

INTERNATIONAL JOURNAL OF INSTITUTIONAL PHARMACY AND LIFE SCIENCES

Pharmaceutical Sciences

Review Article.....!!!

Received: 27-01-2015; Revised: 02-02-2015; Accepted: 03-02-2015

NATURAL POLYMERS IN PHARMACEUTICAL FORMULATION

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Keywords:

Natural polymer, Gum,
Mucilage, Pharmaceutical
application

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ABSTRACT

Nature has provided us a wide variety of materials to help improve and sustain the health of all living things either directly or indirectly. The products from natural polymers have become an integral part of human health care system because of some side effects and toxicity of synthetic drugs. Natural polymers are basically polysaccharides so they are biocompatible and without any side effects. The release mechanism of the drug from these polymers is by Degradation, Diffusion and Swelling. Polymers have been in use for many years with the aim of facilitating the effectiveness and efficiency of drugs and their delivery. Natural polymers possess wide scope in food and cosmetic industries. Natural polymers can be used as the means of achieving predetermined rates of drug delivery and their physico-chemical characteristics with the ease of availability provide a platform to use it as a polymer for drug delivery systems. Gums, mucilages, resins and plant extracts are widely used natural materials for conventional and novel dosage forms. The present article highlights the available information on natural polymers and their versatile use.

INTRODUCTION

Natural polymers such as proteins, enzymes, muscle fibers, polysaccharides and gummy exudates are being used effectively in formulating the variety of pharmaceutical products. They are widely used in pharmaceutical industry and also well suited for pharmaceutical and cosmetic product development.

The use of natural polymers for pharmaceutical applications is attractive because they are readily available, relatively inexpensive, nontoxic, stable, capable of multitude of chemical modifications and potentially degradable and compatible due to their natural origin. The specific application of plant-derived polymers in pharmaceutical formulations include their use in the manufacture of solid monolithic matrix systems, implants, films, beads, microparticles, nanoparticles, inhalable and injectable systems as well as viscous liquid formulations. These have also been utilized as viscosity enhancers, stabilisers, disintegrants, solubilisers, emulsifiers, suspending agents, gelling agents, bioadhesives and binders.

The use of natural polymers in cosmetics is highly developed, and innovative advances in polymer science and nanoscience are driving the creation of scientifically sophisticated products. A diverse range of polymers are used in cosmetics and personal care as film formers. Fixatives, Rheology modifiers, associative thickeners, foam stabilizers and destabilizers, emulsifiers, stimuli responsive agents, skin-feel beneficial agents and antimicrobials. Gums and mucilages are widely used natural materials for conventional and novel dosage forms. Gums are considered to be pathological products formed following injury to the plant or owing to unfavorable conditions, such as drought, by a breakdown of cell walls while, mucilages are generally normal products of metabolism, formed within the cell and/or are produced without injury to the plant.

Guar gum

Guar is also known as cluster bean. Guar gum is a seed gum produced from the powdered endosperm of the seeds of *Cyamopsis tetragonolobus* (Leguminosae). Chemically, guar gum is a polysaccharide composed of the sugars, galactose and mannose. It is made up of a linear chain of β -D-mannopyranose joined by β -(1–4) linkage with α -D-galactopyranosyl units attached by 1, 6- links. Water soluble part of guar gum consist mainly galactomannan which is composed of about 34.5% of galactose anhydride and about 63.4% of mannose anhydride. It is known as guaran which constitute a major part of the gum. Guar gum hydrates and swells in cold water forming viscous colloidal dispersions or sols. This gelling property retards the drug release and makes it a flexible carrier for extended release dosage forms. It is

practically insoluble in organic solvents. Strong acids cause hydrolysis and loss of viscosity, and alkalies in strong concentration also tend to reduce viscosity. It degrades at extreme pH and temperature (e.g. pH 3 at 50°C) and it remains stable in solution over pH range 5-7. Pharmaceutically, it is used as carrier for oral extended release drug delivery. In colon targeted drug delivery it has high potential to serve as a carrier for oral controlled release matrix systems and as cross-linked microspheres. It is used as a binder, disintegrant, thickening agent, stabilizer, emulsifier, bulk laxative, appetite suppressant, sustained release agent, additive and suspending agent in paper, food, pharmaceutical and cosmetics industry. It is also used as thickener for lotions and creams. Triacetate derivative of galactomannan from guar gum can be used to cast into strong, transparent, flexible films^{1,8,4,16,17,12}.

Locust bean gum

Locust Bean Gum (LBG), also known as Carob Gum is obtained from the refined endosperm of seeds from the carob tree *Ceretonia siliqua* Linn. (Leguminosae). It is a non-starch polysaccharide consisting of galactose and mannose in the ratio 1:4 and hence they are known as galactomannan. Locust bean gum consists mainly of a neutral galactomannan polymer made up of 1, 4-linked D-mannopyranosyl units and every fourth or fifth chain unit is substituted on C6 with a D-galactopyranosyl unit. Locust bean gum is a neutral polymer and its viscosity and solubility are therefore little affected by pH changes within the range of 3-11. In pharmaceutical formulations, Locust bean gum is used as a binder, flocculating agent, thickening and stabilizing agent. In the present investigation, locust bean gum is used in the form of compression coat applied over core tablets were evaluated as a suitable carrier for colonic drug delivery. Locust bean gum was used to produce matrix tablets with and without the cross-linker; it is not a good suspending agent because of ceratoniase which causes the eventual break down of the suspension. In another study, sustained release of diclofenac sodium could be obtained for minimatrix systems made from locust bean gum.⁵⁴ A commercially available tablet system (TIMERx®) developed by the Penwest Pharmaceuticals Company consisting of locust bean gum and xanthan gum showed both *in vitro* and *in vivo* controlled release potential^{2,8,10,12}.

Karaya Gum

Karaya gum, also known as Indian tragacanth or Sterculia gum is a vegetable gum produced as an exudate obtained from the trees of *Sterculia urens* (Sterculiaceae). Karaya gum consists of an acetylated, branched heteropolysaccharide with a high component of D-galacturonic acid and D-glucuronic acid residues. It does not contain methoxyl groups. Karaya gum is

widely used as bulk laxative. This gum is very less expensive and currently used in a variety of products, including cosmetics, hair sprays, and lotions, to provide bulk. Gum is least soluble of commercial plant exudates, but it absorbs water rapidly and swells to form viscous colloidal solutions even at low concentrations. Pharmaceutically, it is used as a Suspending agent, emulsifying agent, stabilising and thickening agent, matrix forming agent in sustain release tablets and it has also been used in food, paper and textile industries. The powdered gum is used in lozenges, pastes and dental fixative powders and it has proved particularly useful as an adhesive for stoma appliances. The cross linked Tragacanth (Epichlorhydrin) exhibits superior wicking and swelling action and hence can be used as a potential disintegrant^{4,12,19}.

