www.sphinxsai.com

International Journal of PharmTech Research
CODEN (USA): IJPRIF ISSN : 0974-4304
Vol.6, No.2, pp 412-420, April-June 2014

Tamarind Seed Polysaccharide and its Modifications- Versatile Pharmaceutical Excipients – A Review

Rashmi Manchanda*, S.C. Arora, Rajesh Manchanda

RKSD College of Pharmacy, Kaithal – 136027, Haryana, India.

***Corres.Author: rashmipharma23@yahoo.in**
Mobile no 09813381804

Abstract: In recent years there has been an important development in different dosage forms for existing and newly designed drugs and natural products, semi- synthetic as well as synthetic excipients often need to be used for a variety of purposes. Gums and mucilages are widely used natural materials for conventional and novel dosage forms. With the increasing interest in polymers of natural origin, the pharmaceutical world has compliance to use most of them in their formulation. In the present review we have discussed naturally derived polysaccharide as a potential candidate for novel drug delivery system. These natural materials have advantages over synthetic ones since they are chemically inert non-toxic, less expensive, biodegradable and widely available. They can be modified in different ways to obtain tailor made materials for drug delivery system and thus can compete with the available synthetic excipients. Controlled release drug delivery systems are gaining importance in last few decades for their clinical benefits which are not obtained from conventional oral drug delivery systems. Hydrophillic matrices involving natural polysaccharides are an interesting option for developing sustained release formulations. One such polysaccharide is tamarind seed polysaccharide (TSP) isolated from seed kernel of Tamarindus indica. The utility of TSP and modified TSP as an excipient in novel drug delivery systems is the main focus of this review.

Key words: Tamarind seed polysaccharide (TSP), Carboxymethyl -TSP, Grafting, Thiolated –TSP, Cross-linking, Controlled release.

Introduction

Today, the whole world is increasingly interested in natural drugs and excipients. In recent years, plant derived polymers have evoked tremendous interest due to their diverse pharmaceutical applications such as diluent, binder, disintegrant in tablets, thickeners in oral liquids, protective colloids in suspensions, gelling agents in gels and bases in suppositories. They are also used in cosmetics, textiles, paints and paper making. These polymers such as natural gums and mucilage are biocompatible, cheap and easily available and are preferred to semi synthetic and synthetic excipients because of their lack of toxicity, low cost, availability, soothing action and non irritant nature. Further more, they can be modified to obtain tailor made materials for drug delivery systems allowing them to compete with the synthetic products that are commercially available. Many kinds of natural gums are used in pharmaceutical industry and are regarded as safe for human consumption.

Gums are considered to be pathological products formed following injury to the plant or owing to unfavourable conditions, such as drought, by a breakdown of cell walls (extra cellular formation; gummosis) while, mucilages are generally normal products of metabolism, formed within the cell (intracellular formation) and/or are produced without injury to the plant. Gums readily dissolve in water, whereas, mucilage form slimy masses. Gums are pathological products, whereas mucilages are physiological products(1).Acacia, tragacanth, and guar gum are examples of gums while mucilages are often found in different parts of plants. For example, in the epidermal cells of leaves (senna), in seed coats (linseed,psyllium), roots (marshmallow), barks (slippery elm) and middle lamella (aloe)(2). Gums and mucilages have certain similarities—both are plant hydrocolloids. They are also translucent amorphous substances and polymers of a monosaccharide or mixed monosaccharides and many of them are combined with uronic acids. Gums and mucilages have similar constituents and on hydrolysis yield a mixture of sugars and uronic acids. Gums and mucilages contain hydrophilic molecules, which can combine with water to form viscous solutions or gels. The nature of the compounds involved influences the properties of different gums.Linear polysaccharides occupy more space and are more viscous than highly branched compounds of the same molecular weight. The branched compounds form gels more easily and are more stable because extensive interaction along the chains is not possible.

