Original Article'

Tamarind Seed Polysaccharide: An Emerging Excipient for Pharmaceutical Use

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ABSTRACT

Currently, various plant polysaccharides have been studied for their diverse applications as excipients like binders, granulating agents, disintegrants, emulsifiers, suspending agents, gelling agents, mucoadhesive agents, matrix-formers, release retardants, enteric resistants, *etc.,* in various pharmaceutical dosage forms. Among these, tamarind seed polysaccharide is an emerging excipient, which is beingused and investigated for the preparation of various dosage forms like suspensions, emulsions, tablets, gels, creams, beads, spheroids, microparticles, nanoparticles, ophthalmic preparations, and buccal patches, *etc*. The current chapter deals with a comprehensive and useful discussion on pharmaceutical applications of tamarind seed polysaccharide withits some important features like source, isolation, chemical composition and properties.

Key words: Tamarind Seed Polysaccharide, Excipient, Drug Delivery, Sustained Drug Release.

INTRODUCTION

Polysaccharides are high molecular weight polymers possess complex and branched tructures with many monosaccharidic residues that are joined each other by *O*-glycosidic linkages.[1] These are hydrophilic and gel-formic materials.[2] The current socio-economic situation of the modern world has elevated the interest on the use of natural polysaccharides as replacement of synthetic biopolymers in various biomedical applications.[3-6] Natural polysaccharides are obtained from algal, plant, animal and microbial origin.[7]With the improvement of biotechnology, several natural polysaccharides are produced *in vitro* by enzymatic process. Plant polysaccharides are a popular natural bio-polysaccharide group, which are non-toxic, biodegradable, less expensive and freely available in the natural sources.[8-11] These are found mainly in exudates materials, fruits, seeds, roots, rhizomes, leaves, pods, *etc.*[12] The fact for increasing significance of the use of plant polysaccharides is that the plant sources are renewable if cultivated or harvested in a sustainable manner and they are able to provide a constant supply of raw materials.[13] The use of plant polysaccharides in pharmaceutical applications including drug delivery is evolving from their traditional auxiliary function in formulations towards their active role as drug performance enhancers in terms of stability, drug release, target specificity and bioavailability.[9-12] Currently, an enormous numbers of plant polysaccharides have been isolated from various commonly available local plant sources.[14-18] Even these plant polysaccharides have been utilized in the formulation of various kinds of pharmaceutical products as excipients.[2-10-12-19-34] Among various plant polysaccharides, tamarind seed polysaccharide is one of the emerging biopolymers, which is a galactoxylan extracted from the tamarind kernel and have found its wide and potential applications in food, cosmetic and pharmaceutical fields.[35,36] Recent years, tamarind seed polysaccharide is being used

Submission Date: 09-01-2017;
Revision Date: 02-03-2017;
Accepted Date: 30-03-2017

DOI: 10.5530/ijper.51.2s.60

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as useful pharmaceutical excipients in various dosage forms. The current article deals with a comprehensive and useful discussion on pharmaceutical applications of tamarind seed polysaccharide. Beside this, some important features of tamarind seed polysaccharide like source, isolation, chemical composition and properties are also discussed in brief.

Sources and isolation

Tamarind (*Tamarindus indica*) tree, commonly known as *imli* (Hindi), 'Indian date', is a large evergreen tree belonging to the family: Fabaceae and is cultivated throughout almost the whole India and also in other Southeast Asian countries.[37] Indian production of tamarind is about 0.3 million tons per year.[38] Tamarind seed comprises the seed coat or testa (20-30%) and the kernel or endosperm (70-75%) and it contains 67.1 g/Kg crude fibre with higher percentage of carbohydrate in the form of sugars.[39] Tamarind seed polysaccharide is a cell wall storage material present in tamarind seed and is extracted from tamarind seed powder.[39,40] The isolation method of tamarind seed polysaccharide was first derived in laboratory by Rao *et al*., 1946.[41] The procedure was improved by Rao and Srivastava,[42] in 1973 and further modified by Nandi,[43] in 1975 on a laboratory scale. In the literature, several researchers have reported different methods of tamarind seed isolation procedures. Mainly, these procedures can be classified as chemical methods and enzymatic methods. In chemical method, tamarind kernel powder is soaked in boiled water. Then, the extracted mucilage is filtered. The filtered mucilage is added to equal amount of acetone to produce precipitation of tamarind seed polysaccharide, which is then concentrated and dried.[44] In the enzymatic method, the tamarind kernel powder is mixed with ethanol and then, it is treated with the enzyme protease. After this, it is centrifuged and then, the supernatant is added to ethanol for precipitation. The precipitate is separated and dried.[45]