Gellan gum

Gellan gum is an anionic microbial polysaccharide secreted from *Pseudomonas elodea*. It is produced as a fermentation product by a pure culture of microbe. Gellan gum, also commercially known as Phytigel or Gelrite. It is an anionic high molecular weight, deacetylated extracellular linear polysaccharide comprising glucuronic acid, rhamnose and glucose. This gum has an outstanding flavor release, high gel strength, an excellent stability, process flexibility, high clarity, good film former and thermally reversible gel characteristics. It is also used as a texturizing and suspension hydrocolloid agent. This gum has been considered as a potential carrier for different floating dosage forms by various investigators. Gellan gum is a food additive that acts as a thickening or gelling agent, and can produce gel textures in food products ranging from hard and brittle to fluid. Pharmaceutically aqueous solutions of gellan are used for ophthalmic preparation and for oral drug delivery and also in microspheres. Gellan gum is used in ophthalmic drug delivery, as sustain agent, beads, hydrogels, floating in-situ gelling, controlled release beads, disintegrating agent^{16, 10, 22}.

Honey locust gum

It is known botanically as *Gleditsia triacanthos*, and belongs to the order Leguminosea (suborder Mimoseae). The gum is obtained from the seeds. The seed contains proteins, fats, carbohydrates and fibers. The gum contains 88% D-galacto-D-mannoglycan, 4% pentan, 6% of proteins, 1% cellulose and 1% ash. Plant seed galactomannan, composed of a 1-4 linked β -D-mannan backbone with 1- 6-linked α -D-galactose side groups. This neutral polymer is only slightly soluble in cold water; it requires heat to achieve full hydration, solubilization and maximum viscosity. Pharmaceutically it is used to produce matrix tablet at different concentrations (5% and 10%) by wet granulation method. Theophylline was chosen as a

model drug. The matrix tablets containing hydroxyl ethyl cellulose and hydroxyl propyl methylcellulose as sustaining polymers at the same concentrations were prepared and a commercial sustained release (CSR) tablet containing 200 mg theophylline was examined for honey locust gum performance. No significant difference in in-vitro studies was found between CSR tablet and the matrix tablet containing 10% honey locust gum^{8,19}.

Tamarind Gum

Tamarind Gum, also known as Tamarind Kernel Powder (TKP), is obtained from the endosperm of the seed of the tamarind tree, *Tamarindus indica* (Leguminosae). Gum is extracted from the seeds. Tamarind gum is a polysaccharide composed of glucosyl: xylosyl: galactosyl in the ratio of 3:2:1. Xyloglucan is a major structural polysaccharide in the primary cell walls of higher plants. Xyloglucan has a (1,4)-D-glucan backbone that is partially substituted at the O-6 position of its glucopyranosyl residues with "-D-xylopyranose". It is insoluble in organic solvents and dispersible in hot water to form a highly viscous gel such as a mucilaginous solution with a broad pH tolerance and adhesivity. Tamarind gum is non Newtonian and yield higher viscosities than most starches at equivalent concentrations. This has led to its application as stabilizer, thickener, gelling agent and binder in food and pharmaceutical industries. In addition to these, other important properties of tamarind seed polysaccharide (TSP) have been identified recently. They include non carcinogenicity, mucoadhesivity, biocompatibility, high drug holding capacity and high thermal stability. This has led to its application as excipient in hydrophilic drug delivery system. Pharmaceutically, it is also applicable for Hydrogels, mucoadhesive delivery for ocular purposes, spheroids, nasal drug delivery^{3,4,8}.

Ghatti gum

Gum ghatti or Indian gum ghatti obtained from *Anogeissus latifolia* (Combretaceae). Ghatti gum consists of calcium salt of a complex high molecular weight polysaccharide made up of sugars and uronic acid units. One of the polysaccharide acid, ghattic acid contains mainly arabinose, galactose, mannose, xylose and galacturonic acid. On hydrolysis of ghatti gum, it also affords aldobiouronic acid 6-0-β-Dglucopyranosyl uronic acid and D- galactose which is also found in gum acacia. Pharmaceutically it is used as binder, emulsifier, stabilizer, thickener and suspending agent it gives stable oil in water emulsion and, therefore, used in formulation of oil soluble vitamin preparation. Gum is edible. In India, it is administered as a good tonic to women after childbirth¹⁹.

Xanthan Gum

Xanthan gum is a high molecular weight extracellular polysaccharide produced by pure culture aerobic fermentation of carbohydrate with gram-negative bacterium *Xanthomonas campestris*. The primary structure of this naturally produced cellulose derivative contains a cellulosic backbone (β -D-glucose residues) and a trisaccharide side chain of β -D-mannose- β -D-glucuronic acid- α -D-mannose attached with alternate glucose residues of the main chain. This gum develops a weak structure in water, which creates high viscosity solutions at low concentration. Anionic character of this polymer is due to the presence of both glucuronic acid and pyruvic acid groups in the side chain. This gum is a cream coloured powder that is soluble in hot or cold water with high viscosity even at low concentrations. Xanthan gum is found in a number of drug formulations including cefdinir oral suspension and nitazoxanide tablets. Xanthan gum is used most frequently as a stabilizer in suspensions and emulsions at concentrations below 0.5%, higher concentrations in aqueous media yield viscous solutions that are jelly like in nature. Concentrated xanthan gum solutions resist flow due to excessive hydrogen bonding in the helix structure, but they display shear-thinning rheology under the influence of shear flow. This feature of xanthan gum solutions is critical in food, pharmaceutical, and cosmetic manufacturing processes. Oxycodone hydrochloride extended-release tablets contain TIMERx, which consists of xanthan gum, and locust bean gum for controlled delivery. Rectal delivery of morphine can be controlled using cyclodextrins as an absorption enhancer and xanthan as a swelling hydrogel. This combination produces a sustained plasma level of morphine and increases its rectal bioavailability^{16,17,12}.

Tara Gum

Tara gum is obtained from the endosperm of seed of *Caesalpinia spinosa*, commonly known as Tara (Leguminosae or Fabaceae). Tara gum is a white, nearly odorless powder. The major component of the gum is a galactomannan polymer similar to the main components of guar and locust bean gums, consist of a linear main chain of (1-4)- β -D-mannopyranose units with α -D-galactopyranose units attached by (1-6) linkages. The ratio of mannose to galactose in tara gum is 3:1 and produces highly viscous solutions, even at 1% concentration. Tara gum requires heating to disrupt aggregation and full dissolution, whereas guar gum is soluble in cold water. Pharmaceutically it is used as a controlled release carrier in the formulation of gastro retentive controlled release tablets and emulsions for drugs like metformin hydrochloride, ciprofloxacin hydrochloride nimodipine, nifedipine, carvedilol, and clozapine

has been claimed in patents. Using tara gum in combination increases floating time of the dosage form thus showing good gastro retentive property. Tara gum was also used in formulation of emulsions. Tara gum has been considered as a possible replacement for carob gum in the formulation of kappa carrageenan- galactomannan mixed gels⁸.

Grewia gum

Grewia gum is a polysaccharide obtained by extraction from the inner stem bark of the edible plant *Grewia mollis* (Tiliaceae). The gum is a typically amorphous polysaccharide gum containing glucose, rhamnose, galactose, arabinose and xylose as neutral sugars. The gum slowly hydrates in water, dispersing and swelling to form a highly viscous dispersion exhibiting pseudo plastic flow behavior. Fractions of the gum obtained by centrifugation successively at 4500 rpm for 30 minutes with average molecular weights between 230 and 235 kDa showed improved aqueous solubility that was useful in delivering more solids to the substrate when used as a film coating agent. *Grewia mollis* as a potential pharmaceutical excipient has been on since the last decade and has been investigated for its phytochemical, toxicological and histopathological properties. The study showed that tannins, saponins, flavonoids, glycosides, balsam, phenols, terpenes, steroids were present while alkaloids were absent. The gum has been isolated and reported to contain glucose, galactose, rhamnose, arabinose and xylose as the monosaccharide components. The study further demonstrated that the plant is safe for human consumption with LD 50 of 1500 mg/kg body weight. The extracts showed no structural effects on the liver and heart. Pharmaceutically it is used as film coating and binding agent^{10,11}.

