

# An Overview of Natural Polysaccharides as Biological Macromolecules: Their Chemical Modifications and Pharmaceutical Applications

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## Abstract

Any pharmaceutical formulation contains two ingredients one is the active ingredient and other is an excipients. An excipient helps in the manufacturing of dosage form and it also improves physicochemical parameters of the dosage form. Polymers play an important role as excipients in pharmaceutical dosage form. They influence drug release and should be compatible, non-toxic, stable, economic etc. Biopolymers, synthetic polymers and their derivatives are commonly used in medicine and pharmacy. They are broadly classified as natural polymers and synthetic polymers. Nowadays, due to many problems associated with drug release and side effects manufacturers are inclined towards using natural polymers and their derivatives. Natural polymers are basically polysaccharides so they are biocompatible and without any side effects. This review article aims at discussing various sources, pharmaceutical applications and the different techniques used for modification of natural polymers.

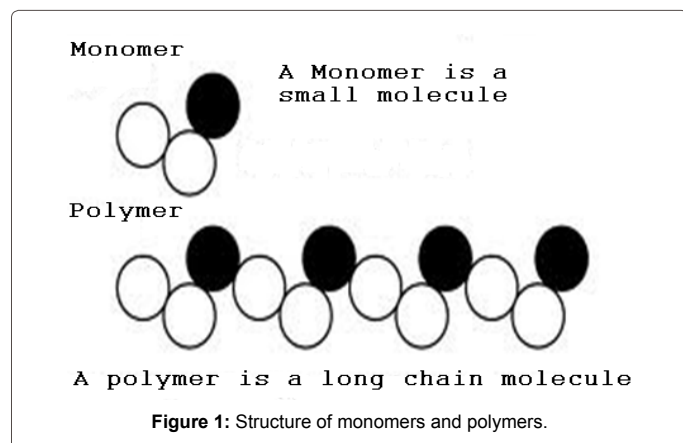
**Keywords:** Natural polymer; Polysaccharides; Grafting

## Introduction

A polymer is macromolecules composed of repeating structural units which are connected by covalent chemical bonds (Figure 1). The term "polymer" is derived from the ancient Greek word *polus* which means "many or much" and *meros*, meaning "parts". It refers to a molecule whose structure is composed of multiple repeating units, having a characteristic of high relative molecular mass and attendant properties. The units composing polymers derive from low relative molecular mass molecule. The term was coined in 1833 by Jöns Jacob Berzelius, though with a definition distinct from the modern IUPAC definition [1]

Polysaccharides are a diverse class of polymeric materials of natural (animal, plant, algal) origin formed via glycosidic linkages of monosaccharides [2]. Depending upon the nature of the monosaccharide unit, polysaccharides are classified as linear or branched chain polysaccharides. Polysaccharides possess a number of reactive functional groups in their chemical structure, including hydroxyl, amino, and carboxylic acid groups, indicating the possibility for chemical modification [3]. Molecular weight of naturally occurring polysaccharide varies between hundreds to thousands of Daltons, further increasing diversity [4].

Although synthetic and natural polymers are available, the use of



natural polymers for pharmaceutical applications is attractive because they are economical, readily available and non-toxic. They are capable of chemical modifications, potentially biodegradable and with few exceptions, also biocompatible [5]. Substances of plant origin pose several disadvantages like being synthesized in small quantities and in mixtures that are structurally complex, which may differ according to the location of the plants as well as other variables such as the season. This may result in a slow and expensive isolation and purification process. Also there is another issue which is become increasingly important is that of intellectual property rights [6,7]. The plant-derived polymers not only have applications in pharmaceutical formulations like their use in the manufacture of solid monolithic matrix systems, implants, films, beads, microparticles, nanoparticles, inhalable and injectable systems but also in viscous liquid formulations [8-10]. In these dosage forms, polymeric materials play different roles such as binders, matrix formers or drug release modifiers, film coating formers, thickeners or viscosity enhancers, stabilizers, disintegrants, solubilisers, emulsifiers, suspending agents, gelling agents and bioadhesives [11].

## Different Sources, Chemical Composition and Applications of Natural Polysaccharides

Table 1-6 provides the information regarding source, chemical constituents and application of different natural polysaccharides.