Chemical composition and properties

Chemically, tamarind seed polysaccharide is a highly branched polysaccharide composed of (1 → 4)-β-D-glucan backbone substituted with side chains of α-D-xylopyranose and β-D-galactopyranosyl (1 → 2)-α-D-xylopyranose linked (1 → 6) to glucose residues Figure 1.[44,46] About 80 % of glucose residues are substituted by xylose residues (1-6 linked) and partially substituted by p-1-2 galactose residues.[47] Tamarind seed polysaccharide consists of glucose, xylose and galactose monomer units in the molar ratio of 2.8:2.25:1.0.[46]Thus, tamarind seed polysaccharide is regarded as a galactoxyloglucan.[48] It is noncarcinogenic, biocompatible and stable in acidic pH.[47-49]However, it insoluble in organic solvents such as methanol, ethanol, acetone, ether and in cold water.[40] Native tamarind seed polysaccharide is exhibited a tendency to self-aggregation, when dispersed in aqueous solvents. The aggregates consist of lateral assemblies of single polysaccharide strands showing behaviour. This can be well described by the worm-like chain or by the Kuhn's model.[39]It has excellent ability to swell in water and forms the mucilaginous solution after heating up showing a typical non-Newtonian rheological behavior and pseudoplastic properties.[39-46] Therefore, it has hydrophilic, gel-forming and bioadhesive properties.[46-50] Because of these properties, it is also in preparation of hydrogels.[51-53] Tamarind seed polysaccharide is found non-irritant with haemostatic activity.[54] It has shown hepatoprotective activity also.[55]

Pharmaceutical applications

Currently, various plant polysaccharides have been studied for their diverse pharmaceutical applications in a variety of pharmaceutical dosage forms such as tablets, capsules, gels, emulsions, suspensions, creams, beads, spheroids, microparticles, nanoparticles, ophthalmic preparations, transdermal and buccal patches, *etc.*[9-12] These plant polysaccharides have also been utilized as binders, granulating agents, disintegrants, emulsifiers, suspending agents, gelling agents, mucoadhesive agents, matrix-formers, release retardants, enteric resistants, *etc.*, in various dosage forms.[12-56-64]Among these plant polysaccharides, tamarind seed polysaccharide is emerging as a potential excipient material for pharmaceutical applications. The use of tamarind seed polysaccharide for the preparation of various pharmaceutical dosage forms is discussed below.

Suspensions and emulsions

Tamarind seed polysaccharide was investigated as suspending agents in various pharmaceutical suspensions.[65,66] In these studies, researchers have found the suitability of tamarind seed polysaccharide as suspending agent to produce stable suspensions. It was found to reduce the settling rate of solid particles of these prepared suspensions and to permit also in the easy redispersion of any settled particles.[65] In an investigation, the suspending properties of tamarind seed polysaccharide in paracetamol suspension was compared with some commonly used suspending agents like tragacanth, Arabica gum, and gelatin.[66] From these investigations, a promise in the use of tamarind seed polysaccharide as suspending agent in pharmaceutical suspension was indicated.

Tamarind seed polysaccharide was also investigated as emulsifier in the preparation of emulsions.[61] In an investigation by Kumar *et al.*, a comparative study on castor oil emulsions with using tamarind seed polysaccharide as emulsifier and gum acacia showed the effectiveness of 2% w/v tamarind seed polysaccharide than 10% w/v gum acacia.[67]

Tablets

Tamarind seed polysaccharide was already studied as excipients like binders, matrix formers and release modifiers in pharmaceutical tablet formulations. It was investigated as effective binder for weight granulation and direct compression in various tablets.[68] When tablet binding character of tamarind seed polysaccharide in pharmaceutical tablets for various types of drugs, it was observed that these tablets exhibited slower drug release profiles. This was attributed to the hydrophilicity, viscosity and higher swelling of tamarind seed polysaccharide.[68]

Tamarind seed polysaccharide was investigated as matrix formers in matrix tablets of various drugs.[37-39] In most of the cases, matrix tablets are formulated to make sustained release or controlled release formulations for which these require release modifiers or release retardants. Due to its hydrophilic property, tamarind seed polysaccharide was widely used in various matrix tablets as matrix former and release retardant.[69-77]Along with sustained drug release profiles, some matrix tablets composed of tamarind seed polysaccharide exhibited a mucoadhesive property, which was found helpful in gastroretentive drug delivery.[81-84] Table 1 presents some examples of tablets in which, tamarind seed polysaccharide was used as binder, matrix former, release retardant and mucoadhesive.