Albizia gum

Albizia gum is obtained from the incised trunk of the tree *Albizia zygia* (Leguminosae) and is shaped like round elongated tears of variable color ranging from yellow to dark brown. It consists of β -1-3-linked D-galactose units with some β 1-6-linked D-galactose units. The genus *Albizia* containing some twenty-six species is a member of the Mimosaceae, a family which also includes the gum-bearing genera *Acacia* and *Prosopis*. Only two species of *Albizia*, *A. zygia* and *A. sassa*, are however, known to produce gum. Albizia gum has been investigated as a possible substitute for gum arabic as a natural emulsifier for food and pharmaceuticals. Albizia gum has use as a binding agent, suspending agent. To study Khaya and albizia gums were evaluated as compression coatings for target drug delivery to the colon using Indomethacin and Paracetamol as model drugs. The core tablets were compression-coated khaya gum & albizia gum respectively and also a mixture of khaya and albizia gum

(1:1). These gums were tried as coating materials in compression-coated tablets, which degraded, by the colonic microflora, thereby releasing the drug^{11,19}.

Khaya gum

Khaya gum is a polysaccharide obtained from the incised trunk of the tree *Khaya grandifoliola* (Meliaceae). It is known to contain highly branched polysaccharides consisting of D galactose, L-rhamnose, D-galacturonic acid and 4-O-methyl-D-glucuronic acid. Khaya gum has been shown to be useful as a binding agent in tablet formulations. Khaya gum is a hydrophilic polymer and has been shown to possess emulsifying properties comparable with acacia gum. The fact that the gum is naturally available, inexpensive and non-toxic has also fostered the interest in developing the gum for pharmaceutical use. Pharmaceutically, it is applicable as suspending agent and binding agent in tablet formulation. Further work has also shown its potential as a directly compressible matrix system in the formulation of controlled release tablets. Khaya gum and albizia gum have potential for drug targeting to the colon^{8,19}.

Hakea gum

Hakea gum a dried exudates from the plant *Hakea gibbosa* (Proteaceae). Gum exudates from this species have been shown to consist of L-arabinose and D-galactose linked as in gums that are acidic arabinogalactans (type A). Molar proportions (%) of sugar constituents Glucuronic acid, Galactose, Arabinose, Mannose, Xylose is 12:43:32:5:8. Gum was investigated as a sustained release and mucoadhesive component in buccal tablets. These results demonstrate that *Hakea gibbosa* not only may be used to sustain the release but also can act as bioadhesive polymer. In this study, time required for 90% of the drug was used as basis for comparison. It was observed that formulation which did not contain hakea gum showed 90% release of the drug in about 14 minutes. While when hakea gum was used in concentration of 32 mg per tablet, it was seen that 90% release of the drug took place in around 165 minutes^{10,11}.

Cordia gum

Cordia gum (Indian cherry) obtained from raw fruits of *Cordia oblique* (Boraginaeae). Cordia gum as a novel sustained release matrix forming material in tablet formulations using diclofenac as model drug. Cordia mucilage can be used as expectorant, is effective in treating lung disease and raw gum can be used in gonorrhea. Gum Cordia can be used for enteric resistant, controlled release agent, tablet binder, emulsifier, in Microparticulate drug delivery. Cordia used as novel polymer-surfactant nanoparticles for ophthalmic delivery of fluconazole using surface methodology. It also used as preparation of transdermal Films^{11,19}.

Moi gum

The gum is obtained from leaves, stems and fruits and is most abundant in the bark of the stem *Lannea coromandelica* (Anacardiaceae). This gum is yellowish white colour in fresh and on drying becomes dark. Gum ducts are present in leaves, stems and fruits and are most abundant in the bark of the stem. The roots contain cluytyl ferulate; heartwood gives lanosterol; bark, dlepi- catechin 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. Moi gum was evaluated as microencapsulating agent and release rate controlling material. Microspheres were prepared by solvent evaporation technique. Moi gum produced microspheres having acceptable size and morphology. Microspheres formulated using moi gum showed sustained release beyond 10 hours in comparison to guar gum but when used in 1 : 1 ratio microspheres showed more sustained release^{8,11,19}.

Acacia gum

Acacia gum, Indian gum or gum Arabica is the dried gummy exudates from the stems and branches of *Acacia Senegal* (Leguminosae) or *Acacia Arabica* (Combretaceae). Synonyms are gum acacia; gummi africanum; gum arabic; gummi arabicum; gummi mimosae; and talha gum. Acacia gum consist of a glycosidal acid of high molecular weight, which has been termed arabic acid, combined with potassium, magnesium and calcium. Structurally, gum arabic is a branched molecule of 1, 3-linked β -D galactopyranosyl units. It consists of monosaccharide sugars such as arabinose, glucuronic acid and rhamnose. Gum arabic or gum acacia is best known for its emulsifying property and its solution viscosity at very high solid concentration. It is used as a general stabilizer in emulsions and used as an osmotic suspending and expanding agent to prepare a monolithic osmotic tablet system, binding agent for tablets and emollient in cosmetics. Its demulcent properties are employed in various cough, diarrhoea and throat preparations. It has widespread use in the food, drinks and other industries. Pharmaceutically, it is more applicable as a matrix microencapsulating agent for the enzyme, endoglucanase, which proofed to give slow release of the encapsulated enzyme and in addition increased its stability^{10,12,19}.

Tragacanth gum

Gum tragacanth is the dried gummy exudation obtained from *Astragalus gummifer* (Leguminosae). Gum tragacanth is a branched, heterogeneous, and anionic carbohydrate which consists of a water-soluble fraction known as tragacanthin (8-10%) and a water

swellable fraction known as bassorin (60-70%). Bassorin and tragacanthin composition differ particularly in terms of their uronic acid and methoxyl content; it has been suggested that bassorin is a complex structure of polymethoxylated acids and on demethoxylation, probably yields tragacanthin. It contains about 15% of methoxy group which swell in water; this constituent of gum is responsible for its high viscosity. Pharmaceutically, it is applicable as sustained release agent. It is used as emulsifying and Suspending agent, demulcent, emollient in cosmetics and stabilizer, it has been used as diluents in tablet formulations^{10,19}.

Okra gum

Okra gum, obtained from the fruits of *Hibiscus esculentus* (Malvaceae), is a polysaccharide consisting of D-galactose, L-rhamnose and L-galacturonic acid with some fractions of glucose, mannose, arabinose and xylose. Okra gum is used as a binder. Okra gum is a useful hydrophilic matrixing agent in sustained drug delivery devices. Okra has been used as food and it has been evaluated as a binder in paracetamol tablet formulation, control release, film coating, bio-adhesive and suspending agent. Okra gum maybe useful as hydrophilic matrixing agent in sustained drug delivery devices. Polymer for the development of a gastric floating dosage form. Okra polysaccharide is also used as a microbially triggered material for Colon targeted tablet formulation and also as the carrier^{8,10,19}.