Disadvantages of Synthetic Polymers

The synthetic polymers have certain disadvantages such as high cost, toxicity, environmental pollution during synthesis, nonrenewable sources, side effects, and poor patient compliance. They need long development time for synthesis compared to natural polymer. Acute and chronic adverse effects like skin and eye irritation are observed with synthetic polymers like methyl methacrylate and poly- (methyl methacrylate) (PMMA)(3). Another synthetic polymer, povidone have shown the formation of subcutaneous granulomas at the injection site (4). Carbomer dust is irritating to the eyes, mucous membranes and respiratory tract(5). Some disadvantages of biodegradable polymers used in tissue engineering applications are their poor biocompatibility, release of acidic degradation products, poor processing ability and rapid loss of mechanical properties during degradation.

Advantages of Natural Polymers:

Natural plant–based materials have various advantages like: -

Biodegradable- Naturally available biodegradable polymers represent truly renewable source and they have no adverse impact on humans or environmental health

Biocompatible and non-toxic- Chemically, nearly all of these plant materials are carbohydrates composed of repeating sugar (monosaccharides) units. Hence, they are non-toxic.

Low cost—it is always cheaper to use natural sources.

Capable of chemical modifications- Modified polymers can meet the requirements of drug delivery systems and thus can compete with synthetic excipients.

Better patient tolerance as well as public acceptance and local availability are some other advantages of natural polymers.

Natural plant – based polymers can either be: -

1) shrubs/tree exudates—gum arabica, gum ghatti, gum karaya, gum tragacanth,

2) Seed gums—guar gum, locust bean gum, starch, amylose, cellulose

3) Extracts—pectin, larch gum

4) Tuber and roots—potato starch

Among hydrophilic polymers, polysaccharides are the choice material due to their non-toxicity and acceptance by regulating authorities (6)]. Polysaccharides like cellulose ethers (7), xanthan gum (8) , scleroglucan (9), locust bean gum(10), and gaur gum(11) are some of the natural polysaccharide which have been evaluated in

hydrophilic matrix for drug delivery system. Although tamarind seed polysaccharide (TSP) is used as ingredient in food material and in pharmaceuticals has not been evaluated as hydrophilic drug delivery system. TSP is a galactoxyloglucan isolated from seed kernel of Tamarindus indica. Xyloglucan is a major structural polysaccharide in the primary cell wall of higher plants.It possesses properties like high viscosity, broad pH tolerance and adhesively (12). This led to its application as stabilizer, thickener, gelling agent and binder in food and pharmaceutical industries. In addition to these other important properties of TSP have been identified recently. They include non-carcinogenicity (13) mucoadhesivity, biocompatibility (14), high drug holding capacity (15) and high thermal stability (16). This led to its application as excipient in hydrophilic drug delivery system (14,15). Since TSP is an important excipient, the present study was undertaken to elucidate release kinetics of both water soluble and water insoluble drugs from this matrix.

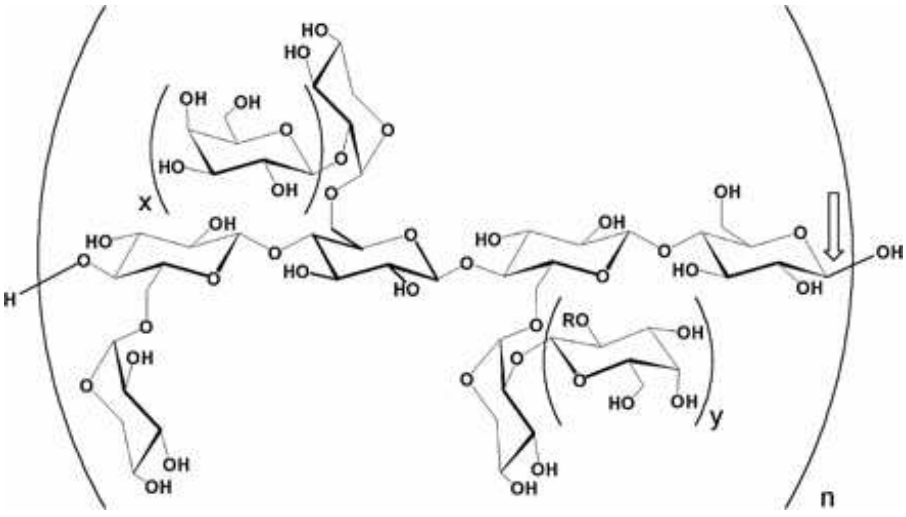
Tamarind seed polysaccharide is a seed gum having wide application in pharmaceutical industry. Tamarind seed is a by – product of the commercial utilization of the fruit however it has several uses. Wasted decorticated kernels contain 46 to 48 % of a gel forming substance. Polysaccharides obtained from tamarind seed kernels form mucilaginous dispersions with water.