## Modification of Natural Polymers

The intrinsic structure and properties of nonionic, anionic, and cationic gums make them found extensive application in various

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Common name	Botanical name	Chemical constituents	Application	References
Okra ( <i>Lady's finger, Gumbo, Bhindi</i> )	<i>Abelmoschus esculentus (Malvaceae)</i>	Galactose, galacturonic acid, and rhamnose and with some fractions of glucose, mannose, arabinose and xylose	Suspending agent, disintegrating agent	[12-14]
Phoenix mucilage ( <i>Date palm, Pindakharjura, Khajur</i> )	<i>Phoenix dactylifera (Palmaceae)</i>	Fructose, sucrose, mannose, glucose and maltose in addition to small amounts of polysaccharides such as pectin (0.5 - 3.9%), starch and cellulose	Binder	[15]
Cordia Mucilage ( <i>Bhokar, Semar, Vidi</i> )	<i>Cordia Obliqua (Boraginaceae)</i>	Arabinose, galactose, pyrralinoses	Expectorant, gonorrhoea treatment, tablet binder, emulsifier	[16]
Jackfruit ( <i>Ceylon jack</i> )	<i>Artocarpus heterophyllus (Moraceae)</i>	Galactomannans, starch	Suspending agent, emulsifying agent, Binder, mucoadhesive, release retardant	[17,18]

**Table 1:** Source, chemical constituents and application of polysaccharides obtained from fruits.

Common name	Botanical name	Chemical constituents	Applications	References
Tamarind seed polysaccharide ( <i>Imli, Chinch</i> )	<i>Tamarindus indica (Fabaceae)</i>	Glucosyl : xylosyl : galactosyl in the ratio of 3:2:1	Formulation of matrix tablets, biodegradable carrier for colon specific drug delivery, novel bioadhesive	[19,20]
Fenugreek mucilage ( <i>Methi</i> )	<i>Trigonella foenum-graceum (Leguminosae)</i>	Galactomannans	Matrix formulation, release retardant.	[21]
Locust Bean Gum ( <i>carob gum</i> )	<i>Ceretonia Siliqua (Leguminosae)</i>	D-galacto-D-mannoglycan, cellulose, pentan, galactomannan.	Superdisintegrant, in controlled delivery system, in colonic drug delivery.	[22-24]
Tara gum ( <i>Taya, Spiny hold back</i> )	<i>Caesalpinia spinosa (Leguminosae or Fabaceae)</i>	Mannose : galactose in ratio 3:1	Thickening agent, stabilizer, in formulation of gastroretentive controlled release tablets	[25]
Honey locust gum ( <i>Thorny Locust</i> )	<i>Gleditsia triacanthos (Leguminosae)</i>	galactomannan	In formulation of matrix tablets.	[26]
Cassia Tora mucilage ( <i>Tarota, Takla, Cassia semen</i> )	<i>Cassia tora (Caesalpinaceae)</i>	Arabinose and glucose	Binding, suspending agent.	[27,28]
Mimosa scrabella	<i>Mimosa scabrella (Mimosaceae)</i>	Galactomannan -mannose: galactose ratio of 1.1:1.	Release-controlling agent	[29]
<i>Mimosa pudica</i> ( <i>Touch-me-not, Chui-mui, Lajalu</i> )	<i>Mimosa pudica (Mimosaceae)</i>	d-Xylose and d-glucuronic acid.	Swelling agent, in formulation of controlled delivery system	[30]
<i>Ocimum mucilage</i> ( <i>Sweet basil, Ram Tulsi, Sabje, Sabza</i> )	<i>Ocimum americanum (Lamiaceae)</i>	Xylose, arabinose, rhamnose and galacturonic acids	Tablet disintegrant	[31,32]
Black gram ( <i>urad dal</i> )	<i>Vigna mungo (Fabaceae)</i>	Protein, fat, fibre, minerals, carbohydrates	Suspending agent, matrix forming agent for sustained release tablet.	[33,34]
<i>Gulmohar mucilage</i> ( <i>goldmohar</i> )	<i>Delonix regia (Fabaceae)</i>	Glucomannose	Tablet binder	[35]

