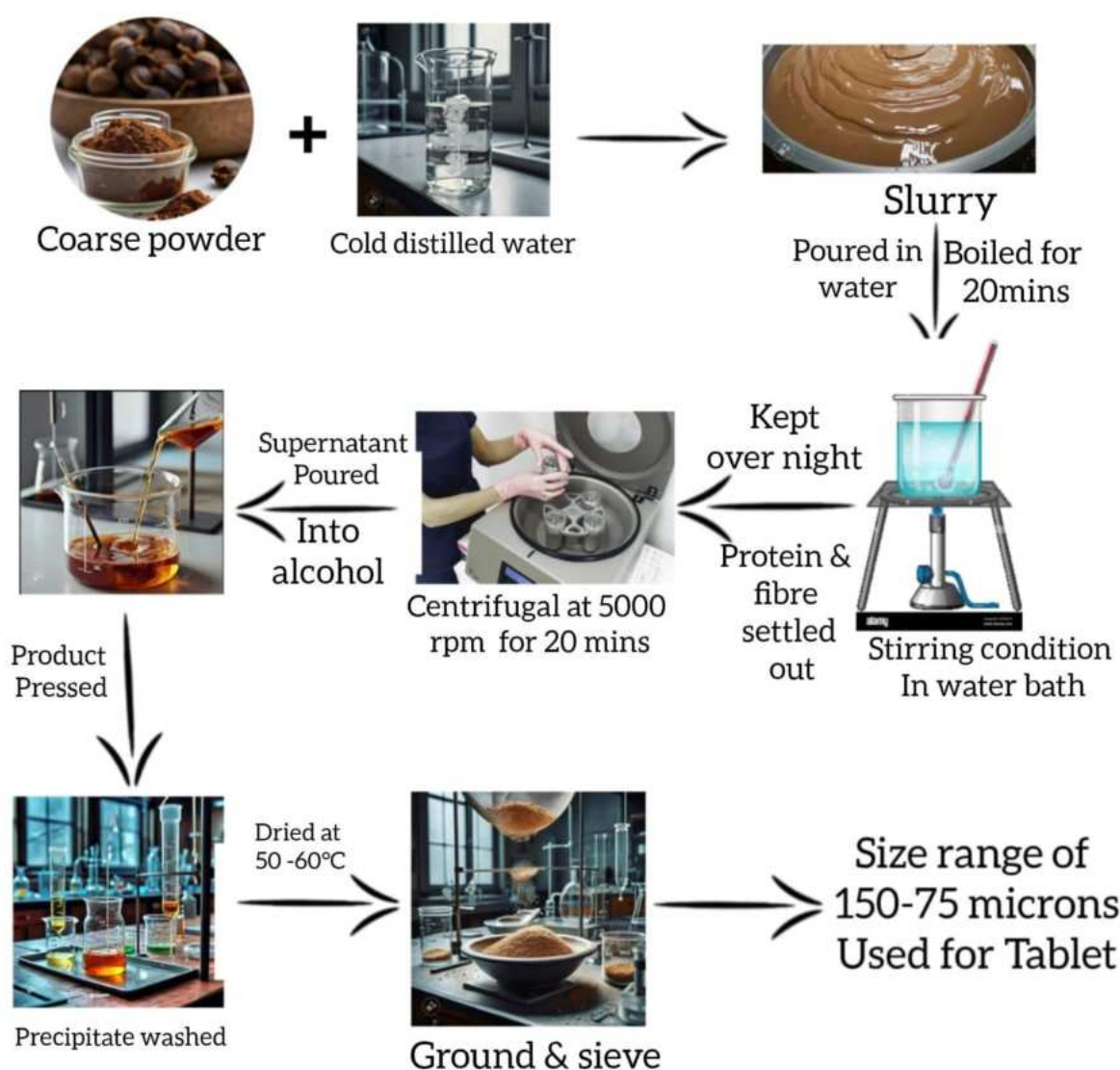


Fig.1.7 shows the extraction process of tamarind seed polysaccharides (TSP) from tamarind seed, illustrating the sequence from seed preparation to final product.

TAMARIND SEED ACTS AS AN EXCIPIENT IN:

