INTERNATIONAL JOURNAL IN PHARMACEUTICAL SCIENCES

Journal Homepage: https://www.ijpsjournal.com

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Review Article

Natural Polymers as Excipient in Formulation of Novel Drug Delivery System

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ARTICLE INFO

Received: 29 July 2023
Accepted: 01 Aug. 2023
Published: 09 Aug. 2023

Keywords:
Natural, polymer, novel, gum, mucilage, excipient

DOI:
10.5281/zenodo.8229107

ABSTRACT

The therapeutic formulation has two main components which are active pharmaceutical ingredients and excipients to support into the production process in addition to enhancing medication distribution. In manufacturing dosage forms, to improve physicochemical parameters and to improve the stability of the dosage form excipients have proven to be very helpful. Excipients are currently utilized in novel drug delivery technology to fulfil customized functions, and in some cases, they directly or indirectly influence the extent and rate of drug release and effectiveness. Advances in polymer science have led to the development of novel drug delivery systems, which include microspheres, nanoparticles, tablets, gels, transdermal patches, dermal patches, implants, niosomes, and liposomes. The herbal or natural excipients have great merit over their synthetic polymers as these are non-hazardous, easily accessible, chemically inert, biodegradable, less expensive, eco-friendly, biocompatible, and economical. Gums and mucilage are widely used natural materials for conventional and novel dosage forms. Thus, the present study aims to highlight the numerous applications of natural plant mucilage and gum as gelling, thickening, suspending, binder, diluent, lubricant, and disintegrant in different types of formulations, as well as in the sectors of food and cosmetics. We outline the advancements throughout this review in polymeric science, natural extracted plant mucilage and gums have been assessed for medicinal purposes, which have diversified scopes in the design during formulations.

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

INTRODUCTION

A polymer is a massive macromolecule built from repeating fundamental segments. These fundamental segments are typically connected by covalent chemical connections [1]. Polymers are very beneficial for the design of modified-release drug delivery systems and have been effectively used in the formulation of solid, liquid, and semisolid dosage forms. Both synthetic and natural polymers are getting a lot of research for this purpose. Polymers are used in a variety of pharmaceutical applications, including tablet binders and viscosity and flow regulators for liquids, suspensions, and emulsions. Polymers can be employed as film coatings to improve medication stability, change drug release properties, and cover up a medicine's disagreeable taste [2]. Excipients are substances that are utilized to deliver medications, serving just as an inert vehicle for the active principle or principles [3]. Excipients are mostly utilized to give the bulk of the formulation because they contain a powerful medication that cannot be administered on its own and to ensure consistency of the medication in a dose form. There are many different excipients utilized [4]. Natural polymers are biological in origin due to their biological characteristics, including cellular identification and interaction, enzymatic decomposition, resemblance to the extracellular matrix, and chemical versatility. They are ideal materials for delivering medications. Typically, plants and animals are the suppliers of these polymers in nature, for instance, proteins, cellulose, carbohydrates, resins, etc [5].

MUCILAGES AND GUMS: The gums are seen as pathogenic chemicals that are produced when the plant's cell walls break down as a result of damage or adverse circumstances, such as drought (gummosis, external to the cell formation), while mucilage is usually a healthy by-product of metabolism that is produced within the cell (production inside cells) and without wrecking the plant [6]. Mucilage forms slime clumps, whereas gums swiftly dissolve in water. Mucilage is a physiological compound, while gums are pathological products [7]. Gums are found in a large number of families, such as Sterculiaceae, Leguminosae, Meliaceae, Rutaceae, Anacardiaceae, Rosaceae, and Combretaceae [8]. Gums can be discovered in a wide variety of plant components. Some gums come from the epidermis of seeds, while others are made by extracting them from the leaves and bark of plants. Gums are the macromolecules of carbohydrates that can bond with water to produce a gel. Gums primary chemical components are arabinose, galactose, mannose, and glucuronic acid. Gums frequently contain minerals and protein molecules in their composition. Gums are transparent, amorphous compounds that plants make. Gums can be partially or entirely solvable into water. In alcohol, they cannot be dissolves and the majority of pure solvents. With water, they swell or absorb to create viscous, sticky solutions. Levorotary plant hydrocolloids that can be anionic or non-ionic polysaccharides are often found in an aqueous solution of gum. Mucilage and gums are both plant hydrocolloids which impart some similarities [9, 10]. These are likewise transparent amorphous materials made of monosaccharide or mixed monosaccharide polymers, and many of them include uronic acids. Gums and mucilage have similar chemical makeups, and when hydrolyzed, they produce a mixture of carbohydrates and uronic acid. Substances with hydrophilic properties occur in gums and mucilage, and since they interact with water, they can form dense solutions or gels [11]. The distinctive characteristics of various gums are influenced by the types of chemicals involved. In comparison to highly branched molecules of the same molecular weight, linear polysaccharides take up more space and are more viscous. Due to the impossibility of substantial connections along the chains, the

branched compounds gel more readily and are more durable [12].