General properties of Tamarind seed polysaccharide

Purified TSP is a high-molecular-weight, neutral branched polysaccharide consisting of cellulose like backbone that carries xylose and galctoxylose substances (17). Chemical residues are similar to that of mucin MUC-1 and Epsialin (18). It is insoluble in organic solvents and dispersible in warm mater to form a highly viscous gel as a mucilaginous solution with a broad pH tolerance and adhesivity (12). In addition, it is non-toxic and non-irritant with a haemostatic activity. It is a galactoxyloglucan, belongs to the xyloglucan family, and possesses roperties such as non-Newtonian rheological behaviour, mucomimetic, mucoadhesive and pseudo plastic properties (15,19).

Chemical Structure

Chemically, tamarind kernel powder is a highly branched carbohydrate polymer. TSP is a polymer with an average molecular weight of 52350 daltons and a monomer of mainly three sugars- glucose, galactose and xylose in a molar ratio of 3:2:1. A polymer consists of cellulose-type spine which carries xylose and galactoxylose substituents. About 80% of glucose residues are substituted by xylose residues (1-6 linked), which themselves are partially substituted by p-1-2 galactose residues. The exact sequential distribution of branches is not known. TSP is a branched polysaccharide with a main chain of Â-D-1-glucopyrynosyl units, with a side chain consisting of single D-xylopyranosyl unit attached to every 2nd, 3rd and 4th D glucopyrynosyl unit through1-6 linkage as in Figure 1[12].



Isolation of Tamarind Seed Polysaccharide

Method – 1

The seeds of Tamarindus indica are washed thoroughly with water to remove the adhering materials. Then, the reddish testa of the seeds is removed by heating seeds in sand in the ratio of 1:4 (Seed: Sand). The testa is removed. The seeds are crushed lightly. The crushed seeds of Tamarindus indica are soaked in water separately for 24 h and then boiled for 1 h and kept aside for 2 h for the release of mucilage into water. The soaked seeds are taken and squeezed in a muslin bag to remove marc from the filtrate. Then, equal quantity of acetone is added to precipitate the mucilage. The mucilage is separated. The separated mucilage is dried at temperature 50°C, powdered and passed through sieve number 80. The dried mucilage is powdered and stored in airtight container at room temperature (20).

Method - 2

The isolation of TSP can also be performed by following the method reported earlier (11). 20 g of tamarind kernel powder is added to 200 ml of cold distilled water to prepare slurry. The slurry is poured into 800 ml of boiling distilled water. The solution is boiled for 20 min with continuous stirring. The resulting solution is kept overnight and centrifuged at 5000 rpm for 20 min. The supernatant liquid is separated and poured into twice the volume of absolute alcohol with continuous stirring. The precipitate obtained is washed with absolute ethanol and air-dried. The dried polymer is milled, passed through sieve no.60 and stored in a desiccator until further use.

Chemical Modifications of Tamarind seed polysaccharide (TSP) : -

[1] Carboxymethylation of TSP : -

Carboxymethyl xyloglucan is derivative of xyloglucan and the microbial resistance of CM- xyloglucan is much better than that of plain powder. The viscosity of CM- xyloglucan in solutions is higher compared to native gum. Derivatization of xyloglucan i.e. CM-xyloglucan disrupts the organization and exposes the polysaccharide network for hydration which results in higher viscosity due to this it's swelling index is also higher as compared to Xyloglucan.The presence of carboxymethyl groups makes the molecule resistant toward enzymatic attack. (21) Since carboxymethyl xyloglucan is having improved properties which are required for the retardation of release, it can be used as an excipient in hydrophillic drug delivery system.

[2] Thiol – functionalization of TSP :-

Thiol-functionalization of tamarind seed polysaccharide can be carried out by esterification with thioglycolic acid. Thiol-functionalization can be confirmed by SH stretch in Fourier-transformed infra-red spectra. The results of differential scanning colorimetry and X-ray diffraction study indicate increase in crystallinity (22).