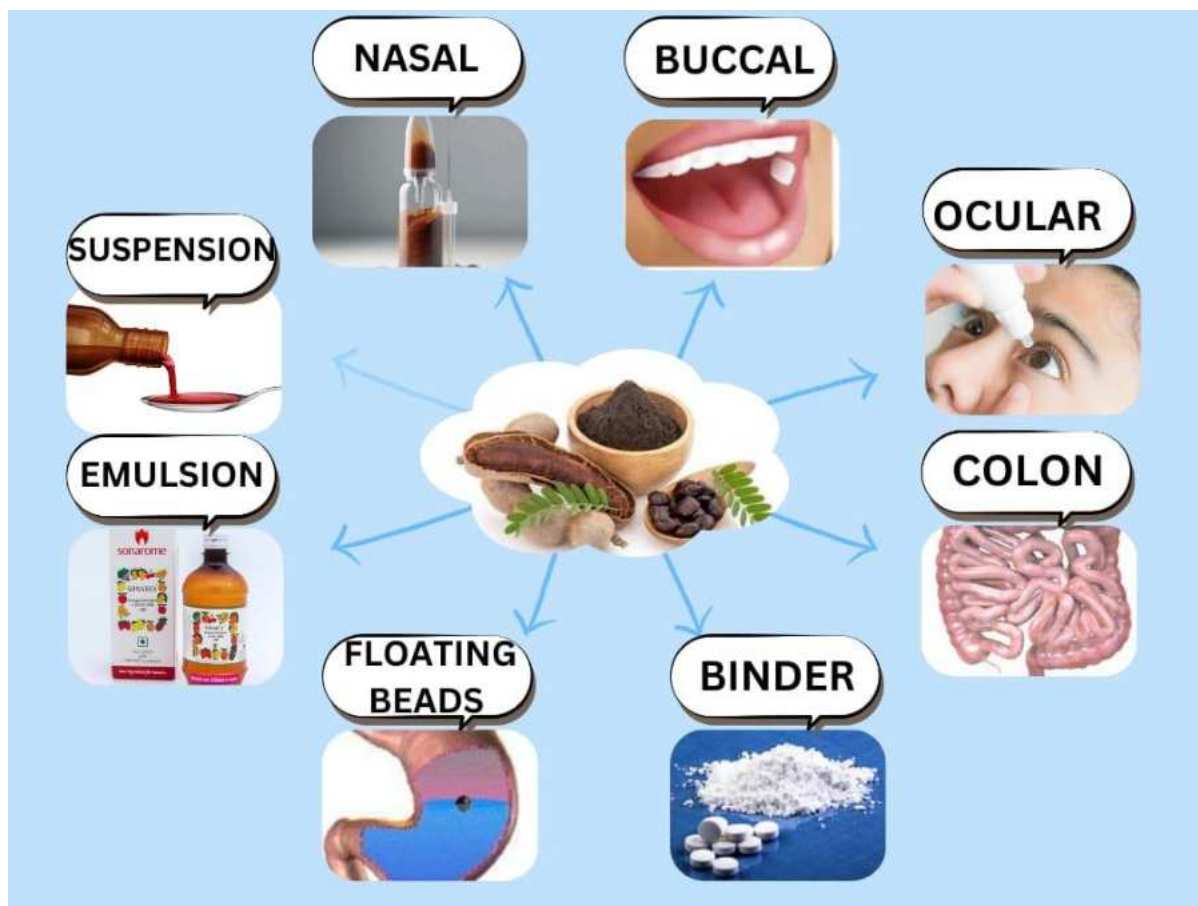


Fig.1.8 illustrating tamarind seed used as an excipient in pharmaceutical formulation highlighting its use in drug delivery

#### Bio-Adhesive

When compared to tablets made from xanthan gum and carboxycellulose, it was discovered that the former had a more disagreeable taste over time. Still, it also showed an extended residence period in the mouth cavity [6]. A type of polysaccharide that has received much research attention as a bioadhesive polymer is tamarind seed polysaccharide (TSP) [19].

#### Mucoadhesive

TSP is a viscosity enhancer that exhibits bioadhesive, mucoadhesive, and mucomimetic properties [20].

#### Nasal Delivery System

Owing to its mucociliary clearance and geometric complexity, targeted delivery and retention of drug formulations to the olfactory target site for nose-to-brain drug absorption remains a significant issue. Potential benefits of a direct nose-to-brain route include a quicker start of medication action, a reduction in dosages required for an equivalent or greater therapeutic impact, avoidance of systemic side effects, and a circumvention of the liver's "first-pass" metabolism [21]. Because the intranasal route's time profile of drug concentration is similar to that of the intravenous route, it is considered a favorable approach. Most often, intranasal administration presents a potentially workable substitute for different medication delivery methods. It is suitable for the systemic and local delivery of many medicinal substances [22]. Tamarind seed polysaccharide was shown to have higher pH, viscosity, and gelling properties than synthetic polymers like carbopol 934 and HPMC, which are frequently utilized as mucoadhesive agents in nasal medication administration systems [9].

#### Buccal Delivery System

When compared to the oral route of medication administration, buccal delivery offers an appealing substitute, especially when it comes to addressing the shortcomings of oral administration [23]. The maximum time for buccal delivery is between two and six hours. Compared to pills and gels, a mucoadhesive buccal film is smaller, thicker, and has better patient compliance, which results in several advantages [24]. The buccal route is a favorable technique of medicine distribution because of its local and systemic effects. There are several benefits when compared to an oral course. These benefits include the capacity to prevent first-pass digestion, availability, reasonable patient acknowledgment, consistency, and the freedom to take the measurement framework off whenever needed [25]. Because of its breadth of smooth muscles and generally immobile mucosa, the buccal mucosa among the transmucosal routes has great accessibility and is therefore suited for the administration of retentive dosage forms. Metoprolol succinate is a commonly used medication for treating essential hypertension and angina pectoris. It is a selective  $\beta_1$ -adrenergic antagonist without intrinsic sympathomimetic effect. Due to strong first-pass metabolism, even though it is entirely absorbed from the gastrointestinal tract, only about 50% of it is available systemically. It is hence a good candidate for administration by buccal route. In the current investigation, TS and grafted TS (GTS) were used to create a flexible buccal patch that delivers metoprolol succinate [26].