**Table 2:** Source, chemical constituents and application of polysaccharides obtained from seeds.

Common name	Botanical name	Chemical constituents	Applications	References
<i>Albizia gum</i> ( <i>Albizia Brownie, Inga zygia</i> )	<i>Albizia zygia (Leguminosae)</i>	Galactose	Emulsifier, tablet coating.	[36,37]
Almond gum ( <i>Almond, badam</i> )	<i>Prunus amygdalus (Rosaceae)</i>	Aldobionic acid, L-arabinose, L-galactose, D-mannose	Emulsifier, suspending agent, glazing agent, stabilizer, thickner, binder	[38]
Cashew gum ( <i>cashew, kaju</i> )	<i>Anacardium occidentale (Anacardiaceae)</i>	Galctose, arabinose, rhamnose, glucose, glucuronic acid	Gelling agent, binder, used in formulation of controlled delivery system	[39-41]
Moringa oleifera gum ( <i>Moringa, drumstick tree, benzoil tree</i> )	<i>Moringa oleifera (Moringaceae)</i>	arabinose, galactose and glucoronic acid	Gelling agent, binder, release retardant, disintegrant	[42-44]
Gum damar ( <i>Black Dammar, Indian white mahogany, Daamar</i> )	<i>Shorea wiesneri (Dipterocarpaceae)</i>	Beta and alpha resins, dammarol acid	Binder, sustained release matrix, microencapsulating agent	[45,46]
Gum Copal ( <i>Indian copal tree, Malabar tallow tree, Chandrusa</i> )	<i>Bursera bipinnata (Burseraceae)</i>	Agathic acid, cis-communic acid, trans-communic acid, polycommunic acid, sandaracopimaric acid, agathalic acid, monomethyl ester of agathalic acid, agatholic acid and acetoxy agatholic acid	Swelling agent, release retardant, film forming agent, carrier for colon specific drug delivery	[45,47,48]
Kondagogu Gum ( <i>Bombax gossypium, Maximiliana gossypium, Galgal, Ganeri, Kondagogu</i> )	<i>Cochlospermum religiosum (Bixaceae)</i>	Rhamnose, galacturonic acid, glucuronic acid, D-glucose, galactose, arabinose, mannose and fructose	In formulation of Gastric floating drug delivery system, emulsifier	[49-51]
Bhara gum ( <i>Vibhitaka, Aksha, Belleric myrobalan</i> )	<i>Terminalia bellerica (Combretaceae)</i>	$\beta$ - sitosterol, gallic acid, ellagic acid, ethyl gallate, galloyl glucose and chebulaginic acid	Release retardant	[52]
Hakea gum	<i>Hakea gibbosa (Proteaceae)</i>	L-arabinose and D-galactose, glucuronic acid, mannose, xylose	Mucoadhesive, release retardant, bioadhesive polymer	[53,54]
Grewia gum	<i>Grewia mollis (Tiliaceae)</i>	Glucose, rhamnose	Binder, film forming agent, release retardant	[55-58]
Olibanum gum ( <i>Indian frankincense, Shallaki, Dhupali</i> )	<i>Boswellia serrate (Burseraceae)</i>	Resin acids, polysaccharides, boswellic acid	Matrix forming agent, binder, microencapsulating agent	[59-61]
Terminalia gum	<i>Terminalia randii (Combretaceae)</i>	$\beta$ - sitosterol, gallic acid, ellagic acid, ethyl gallate, galloyl glucose and chebulaginic acid	Binder	[62]

**Table 3:** Source, chemical constituents and application of polysaccharides obtained from Exudates.

Common name	Botanical name	Chemical constituents	Applications	References
Cocculus mucilage (moonseed)	<i>Cocculus hirsutus</i> (Menispermaceae)	Polysaccharides and a gelatinous material	Pharmaceutically used as binding agent, gelling agent	[63]
Aloe mucilage (Aloe, Gheekumari, Korpad)	<i>Aloe barbadensis</i> (Liliaceae)	Contains 1, 8 dihydroxy anthraquinone derivatives and their glycosides, Acemannan, arabinan, arabinorhamnogalactan, galactan, galactogalacturan, glucogalactomannan, galactoglucoarabinomannan and glucuronic acid.	Formulation of controlled delivery system.	[64,65]
Hibiscus mucilage (shoe-flower plant, China rose, and Chinese hibiscus)	<i>Hibiscus rosa-sinensis</i> (Malvaceae)	L-rhamnose, D-galactose, Dgalactouronic acid, and D- glucuronic acid	Sustained release matrix	[66,67]