[3] Grafting of TSP : -

TSP has limitations like uncontrolled rate of hydration, drop in viscosity on storage and susceptibility to microbial contamination. These disadvantages can be overcome by suitable grafting of TSP. Grafting is a method where monomers are covalently bonded onto the polymer chain and are grafted with synthetic polymers for the production of better natural products with less side effects and minimum loss of the initial properties of the substrate. Some of the disadvantages of TSP can be overcome by suitably grafting the TS with methyl methacrylate (MMA). Chemical method of grafting by potassium per sulphate and ascorbic acid redox pair can be selected. The physical characterization reveals no drop of viscosity on storage, controlled rate of hydration of grafted tamarind seed polysaccharide (GTS). The chemical and spectral characterization can confirm the grafting procedure. (23).

[4] Crosslinking of TSP with epichlorohydrin:

TSP can be cross-linked with epichlorohydrin and it can be confirmed by FTIR.The cross-linked TSP exhibits superior wicking and swelling action and hence can be used as a superfunctional disintegrant. Cross-linked TSP was found to be more effective in retarding the drug release compared to TSP without cross-linking.(24)

Pharmaceutical Applications

TSP is an interesting candidate for pharmaceutical use. It is used as a carrier for variety of drugs for controlled release applications. Many techniques have been used to manufacture the TSP as well as modified TSP-based delivery systems, which makes it an exciting and promising excipient for the pharmaceutical industry for the present and future applications. The following matter explains the wide use of TSP in pharmaceutical industry.

In Sustained Drug Delivery

It is a potential polysaccharide having high drug holding capacity which can sustained the release of drugs.

Phani Kumar G.K. et al, studied sustained release matrix tablets of Lornoxicam using Tamarind seed polysaacharide (TSP). The main accusative of this study was to maintain therapeutic blood or tissue levels of drug for extended period of time with minimum adverse effects. After 24 hours tablets with 20% TSP binder showed maximum drug release . The drug release followed Zero order kinetics via, swelling, diffusion and erosion. (25)

Parasuram Rajam Radhika etal studied formulation of Aceclofenac sustained release matrix tablets using hydrophillic natural gum like TSP and Guar gum. It is clear through the dissolution study and the kinetic release study of the Aceclofenac matrix tablets prepared using TSP retarded upto 24 hours and tamarind gum is best suitable for sustained release formulation by direct compression method.(26)

Arkhel Alka etal aimed at development and characterisation of sustained release matrix tablets of Lamivudine by using combination of TSP with ethyl cellulose for treatment of HIV. The drug release was decreased with the increase in TSP concentration and with the addition of ethyl cellulose. Drug release kinetics was explained by Higuchi's equation, as the plots showed the highest linearity, but a close relationship was also noted with zero-order kinetics. The in vivo investigation in rabbits showed sustained release pharmacokinetic profile of lamivudine from the matrix tablets formulated using TSP and ethyl cellulose. The optimized formulation was also subjected for stability testing and was found to have good stability with no appreciable drug degradation. Hence, it was found to be a better combination for the formulation of sustained release matrix tablets of lamivudine.(27)

R. Deveswara etal aimed to isolate tamarind seed polysaccharide from tamarind kernel powder, and crosslinking of isolated polysaccharide with epichlorohydrin.The release behaviour of drugs, diclofenac sodium and ketoprofen from isolated tamarind seed polysaccharide and cross linked tamarind seed polysaccharide was studied as release retardant This study provided an insight into the release mechanism of diclofenac sodium and ketoprofen from both TSP and crosslinked TSP matrix tablets. Based on findings it was concluded that crosslinked TSP is more effective in retarding the drug release when compared to the TSP without crosslinking. Thus, the isolated tamarind seed polysaccharide and crosslinked TSP can be used for retarding the drug release for prolonged period of time.(28)

Ashwini R. Madgulkar etal studied to determine the release modifying effect of Carboxymethyl xyloglucan for oral drug delivery. Sustained release matrix tablets of tramadol HCl were prepared by wet granulation method using Carboxymethyl xyloglucan as matrix forming polymer. Sustained drug release following Matrix kinetics attained in the current study indicated that the hydrophilic matrix tablet prepared using Carboxymethyl xyloglucan and HPMC K100M, can successfully be employed to sustain the drug release up to 8 to 12 hours. Carboxymethyl xyloglucan played major role in sustaining release of Tramadol at later stage of release profile, were as HPMC K100M prevented the burst effect by controlling the sudden release of drug from the dosage form at the initial stage of the release profile.(29)

Binder in tablet dosage form

Evaluations of tamarind seed polyose as a binder for tablet dosage forms was taken up for the wet granulation as well as direct compression methods. The results indicated that tamarind seed polyose could be used as binder for wet granulation and direct compression tabletting methods [30].