Recently, some investigations were performed by various researchers, where modified forms of tamarind seed polysaccharide were used as matrix materials in the formulation of matrix tablets for sustained drug release.[85-88] Ghosh and Pal have investigated the formulation of aspirin matrix tablets using polyacrylamide-grafted tamarind seed polysaccharide.[85] These matrix tablets exhibited controlled drug release (zero-order) behaviour Figure 2. It has been also found that the drug release rate from these matrix tablets was decreasing with increment of % grafting. The drug release was lower in acidic pH and was much higher in neutral pH as well as alkaline pH. Sravani *et al.*, formulated diclofenac sodium and ketoprofen matrix tablets using tamarind seed polysaccharide and epichlorohydrin-crosslinked tamarind seed polysaccharide as release retardants.[86] The drugs (diclofenac sodium and ketoprofen) release from these matrix tablets showed prolonged release of drugs over 8 h. The drug release rates from the tablets containing crosslinked tamarind seed polysaccharide were slower than that of without crosslinking. In an investigation by Kulkarni *et al.*, interpenetrating polymer network hydrogel tablets of tamarind seed polysaccharide and sodium alginate were formulated for controlled release of a water soluble drug propranolol.[87] The interpenetrating polymer network hydrogel tablets containing propranolol and propranolol-resin complex (resinate) were prepared by wet granulation-covalent crosslinking method. These tablets showed drug release up to 24 h. In another study, Jana *et al.*,have formulated interpenetrating polymer network matrix tablets by direct compression of aceclofenac-loaded chitosan-tamarind seed polysaccharide interpenetrating polymer network microparticles.[88] These tablets exhibited sustained release of aceclofenac over 8 h in *in-vitro* dissolution, which were also found comparable with marketed commercial tablets.

Oral multiple-unit systems

Tamarind seed polysaccharide has also been utilized in the development of various multiple-unit systems like nanoparticles, microparticles, beads, spheroids, *etc* for oral use. The multiple-unit systems are able to mix with gastrointestinal fluid and distributed over a longer area in the GIT, which results the absence of impairing of performances due to failure of a few units and more predictable drug release.[89] Moreover, multiple-unit systems avoids the vagaries of gastric emptying and different transit rates through the GIT, thereby, drugs release more uniformly and prevent the exposure to high drug concentration, when compared with single-unit dosage forms. Multiple-unit systems also reduce the chances of dose dumping and localized mucosal damage.[90]

Spheroids

Diclofenac sodium containing spheroids were formulated using tamarind seed polysaccharide by extrusion-spheronization technique.[91] These spheroids exhibited controlled (zero order) *in-vitro* drug release over a period of 8 h. A correlation was observed among the swelling index, viscosity, and *in-vitro* dissolution profile of the spheroids.

Controlled release microparticles/beads

Novel pH-sensitive tamarind seed polysaccharide-alginate composite beads for controlled release of diclofenac sodium were developed through ionotropic-gelation technique.[44] These beads were of 0.71 ± 0.03 to 1.33 ± 0.04 mm in size. The drug encapsulation efficiency of these beads was within the range between 72.23 ± 2.14

to 97.32 ± 4.03 % with sustained *in-vitro* drug release of 69.08 ± 2.36 to 96.07 ± 3.54 % after 10 h Figure 2. The *in-vitro* drug release from these beads containing diclofenac sodium was followed controlled release (zero-order kinetics) pattern with case-II transport mechanism. The swelling and degradation of the developed beads were found to be influenced by different pH of the test medium.

Interpenetrating polymer network microparticles

In an investigation, Kulkarni *et al*., developed diltiazem-Indion 254® complex entrapped interpenetrated polymer network microbeads made of tamarind seed polysaccharide and sodium alginate blend for controlled release of diltiazem HClthrough combined ionotropic gelation and covalent cross-linking.[92] The size of these microbeads varied from 986 to 1257 mm.These microbeads exhibited 78.15 to 92.15% of drug entrapment efficiency. The *in-vitro* drug release from thesemicrobeads prepared with uncomplexed drug (plain diltiazem) showed drug release up to 4 h and those microbeads prepared with diltiazem-Indion 254® complex exhibited drug release up to 9 h. The*in-vivo* evaluation of tamarind seed polysaccharide-alginate interpenetrated polymer network microbeads in Wister rats exhibited comparatively higher *AUC* values signifying the greater bioavailability of diltiazem.