Bhara gum

Bhara gum is a yellowish natural, extracted from the bark of *Terminalia bellerica* (Combretaceae). Main chemical constituents are tannins which mainly include s- sitosterol, gallic acid, ellagic acid, ethyl gallate, galloyl glucose and chebulaginic acid. Pharmaceutically, it is applicable in a new sustained release microencapsulated drug delivery system. The microcapsules were formulated by ionic gelation technique using famotidine as the model drug. The effect of different drug: bhara gum ratio drug release profile was examined and compared with guar gum. Microcapsules employing bhara gum exhibited slow release of famotidine over 10 hour. It has been mainly used as a demulcent, purgative and as an emulgent in cosmetic industries^{8,11,19}.

Neem gum

Neem gum is obtained from the trees of *Azadirachta indica* (Meliaceae). Neem gum contains mannose, glucosamine, arabinose, galactose, fucose, xylose and glucose. Pharmaceutically it used as binding agent in sustained release matrix tablets of Nimesulide using the fruit mucilage of *Azadirachta indica* was studied^{11,19}.

Gum copal

Gum copal is a natural resinous material of plant *Bursera bipinnata* (Burseraceae). Copal, a resinous material, which is obtained from the plants of araucariaceae and caesalpinaceae, a subfamily of leguminoaceae. Copal resin contains agathic acid, a diterpenoid and related loblane compounds along with cis-communic acid, trans-communic acid, polycommunic acid, sandaracopimaric acid, agathalic acid, monomethyl ester of agathalic acid, agatholic acid and acetoxymethyl agatholic acid. Copal resin obtained from leguminoaceae family which contains copalic acid, pimaric acid, isopimaric acid, dehydroabietic acid, dehydroabietic acid and abietic acid. Medicinally, Copal is used in the treatment of headache, fever, burns and stomach ache. In dentistry, it is used as binding media in dental products and in treatment of micro leakage in teeth. Pharmaceutically it is used as matrix-forming material and coating material for sustained release and colon-targeted drug delivery. Copal resin was investigated as a film forming agent, it produces glossy films with good weather protection properties. It has excellent binding properties. It has been mainly used as an emulsifier and stabilizer for the production of colour, paints, printing inks, aromatic emulsions and meat preservatives^{8,11,19,33}.

Gum dammar

Gum dammar is a natural gum of plant *Shorea Wiesneri* (Dipterocarpaceae). Most is produced by tapping trees; however some is collected in fossilized form from the ground. The gum varies in colour from clear to pale yellow, while the fossilized form is grey-brown. It contains about 40% alpha-resin (resin that dissolves in alcohol), 22% beta resin, 23% dammarol acid and 2.5% water. It has been mainly used as an emulsifier and stabilizer for the production of colour, paints, inks and aromatic emulsions in food and cosmetic industries. It has been used for water-resistant coating and in pharmaceutical and dental industries for its strong binding properties. Gum dammar was investigated as a novel microencapsulating material for sustained drug delivery^{8,11,19,33}.

Hupu gum (gum kondagogu)

Hupu gum is a naturally occurring exudate from the tree *Cochlospermum gossypium*. It is composed of major neutral sugars like arabinose, galactose, rhamnose, mannose, α -D glucose, and sugar acids like D-glucouronic acid, and D-galactouronic acid. Hupu gum is also composed of higher uronic acid content, protein, tannin and soluble fibers. Gum is sweet, cooling and useful in diarrhoea, dysentery, cough, pharyngitis, and also used as a pharmaceutical aid. It used as substitute for gum tragacanth. Pharmaceutically it is suitable

polymer for sustained release gastric floating system. It is a good emulsifying agent even at low concentrations and it shows mucoadhesive properties^{8,19}.

Beal fruit gum

Beal fruit gum is obtained from fruits of *Aegle marmelos* (Rutaceae). The pulp contains carbohydrates, proteins, vitamin C, vitamin A, angelenine, marmeline, dictamine, O-methylfordinol and isopentyl half ordinol. The neutral oligosaccharides were characterized as 3-0-beta-D-galactopyranosyl-L-arabinose, 5-0-beta-Dgalactopyranosyl-L-arabinose, and 3-0-beta-D-galactopyranosyl-D-galactose, and the acidic oligosaccharides. *Aegle marmelos* gum is used as mucoadhesive in sustained release matrix tablet¹⁹.

***Grevillea robusta* gum**

This gum under study, newly explored pharmaceutically by the plant of *Grevillea robusta* belonging to family Proteaceae, is being explored in extended release formulation as a binder. *Grevillea robusta* tree produces a gum exudate at the point of injury. The gum also exudes naturally. The gum is yellowish brown when fresh and blackens upon ageing on the tree. Sometimes tears are bright red probably due to the presence of tannins or other impurities. *Grevillea robusta* gum readily dissolves in water & solution is highly viscous with a pH of 6.5. It is insoluble in either hot/cold ethanol or benzene. *Grevillea robusta* gum and resin by virtue of their solubility, viscosity, and relatively high resistance to hydrolysis, may have industrial applications. The grevillea exudates were found to be much more resistant to acid hydrolysis than those of the acacia genus. Chemical constituents of the gum can be obtained by partial acid hydrolysis of *Grevillea robusta* gum, which causes removal of most of the L-arabinose residues (44% of the total carbohydrate), yields a polysaccharide containing the galactose, arabinose, mannose and uronic acid in the molar ratios 3:1:1:2. The gum of *Grevillea robusta* is natural calcium and magnesium salt of a complex polysaccharide acid composed of D-glucuronic acid attached to D-galactose and L-arabinose. *Grevillea robusta* was found promising candidate to be used as pharmaceutical excipient¹⁹.

***Moringa oleifera* gum**

A natural gum obtained from plant *Moringa oleifera* (Moringaceae). Gum was extracted by using water as solvent and precipitated using acetone as non-solvent. It is a polyuronide constituting of arabinose, galactose and glucuronic acid in the preparation of 10:7:2, rhamnose present in traces. In study potentials of moringa olifera gum was used as gelling agent, suspending agent, binder, release retardant in tablet formulations, and the effect of calcium sulpha dehydrate, lactose diluents on release of propranolol hydrochloride. Another

study moringa gum used as a disintegrant. In cosmetics, *Moringa oleifera* tree that purify hair and skin and offer protection against the effects of pollution. Moringa seed oil, known as Behen oil is widely used as a carrier oil in cosmetic preparations. Moringa oil is light and spreads easily on the skin. It is good oil for use in massage and aromatherapy applications. It can be used in body and hair care as a moisturizer and skin conditioner. Other uses include soap making and for use in cosmetic preparations such as lip balm and creams. *Moringa oleifera* butter, a semisolid fraction of Moringa oil, is used in baby products to contribute a free radical resistant emollient with exceptionally long lasting skin soften^{10,11,19}.

***Delonix regia* gum**

Delonix regia gum is a natural polysaccharide was isolated from the seeds of the plant, *Delonix regia* (family: leguminosae & sub family: Fabaceae). In India, it is referred to as Gulmohar. *Delonix regia* seed gum used as a binder, its use in low concentration will improve the balance between the binding and disintegration properties of tablets, while its use at high concentration could serve desire for a modified/sustained release tablet formulation¹⁹.