### Ocular Delivery system

The buccal route is a favorable technique of medicine distribution because of its local and systemic effects. There are several benefits when compared to an oral course. These benefits include the capacity to prevent first-pass digestion, availability, reasonable patient acknowledgment, consistency, and the freedom to take the measurement framework off whenever needed [27]. Its mucoadhesive and nontoxic properties aid in the topical application of medication retention for an extended period. According to one study, using TSP to administer a medication increases its penetration into the aqueous humor of the eye. The two characteristics that make TSP an excellent carrier for ocular medication administration are its extended corneal half-life and permeability enhancer. Researchers have experimentally explored TSP and its nanocomposite for topical delivery of ocular medications such as Timolol, Fluoroquinolones, Gentamycin, etc., in addition to its FDA-approved commercial use as one of the tear substitutes. In rabbits, the impact of an ophthalmic preparation with 1 or 2% TSP plus 0.5% timolol ( $\beta$ adrenergic blocker solution) on intraocular pressure (IOP) was assessed. Due to the formulation's 12-hour duration of action, it was determined that timolol plus TSP would be a useful combination for treating excessive IOP (D'amico M 1999). In a similar vein, tamarind gum has been investigated as a novel bioadhesive material generating in situ gelling systems for pilocarpine, another ocular medication that is known to reduce IOP [28]. The dry eye condition is treated with TSP eye drops. TSP was utilized to treat experimental *Pseudomonas aeruginosa* and *Staphylococcus aureus* keratitis in rabbits by ocular administration of 0.3% rifloxacin. In both diseased and uninfected eyes, the polysaccharide dramatically raises the intraocular penetration of rifloxacin. *Staphylococcus aureus* can be continuously reduced in the cornea even when the period between treatment administrations is prolonged thanks to polysaccharides. The results suggested that TSP prolongs the precorneal residence time of antibiotics and boosts the drug accumulation in the cornea, perhaps by slowing the washout of topically applied medicines [29]. Examine the efficacy of the in-situ gelling-based carboxymethyl tamarind ophthalmic drug delivery system for dorzolamide hydrochloride in terms of precorneal retention and ocular bioavailability [8].

### Colon Targeted Drug Delivery

To safeguard the medication during its passage through the upper gastrointestinal tract and enable drug release in the colon, colon-focused drug delivery is necessary. Tamarind seed polysaccharide has also been studied as a biodegradable drug delivery target for the colon [9].

When manufactured as matrix tablets using wet granulation, the polysaccharide from the tanning seed can prevent the medication from being fully released into the upper GIT's physiological conditions and instead release it into the colon. According to in vitro biodegradability tests, TSP degrades in colon-like circumstances when rat feces are present. TSP's capacity to release the medication in Sorenson's phosphate buffer with RCC at pH 6.8 was shown in in vitro drug release experiments conducted in environments that replicated mouth-to-colon transit. The tamarind seed polysaccharide was substantially destroyed by RCC 4% w/v after 7 days of enzyme induction, and its presence in the dissolution medium offered the ideal conditions for determining the polysaccharide's sensitivity to colonic bacterial breakdown [30]. Using xanthan gum as a carrier, Thiruganesh Ramasamy and associates reported colon-targeted drug delivery systems for Aceclofenac. In order to effectively transfer Aceclofenac to the colon, a multilayer coated system that is resistant to gastric and small intestinal conditions but is readily broken down by colonic bacterial enzymes was designed for this investigation. Aceclofenac release from the eudragit-coated system was resisted by the stomach and small intestine. It was discovered that the breakdown of the xanthan gum membrane by bacterial enzymes was the cause of the sharp rise in Aceclofenac release in the simulated colonic fluid [31].

#### Binder In Tablet Dosage Form

TSP has been shown in numerous tests to be an effective tablet formulation binder. Direct compression was used to study the creation of tramadol hydrochloride sustained-release tablets by Phani et al., 24. In the same ratio as TSP, other rate-controlling polymers such as guar gum, sodium carboxymethyl cellulose (Na CMC), and hydroxypropyl methylcellulose (HPMC) K4M were also employed as the binder [32]. Powdered tamarind seed gum provides a solution with a high viscosity. As a result, tamarind seed is being developed by researchers as a binder for diclofenac sodium tablets that are made using the dry granulation method [33].

#### Floating Beads

The polysaccharide from tamarind seeds was utilized to create floating gastroretentive beads. Low-density oil was trapped in these beads to provide buoyancy for an extended amount of time [9]. Evaluation of the emulsion-gelation method's groundnut oil-entrapped tamarind seed polysaccharide (TSP)-alginate floating beads carrying diclofenac sodium for gastroretentive administration system [34].

## Emulsion

The polysaccharide found in tamarind seeds has also been studied as an emulsifier for making emulsions. A comparative study of castor oil emulsions and the use of tamarind seed polysaccharide was conducted by Kumar et al. The emulsifier and gum acacia demonstrated that 2% w/v tamarind seed polysaccharide was more effective than 10% w/v gum acacia [9].

## Xyloglucan use;

### Preparation Of Nano Emulsion:

A stable nanoemulsion formulation was created by homogenizing Tween80 castor oil and xyloglucan (X2) at 20,000 rpm for 15 minutes utilizing high energy.

### Preparation Of Dry Emulsion:

50% dry powder mass was used to prepare the liquid o/w-emulsions. In a high-speed colloid mill running for three minutes at 24,000 rpm, the aqueous solution comprising dissolved HPMC or HPMC with Xyloglucan (X2) and coconut oil was homogenized. At 70°C, the liquid o/w-emulsions were dried.

### Preparation Of Film:

The 1% xyloglucan (X2) solution was made by dissolving it in a 10% w/v propylene/glycerol solution. After adding 20 grams of the aforementioned solution to a Petri dish, it was placed in an oven set at 60°C to finish drying. Before being used, the dried films were taken out of the Petri dish and placed in a desiccator [35].