Jana *et al*., have formulated aceclofenac-loaded chitosan-tamarind seed polysaccharide interpenetrating polymeric network microparticlesthrough covalent cross-linking by glutaraldehyde at pH 5.5.[48] The average particle sizes were found 490.55 ± 23.24 to 621.60 ± 53.57 µm. The scanning electron microscopy (SEM) showed almost spherical microparticles without agglomeration Figure 3. The drug entrapment efficiency was found within 85.84 ± 1.75 to 91.97 ± 1.30%. *In-vitro* drug release from thesemicroparticles containing aceclofenac was evaluated using dialysis bag diffusion technique in phosphate buffer (pH 6.8), which showed sustained aceclofenac release over 8 h Figure 4. The *in-vitro* aceclofenac release followed the Korsmeyer-Peppas modelwith anomalous (non-Fickian) diffusion mechanism. These microparticles containing aceclofenac showed sustained *in-vivo* anti-inflammatory effect incarrageenan-induced rats over prolonged period after oral administration.

Mucoadhesive microparticles/beads

Recently, tamarind seed polysaccharide was employed as mucoadhesive polymer blends to develop mucoadhesive microparticles and beads.[93-96]Mucoadhesive beads containing metformin HCl made of low methoxy pectin-tamarind seed polysaccharide polymer-blends were developed through ionotropic-gelation technique and optimized.[93] The optimized calcium pectinate-tamarind seed polysaccharide beads containing metformin HCl showed drug encapsulation efficiency of 95.12 ± 4.26% and mean diameter of 1.93 ± 0.26 mm. The SEM photograph of bead morphology indicated spherical shaped beads with rough surface Figure 5. The *in-vitro* drug release at 10 h was 46.53 ± 3.28% Figure 6. Another metformin HCl-loaded tamarind seed polysaccharide-blended gellan gum mucoadhesive beadsthrough iono-

Table 1: Use of tamarind seed polysaccharide in tablets as binder, matrix former and release retardant

Tablets	Applications as excipient	References
Ibuprofen tablets	Binder, Release-retardant	[68]
Tramadol HCl tablets	Binder	[69]
Diclofenac sodium tablets	Binder	[70]
Acyclovir matrix tablets	Matrix-former, release-retardant	[71]
Aceclofenac matrix tablets	Matrix-former, release-retardant	[72]
Diclofenac sodium matrix tablets	Matrix-former, release-retardant	[73-74]
Lornoxicam matrix tablets	Matrix-former, release-retardant	[75]
Lamivudine matrix tablets	Matrix-former, release-retardant	[76]
Ketoprofen matrix tablets	Matrix-former, release-retardant	[77]
Propranolol HCl matrix tablet	Matrix-former, release-retardant	[78]
Aceclofenac matrix tablets	Matrix-former, release-retardant	[79]
Clarithromycin matrix tablets	Matrix-former, release-retardant	[80]
Salbutamol sulphate mucoadhesive sustained release tablets	Matrix-former, release-retardant, mucoadhesive	[81]
Terbutaline sulphate mucoadhesive sustained release tablets	Matrix-former, release-retardant, mucoadhesive	[82]
Verapamil HCl floating-bioadhesive tablets	Matrix-former, release-retardant, mucoadhesive	[83]

tropic-gelation were developed and optimized by the same research group.[94] The mean diameter of optimized beads was 1.70 ± 0.24 mm and the drug encapsulation efficiency was 95.73 ± 4.02%.The SEM photograph indicated spherical beads with an irregular and rough surface consisting of characteristic large wrinkles and cracks Figure 7. The *in-vitro* drug release at 10 h was 61.22 ± 3.44 %Figure 8. Both the metformin HCl-loaded beads followed the controlled (zero-order) release pattern with super case-II transport mechanism.[93,94]The *ex-vivo* wash off of both these beads in intestinal mucosa exhibited good mucoadhesivity, which was found faster in alkaline pH than acidic pH. This could be due to ionization of carboxyl and other functional groups of the matrix structure, which increased their solubility reducing the adhesive strength. Both the mucoadhesive beads showed a significant hypoglycemic effect in alloxan-induced diabetic rats over prolonged period after oral administration.[93,94]