***Mucuna* gum**

Mucuna gum obtained from *Mucuna flagillepes* (Papillionaceae). Mucuna composed of mainly D-galactose along with D-mannose and D-glucose. An investigation into the suitability of microspheres of glibenclamide with mucuna gum for oral delivery was studied, they shows good in vitro properties. Mucuna gum is good suspending agent, stabilising agent in dosage formulations such as suspensions and emulsions, a good binder in tablets and a good candidate for bioadhesive drug delivery¹⁹.

***Leucaena leucocephata* gum**

Leucaena gum obtained from *Leucaena leucocephata* (Fabaceae). *Leucaena leucocephata* leaves and seeds contain lipids, crude protein and carbohydrates. The seeds contain tannin and oxalic acid. The leaves and seeds also contain a toxic and non-protein substance known as mimosine. A seed contains 25 percent gum and are highly viscous solutions at low solute concentrations. The seeds of leucocephata have great medicinal properties and are used to control stomachache, as contraception and abortifacient. Seed oil shows antimicrobial activity. Sulfated glycosylated form of polysaccharides from the seeds was reported to possess significant cancer chemo-preventive and anti-proliferative activities. The extracts of the seeds has reported as anthelmintic, antidiabetic and has a broad spectrum antibacterial activity. Seed gum used as emulsifying agent, suspending agent, binder in tablets, disintegrating agent in tablets¹⁹.

Balangu gum

Balangu gum obtained from *Lallemantia royleana* (Labiateae). Balangu seed gum (BSG) contains 61.74% carbohydrates, 0.87% proteins, 29.66% crude fiber and 8.33% ash. Because of high mucilage content, the seeds adsorb water quickly by hydration and produce a sticky, turbid and tasteless liquid, which can be used as a new source of food hydrocolloid in food formulations¹⁹.

***Mimosa pudica* mucilage**

Gum is obtained from seeds of *Mimosa pudica* (family Mimosaceae), commonly known as sensitive plant. Seeds of *Mimosa pudica* yield mucilage, which is composed of D-xylose and D-glucuronic acid. Mimosa seed mucilage hydrates and swells rapidly on coming in contact with water. Earlier the seed mucilage was evaluated for binding and disintegrating agent. It is used in preparing sustained release matrix tablets of Diclofenac sodium. In this study different batches of tablets were formulated and their drug releases were checked. It was observed that as the proportion of the *Mimosa pudica* seed mucilage increases, there is a decrease in release of drug, the mechanism of release being diffusion for tablets containing higher proportion of mucilage, and a combination of matrix erosion and diffusion for tablets containing smaller proportion of mucilage. Studies showed that as the proportion of the mucilage increased, there was a corresponding increase in increase in percent swelling and decrease in percent erosion of the tablets^{4,8,11}.

Hibiscus mucilage

The mucilage is extracted from the fresh leaves of *Hibiscus rosa-sinensis* (Malvaceae). *Hibiscus rosa-sinensis*, commonly known as China rose is a popular landscape shrub. The plant contains cyclopropanoids, methyl sterulate, methyl-2-hydroxysterulate, 2-hydroxysterulate malvate, and roasterol. Mucilage of *Hibiscus rosa-sinensis* contains L-rhamnose, D-galactose, D-galactouronic acid, and D-glucuronic acid. The leaves are used in traditional medicines as emollients and aperients to treat burning sensations, skin disease, and constipation. *Hibiscus rosa-sinensis* leaves mucilage can be used as an effective matrix forming polymer for preparing sustained release matrix tablets. It is subjected to toxicity studies for its safety and preformulation studies for its suitability as a disintegrating agent.

In a study the use of its mucilage for the development of sustained release tablet has been reported. Matrix tablet containing dried mucilage and diclofenac sodium (DS) was prepared through direct compression techniques. It was found that mucilage can be used as release-retarding agent for 12 h, when the drug-mucilage ratio was 1:1.5^{4,8,19}.

Aloe Mucilage

Aloe mucilage is obtained from the leaves of *Aloe barbadensis* Miller. Aloe vera leaves and the exudates arising from the cells adjacent to the vascular bundles. The bitter yellow exudates contain 1, 8 dihydroxy anthraquinone derivatives and their glycosides. Many investigators have identified partially acetylated mannan (acemannan) as the primary polysaccharide of the gel, while others found pectic substance as the primary polysaccharide. Other polysaccharides such as arabinan, arabino rhamnogalactan, galactan, galactogalacturan, glucogalactomannan, galacto glucoarabinomannan and glucuronic acid containing polysaccharides have been isolated from the *Aloe vera* inner leaf gel part. In the pharmaceutical industry, it has been used for the manufacture of topical products such as ointments and gel preparations, as well as in the production of tablets and capsules. The mucilage produced direct compressible matrix tablets that showed good swelling and sustained release of the model drug. The dried *A. vera* gel polysaccharide component therefore showed excellent potential to be used as an excipient in the formulation of direct compressible sustained- release matrix type tablets^{20,4,812,19}.

Fenugreek mucilage

Mucilage is obtained from seeds of *Trigonella Foenum-graceum*, commonly known as Fenugreek, is an herbaceous plant (family: Leguminosae). Fenugreek seeds contain a high percentage of mucilage (a natural gummy substance present in the coatings of many seeds). Although it does not dissolve in water, mucilage forms a viscous tacky mass when exposed to fluids. Like other mucilage- containing substances, fenugreek seeds swell up and become slick when they are exposed to fluids. Fenugreek mucilage at a concentration of about 66% w/w was found to be a better release retardant⁴.

Cassia tora mucilage

Cassia tora mucilage derived from the seeds of *Cassia tora* (Caesalpiniaceae). It is locally known as charota. Cassia is used as tonic, carminative and stimulant. Cassia contains 1-2 % volatile cassia oil which is mainly responsible for the spicy aroma and taste. The primary chemical constituents of Cassia include cinnamaldehyde, gum, tannins, mannitol, coumarins and essential oils (aldehydes, eugenol, and pinene); it also contains sugars, resins and mucilage among other constituents. Seed mucilage of *Cassia tora* was evaluated as suspending agent and binding agent^{11,19}.

Phoenix mucilage

Phoenix mucilage is obtained from the dried fruit of *Phoenix dactylifera* (family Palmaceae). It is a brown colour date fruit composed of amino acids and proteins, carbohydrates, fatty acids, salts and minerals, and dietary fiber. Carbohydrates make up to 44 - 88% of the fruit which include mainly reducing sugars such as fructose, sucrose, mannose, glucose and maltose in addition to small amounts of polysaccharides such as pectin (0.5 - 3.9%), starch and cellulose. The protein content is approximately 2.3 - 5.6% with 23 amino acids which include alanine, aspartic acid, serine, glutamic acid, threonine, proline and glycine. Binding properties of date palm mucilage was successfully evaluated. The tablets manufactured using phoenix mucilage were found to be less friable than tablets manufactured using acacia and tragacanth. As the concentration of the gum increased the binding ability improved, producing good uniformity in weight and hardness of the tablets^{11,19}.