**Table 4:** Source, chemical constituents and application of polysaccharides obtained from Leaves.

Common name	Botanical name	Chemical constituents	Applications	References
<b>Polysaccharides obtained from whole plants</b>				
Neem gum (Neem, Cherish)	<i>Azadirachta indica</i> (Meliaceae)	Mannose, glucosamine, arabinose, galactose, fucose, xylose and glucose	Binder, release retardant	[68,69]
Moi gum (Wodier, Jingini, Jhingan)	<i>Lannea coromandelica</i> (Anacardiaceae)	Roots contain cluytlyl ferulate; heartwood gives lanosterol; bark, dlepicatechin and (+) leucocyanidin; flowers and leaves, ellagic acid, quercetin and quercetin-3 arabinoside. Flowers also contain iso-quercetin and morin. Leaves in addition contain beta sitosterol, leucocyanidin and leucodelphinidin	Microencapsulating agent, release retardant	[70]
<b>Polysaccharides obtained from microbial source.</b>				
Curdlan	<i>Agrobacterium</i> spp. (Rhizobiaceae)	Glucose	Food additive (for example, as a thickener or a gelling agent), as controlled delivery system.	[71]
Gellan	<i>Sphingomonas</i> spp. (Sphingomonadaceae)	Glucose, rhamnose and glucuronate	Culture media additive, food additive (for example, as a gelling agent) or for encapsulation	[71]
Colanic acid	<i>Escherichia coli</i> (Enterobacteriaceae)	Fucose, glucose, glucuronate and galactose	Viscosity enhancer	[71]
K30 antigen	<i>Escherichia coli</i> (Enterobacteriaceae)	Mannose, galactose and glucuronate	Viscosity enhancer, controlled drug releasing agent.	[71]

**Table 5:** Source, chemical constituents and application of polysaccharides obtained from Whole plant and microbial source.

Common name	Botanical name	Chemical constituents	Applications	References
Konjac glucomannan (Devil's tongue, voodoo lily, snake palm, or elephant yam)	<i>Amorphophallus konjac</i> (Araceae)	D-Glucose and D-mannose	Controlled release matrix, gelling agent,	[72,73]
Taro (arvi)	<i>Colocasia Esculenta</i> (Araceae)	Galactose and arabinose	Binder, mucoadhesive polymer, matrix forming agent.	[74]

**Table 6:** Source, chemical constituents and application of polysaccharides obtained from Tubers.

areas, but the raw gum also emerges some drawbacks and cannot meet all application requirements for some special purpose. Thus, the modification of gums with acrive small molecules was conducted because the derivatives can not only bring the favorable properties due to the introduction of functional groups, but also keep the intrinsic advantages of gums to the greatest degree [75] and so the chemical modification always plays a dominant role to improve gums and open prospects for extending the application of raw gums. Generally, the chemical functionalization of gums mainly includes the esterification, etherification, and cross-linking reactions of hydroxyl groups.

### Purpose of modification

**To target at a particular site:** 5-amino salicylic acid drug used for ulcerative colitis was formulated using cross linked chitosan. It showed disintegration in intestine and absorption occurred in small intestine which wasn't seen in the formulation with chitosan [76].

**To make the polymers more heat or moisture resistant:** Cellulose acetate is more heat resistant than cellulose. Studies have been performed on modifications of polymers and it was found to decrease degradation rate of the polymer thus making it heat and moisture resistant [77]

**To alter its solubility, more sustainable:** Derivatisation of

chitosan showed increased solubility in water as well as other organic solvents. Enzymatic method using hemicellulose enzyme was used to hydrolyse chitosan and reduce its molecular weight thus increasing its solubility [78]

**To make it more flexible, more transparent, and more compatible and/or biodegradable:** Kappa carrageenan has been subjected to play an important role as free radical scavengers in vitro and antioxidants for prevention of oxidative damage in living organisms. Although k-carrageenan has wide application range, it suffers from certain drawback like biodegradability, which limits its use considerably [79].

**Biopolymers may also have unique characteristics such as antimicrobial effects, which can be used to add value to end products:** Chitosan has antimicrobial activity and it has been tried to develop by derivatisation [80].