## Suspension

Tamarind seed polysaccharide (TSP) has a wide range of pH tolerance, high viscosity, mucoadhesive nature, lack of carcinogenicity, and biocompatibility. Due to their thermodynamic instability, suspensions need a suspending agent that can easily disperse any settled particle matter and slow down the pace of settling. An attempt has been made by R. Deveswaran et al. to formulate nimesulide suspension using this polysaccharide as a suspending agent. They discovered that TSP powder works well as a suspending agent [6]. It was observed that the solution containing 2% gum tragacanth and gum acacia caked after 30 and 25 days, respectively. On the other hand, redispersing the gum tamarind suspension was simple. The taste of tamarind gum is not poisonous. Thus, it can be said that gum tamarind is a superior pharmacological adjuvant and can be utilized as a suspending agent [36]. Analysis

of the employing of TSP as a stabilizing agent in nimesulide suspension formulation revealed that it functions as a stable suspending agent, slowing down the rate of settling and facilitating the simple redispersion of any settled particle matter [1].

#### Sustained Drug Delivery

Tamarind seed polysaccharide has also been used in the creation of spheroids, beads, microparticles, and other multiple-unit systems. There are several kinds of polysaccharide-based tamarind seed multiple-unit systems for sustained medication administration in the literature. A variety of techniques, including extrusion-spheronization, ionotropic gelation, covalent crosslinking, combined ionotropic gelation/covalent crosslinking, and ionotropic emulsion-gelation, were used to formulate all of the reported tamarind seed polysaccharide-based multiple-unit systems for sustained drug delivery. This polysaccharide possesses a high drug-holding capacity and can maintain drug release over time [37].

To cure HIV, Arkhel Alka et al. developed and characterized sustained-release matrix tablets of lamivudine utilizing a mixture of TSP and ethyl cellulose. The addition of ethyl cellulose and an increase in TSP concentration resulted in a decrease in drug release. Plots with the highest linearity were found to be consistent with drug release kinetics, which was explained by Higuchi's equation. However, zero-order kinetics was also found to be closely related. The prolonged-release pharmacokinetic profile of lamivudine from matrix tablets prepared with TSP and ethyl cellulose was demonstrated in the *in vivo* experiment conducted in rabbits. Stability testing was also conducted on the optimized formulation, and the results showed good stability and no discernible drug degradation. Therefore, it was discovered to be a superior combination for the manufacturing of lamivudine sustained-release matrix tablets [38].

#### Nano Formulation

The creation of nanomedicine has spurred interest in pharmaceutical research once again with the introduction of nanotechnologies. The goal of nanomedicine formulations is to improve systemically administered chemotherapeutic drug therapy by boosting the drug's tissue bioavailability using nanometer-sized carrier materials. In comparison to traditional approaches, nanomedicine offers a novel way to administer medications through various pathways while providing secure and more efficient treatments [39].

#### Ophthalmic Delivery

A poor water-soluble antimuscarinic medication is tropicamide. During ocular surgery and dilated funduscopy, its 1% w/v aqueous solution is frequently employed to induce mydriasis. The drug is mildly basic. pH 5.0 is an acidic buffer used in its solutions to promote solubility. However, this leads to increased lacrimation, which decreases its bioavailability and raises its irritation potential. The formulation of tamarind seed xyloglucan (TSX) nano aggregates loaded with tropicamide was improved in this work utilizing two independent variables and Central Composite Design. To prepare the ocular formulation of tropicamide (1%, w/v), the optimum batch of xyloglucan nano aggregates loaded with tropicamide was utilized [40].

#### Oral Nanocarrier

The first line of treatment for serious, potentially fatal systemic infections is the polyene macrolide antibiotic amphotericin B (AmB). For many illnesses, including leishmaniasis, intravenous infusion of AmB is still the cornerstone and gold standard treatment. Based on current research, AmB's efficacy is increased by its interaction with ergosterol found in fungal cell membranes. Its great affinity for cholesterol in the host cell wall, on the other hand, leads to aggregation in physiological fluids, which causes deleterious consequences. Cell death is the result of ion channels forming as a result of AmB binding to ergosterol. Acute hazardous adverse effects of combined water-soluble formulations of AmB have been documented by several studies. On the other hand, AmB monomeric versions are safe and effective in several trials. To the most effective of our knowledge, amphotericin B oral formulations have not been made using CMTSP.

Consequently, we proposed the formulation and encapsulation of AmB as a new oral drug delivery platform with improved mucoadhesiveness within the biocompatible polysaccharide core of CMTSP. Aggregation is inhibited by the hydrophilic polysaccharide chains that are lengthy and intercalate the hydrophobic chains that are typical of AmB. AmB monomerization will be further stabilized by AmB's polar groups interacting with many polysaccharides' functional groups. The sustained integration of amphotericin B (AmB), which is weakly soluble in water, into mucomimetic carriers for drugs would thereby increase the encapsulated drug's bioavailability and effectiveness [41].

#### Nano Emulsion

**Effect of tamarind (*Tamarindus indica* L.) seed polysaccharide on physical properties of itraconazole loaded nanoemulsions.**

The effect of tamarind (*Tamarindus indica* L.) seed polysaccharide on the physical properties of itraconazole-loaded nanoemulsions generated by simple homogenization (20,000 rpm, 15 min). Itraconazole, a substance having limited solubility in water, was used as a model drug. 20–50% w/w of castor oil, oleic acid, and caprylic/capric triglyceride were used as an oil phase. Polysorbate 80 and sorbitan sesquiplane 83 were used as emulsifiers, and tamarind seed polysaccharide was employed as a co-emulsifier. Formulations containing 30% oil and 2030% w/w polysorbate 80 were able to create nanosized emulsions (100–500 nm); however, even at 3% emulsifier content, tamarind seed polysaccharide alone was unable to produce nanoemulsions.