Psyllium husk (Isapgulla)

Psyllium mucilage is obtained from the seed coat of *Plantago ovata* by milling the outer layer of the seeds. It contains a high proportion of hemicelluloses, composed of a xylan backbone linked with arabinose, rhamnose, and galactouronic acid units (arabinoxylans). The gel forming fraction of the alkali extractable polysaccharides is composed of arabinose, xylose and traces of other sugars. They are soluble in water, expanding and becoming mucilaginous when wet. It is white fibrous material, hydrophilic in nature and forms a clear colorless mucilaginous gel by absorbing water. Psyllium is widely used as a fiber supplement for the treatment of constipation. It also used for the treatment of diarrhea, crohns disease (inflammatory bowel ulcerative colitis disease), colon cancer, obesity in children and adolescents high cholesterol and diabetes. Psyllium seed husk has been successfully evaluated as binder, disintegrant, release retardant, hydrogels, gastro retentive agent, microparticals. It form hydrogels through radiation-induced cross-linking for controlled release of 5-fluorouracil as a model drug. Psyllium husk was used in combination with other excipients such as hydroxypropyl methylcellulose to prepare a novel sustained release, swellable and bioadhesives gastro retentive drug delivery systems for ofloxacin^{8,10,22}.

Rosin

Rosin, also called colophony or Greek pitch, is a natural non-volatile resinous mass obtained from *Pinus palustris*. Physico-chemical characteristics and ease of availability of rosin provide a platform to use it as a polymer for different drug delivery systems. It primarily contains resin tricyclic diterpene carboxylic acids (abietic and pimaric) and a few amounts of

nonacidic components. Esters of rosin are reported to have good film forming properties and can be used for enteric coating and delayed release of drugs. Rosin and rosin-based polymers have drug delivery applications achieving sustained/controlled release profiles. Rosin a natural biomass, is used as a matrix forming polymer for tablet formulations. Rosin has been used to prepared spherical microcapsules. Rosin based polymer has been used as film coating materials; coated pellets were prepared using diclofenac sodium as a model drug and sustained release of the drug was achieved. Rosin polymer has used as the transdermal drug delivery system. Rosin combination with polyvinyl pyrrolidone and dibutyl phthalate (30 % w/w) produces smooth film with improved elongation and tensile strength. Polymerized rosin films containing hydrophobic plasticizers showed excellent potential as coating materials for the preparation of sustained release dosage forms^{5,1,10,12}.

Zein

Zein an alcohol-soluble protein contained in the endosperm tissue of *Zeamais*, occurs as a by-product of corn processing. Zein has been employed as an edible coating for foods and pharmaceuticals for decades. Zein is an inexpensive and most effective substitute for the fast disintegrating synthetic and semi synthetic film coatings currently used for the formulation of substrates that allow extrusion coating¹.

Collagen

Collagen is the most widely found natural protein in mammals and is the major provider of strength to tissue. It is fabricated from glycine-proline-(hydroxy) proline repeats to form a triple helix molecular structure. So far, nineteen types of collagen molecules have been isolated, characterized, and reported in both medical and pharmaceutical applications. Collagen has been widely used in pharmaceutical applications due to the fulfillment of many requirements of a drug delivery system such as good biocompatibility, low antigenicity, and degradability upon implantation. Furthermore, collagen gels are one of the first natural polymers to be used as a promising matrix for drug delivery and tissue engineering. Biodegradable collagen-based systems have served as 3D scaffold for cell culture, survival of transfected fibroblasts, and gene therapy. In this case, collagen scaffolds were fabricated through introducing chemical cross-linking agents (i.e., glutaraldehyde, formaldehyde, carbodimide) or by physical treatments (i.e., UV irradiation, freeze-drying, and heating)^{1,6,13}.

Gelatin

Gelatin is a common natural polymer or protein which is obtained by partial hydrolysis of collagen derived from skin, white connective tissue and bones of animals. The process

coverts insoluble collagen into soluble gelatin, the solution of which is then purified and concentrated to a solid form. It is soluble in a hot mixture of glycerol and water and in 6N acetic acid, whereas it is practically insoluble in alcohol, chloroform fixed oils, volatile oils and ether. It has been used in pharmaceutical and medical applications due to its outstanding properties such as biodegradability, biocompatibility, and low antigenicity. Gelatin is one of the natural polymers used as support material for gene delivery, cell culture, and more recently tissue engineering. It has been reported that it is possible to incorporate liposome-loaded bioactive compounds into PEG-gelatin gel which function as porous scaffold gelatin-based temporary depots with controlled drug release over prolonged periods of time. Gelatin is used in the preparation of paste, pastilles, suppositories, coating of tablets and manufacturing of hard and soft capsule shells. Gelatin typically constitutes the shells of pharmaceutical capsules in order to make them easier to swallow. Hypromellose is a vegetarian-acceptable alternative to gelatin, but is more expensive to produce. It is also used for the microencapsulation of drugs and other industrial materials. Specially purified and pyrogen free gelatin are available for intravenous injection and a grade with big bloom strength is used for making gelatin capsules and for bacteriological culture media^{6,13,23}.

Albumin

Serum albumin was conjugated to poly-(ethylene glycol) (PEG) and cross-linked to form mono- poly ethylene glycocylated albumin hydrogels. These hydrogels were used as a basis for drug carrying tissue engineering scaffold materials, based on the natural affinity of various drugs and compounds for the tethered albumin in the polymer network¹³.

Pectin

Pectins are non-starch, linear polysaccharides present in the walls that surround growing and dividing plant cells. They are predominantly linear polymers of primarily α -(1,4)-linked D-galacturonic acid residues interrupted by 1,2-linked L-rhamnose residues. It is soluble in water, insoluble in ethanol (95%) and other organic solvents. The main sources of commercial pectin are citrus peel (lemon, lime and grapefruit), apple pomace and sugar beet pulps. The main component of pectin is d-galacturonic acid, which is in part esterified via methylation. Depending on its methoxyl content, pectin is classified as high methoxyl (HM, 50% or more esterification) and low methoxyl (LM, less than 50% esterification). Pectins can form a gel in an aqueous solution if certain conditions are existed. For instance, high methoxyl pectins require a minimum of 65% soluble solids and low pH (<3.5) to form a gel, whereas low methoxyl pectins require calcium and may form a gel at a much lower solid

content, that is, 20%. Pectin used as a gelling agent, thickeners, texturisers, emulsifiers and stabilisers in food, pharmaceutical, and many other industries. Pectin gel beads have been shown to be an effective medium for controlling the release of a drug within the gastrointestinal tract. Pectin has been investigated as excipients in many different types of dosage forms such as film coating of colon-specific drug delivery systems when mixed with ethyl cellulose, microparticulate delivery systems for ophthalmic preparations and matrix type transdermal patches. Pectin can be found in amlexanox oral paste^{1,16,12}.

Alginates

Alginates are natural polysaccharide polymers isolated from the brown sea weed (Phaeophyceae) and marine algae such as *Laminaria hyperborea*, *Ascophyllum nodosum* and *Macrocystis pyrifera*. They are hydrophilic, non toxic, biodegradable, linear polymer consisting of 1-4' linked- β -D-mannuronic acid and β -L-glucuronic acid residues arranged as blocks of either type of unit or as a random sharing of each type. It is practically insoluble in ethanol (95%), ether, chloroform and slowly soluble in water, forming viscous colloidal solution. Alginic acid can be converted into its salts, of which sodium alginate is the major form currently used. Alginate and their derivatives are widely used by many pharmaceutical scientists for drug delivery and tissue engineering applications. Various applications in drug delivery are in matrix type alginate gel beads, in liposomes, in modulating gastrointestinal transit time, for local applications and to deliver the bio molecules in tissue engineering applications. Alginates have been used and investigated as stabilizers in emulsions, suspending agents, tablet binders and tablet disintegrants. The gelling properties of alginates' guluronic residues with polyvalent ions such as calcium or aluminium allow cross-linking with subsequent formation of gels that can be employed to prepare matrices, films, beads, pellets, microparticles and nanoparticles. Alginate-based systems have been successfully used as a matrix for the encapsulation of stem cells and for controlled release of proteins, genes, and drugs. In addition, alginate-based systems have been used as depots for bioactive agent-loaded liposomes, for slow drug release. Alginates have proven to be effective for the symptoms of malignant wounds. Alginates are ideal for bleeding wounds as they have haemostatic properties^{1,16,12}.