**To reduce the toxicity:** Guar gum blocks your gastrointestinal track contributing to blockage of absorption of other critical substances. For example, large amounts of guar gum may prevent metformin, an antidiabetic drug, from being absorbed in the intestines. In diabetic patient where it is necessary to have stable concentration of metformin, severe fluctuation can be seen because of guar gum. This can be reduced by use of its derivative [81].

**Structural elucidation:** The degree of substitution of cellulose and its derivative can be recognized by use of NMR technique [82,83].

## Derivatives of Natural Gums

### Carboxyl derivatives

It includes the addition of carboxyl or  $-\text{COONa}$  group on the substrate. It uses different reagent to increase the hydratability and solubility of gum. The carboxymethyl derivative of cashew gum has negative charges, and can form physical complex with the cationic polymer such as chitosan.

### Hydroxyethyl derivatives

The hydroxyethyl derivatives of gum can be prepared from natural gum via an irreversible nucleophilic substitution. The derivatives show better colloid properties than the raw gums, better solubility and thermal stability in solution, good dispersibility in water, and high compatibility with anionic, cationic, and nonionic surfactants.

### Vinyl-functionalized derivatives

Many gums show poor reactivity and hence require addition of vinyl group so as to increase the reactivity for grafting purpose. Glycidyl methacrylate (GMA), acrylic acid, acryloyl chloride, and maleic anhydride are most commonly used modifying agents. Thus far, the vinyl-functionalized Arabic gum, guar gum, cashew gum [75], xanthan gum [76], and pectin [77] were prepared under basic condition.

### Cationic derivatives

The cationic derivatives of gum have positive charges due to the introduction of cationic functional groups such as amino, ammonium, imino, sulfonium, or quaternary phosphonium groups [78,79].

### Amphoteric derivatives

Amphoteric natural polymer contains both anionic and cationic substituents on its structure, which exhibits distinct properties in contrast to the individual anionic or cationic polymer and receives extensive applications in fine chemicals, papermaking, dyeing, and package materials [80-82]. The common methods to prepare amphoteric derivatives of gum include the following: (1) simultaneously modifying gum with anionic and cationic modifier [83] and (2) modifying gum with an amphoteric modifier [84].

### Hydrophobic derivatives

The natural gums are mainly hydrophilic and soluble in aqueous medium, but it cannot meet the requirements for the application in organic solvent system. Other polysaccharide (i.e., starch, cellulose, chitosan) may form hydrophobic derivatives by introducing short chain hydrocarbon substituents through etherification reaction and show solubility in organic solvents [85].

## Techniques of Derivatisation

“Physiosorption”, “grafting”, and “crosslinking” are the techniques used for the process of derivatisation of a polymer. The term physiosorption is related to physical attractive forces which is a reversible and is achieved by the end functionalized polymers on to the solid surface or self - assembly of polymeric surfactants. The term “grafting” can be described as the covalent attachment process and irreversible. Grafting can be done either by “grafting to” in which functionalized monomer react with backbone polymer to form

grafted one or “grafting from” in which substrate is treated with some method to generate immobilized initiators followed by polymerization. The “crosslinking” is irreversible process in which the association of polymers through a chemical bond occurs. It may be intra and intermolecular.

### Grafting by chemical routes

In this method redox reagents are used which produce the free radicals. These free radicals are then used for grafting. The technique is simple to carry out, feasibility exists at room temperature and also the extent of grafting can be controlled by controlling the reaction variables like reaction time, temperature, monomer concentration.

The probable reaction pathways are described below.

#### With Fenton's reagent ( $\text{Fe}^{2+} / \text{H}_2\text{O}_2$ )

An hydroxyl radical is generated by the reaction of  $\text{Fe}^{2+}$  and  $\text{H}_2\text{O}_2$ . The hydroxyl radical abstracts the hydrogen atom from the polymeric substrate, producing the free radical on it. The monomer molecules in the vicinity of the polymeric substrate become the acceptor of the radicals, which results in chain initiation. Thereafter, they become the free radical donors to the neighboring molecules. In this way, the grafted chains usually grow. These grafted chains terminate by coupling to yield the grafted copolymer [86]

**(a) With  $\text{Fe}^{2+}$  / Persulphate:** Persulphate and a ferrous ion act as a source of  $\text{SO}_4^{\cdot-}$ .

**(b) With Persulphate and Reducing Agent:** Persulphate and a reducing agent like, sodium bisulphite, thiosulphate, or  $\text{Ag}^+$  are also the source of  $\text{SO}_4^{\cdot-}$ , which subsequently produces  $\text{OH}^{\cdot}$ .