By introducing 1-3% tamarind seed complex sugar to dosage forms containing 20% polysorbate 80, the size of the emulsion droplets was decreased. For the dosage forms containing 3% tamarind seed polysaccharide, the particle size of the quantum emulsion decreased as the polysorbate 80 level rose. The inclusion of itraconazole did not affect the size of the nanoemulsion droplet. The range of zeta potentials was -16.97 to -16.41 mV. The viscosity varied between 1,595 and 1,067 cPs. The nanoemulsions held their stability for at least 14 days at 8 C. The results suggest that tamarind seed polysaccharide, a safe, biodegradable, and edible biopolymer, may find application as a co-emulsifier in nanotechnology [42].

**Nanoparticle Loaded Trypsin Inhibitor**

Tamarind seed-derived trypsin inhibitor (TTI) has anti-inflammatory and satietogenic properties. To preserve TTI's stability and protection throughout the gastrointestinal system, the author disclosed performing TTI encapsulates by tiny particles in pure chitosan and whey protein isolate (ECW). Filtration monitoring of the antitrypsin activity allowed for the determination of the relationship between TTI and the encapsulated agents [43].

## THERAPEUTIC ACTIVITY OF TAMARIND SEED

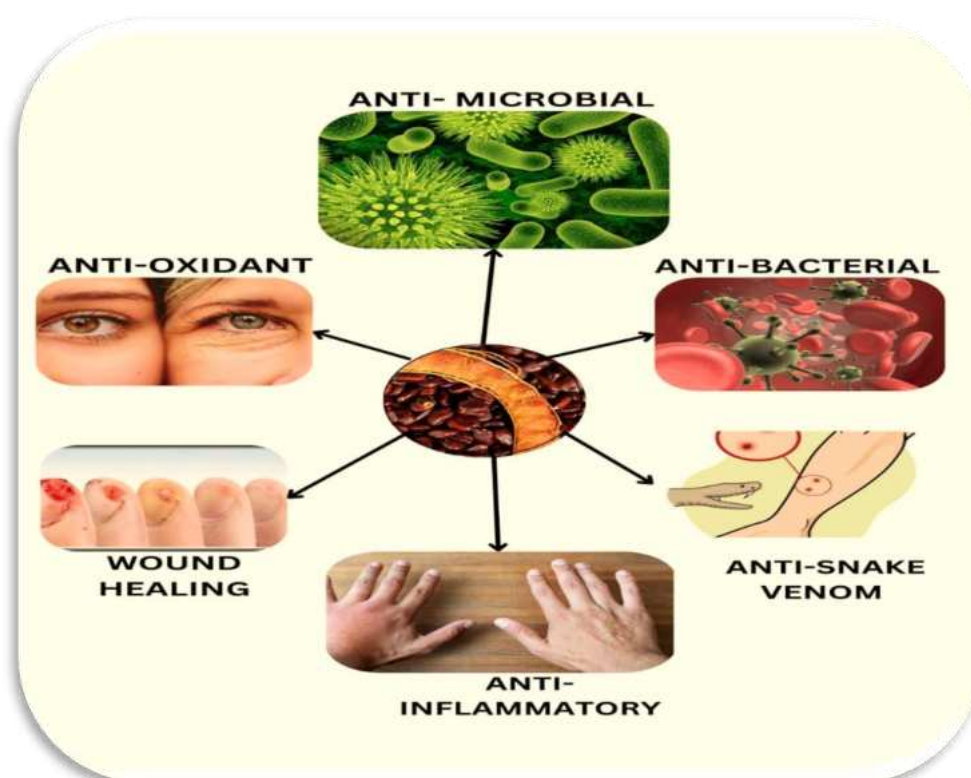


Fig.1.9. key properties of tamarind seed relevant to its use as an excipient in pharmaceutical application.

#### Anti-Oxidant

A good source of free radicals is the sweet kind of tamarind seeds. The results of the study demonstrate the antioxidant properties of tamarind seed extracts. It has also been stated that the antioxidant action of tamarind seed extract is attributed to its flavonoids and phenols [44]. The results of the study demonstrate the antioxidant activity of tamarind seed extract. It has also been stated that the antioxidant activity of tamarind seed extract is attributed to its flavonoids and phenols [45]. According to research by Subjoin et al., tamarind indicia seeds and pericarp include phenolic antioxidant compounds. When compared to artificial

antioxidants such as butylated hydroxyl ascorbic acid and anisole, all of the extracts demonstrated strong antioxidant activity against the linoleic acid emulsion systems [46].

#### Anti-Microbial

Tamarinds indica extract (pulp and seeds) was prepared using a 1:1 water-alcohol method of extraction at various strengths (25, 50, 70, and 100 mg/ml). to compare the susceptibility of a few types of bacteria—such as *E. coli*, *Pseudomonas*, *Staph aureus*, and *Bacillus cares*—to the various concentrations of the extract stated above in relation to the antibiotics Ampicillin, Tetracycline, and Amoxicillin [47]. The antibacterial activity and phytochemical characterization of Tamarinds indica's ethanoic bark extract. The tamarind seed fraction and hydroalcoholic extracts were also tested for antibacterial properties [48]. The hydroalcoholic extract and tamarind seed fraction's antimicrobial activities were also assessed [49]. The ethanoic extract from *T. indica* was found to possess antibacterial properties against both MDR Gram+ve (*S. aureus*) and Gram–ve (*P. aeruginosa*) isolates [50]. Using the technique of the paper diffusion disc method, the antibacterial activity of the concentrated extracts was assessed by measuring the dimensions of the area of resistance against gram-positive and gram-negative microbes and fungi. Tamarind fruits and leaves were separately extracted with alcohol and water and then evaporated at 40°C in a circular evaporator [51,52].