KINDS OF GUMS:

Gums are categorized into three main kinds:

A) Organic

B) Customized

C) Artificial

A. Organic gums: They arise from organic resources like tree exudates, hydrocolloids of certain legume seedlings as well as coastal like gums of guar, arabica, tamarind [13]. The primary components in many pharmaceutical products are plant-based mucilage and gums because of their bioavailability, ease of access, non-toxicity, and affordable pricing [14, 15].

B. Customized gums: These are naturally occurring gums that have undergone chemical modification, or they are starch or cellulose derivatives. Ex: carboxymethylcellulose [16].

C. Artificial gums: These chemical products are wholly synthetic. Ex: polyethylene oxide and polyvinyl pyrrolidone [17].

CLASSIFICATION OF GUMS AND MUCILAGES:

A. According to shape:

1. Linear: Amylose, Pectin, Algins, Cellulose

2. Branched

- Small branch: Galactomannans, Xanthan, Xylan
- Branch-on-branch: Arabic gum, Amylopectin, Tragacanth

B. According to the source:

1. Animal origin: Chondroitin sulfate, Hyaluronic acid, Chitin, Chitosan

2. Plant origin

- Seed gums: Locust bean Gum, Starch, Amylose, Amylose, Cellulose, Guar Gum
- Tuber and roots: Potato starch
- Shrubs/tree exudates: Tragacanth, Albizia gum, Ghatti gum, Khaya gum, Arabica gum Karaya gum
- Extracts: Larch gum, Pectin

3. Microbial origin (bacterial and fungal): Baker's yeast glycan, Zanflo, Pullulan, Scleroglucan, Lentinan, Xanthan, Emulsan, Krestin, Curdian, Schizophyllan, Dextrin

4. Marine origin/algal (seaweed) gums: Alginic acid, Laminarian, Agar, Carrageenan

5. Semi-synthetic

- Cellulose derivatives: Carboxymethyl cellulose, methylcellulose, Hydroxyethylcellulose, Hydroxypropyl methylcellulose, Microcrystalline cellulose
- Starch derivatives: Starch acetate, Starch phosphate, Hetastarch

6. Prepared gums

- Cellulose derivatives
- Starch and its derivatives, dextrin
- Biosynthetic gums Xanthan, Scleroglucan, dextrin

C. According to the charge:

1. Anionic Polysaccharides

- organic: Pectin, Arabic gum, Xanthan gum, Karaya gum, Chondroitin sulfate, Hyaluronic acid, Tragacanth, Alginic acid
- Semi-organic: Chitin, Cellulose gum, Carboxymethyl

2. Cationic Polysaccharides

- Cationic: Hydroxyethyl cellulose (HEC)
- organic: Chitosan
- Semi-Natural: Cationic Guar gum.

3. **Non-ionic Polysaccharides**

- organic: Dextrin, Guar gum, Starch
- Semi-organic: Cellulose Ethers (Ex: Nitrocellulose, Methylcellulose, Hydroxyethylcellulose)

4. Amphoteric Polysaccharides

- Semi-organic: Modified Potato starch, N-hydroxyl-Dicarboxyethylchitosan, Carboxymethyl chitosan

5. Hydrophobic Polysaccharides

- Semi-organic: Polyquaternium, Cetylhydroxyethylcellulose

D. According to monomeric units in chemical structure:

1. Homoglycans: Cellulose, Amylose, Arabinanas
2. Di heteroglycans: Galactomannans, Algins, Carrageenan
3. Tri-heteroglycans: Gellan, Xanthan, Arabinoxylans
4. Tetra-heteroglycans: Psyllium seed gum, Arabic gum
5. Penta-heteroglycans: Tragacanth, Ghatti gum [18]

BENEFITS OF NATURAL POLYMERS:

1. **Biodegradable:** All living creatures synthesise polymers that degrade into nutrients that are easily accessible in nature. Those are actual renewable resource, and they are not harmful to humans or environmental health [18].
2. **Non-hazardous and biocompatible:** The majority of these plant constituents are carbohydrates and are made up of monosaccharide repeats. As a result, they are harmless in comparison to artificial polymers [19].
3. **Economic:** Those are less expensive, and their manufacturing costs are lower than those of synthetic materials [20].
4. **Better patient leniency as well as societal acceptance:** Natural materials have less risk of having side effects and negative impacts than synthetic ones. Ex: Povidone, PMMA [17].
5. **Environmental-friendly:** Processing gums and mucilage from different sources are easily collected in different seasons in large quantities due to the simple production processes involved [21].
6. **Domestic accessibility (especially in underdeveloped nations):** Governments in developing nations encourage plant cultivation like guar gum and tragacanth due to their numerous uses in a diverse range of industries [18].