**(c) With  $\text{Fe}^{2+}$  / Hydroperoxides:** Hydroperoxides and  $\text{Fe}^{2+}$  generate free radicals via thermal decomposition. The resulting  $t\text{-BuO}^{\cdot}$  participates in hydrogen abstraction to generate  $\text{OH}^{\cdot}$  and the macro radical on the polymeric backbone.

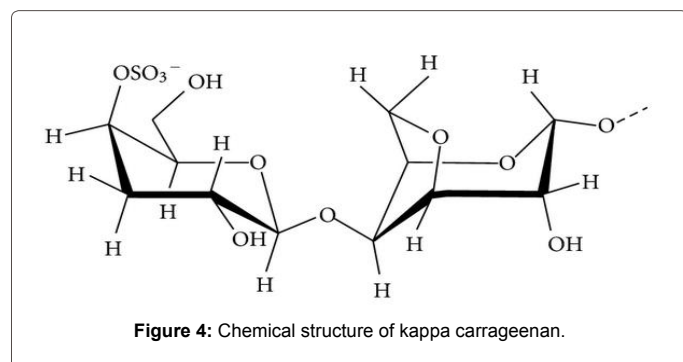
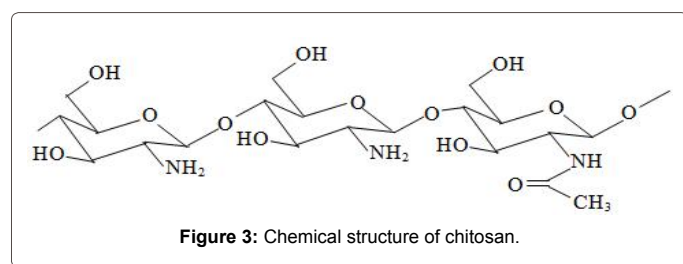
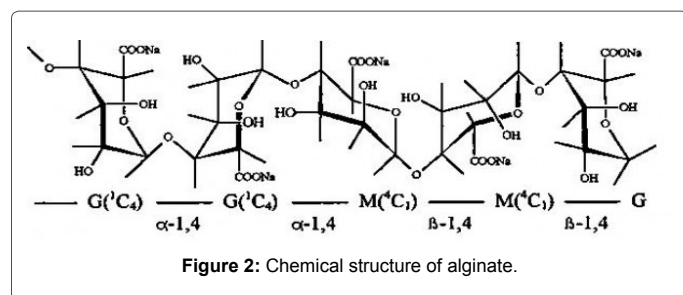
**(d) By Direct Oxidation:** In this method, unlike the above ones the radicals are generated on the backbone itself by use of transition metal ions (e.g.,  $\text{Ce}^{4+}$ ,  $\text{Cr}^{6+}$ ,  $\text{V}^{5+}$  and  $\text{Co}^{3+}$ ). The metal ions with low oxidation potential are the proper choices for the reaction. These highly reactive ions are responsible for initiating graft copolymerization.

**(e) Using Metal Chelates:** Controlling redox potential helps in avoiding unwanted reaction. This can be achieved by the use of metal chelates in the grafting reaction. The metal ion forming complex with the monomer decomposes to the free radical, which undergoes a chain transfer to the polymer.

**(f) By Indirect Method:** The secondary free radicals are generated in the system and may ultimately induce the free radical sites required for grafting [87].

### Crosslinking

It also refers to use of different crosslinking agents and initiators; the mechanism is similar to the grafting reaction. In this chemical pretreatment (e.g., ozonation, diazotization, and xanthation) is done on the polymer backbone which generates free radicals that provide sites for grafting. It occurs till all monomers have been consumed. In these reactions  $R_i < R_p$ , where, as for the conventional free radical grafting,  $R_i > R_p$  ( $R_i$  and  $R_p$  are the rate of initiation and propagation). Also dynamic equilibrium occurs between a propagating radical and dormant species. Predetermination of molar mass of the grafted/crosslinked polymer molecules is possible by use of osmometry and



small-angle laser light scattering [88]. Crosslinked sodium alginate and hydroxyl ethyl cellulose beads were used for controlled release of ibuprofen and diclofenac sodium [89].