Colon targeting

Tamarind seed polysaccharide is useful for colon specific drug delivery because of biodegradable and hydrophilic nature. Its low swellability and high viscosity is another reason for its application as excipient in colon specific drug delivery systems. It is also susceptible to the colonic bacterial enzymes.

The potential use of TSP as a carrier for colonic drug delivery can be demonstrated as;

M.U.Mishra evaluated TSP as a biodegradable carrier for colon specific drug delivery. The study aimed to develop matrix tablet based formulation using TSP which protects the drug in upper GIT and release the major amount of drug in colon due to degradation by bacterial enzymes. In-vitro degradability studies suggested that TSP is degraded in the presence of rat caecal contents under conditions mimicking colon. In-vitro drug release studies under conditions mimicking mouth to colon transit demonstrated the ability of TSP to release the drug in Ph 6.8 Sorensons phosphate buffer with RCC. The RCC 4% w/v level after 7 days of enzyme induction degraded tamarind seed polysaccharide remarkably and its presence in dissolution medium provided best conditions for assessing the susceptibility of tamarind seed polysaccharide to colonic bacterial degradation.(30)

In ocular drug delivery

TSP is used for production of thickened ophthalmic solutions having a pseudo plastic rheological behaviour and mucoadhesive properties. The solution is used as artificial tear and as a vehicle for sustained release ophthalmic drugs. TSP is an adhesive thereby prolongs the retention time of formulation onto the surface of eye unlike other eye preparations. Furthermore, the TSP drops did significantly better job of relieving several key subjective symptoms of dry eye syndrome namely trouble blinking, ocular burning, and having sensation of having something in someone's eye [31]. It also increases the resident time of the drug to the cornea, e.g. Â-blockers. The effect of an ophthalmic preparation containing timolol and TSP on intra-ocular pressure was evaluated in rabbits and found to decrease considerably.

Administration of vicosified preparations produced antibiotic concentrations both in aqueous humor and cornea that were significantly higher than those achieved with the drugs alone. The increased drug absorption and the prolonged drug elimination phase obtained with vicosified formulations indicate the usefulness of the TSP as an ophthalmic delivery system for topical administration of antibiotics. Eye drops from TSP are used to treat dry eye syndrome.

Sahoo Soumendra etal studied a biodegradable glycosaminoglycan and a galactoxyloglucan polysaccharide extracted from tamarind seed polysaccharide been found to have a wide application in pharmaceutical industry specially in ophthalmic applications. A mucoadhesive polymer extracted from tamarind seeds (xyloglucan, or tamarind seedpolysaccharide [TSP]) has been described as a viscosity enhancer showing mucomimetic, mucoadhesive, several features make TSP an attractive candidate as a vehicle for ophthalmic medicaments, since it (i) is completely devoid of ocular toxicity ; (ii) has recently been put on the market as a tear fluid substitute because of its activity in preventing alterations of the corneal surface known as keratoconjunctivitis sicca ; (iii) increases the corneal wound healing rate; (vi) reduces the in vitro toxicity exerted by timolol, methiolate, and fluoroquinolones on human conjunctival cells ; and (v) significantly increases the corneal accumulation and intraocular penetration of Gentamicin and ofloxacin when administered topically to healthy rabbits.(32)

As a Mucoadhesive Polymer

Yerram Chandramouli etal evaluated tamarind seed polysaccharide (TSP)as a mucoadhesive and controlled release component of Ciprofloxacin HCl mucoadhesive matrix tablet. It was prepared using polymers like TSP, HPMC K-100 and Xantham gum as release retardants. It was found that increase in concentration of the polymers decreases the drug release.(33)

H Kaur etal studied thiol-functionalization of tamarind seed polysaccharide by esterification with thioglycolic acid. Thiolated TSP showed better crystallinity and mucoadhesivity.(34)