Agar

Agar is also known as Japanese Isinglass, Chinese- Isinglass or Vegetable Gelatin. Agar is the dried gelatinous substance obtained from *Gelidium amansii* (Gelidaceae) and several other species of red algae like, *grailaria* (Gracilariaceae) and *Pterocladia* (Gelidaceae). Agar

consists of a mixture of agarose and Agaropectin. Agarose (a neutral gelling fraction) is responsible for gel strength of agar and is composed of (+) – galactose and 3, 6-anhydro-(–)-galactose moieties. It contains about 3.5% cellulose and 6% of nitrogen containing substance. Agaropectin is (a sulphated non-gelling fraction) responsible for the viscosity of agar solutions, and comprises of sulphonated polysaccharide in which both uronic acid and galactose moieties are partially esterified with sulphuric acid. In short, it is believed to be a complex range of polysaccharide chains having alternating α – (1,3) and β –(1,4) linkages and varying total charge content. Agar gives gels without flavour and does not need the additions of cations with strong flavours (potassium or calcium) it can be used without problems to gel food products with soft flavours. Its gel has an excellent reversibility allowing it to be repeatedly gelled and melted without losing any of the original properties. Pharmaceutically it is used as Suspending agent, emulsifying agent, gelling agent in suppositories, surgical lubricant, tablet disintegrates, medium for bacterial culture, laxative. It also used in preparation of jellies^{10, 12}.

Chitosan

Chitosan is a natural polycationic copolymer consisting of glucosamine and N-acetyl glucosamine units. It is mostly obtained by deacetylation of chitin derived from the exoskeleton of crustaceans like shrimp, crab, lobster and other shellfish. They are highly stable, safe, biocompatible, biodegradable, non-toxic, and hydrophilic and gel forming in nature. These properties make chitosan a good candidate for the development of various conventional and novel gastrointestinal dosage forms. The most important property of chitosan with regards to drug delivery is its positive charge under acidic conditions. Chitosan is a novel drug carrier material and it improves the dissolution rate of controlled release matrix tablets. Chitosan is a cationic polymer and has been investigated as an excipient in controlled delivery formulations and mucoadhesive dosage forms because of its gelling and adhesive properties. The bitter taste of natural extracts such as caffeine has been masked using chitosan. Chitosan can potentially be used as a drug carrier, a tablet excipient, delivery platform for parenteral formulations, disintegrant, and tablet coating. Gels based on chitosan and ovalbumin protein have been suggested for pharmaceutical and cosmetic use. Chitosan can also be mixed with nonionic surfactants such as sorbitan esters to make emulsion like solutions or creams. It is also used in preparation of microspheres, as carrier for protein as nanoparticles and colon specific drug delivery^{1,16,6,12}.

Carrageenans

Carrageenan is sulphated polysaccharide extract of the seaweed called carrageen; or Irish moss, the red algae obtained from *Chondrus Crispus* (Rhodophyceae). Carrageenans obtained by extraction with water or aqueous alkali and recovered by alcoholic precipitation, drum drying or freezing. Carrageenan is a sulfated linear polysaccharide of galactose and anhydrogalactose. If carrageenan is used in a solution containing proteins, the solution becomes gel or viscous due to a complex formation between carrageenan and charged amino acids of the protein. Carrageenan extracted from seaweed is not assimilated by the human body and provides only bulk but no nutrition. There are three basic types of carrageenan - kappa (κ), iota (ι) and lambda (λ) respectively. The λ -type carrageenan results in viscous solutions but is non-gelling, while the κ - type carrageenan forms a brittle gel. The ι -type carrageenan produces elastic gels. Both kappa and iota carrageenan can be used for controlled delivery application as they display gelling properties under certain circumstances. Donepezil hydrochloride orally disintegrating tablets and cefpodoxime proxetil oral suspension contain carrageenan. In capillary electrophoresis, a sulfated polysaccharide such as carrageenan can be used to separate the enantiomers of weakly basic pharmaceutical compounds. They are widely used in the food and other industries as thickening and stabilizing agents. Carrageenan is a good substitute for gelatin in hard and soft gel capsules. It forms stable emulsions with insoluble drug preparations, enhances homogeneity in colloidal suspension, film forming agent in crystal clear soft capsules, acts as gelling agent in antacid gels. Tooth paste, creams lotions and other cosmetic products are also prepared by using carrageenan^{1,16}.

Inulin

It is a polysaccharide from the bulbs of Dehlia, *Inula helenium* (Compositae), roots of Dandelion, *Taraxacum officinale* (Compositae), Burdock root, *Saussurea lappa* (Compositae) or chicory roots, *Cichonium intybus* (Compositae). Inulin consists of a mixture of oligomers and polymers that belong to the group of gluco-fructans and occur in plants such as garlic, onion, artichoke and chicory. The inulin molecules contain from two to more than 60 fructose molecules linked by β -2,1- bonds. Inulin is resistant to digestion in the upper gastrointestinal tract, but is degraded by colonic microflora. Inulin with a high degree of polymerization was used to prepare biodegradable colon-specific films in combination with Eudragit® RS that could withstand break down by the gastric and intestinal fluids. It was shown in another study where different Eudragits® were formulated into films with inulin that when a combination of Eudragit® RS and Eudragit® RL was mixed with inulin it exhibited better swelling and

permeation properties in colonic medium rather than other gastrointestinal media. Methylated inulin hydrogels were developed as colon-specific drug delivery systems and investigated for water uptake and swelling. The hydrogels exhibited a relatively high rate of water uptake and anomalous dynamic swelling behaviour. Inulin derivatised with methacrylic anhydride and succinic anhydride produced a pH sensitive hydrogel by UV irradiation that exhibited a reduced swelling and low chemical degradation in acidic medium, but it had a good swelling and degradation in simulated intestinal fluid in the presence of its specific enzyme, inulinase^{1,10,12}.

Hyaluronic acid

Hyaluronic acid (also called as Hyaluronan and Hyaluronate (HA) and Sodium hyaluronate (SA) is sodium salt form of hyaluronic acid) is a biodegradable, biocompatible, and viscoelastic linear polysaccharide. It is a naturally occurring biopolymer, which serves important biological functions in bacteria and higher animals including humans. Hyaluronic acid consists of *N*-acetyl-d-glucosamine and betagluconic acid and has been used as fluid supplement in arthritis, in eye surgery, and to facilitate healing of surgical wounds. Naturally occurring hyaluronic acid may be found in the tissue of higher animals, particularly as intercellular space filler. It is found in greatest concentrations in the vitreous humor of the eye and in the synovial fluid of articular joints. Hyaluronic acid solutions are characteristically viscoelastic and pseudoplastic. The viscoelastic property of hyaluronic acid solutions that is important in its use as a biomaterial is controlled by the concentration and molecular weight of the hyaluronic acid chains. As a microcapsule, it can be used for targeted drug delivery. Solaraze gel for the topical treatment of actinic keratoses is composed of 3% sodium diclofenac in 2.5% HA gels. Hyaluronan is biocompatible and non-immunogenic and has been suggested as a drug carrier for ophthalmic, nasal, pulmonary, parenteral, and dermal routes. Sodium hyaluronate topical (Septrafilm), which is used to reduce scar tissue as a result of abdominal or pelvic surgery, is a bioresorbable membrane containing sodium hyaluronate^{13,18}.