### Enzymatic technique

The graft and crosslinking reactions with the help of enzymes (i.e., biological proteinaceous catalyst) are the features of this technique. Oxidoreductase enzymes (horse-radish peroxidase, Tyrosinase, etc.) are focused in the literature as they are capable of forming free radicals (e.g., phenol/amine derivatives) by abstracting electrons or by supplying molecular oxygen to the molecules. The active species formed then either condense each other or react with the nucleophiles the reactions are milder and there is less use of harsh chemicals. Initiation needs the enzyme to form the free radicals and is followed by non-enzymatic reactions. Enzyme selectivity and specificity makes the reaction simple and offers the potential for better controlling macromolecular structure without the need of protection or deprotection steps. It can be coupled with the other polymerization methods [90].

### Applications of Derivatisation

#### Alginate

It is a water-soluble linear polysaccharide extracted from brown seaweed and is composed of alternating blocks of 1–4 linked L-glucuronic and D-mannuronic acid residues as shown in Figure 2. Some modifications of alginate for drug delivery are Alginate combined with

chitosan [90], thiolated alginate-albumin nanoparticles [91], alginate-polyoxamer microparticles, Hydrated thiolated alginate, alginate-poly (lactic-co-glycolic acid) nano/micro hydrogel matrices, chitosan-Ca-alginate microspheres, alginate modified by microenvironmental interaction with calcium ion, polyethylene glycol-anthracene modified alginate [92], photocrosslinked heparin-alginate hydrogels, alginate-guar gum hydrogel, Micelles/sodium- alginate composite gel beads [93], scleroglucan/alginate/borax gels [94], dual cross linked alginate [95].

#### Chitosan

The chemical structure of chitosan has been shown in Figure 3. Some modification of chitosan are carboxymethylation [96,97], carboxyethylation [98], reductive amination with phosphorylcholine glycerol aldehydes [99], sulfation [100], N- or O-acylation alkylation [101-104], quaternarization [105-107], thiolated chitosan [108], phosphorylated chitosan [109,110], grafted chitosan [111]. Chitosan phthalate is less hydrophilic than chitosan succinate. The relative pharmacological efficacy for chitosan phthalate and chitosan succinate microspheres was almost three-fold higher than the efficacy of the oral insulin administration [112]. Among viral and non-viral delivery vectors, the use of non-viral vectors such as chitosan or its derivatives is attractive, since these polymers are biodegradable, biocompatible, with low toxicity and high cationic potential. Even though much of the technology-base has been well established for targeted delivery of plasmid DNA using chitosan and its derivatives, only recently, has the technology been applied to the targeted delivery of si RNA [113]. Derivatives of chitosan have been used in development of micro and nanoparticles [114].

#### Carrageenans

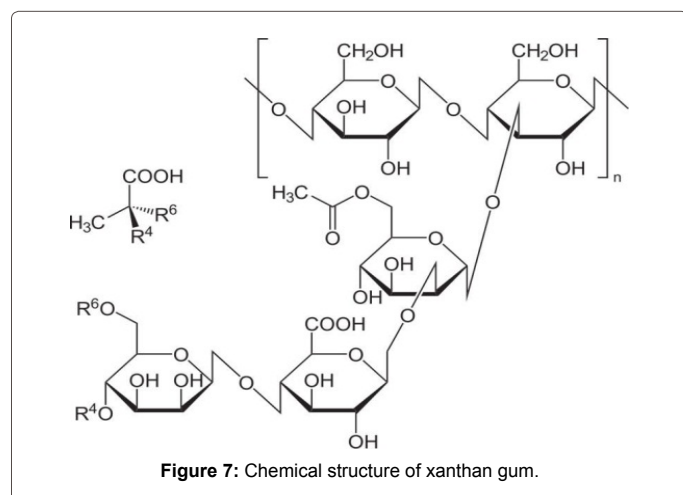
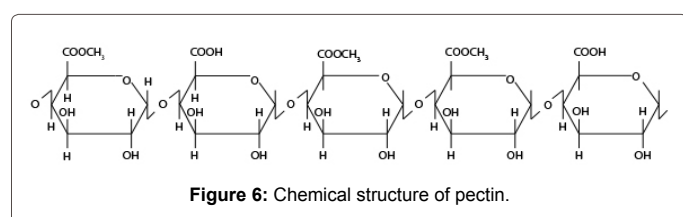
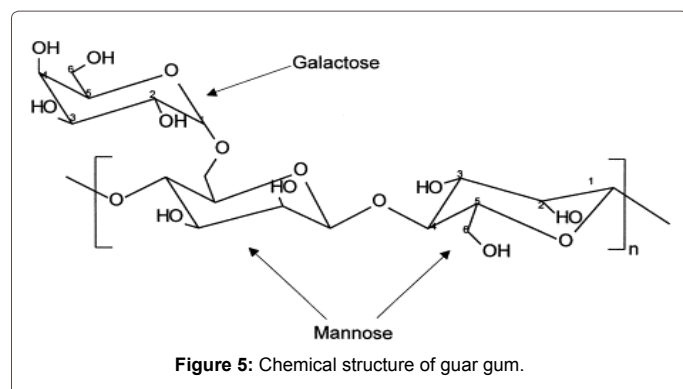
Figure 4 gives an idea about the structure of kappa carrageenan. Some modified forms of carrageenan for drug delivery is iota-carrageenan combined with locust bean gum [115], carrageenan combined with gellan gum [116], chitosan/carrageenan nanoparticles [117], agarose-carrageenan hydrogels [118]. Microencapsules with carrageenan-locust bean gum mixture in a multiphase emulsification technique for sustained drug release of gentamycin sulphate.