The same research group has developed also tamarind seed polysaccharide-blended alginate mucoadhesive beads and microspheres through ionotropic-gelation.[95,96] Mucoadhesive beadscomposed of tamarind seed polysaccharide-alginate blends for oral delivery of metformin HCl were developed and optimized.[95] The optimized beads exhibited 94.86 ± 3.92% drug encapsulation efficiency and average diameter of 1.24 ± 0.07 mm. The *in-vitro* drug release exhibited sustained drug release over 10 h and followed controlled-release (zero-order) pattern with super case-II transport mechanism. In another investigation, the same group developed and evaluated tamarind seed polysaccharide-alginate mucoadhesive microspheres containing gliclazide by varying ratios of polymer-blends and calcium chloride concentrations in cross-linking solution through ionotropic-gelation.[96] The drug entrapment efficiencies in these microspheres were 58.12 ± 2.42 to 82.78 ± 3.43% w/w; whereas microparticle sizes were 752.12 ± 6.42 to 948.49 ± 20.92 µm. These microspheres showed prolonged *in-vitro* release of gliclazide over 12 h. Both the metformin HCl-loaded beads and gliclazide-loaded microspheres made of tamarind seed polysaccharide-alginate blends showed good *ex-vivo* mucoadhesivity with the biological membrane in wash-off test.[53,54] *In vivo* performances of these mucoadhesive beads and mucoadhesive microspheres in alloxan-induced diabetic

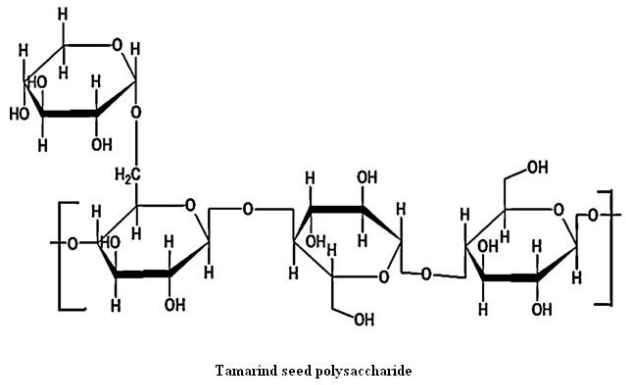

Figure 1: Chemical structure of tamarind seed polysaccharide

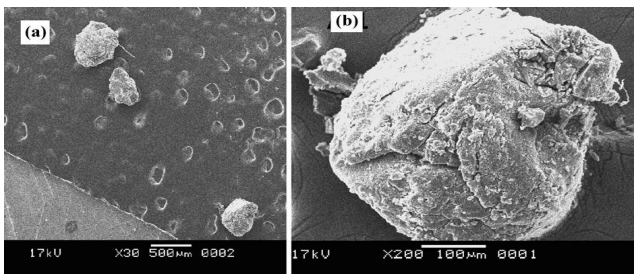

Figure 3: SEM photographs of aceclofenac-loaded chitosan-tamarind seed polysaccharide interpenetrating polymer network microparticles[48] Copyright © 2013 with permission from Elsevier Ltd.

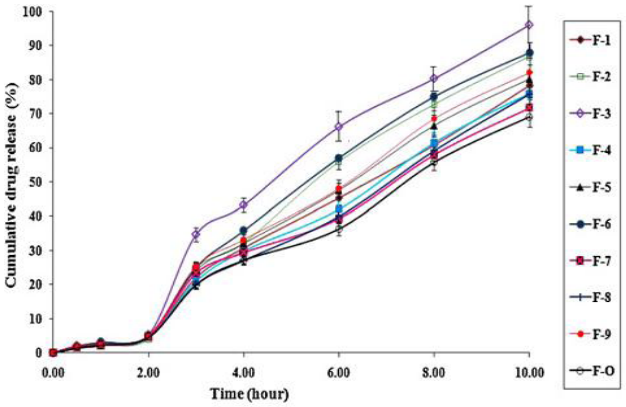

Figure 2: *In-vitro* drug releasing behavior of various ionotropically-gelled tamarind gum-alginate beads of diclofenac sodium[44] Copyright © 2011 with permission from Elsevier Ltd.

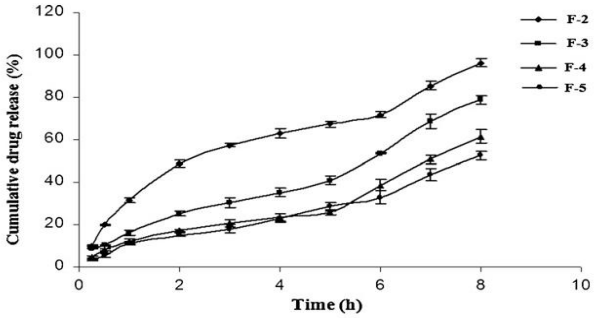

Figure 4: The *in-vitro* drug release from various aceclofenac-loaded chitosan-tamarind seed polysaccharide interpenetrating polymer network microparticles[48] Copyright © 2013 with permission from Elsevier Ltd.

albino rats demonstrated the significant hypoglycemic effect on oral administrationand found suitable for management of non-insulin dependent diabetes mellitus with maintenance of blood glucose level.