Starch

Starch is a natural polysaccharide polymeric material widely exists in fruit, root, pedicle, and leaf of plants. Starch is the main carbohydrate in plants and acts as a reserve food supply for periods of growth, dormancy and germination. It occurs in the form of granules (starch grains), the shape and size of which are characteristics of the species. It is comprised of two polymers, namely amylose (a non-branching helical polymer consisting of α -1, 4 linked D

glucose monomers) and amylopectin (a highly branched polymer consisting of both α -1, 4 and α -1, 6 linked D-glucose monomers. Amylose is crystalline in nature and it is soluble in boiling water but amylopectin is insoluble in boiling water. Both fractions are readily hydrolyzed at the acetal link by enzymes. A number of starches are recognized for pharmaceutical use. These include maize (*Zea mays*), rice (*Oryza sativa*), wheat (*Triticum aestivum*), and potato (*Solanum tuberosum*). This polymeric material has enormous applications in the fabrication of different floating dosage forms. Being a biodegradable polymer with well-defined chemical properties, it has a huge potential as a versatile renewable resource for various material applications in food and nonfood areas. The Starch is classified into raw starch and physical-modified starch or chemical-modified starch. Modified starch was tested for general applicability of a new pregelatinized starch product in directly compressible controlled-release matrix systems. Amphoteric starches have been used as wet-end and size-press paper making additives by aid in retention, drainage and strength properties. They can also be used as ceiling tile additives drilling fluid additives, viscosity modifiers and agents in ore recovery operations^{1,6,12,13}.

Cellulose

Cellulose is the most abundant naturally occurring biopolymer. Various natural fibers such as cotton and higher plants have cellulose as their main constituent. It consists of long chains of anhydro-D-glucopyranose units (AGU) with each cellulose molecule having three hydroxyl groups per AGU, with the exception of the terminal ends. Cellulose is insoluble in water and most common solvents; the poor solubility is attributed primarily to the strong intra molecular and intermolecular hydrogen bonding between the individual chains. In spite of its poor solubility characteristics, cellulose is used in a wide range of applications including composites, netting, upholstery, coatings, packing, paper, etc. Controlled release applications for cellulose derivatives include the formulation of membrane controlled drug release systems or monolithic matrix systems. Film coating techniques for the manufacture of membrane controlled release systems include enteric coated dosage forms and the use of semipermeable membranes in osmotic pump delivery systems. Cellulose used in pharmaceutical applications such as filler in tablets, it is microcrystalline cellulose that represents a novel and more useful cellulose powder. Microcrystalline cellulose is mainly used in the pharmaceutical industry as a diluent/binder in tablets for both the granulation and direct compression processes. Microcrystalline cellulose is depolymerised cellulose prepared by treating cellulose with hydrochloric acid to produce free non-fibrous particles^{7,1,6,12,13}.

Lectins

Lectins are proteins which have the ability to reversibly bind with specific sugar / carbohydrate residues and are found in both animal and plant kingdom in addition to various microorganisms. Lectins extracted from legumes have been widely explored for targeted delivery systems. The various lectins which have shown specific binding to the mucosa include lectins extracted from *Ulex europaeus*, soybean, peanut and *Lens culinaris*. The use of wheat germ agglutinin has been on the rise due to its least immunogenic reactions, amongst available lectins, in addition to its capability to bind to the intestinal and alveolar epithelium and hence could be used to design oral and aerosol delivery systems¹.

Glucomannan

Glucomannan is referred to as konjac Glucomannan, which is extracted from the tubers of *Amorphophallus konjac* and is a very promising polysaccharide for incorporation into drug delivery systems. Glucomannan is a hydrocolloidal polysaccharide of the mannan family consisting of β -1,4 linked D-mannose and D-glucose monomers (with acetyl side branches on some of the backbone units), but the mannose: glucose ratio may differ depending on the source. The acetyl groups contribute to its solubility and swelling capacity and assist in making it a soluble natural polysaccharide with the highest viscosity and water-holding capacity. It is very abundant in Nature and this polysaccharide is specifically derived from softwoods, roots, tubers and plant bulbs. Since konjac Glucomannan by itself forms very weak gels, it has been investigated as an effective exponent in controlled release drug delivery devices in combination with other polymers or by modifying its chemical structure. It was shown that konjac Glucomannan gel systems were able to maintain the integrity and control the release of theophylline and diltiazem for 8 hours. Matrix tablets prepared from konjac glucomannan alone showed the ability to sustain the release of cimetidine in the physiological environments of the stomach and small intestines but the presence of β -mannanase (colon) accelerated the drug release substantially^{8,11,12}.

Ocimum basilicum

Ocimum basilicum usually named common basil or sweet basil is an annual plant, with extraordinary medicinal properties and contains several antioxidant compounds. In traditional medicine, *Ocimum basilicum* has been used as an antiseptic, preservative, sedative, digestive regulator and diuretic. It also has been recommended for the treatment of headaches, coughs, infections of upper respiratory tract, kidney mal function and to eliminate toxins. Pharmacologically it is having anti-hyperglycaemic and hypolipidemic effects, anti-giardial,

antioxidant, antimicrobial and cardiac stimulant activity. Pharmaceutically it is used as granulating and binding agent (study elucidate and quantify the compressibility and compatibility of herbal granules prepared by using hydrogel isolated from whole seeds of *Ocimum basilicum* as a novel binder) & Disintegrating agent (ibuprofen dispersible tablets using plantago ovata mucilage powder, *Ocimum basilicum* mucilage powder, plantago ovata husk powder and *Ocimum basilicum* seed powder as disintegrants were prepared and disintegrating property was studied)³³.

Dextran

Dextran is a natural linear polymer of glucose linked by a 1–6 linked glucoyranside, and some branching of 1, 3 linked side-chains. Dextran is synthesized from sucrose by certain lactic-acid bacteria, the best-known being *Leuconostoc mesenteroides* and *Streptococcus mutans*. In pharmaceutics, dextran has been used as model of drug delivery due to its unique characteristics that differentiate it from other types of polysaccharide. This includes water solubility, biocompatibility, and biodegradability. In recent studies, dextran has been regarded as a potential polysaccharide polymer that can sustain the delivery of proteins, vaccines, and drugs. Interleukin-2, which is a highly effective anticancer drug, is among the success obtained in delivering a combination of drug-loaded liposome and injectable dextran hydrogel. Injectable and degradable dextran-based systems for drug delivery were generated by a cross-linking reaction with photo-polymerization or free radical polymerization. A study by Stenekes and coworkers demonstrated the successive encapsulation of a drug-loaded liposome depot into a dextran polymer-based material^{10,13}.

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