#### Anti-Bacterial

Skin microflora, particularly in the axilla, is often composed of gram-positive bacteria such as *Staphylococcus aureus* and *Staphylococcus epidermidis*. By employing twofold serial dilutions in a Mueller-Hinton broth medium, the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of tamarind fruit pulp extract were ascertained by broth microdilution. (Akinyemi, Oluwa, Omomigbehin, 2006; Gunes et al., 2016) [53]. Using a dilution approach, an extract of *T. indica* leaves was found to have antibacterial activities against a variety of bacteria, including *Burkholderia pseudomallei*, *Klebsiella pneumoniae*, *Salmonella paratyphi*, *Bacillus subtilis*, *Salmonella typhi*, *Escherichia coli*, and *Staphylococcus aureus* [54]. The effectiveness of antibacterial agents in pulp and crushed seed extraction concentration was tested for antibacterial properties, and the results were compared with control, tetracycline, amoxicillin, and ampicillin. The test microbes that were employed were *Staph aureus*, *Bacillus*, *E. coli*, and *Pseudomonas* [55].

### Wound Healing Property

One of the main issues facing researchers and medical professionals involves wound healing. In addition to traumatizing the patient, inadequate wound healing increases the demand for financial resources and the need for efficient administration within the health care system [56]. Novel wound dressing films were made using a cross-linked epichlorohydrin solution, after a phosphate loading procedure involving soak. The optimal elasticity and tensile strength of TSP were contingent upon the degree and layer of cross-linking. The antimicrobial and wound-healing properties of these coverings determine their in vivo efficacy. The TSP film-treated groups exhibited considerably higher protein levels and elastic properties of the regenerated tissue, as well as faster epithelialization and greater rates of wound contraction [12]. The research regularly mentions using tamarind to treat cuts, wounds, and abscesses. The most popular application for tamarind bark or leaves is topical application, either by themselves or in conjunction with different species. Other tamarind plant parts, such as fruit, leaf powder, pod husks, or gum, are also utilized in wound healing medications. One of the most significant treatments for wounds brought on by Guinea worm infections was a tamarind leaf decoction. One can use a leaf extract to wash away blemishes, ulcers, wounds, or mouth sores [14]. Many kinds of wounds have been effectively treated by traditional healers using *T. indicia* cork and seed masi (ash). The current research was conducted utilizing an excision wound model on Wister albino rats to assess the wound-healing properties of cork and *T. indicia* seed ash in light of traditional claims and reported activities [57].

### Anti-Inflammatory Activity

The local reaction of living mammalian tissues to damage caused by any agent is known as inflammation. It is an indication of the body's defensive mechanism in response to tissue injury and infection, and it serves to eradicate or restrict the growth of harmful agents as well as remove the ensuing necrotic tissues and organs [58]. Procyanidins, an oligomeric flavonoid present in high concentrations that account for more than 60% of the phytochemicals in *T. indicia* fruit pulp and seeds, have strong analgesic and anti-inflammatory properties [59]. Natural compounds that may have anti-inflammatory properties are often screened using the carrageenan-induced paw edema model of inflammation. According to a hypothesis, the combined effect of many inflammatory mediators causes the production of edema with carrageenan administration. *Tamarindus indica* L. is used to treat inflammatory problems in different regions of the body [60]. In addition to its anti-

inflammatory properties, *Tamarinds indicia* L. (Leguminosae) is commonly used in traditional healthcare in India for the treatment of diabetes type 2 (DM). The goal of the current investigation is to comprehend the relationship between the aqueous seed extract (TSE) of *T. indicia* and its anti-inflammatory and antidiabetic effects in diabetic rats. The goal of the study was to create tamarind extract-based nanoparticles filled with selenium and evaluate their anti-inflammatory properties [61,62].

#### Acaricidal Activity

By using the dipping method, the acaricidal efficacy of *T. indicus* crude extract with water and 10% ethanol in water was evaluated on a loaded female bovine tick (*Boophilus microplus*). [63]. After removing the seeds for seven days at a ratio of 1:2 and 1:5 W/V using water or 10% ethanol, the mature tamarind fruit extract was produced. Following a drop, the ticks' adjusted premature deaths were noted after 24 hours, 48 hours, and 7 days. In the natural extracts of tamarind fruits, the adjusted premature death means of ticks were 56- 70%, 70-89%, and 77-99%, respectively. After dipping at 24 hours, 48 hours, and 7 days, there was no significant difference. The natural acids (oxalic, malic, succinic, citric, and tartaric) in tamarind fruits were also used to biologically test the acaricidal activity using the immersing process. The maximum acute acaricidal activity was demonstrated by oxalic acid concentrations of 0.5% and 1%, which resulted in 56% and 62% mortality of ticks 24 hours after dipping, respectively. The greatest amount of latent acaricidal action (73% tick fatalities at 7 days after dipping) was demonstrated by 1% tartaric acid concentration. The acaricidal activity of a 0.5% mixture of oxalic acid with 0.5% quantities of malic, succinic, citric, and tartaric acids at a 1:1 V/V ratio was examined. The outcome demonstrated that these acid mixtures' acaricidal activity was not more persistent than that of each acid alone [14]. The patchy hemorrhagic swelling on the ticks' skin occurred as a result of both the natural extract and organic acids from tamarind fruits after 15 minutes of immersion. This suggests that a crude tamarind fruit extract made with water or 10% ethanol might be applied in real-world situations to eradicate tropical cattle ticks. Their organic acids, particularly tartaric and oxalic acids, are the active chemicals [63].