In Buccal Drug Delivery

Shailaja T. etal TS can be grafted to form GTS by a simpler, eco-friendly chemical red ox pair method to overcome disadvantages such as uncontrolled rate of hydration and drop in viscosity. Rheological studies of GTS have shown controlled rate of hydration and no drop in viscosity during storage in comparison to TS. The applicability of TS and GTS for film formation and sustained release has been investigated by formulation and evaluation of buccal patches at different percentages of plasticizer and polymers according to central composite design.(35)

Sougata Jana etal In this study, buccal patches of metronidazole were formulated by solvent casting method using tamarind seed polysaccharide (TSP). The patches were crosslinked with epichlorohydrin and different batches were prepared following 2^3 factorial design. The patches were evaluated with respect to their *ex-vivo* drug permeation characteristics, mucoadhesive strength, folding endurance, and buccal residence time. At lower level of cross linker and plasticizer, the drug permeation was the highest (72.72%). The drug release from the patches was dominated by a dissolution-controlled mechanism rather than diffusion. The folding endurance did not vary widely (201-254), however the mucoadhesive strength (6.1-36.5 g) and the residence time (~2-6 h) deviated widely depending upon the formulation variables. The FT-IR spectroscopy revealed no interaction between drug and polymer. Thus the TSP could be a promising vehicle for the fabrication of buccal patches.(36)

As Emulsifying agent

Ravi Kumar etal studied the objective of present investigation was to search for a cheap and effective natural excipient that can be used as an effective alternative for the formulation of pharmaceutical emulsions. For emulsifying activity study, castor oil was taken as a model drug and emulsified with TSP. The comparative stability studies were done with that of the emulsion prepared by taking gum acacia as standard emulsifying agent and it was found that the emulsion prepared with 2%w/v of TSP is more effective in comparison to that of the emulsion prepared by using 10%w/v of gum acacia. Thus this mucilage will be a non-toxic, bio-degradable, cheap, economic and easily available option as an emulsifier. The result of the present study demonstrated that the TSP obtained from the from seed kernel of plant *Tamarindus indica* is having a potential emulsifying property. It is effective in a very low concentration as compared to that of the standard emulsifier (gum acacia) used. While comparing the stability characteristics of emulsions prepared by TSP and that of the gum acacia it has been found that the emulsion prepared with 2%w/v of TSP is more effective in comparison to that of the emulsion prepared by using 10%w/v of gum acacia. Moreover as this plant is widely distributed in nature, tamarind are eaten by the local tribes and used as food supplement available chiefly in India and many other countries and easily available option without destroying the natural sources as compared to that of the other available natural option will be one of the suitable options to utilize as pharmaceutical excipient. Since the primary ingredients are in expensive, devoid of toxicity, biocompatible, biodegradable and easy to manufacture, they can be used in place of currently marketed emulsifier.(37)

As Solubility enhancer

Anamika Satle et al aimed to elucidate the solubility characteristics and dissolution behavior of TSP for water insoluble drugs. Tamarind kernel powder is evaluated for its suitability as a carrier to improve the dissolution rate of poorly water-soluble drug Celecoxcib. Influence of polysaccharide concentration and method of preparation of solid mixtures on dissolution rates was investigated.(38)

Conclusion

The development of novel dosage form of drug delivery systems has resulted in a need for new excipients to support the desired properties. In novel drug delivery systems, polymer plays a vital role. Development of new excipients is time consuming, involves tedious procedures and is highly expensive. Instead, identification of new uses for the existing substances is relatively inexpensive and less time consuming. There has been ever increasing demand for the plant based products as excipients Natural polymers such as tamarind seed polysaccharide have advantages over synthetic and semi-synthetic polymers like low cost, natural origin, less side effects, locally available and better patient tolerance. However, these natural substances suffer with the drawbacks like purity, source and microbial contamination. If these factors can be identified and controlled,

natural substance can be good substitute for synthetic polymers. Natural polymers are used as binding agents, gelling agents, disintegrating agents, sustaining agents in matrix tablets, film forming agents, suspending and emulsifying agents and as solubiliser. Tamarind seed polysaccharide and its derivatives can be widely used as versatile excipients in novel drug delivery systems. Various other modifications of TSP can be made to eliminate certain drawbacks of basic polymer and can be further explored as an excipient in novel drug delivery systems.