Floating beads

Currently, tamarind seed polysaccharide was used in the development of floating gastroretentive beads.[50] In these beads, low density oil was entrapped to attain buoyancy for longer period. Groundnut oil-entrapped tamarind seed polysaccharide-alginate blend floating beads containing diclofenac sodium were developed by ionotropic emulsion gelation method for the use in gastroretentive drug delivery.[50] The optimized beads containing diclofenac sodium showed drug entrapment efficiency of 82.48 ± 2.34% w/w and density of 0.88 ± 0.07 gram/cm^3. The *in-vitro* floatation results of these beads in simulated gastric fluid (pH 1.2) showed good flotation (buoyancy) over 8 h with floating lag-time less than 10 minutes due to their low density. The *in-vitro* drug release showed a sustained release of diclofenac sodium over 8 h in simulated gastric fluid, pH 1.2, indicating controlled release of drug with super case-II transport mechanism.The optimizedfloating beads containing diclofenac sodium exhibited excellent anti-inflammatoryactivity in carrageenan-induced rats over prolongedperiod after oral administration.

Buccal drug delivery

As buccoadhesive polymeric agent, tamarind seed polysaccharide is used in various buccal drug delivery systems including buccal tablets, buccal films and patches.[97-102]Nifedipine buccoadhesive tablets of using tamarind seed polysaccharide were formulated and evaluated for buccoadhesive delivery, which have shown a good mucoadhesivity with the goat buccal mucosa and sustained nifedipine releasing behaviour.[97] Moreover, tamarind seed polysaccharide was compared with HPMC and Na CMC as buccoadhesive agents in these tablets. In another investigation, nitrendipine buccoadhesive tablets were formulated using tamarind seed polysaccharide as mucoadhesive agent.[98] The mucoad-

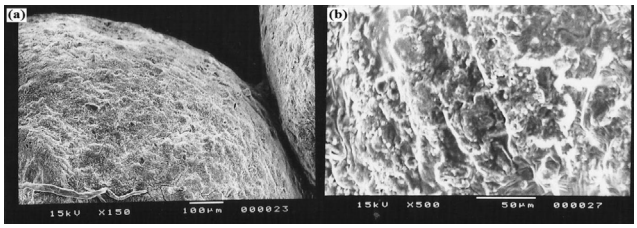

Figure 5: SEM photograph of the optimized calcium pectinate-tamarind seed polysaccharide mucoadhesive beads containing metformin HCl prepared through ionotropic gelation[93] Copyright © 2014 with permission from Elsevier Ltd.

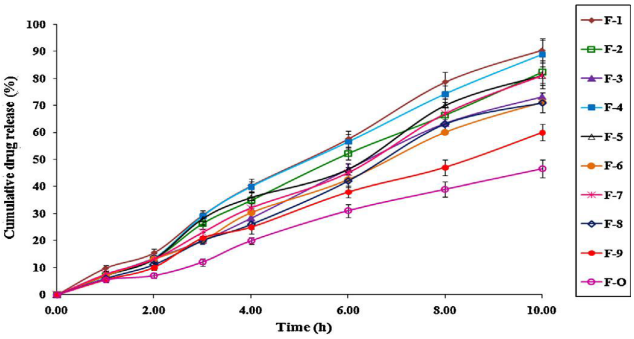

Figure 6: *In-vitro* drug release from various calcium pectinate-tamarind seed polysaccharide mucoadhesive beads containing metformin HCl prepared through ionotropic-gelation [mean ± S.D., n = 3][93] Copyright © 2014 with permission from Elsevier Ltd.

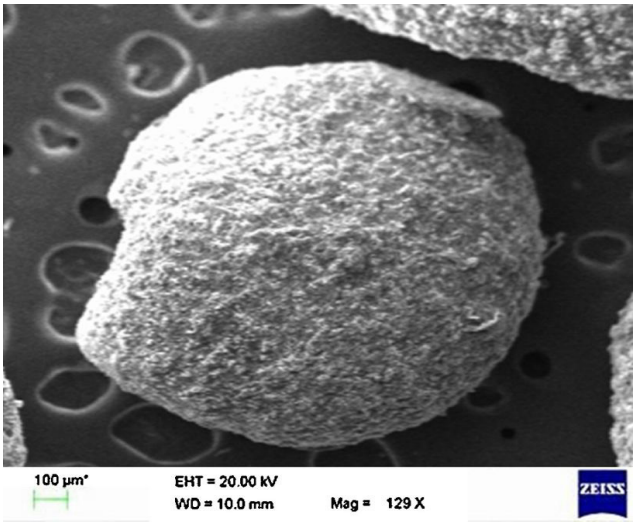

Figure 7: SEM photograph of optimized tamarind seed polysaccharide-gellan gum mucoadhesive beads containing metformin HCl prepared through ionotropic-gelation[94] Copyright © 2014 with permission from Elsevier Ltd.