#### Anti-Snake Venom Activity

The *Tamarindus indica* (TI) plant has a wide range of therapeutic uses, including the traditional treatment of snakebite [64]. In a dose-dependent way, tamarind seed extract suppressed the venom's PLA (2), protease, hyaluronidase, l-amino acid oxidase, and 5'-

nucleotidase enzyme activities. These are the main hydrolytic enzymes that cause localized injury to tissues, swelling, and low blood pressure, which are the initial results of envenomation [65]. Moreover, the extract counteracted the indirect hemolysis brought on by poison as well as the breakdown of the human fibrinogen beta chain. Additionally, it was noted that the extract only slightly prolonged the period of clotting and had a mild effect on it [63]. The myotoxic effects, edema, and bleeding caused by poison were considerably lessened when poison was previously incubated into various amounts of seed extract before the experiments. Animals given seed extract were spared poison-induced toxicity after ten minutes of biting (venom injection). It can be used as a substitute for serum therapy because it inhibits hydrolytic enzymes and has pharmacological effects. Moreover, it is a rich source of possible inhibitors of PLA (2), metalloproteinases, serine proteases, hyaluronidases, and 5-nucleotidases, which are the enzymes involved in several physiopathological human and animal diseases [14].

#### PHYTOCHEMICAL EXAMINATION

The standard tests conducted for the detection of carbohydrates, reducing sugars, tannins, mucilage, and peroxide enzymes included Molisch's test for carbohydrates, reduction of Fehling's solution for reducing sugars, ferric chloride test for tannins, and ruthenium red test for tamarind kernel gum [10].

##### 1. CARBOHYDRATE TEST

###### a) Molisch Test

A few drops of strong sulfuric acid were introduced through the test tube's walls, along with a few drops of alcoholic  $\alpha$ -naphthol, to the Tamarind Kernel gum aqueous solution [10].

###### b) Benedict's Test

Benedict's reagent was applied to the filters and then heated in a water bath. The formation of an orange-red precipitate detected the presence of reducing sugars.

###### c) Fehling's Test

Fehling's A and B solutions were heated, alkali neutralized the filters, and the filters were hydrolyzed with diluted hydrochloric acids. When reducing sugars are present, a red precipitate forms [66].

## 2. ALKALOID TEST

A volume of chloroform equivalent to 0.5 g of the extract was extracted after being combined with 5 ml of ammonia. 5 milliliters of diluted hydrochloric acid were added to this extract. The following alkaloid chemical tests were conducted using the acquired acid layer [67].

### a) Wagner's test

Wagner's reagent was administered to the aqueous solution of Tamarind Kernel gum [10].

### b) Mayer's test

A few drops of Mayer's reagent were applied to one milliliter of the acid layer. Alkaloids were present when a creamy white precipitate started to form.

### c) Hager's test

Hager's reagent was added in a few drops to 1 milliliter of the acid extract. Alkaloids were present, as evidenced by the formation of a yellow precipitate [67].

## 3. TANNINS TEST

### a) Ferric Chloride Test:

Three milliliters of 1% ferric chloride solution were combined with two milligrams of the extract. Tannins are present when a blue, green, or brown color develops.

### b) Gelatin Test:

A small amount of a one percent gelatin solution containing ten percent sodium chloride was combined with approximately 0.5 g of the extract. Tannins were present because a white precipitate started to form [67].

## 4. PHENOLIC COMPOUND TEST

### a) Ferric chloride test:

Add two milliliters of distilled water to one milliliter of extract, then a few drops of 10% ferric chloride. The presence of phenolic groups is indicated by the creation of a blue or black color.

### b) Lead acetate test:

A small amount of lead acetate solution was added to 10 milliliters of the extract. Phenol is present when a yellow-colored precipitate forms [68].

## 5. FLAVANOID TEST

### a) Decolorisation Test:

A few drops of sodium hydroxide solution were added to the extract. The presence of flavonoids was revealed by the formation of a bright yellow color that became colorless when a few drops of diluted HCl were added.

### b) Shinoda Test:

Five milliliters of ethanol, five drops of hydrochloric acid, and half a gram of magnesium turnings were added to the extract. After 15 minutes, the presence of flavonoids is shown by the appearance of pink color.

### c) Lead acetate Test:

A few drops of lead acetate solution were added to the extract. Precipitate those forms in a yellow color suggests the presence of flavonoids.

### d) H<sub>2</sub>SO<sub>4</sub> Test:

A few drops of H<sub>2</sub>SO<sub>4</sub> were applied to the extracts. The development of an orange color signifies the existence of flavonoids [68].

## 6. ANTHROQUINONE TEST

### a) Borntrager's Test:

Five milliliters of the extract were brought to a boil in a water bath using 10% HCl for a short while. After filtering, it was left to cool. Chloroform was added in the same volume to the filtrate. A few drops of ammonia (10%) were heated after being added to the mixture. The development of a pink hue signifies the existence of anthroquinones [68].

## 7. SAPONINS TEST

In a bottle bath, 1 g of each powdered dried stain was individually heated for 10 minutes with 10 ml of distilled water. After being heated, the mixture was filtered and allowed to cool. After that, the tests listed below were conducted.

### a) Demonstration of frothing:

After shaking the filtrate vigorously for two minutes, 2.5 ml of distilled water was diluted to 10 ml (frothing showed the presence of saponin in the filtrate).

b) Demonstration of emulsifying properties:

Two olive oil droplets were added and forcefully shaken for several minutes, resulting in a solution made by diluting 2.5 ml of filtrate to 10 ml with distilled water (above). The creation of a rather stable emulsion suggested the presence of saponins [69].