References

1. Qadry JS, Shah and Qadry's Pharmacognosy, B S Shah Prakashan, Ahmedabad, India, 2008.
2. Evans WC, Trease and Evans: Pharmacognosy, Harcourt Brace & Co., Asia Pvt. Ltd, 14th edn., Singapore, 1996, pp. 213-15.
3. Chang RK, Shukla AJ, Polymethacrylates. In:Raymond CR, Paul JS, Paul JW, ed. Handbook of Pharmaceutical Excipients. The Pharmaceutical Press and The American Pharmaceutical Association, 4th edn., London, 2003, pp. 462-68.
4. Hizawa K, Otsuka H, Inaba H *et al*., Subcutaneous pseudosarcomatous PVP granuloma. Am J Surg Path 1984; 8: 393-98.
5. Kolen JJ, McGinity JW, Wilber WR, Carbomer– 934P. In: Raymond CR, Paul JS, Paul JW, ed. Handbook of Pharmaceutical Excipients. The Pharmaceutical Press and The American Pharmaceutical Association, 4th edn., London, 2003, pp. 89-92.
6. Bonferoni MC, Rossi S, Tamayo M *et al.*, On the employment of λ-Carrageenan in a matrix system, Sensitivity to dissolution medium and comparision with Na carboxymethyl cellulose and Xanthan gum. J Control Release 1993; 26: 119-27.
7. Ford JL, Ribinstein MH, McCaul F *et al.*, Importance of drug type, tablet shape and added diluents on drug release kinetics from hydroxypropyl methyl cellulose matrix tablets. Int J Pharm 1987; 40: 223-34.
8. Talukdar MM, Plaizier-Vercammen J, Evaluation of xanthan gum as a hydrophilic matrix for controlled release dosage form preparations. Drug Dev Ind Pharm 1993; 19: 1037-46.
9. Risk S, Duru D, Gaudy D *et al.*, Natural polymer hydrophilic matrix: Influencing drug release factors. Drug Dev Ind Pharm 1994; 20: 2563-74.
10. Sujja-areevath J, Munday DL, Cox PJ *et al.*, Release characteristics of diclofenac sodium from encapsulated natural gum mini-matrix formulations. Int J Pharm 1996; 139: 53-62.
11. Khullar P, Khar RK, Agarwal SP, Evaluation of guar gum in the preparation of sustained-release matrix tablets. Drug Dev Ind Pharm 1998; 24: 1095-99.
12. Rao PS, Srivastava HC, Tamarind. In: Whistler RL, ed. Industrial Gums. Academic Press, 2nd edn, New York, 1973, pp. 369-411.
13. Sano M, Miyata E, Tamano S *et al.*, Lack of carcinogenicity of tamarind seed polysaccharide in B6C3F mice. Food Chem Toxicol 1996; 34: 463-7.
14. Burgalassi S, Panichi L, Saettone MF *et al*., Development and in vitro/ in vivo testing of mucoadhesive buccal patches releasing benzylamine and lidocaine. Int J Pharm 1996; 133: 1-7.
15. Kulkarni D, Ddwivedi DK, Sarin JPS *et al*., Tamarind seed polyose: A potential polysaccharide for sustained release of verapamil hydrochloride as a model drug. Indian J Pharm Sci 1997; 59: 1-7.
16. Datta R, Bandopadhyay AK, A new nasal drug delivery system for diazepam using natural mucoadhesive polysaccharide obtained from Tamarind seeds. SPJ 2006; 14: 115-119.
17. Gerard T, Tamarind Gum in Hand book of water soluble gums and resins. In: Davidson RL, ed. USA: McGraw-Hill Book Co 1980; 12: 1-23.
18. Hilkens J, Ligtenberg MJ, Vos HL *et al*., Cell membrane-associated mucins and their adhesion modulating property. Trends Biochem Sci 1992; 17: 359-63.
19. Rolando M, Valente C, Establishing the tolerability and performance of tamarind seed polysaccharide (TSP) in treating dry eye syndrome: Results of a clinical study. BMC Ophthalmol 2007; 7: 5 .
20. Giriraj KT, Gowthamarajan K, Brahmaji G *et al*., J Scientific Ind Res 2002; 61: 529-32.