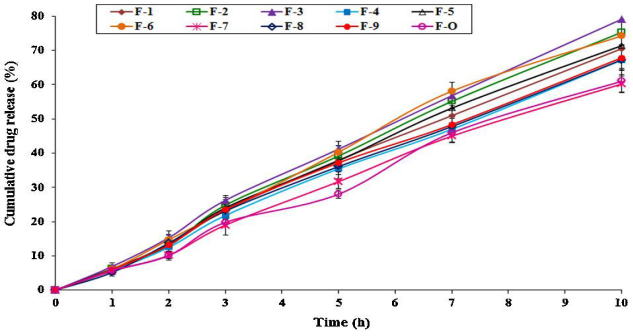

Figure 8: *In-vitro* drug release from various tamarind seed polysaccharide-gellan gum mucoadhesive beads prepared through ionotropic-gelation [mean ± S.D., n = 3][94] Copyright © 2014 with permission from Elsevier Ltd.

hesivity potential of tamarind seed polysaccharide in nitrendipine tablets was compared with polysaccharide isolated from *Ziziphus mauritiana*, HPMC and Na CMC. The results confirmed the usefulness of tamarind seed polysaccharide as mucoadhesive agent in the formulation of buccal tablets. Mucoadhesive buccal films of rizatriptan benzoate were developed using tamarind seed xyloglucan as a mucoadhesive polymer with carbopol 934 P.[99] The *ex-vivo* permeation of rizatriptan benzoate across porcine buccal mucosa using Franz diffusion cell exhibited sustained drug permeation over a prolonged time. In another study, epichlorohydrin cross-linked tamarind seed polysaccharide mucoadhesive patches of metronidazole were formulated, which have exhibited good *ex-vivo* mucoadhesivity with buccal mucosa with sustained drug permeation over a longer period.[100] The drug permeation was found dependent on the degree of crosslinking. In another investigation by Ahuja *et al*., buccal patches of metronidazole using tamarind seed polysaccharide and tamarind seed polysaccharide-g-poly (N-vinyl-2-pyrrolidone) were prepared and evaluated.[101] The *ex-vivo* bioadhesion study showed bioadhesion time of 9.3 h with > 80% of the drug getting released while the buccal patches using tamarind seed polysaccharide showed *ex-vivo* bioadhesion time of 5 h releasing 50% of the drug.

Ocular drug delivery

Tamarind seed polysaccharide was already investigated in the preparation of various ocular drug delivery systems like ocular gels and ocular nanoparticles.[103-107] The high viscosity and mucoadhesive property of tamarind seed polysaccharide make it as a suitable excipient in various ocular formulations for increasing the residence time for various drugs on the cornea. A tamarind gum based *in situ* gelling ocular dosage form of pilocarpine was developed and evaluated for its miotic potential.[103] The combination of tamarind seed polysaccharide, alginate and chitosan was identified to the most successful means for sustained delivery of 80 % pilocarpine in 12 h. *In-vivo* miotic study and ocular irritation study exhibited significant long lasting decrease in pupil diameter of rabbits and well tolerated non-irritating effect with tamarind seed polysaccharide based formulations. In another study, mucoadhesive potential of tamarind seed polysaccharide for ocular administration of hydrophilic and hydrophobic antibiotics like gentamicin and ofloxacin.[104] These ocular formulations were instilled into rabbit eye. The results of the study exhibited that the aqueous humour and corneal concentration of the dose were remarkably higher than the drugs alone. The drug absorptions and drug eliminations for both the drug containing formulations were prolonged by the use of tamarind seed polysaccharide as mucoadhesive agent. Tamarind seed polysaccharide was also investigated for ocular delivery of rufloxacin and ofloxacin to treat bacterial keratitis experimentally induced by *Pseudomonus aeruginosa* and *Staphylococcus aureus* in rabbits.[105] The result indicated significantly increment in intra-aqueous penetration of drugs in both infected and uninfected rabbit eyes. The use of tamarind seed polysaccharide improved the prolongation of precorneal residence time and drug accumulation by these formulations. In an investigation, tropicamide-loaded tamarind seed polysaccharide nanoaggregates were formulated and optimized for the use in ocular drug delivery.[106] The optimized tropicamide-loaded nanoaggregates demonstrated a significantly higher *ex-vivo* corneal permeation of tropicamide across the isolated goat cornea compared to commercial conventional aqueous formulation. The results revealed excellent mucoadhesive properties of these nanoaggregates. These tropicamide-loaded nanoaggregates also exhibited excellent ocular tolerance and biocompatibility as determined by hen's egg test using chorioallantoic membrane and resazurin assay on Vero cell lines. In another investigation, carboxymethyl-modified tamarind kernel polysaccharide was employed to develop ocular nanoparticles containing tropicamide.[107] These nanoparticles were formulated by ionotropic-gelation and optimized Figure 11. The optimized tropicamide-loaded carboxymethyl tamarind kernel polysaccharide nanoparticles showed *ex-vivo* corneal permeation of tropicamideacross isolated goat cornea comparable to its aqueous solution. Further, the *ex-vivo* bioadhesion andocular tolerance nature of these nanoparticles indicated their suitability as ocular delivery system.