## 8. CARDIAC GLYCOSIDE TEST

a) Keller-Killani test:

Along the test tube's side, combine 1 mL of filtrate, 1.5 mL of glacial acetic acid, 1 drop of 5% ferric chloride, and conc. H<sub>2</sub>SO<sub>4</sub>. A blue-colored solution (with a coating of acetic acid).

b) Kedee's test:

Add 4 mL of dried extract, 1–2 mL of methanol, 1–2 mL of alcoholic KOH, 3–4 drops of 1% alcoholic 3,5-dinitrobenzene, and heat. a violet hue that is fading, {Cardenolides}.

c) Test for Cardenolides:

20% NaOH, extract, pyridine, and sodium nitroprusside. Red color that fades to a brownish-yellow hue.

d) Bromine water test:

a few milliliters of bromine water + plant extract. a yellow precipitation.

e) Baljet test:

Baljet's reagent dropped into 2 milliliters of extract. an orange-yellow hue [70].

## 9. TERPENOIDS TEST

a) Salkowski's Test:

To create a layer, gently add 3 ml of concentrated H<sub>2</sub>SO<sub>4</sub> after mixing 5 ml of the extract with 2 ml of chloroform. The inner face may appear reddish-brown, indicating the presence of terpenoids [68].

b) H<sub>2</sub>SO<sub>4</sub> TEST:

3 mL of concentrated H<sub>2</sub>SO<sub>4</sub> (boiled in a water bath) and 5 mL of plant extract (evaporated in a water bath) equals 2 ml of chloroform. A solution with a gray hue [70].

## EVALUATION TEST

a) Swelling index:

The tamarind seed polysaccharide swelling index was calculated using the previously published modified approach. After precisely weighing one gram of TSP powder (#100 mesh

passed), it was moved to a 100 mL stoppered measuring cylinder. It was observed how much powder there was in the measuring cylinder at first. Distilled water was added to get the volume up to the 100 mL level. After being stopped, the cylinder was gently shaken and left for a full day. After 24 hours, the volume that the gum sediment occupied was measured. The Swelling Index (SI) is a percentage that is determined using the following formula.

$$\text{SWELLING INDEX} = \frac{X_T - X_0}{X_T} \times 100$$

Where  $X_T$  represents the height of the enlarged gum after 24 hours and  $X_0$  represents the powder's starting height in the graduated cylinder [71].

b) Bulk density and Bulkiness:

Authors have explained that bulkiness is the inverse of bulk density. A precisely weighed quantity of 50 g was added to a graduated measuring cylinder by a prior investigation. The bulk density equipment was used to fix the cylinder and the volume that the powder occupied was recorded. After that, the powder was tapped in a bulk-density device until a consistent volume was achieved. The bulk volume, or final volume, was recorded [17].

c) Angle of Repose:

The funnel method was used to calculate the angle of repose. A vertically adjustable funnel was used to pour the mixture through until the desired cone height ( $h$ ) was reached. The formula was used to compute the angle of repose ( $\theta$ ) and measure the radius of the heap.

$$\text{The Angle of Repose } \tan \theta = \frac{h}{r} ; \theta = \tan^{-1} \frac{h}{r}.$$

Where  $\theta$  is the angle of repose [72].

d) Tapped density:

"It can be described as a proportion of the powder's tapped capacity to its overall mass. The addition of fine particles blended into the measurement cylinder allowed for its determination. On a firm surface, the measuring cylinder was lightly tapped 500 times, and the amount of powder that settled was recorded. Tapping was done 1000 times, and the volume of the powder was recorded whenever there was a change of greater than 2% between two volumes. Tapping was carried out using a bulk density device once the difference

between successive volumes was less than 2%, and it was stated in g/ml. The formula was as follows:"

$$\text{Tapped density} = \frac{M \text{ (the weight of the powder)}}{V \text{ (powder volume tapped)}} [72].$$

e) Hausner's ratio:

The gum powder's bulk density and tapped density were divided to get the Hausner's ratio. The flow property is better when Hausner's ratio is lower.

$$\text{Hausner's ratio} = \frac{\text{Tapped density of powder (D}_t\text{)}}{\text{Bulk density of powder (D}_b\text{)}}$$

### Correlation between Hausner's Ratio and the Flow Property of Powders

The table.1.3 shows the correlation between Hausner's Ratio and the flow property of powders. It categorizes the flow properties based on different ranges of Hausner's Ratio. [10].

| HAUSNER'S RATIO | FLOW PROPERTY    |
|-----------------|------------------|
| < 1.18          | Outstanding      |
| 1.19 – 1.25     | Well             |
| 1.3 – 1.5       | Moderate to Good |
| > 1.5           | Bad              |
| Above 2         | Extremely Bad    |

Table 1.3

f) Carr's Index

The variation between the tapping and density of bulk divided by the tapped density yielded the gum powder's Carr's index (% compressibility), which is stated as a percentage.

$$\text{Carr's index} = \frac{\text{Tapped density (D}_t\text{)} - \text{poured density (D}_b\text{)}}{\text{Tapped density (D}_t\text{)}} \times 100 [10].$$

## CONCLUSION

The many applications of tamarind seed in the pharmaceutical industry are highlighted in this article; natural excipients are becoming increasingly essential in nearly all formulation types. A novel excipient is being developed to circumvent the existing restrictions on toxicity, compatibility, and cost. This study centers on the potential applications of this polysaccharide in pharmaceutical formulation, including its therapeutic action, physical and chemical characteristics, and function as an excipient in different dosage forms. According to all of these, tamarind seed polysaccharides are a very promising natural pharmaceutical excipient. Their special qualities make them appropriate for various uses, opening the door for more potent and patient-friendly dosage forms. The significance and promise of tamarind seed polysaccharides are highlighted in this conclusion.

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