21. Goyal P, Kumar V, Sharma P, Carboxymethylation of Tamarind kernel powder. Carbohydrate Polymers. 2007; 69: 251–55.
22. Kaur H, Yadav S, Ahuja M *et al*., Synthesis, characterization and evaluation of thiolated tamarind seed polysaccharide as a mucoadhesive polymer. Carbohydrate Polymers 2012; 90: 1543-49.
23. Shailaja T, Latha K, Sasibhushan P *et al*., A novel bioadhesive polymer: grafting of tamarind seed polysaccharide and evaluation of its use in buccal delivery of metoprolol succinate. Der Pharmacia Lettre 2012;4 (2):487-508.
24. S Sumathi, Ray A, Release behaviour of drugs from tamarind seed polysaccharide tablets. J Pharm Pharma Sci 2002; 5(1):12-18.
25. Phani Kumar GK, Battu G, Lova Raju NS, Isolation and Evaluation of tamarind seed polysaccharide being used as a polymer in pharmaceutical dosage forms. Res J Pharma Biol Chem Sci 2011; 2(2): 274-90.
26. Parsuram RR, Kharkate PR, Thangavel SK, Formulation of aceclofenac sustained release matrix tablet using hydrophillic natural gum. Inter J Res Ayur Pharm 2011; 2(3): 851-57
27. Arkhel A, Bhumarkar L, Ramteke S, Formulation development and evaluation of sustained release matrix tablet of lamivudine using tamarind seed polysaccharide. Der Pharmacia Lettre 2011; 3 (4): 20-28.
28. Sravani B, Deveswaran R, Bharath S *et al*., Release characteristics of drugs from cross linked tamarind seed polysaccharide matrix tablets, Der Pharmacia Sinica 2011; 2 (6): 67-76.
29. Ashwini R Madgulkar1 et al, Optimization of carboxymethyl xyloglucan based tramadol matrix tablets using simplex centroid mixture design,Journal of Pharmaceutics,Volume 2013 (2013), Article ID 396468, 11 pages, http://dx.doi.org/10.1155/2013/396468
30. Mishra MU, Khandare JN, Evaluation of tamarind seed polysaccharide as a biodegradable carrier for colon specific drug delivery. Inter J Pharm Pharma Sci 2011; 3(1):139-42.
31. Mishra MU, et al., Tamarind seed polysaccharides: biodegradable polymer for colonic drug delivery. Second International Conference and Indo-Canadian Satellite Symposium on Pharmaceutical Science, Technology, Practice and Natural Products, Conference Chronicle. DDS 2007; 35: 206.
32. Sahoo S, Nayak PL, Release behavior of anticancer drug paclitaxel from tamarind seed polysaccharide galactoxyloglucan. Euro J Scientific Res 2010; 47(2): 197-206.
33. Yerram C, Shaikh F, Amravathi V et al., Evaluation of tamarind seed polysaccharide (TSP) as a mucoadhesive and controlled release component of ciprofloxacin HCl mucoadhesive matrix tablet and comparison with HPMC K-100 and xantham gum. Inter J Current Pharma Clin Res 2012; 2(2): 90-98.
34. Shailaja T, Latha K, Sasibhushan P et al., A novel bioadhesive polymer: grafting of tamarind seed polysaccharide and evaluation of its use in buccal delivery of metoprolol succinate. Der Pharmacia Lettre 2012; 4 (2):487-508.
35. Sougata J, Dibyendu L, Sen KK *et al*., Development and evaluation of epichlorohydrin cross-linked mucoadhesive patches of tamarind seed polysaccharide for buccal application. Inter J Pharma Sci Drug Res 2010; 2(3): 193-98.
36. Kumar R, Patil SR, Patil MB *et al.*, Isolation and evaluation of the emulsifying properties of tamarind seed polysaccharide on castor oil emulsion. Der Pharmacia Lettre 2010; 2 (1): 518-27.
37. Satle A, Solubility enhancement potential of tamarind seed polysaccharide as pharmaceutical excipient. Inter J Pharma Biol Archives 2012; 3(3):456-59.

****