Nasal drug delivery

A nasal drug delivery system of diazepam using tamarind seed polysaccharide as mucoadhesive agent was developed and evaluated.[108] The pH, viscosity and gelling property of tamarind seed polysaccharide was found to be higher in comparison to synthetic polymers like HPMC and carbopol 934 commonly used in nasal drug delivery systems as mucoadhesive agent. The *ex-vivo* mucoadhesivity of the formulations containing tamarind seed polysaccharide using bovine nasal membrane was also evaluated and the result of this study indicated higher mucoadhesive strength than that of HPMC and carbopol 934. *In-vitro* drug release characteristic through Franz-diffusion cell using excised bovine nasal membrane exhibited the effectiveness of tamarind seed polysaccharide as mucoadhesive agent in these nasal

formulations in comparison to that of HPMC and carbopol 934 without and with the permeation enhancer.

Colon-targeted drug delivery

The colon targeted drug delivery is required to protect the drug during its transit through upper gastrointestinal tract and allow the release of drug in the colon. Tamarind seed polysaccharide also was investigated as a biodegradable carrier for colon targeted drug delivery.[109] Ibuprofen matrix tablets containing different concentrations of tamarind seed polysaccharide were formulated by wet granulation technique to protect the drug in upper gastrointestinal tract. These tablets released the major amount of ibuprofen, *in-vitro* in simulated gastric fluid (pH 1.2), simulated intestinal fluid (pH 7.4) and simulated colonic fluid (2% w/v rat caecal contents and 4% w/v rat caecal contents, pH 6.8) before and after enzyme induction. The *in-vitro* biodegradation studies suggested that tamarind seed polysaccharide was degraded in presence of rat caecal contents.

CONCLUSION

The main objective for searching a new excipient is to overcome the short comings of processing cost, availability, toxicity and compatibility. Currently, tamarind seed polysaccharide has gained popularity for its utility of in the preparation of various pharmaceutical dosage forms. The current chapter demonstrates the possibilities of using tamarind seed polysaccharide as promising pharmaceutical excipients in various pharmaceutical formulations in pharmaceutical industry.

CONFLICT OF INTEREST

There is no conflict of interest.

ABBREVIATION USED

SEM: Scanning electron microscopy; **HPMC:** Hydroxypropyl methylcellulose; **Na CMC:** Sodium carboxy methylcellulose.

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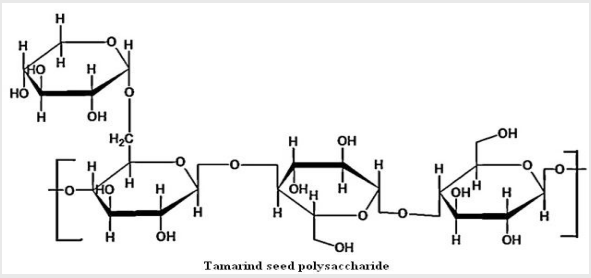
PICTORIAL ABSTRACT



SUMMARY

- Tamarind seed polysaccharide is extracted from tamarind (*Tamarindus indica*) seeds.
- It is a highly branched polysaccharide composed of (1 → 4)-β-D-glucan backbone substituted with side chains of α-D-xylopyranose and β-D-galactopyranosyl (1 → 2)-α-D-xylopyranose linked (1 → 6) to glucose residues.
- It is being used and investigated for the preparation of various pharmaceutical dosage forms like suspensions, emulsions, tablets, gels, creams, beads, spheroids, microparticles, nanoparticles, ophthalmic preparations, and buccal patches, *etc*.

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Cite this article: Nayak AK and Pal D. Tamarind Seed Polysaccharide:An Emerging Excipient for Pharmaceutical Use. Indian J of Pharmaceutical Education and Research. 2017;51(2s):136-46.