#### Guar gum

Guar gum is a galactomannan as shown in Figure 5. Several modifications of guar gum for drug delivery are graft copolymers of N-Vinyl-2-Pyrrolidone onto guar gum for sorption of Fe and Cl ions [119]. Graft copolymer of partially carboxymethylated guar gum-g-N-vinyl-2-pyrrolidone [120], Cross-linking of alginate guar gum with glutaraldehyde [121], carboxymethyl guar films for the formulation of transdermal therapeutic systems [122], graft copolymer H-partially carboxy methylated guar gum-g-methacrylic acid [123]. Complexation of cupric ion-guar gum-graft-acrylamide [124], yttrium crosslinked guar gum-g-acrylamide gel systems [125], Phosphated cross linked guar gum [126], polyester-guar gum/hydroxyl propyl guar gum [127]. Microspheres of Carboxymethyl Guar Gum used were for In Vitro Release of Abacavir Sulfate [128].

#### Pectin

The chemical structure of pectin has been mentioned in Figure 6. To achieve better drug delivery, certain modifications of pectin are done. These are Polyelectrolyte Complex (PEC) film between pectin as an anionic polyelectrolyte and chitosan as a cationic species [129] self-assembling pectin-liposome nano complexes [130], novel pectin-4-aminothiophenole conjugate microparticles [131], pectin/



HPMC polymer mixture [132]. Pectin-NH was prepared by modifying the galacturonic acids carboxyl groups with primary amine groups [133], amidated pectin derivatives with n-propyl-3-aminopropyl-3-propanol or 7-aminoheptyl-substituents [134], thiolated pectin [135], pectin/poly (lactide-co-glycolide) composite matrices [136], mixed pectin/ethylcellulose films, calcium cross-linked pectinate [137,138].

### Xanthan gum

Figure 7 gives the chemical structure of xanthan gum. Some modifications of xanthan for drug delivery are gelatinized starch-xanthan gum hydrogel system, acrylamide-grafted-xanthan gum, Graft copolymerization of ethylacrylate onto xanthan gum, xanthan combined with Konjac glucomannan, xanthan combined with boswellia gum (3:1), xanthan gum combined with guar gum(10:20), xanthan gum combined with locust bean gum in 1:1 ratio [139]. Acrylamide-grafted-Xanthan Gum Copolymer Matrix Tablets were used for Oral Controlled Delivery of Antihypertensive Drugs [140].

### Conclusion

Semi-synthetic polymers have wide application in pharmaceutical

field. There are numerous natural polymers available. Each of these polymers can be derivatised by different method. They show improved physicochemical properties along with the modification obtained by attachment of particular moiety. These derivatives of polymers can be used for development of many pharmaceutical drug delivery systems. There are several natural polymers which are yet to be derivatised. Thus there is great opportunity to the research /development scientist to develop novel polymers by modification of natural polymers.

### Conflict of Interest

The author(s) declare(s) that there is no conflict of interests regarding the publication of this article.

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