LIMITATIONS OF ORGANIC POLYMERS:

1. **Contamination by microbes:** Gums and mucilage are primarily composed of carbohydrates, often have an equilibrium moisture level of up to 10% or more, and are exposed to the atmosphere while being manufactured, all of which enhance the risk of microbial contamination. Yet this may be avoided with good handling and preservative utilization [19, 21].
2. **Batch-to-batch variation:** Natural polymer manufacture is reliant on the environment and other physical conditions, whereas synthetic manufacturing is a regulated process with defined amounts of materials [22, 23].
3. **Quick moisture content:** Due to differences in the gathering of natural resources at various eras as well as changes in species, location, and temperature conditions, the quantity of chemical compounds present in a given substance may vary. Relevant monographs must be constructed regarding the available gums [18, 23].
4. **Slow process:** The production rate cannot be altered since it is influenced by the environment and several other variables. Hence, the pace of the creation of natural polymers is modest.
5. **Heavy metal contamination:** Natural excipients and heavy metal pollution are commonly related [22, 23].
6. **Decreased consistency during preservation:** Degree of consistency within the formulations often rise as mucilage and gums are in exposure to liquid. Given the complexity of gums and mucins (which range from monosaccharides to complex carbohydrates and their by-products), it has been discovered that their viscosity decreases during storage [19, 21].

GENERAL MECHANISM OF DRUG RELEASE FROM POLYMER

The methods by which active compounds can discharge from an avenue of the delivery system are as follows:

1. **Diffusion:** The diffusion occurs as an active substance, such as a drug or another chemical, passes by the polymeric material that makes up the controlled-release gadget. When a medication leaves a polymer matrix and enters the surrounding environment, this is called diffusion. Since the active agent increasingly greater travel distance and resulting longer release diffusion time, the rate of release often declines as it proceeds in systems of this sort. These systems must permit the medication to penetrate via the tiny openings or larger molecules framework of polymeric material in the incorporation route of administration into the physiological state without causing an alteration in polymeric substance.
2. **Degradation:** The need to remove a drug delivery system once the active agent has been released is eliminated by biodegradable polymers, which break down inside the cell as a result of normal biological events. The majority of biodegradable polymers are made to break down by hydrolysing polymeric linkages into physiologically suitable and gradually tiny molecules. A rate of discharge that is equivalent to their area of surface of the medication route of administration results from several deteriorate polymers, most prominently polyorthoesters and polyanhydrides, where the breakdown solely takes place at the polymeric surface.
3. **Swelling:** Polymers are initially dry and they will absorb the water or other body fluids when implanted within the body and swell. The medicine can penetrate through the swollen network into the surrounding atmosphere because swelling enhances the formulation of aqueous solvent content and polymer mesh size [24, 25].

Isolation and purification of gums/mucilage: Picking an appropriate plant section to isolate the gum/mucilage. Identification of plants, character analysis, and chemical evaluation are carried out. Pick a plant component that contains gum or mucin for drying, grinding, and sieving. To completely dissolve the dried gum/mucilage in the distilled water, it must first be heated. After mixing, the mixture is let to remain at room temperature for 6 to 8 hours. The supernatant is eliminated using centrifuge. The residue is rinsed with freshwater, and the rinses are then added to the isolated supernatant. Four iterations of the process are performed. Selecting the appropriate solvents to use for moistening and precipitation. Finally, the supernatant is continuously stirred with twice the amount of acetone. The material that has precipitated is rinsed with distilled water and dried in a vacuum at 50 to 60 C^0 [26, 27].

Table 1: Preliminary confirmatory tests for dried powder mucilage and gums [6, 28, 29]

Sr no.	Name of the test	Test procedure	Observation	Inference
1	Molisch's Test	Take dried powder mucilage 100 mg add Molisch's reagent + conc. H_2SO_4 along the side of the test tube	At junction of two layers violet-green colouration is seen	Presence of carbohydrate
2	Enzyme Test	100 mg of dried mucilage powder should be dissolved in 20 ml of distilled water and 0.5 ml of	Blue color was not developed	Absence of enzyme

		benzidine in 90% alcohol. Mix and let stand for a little while		
3	Iodine Test	1 ml of a 0.2 N iodine solution with 100 mg of dry mucilage powder	Unobserved colour in the resulting solution	Presence of polysaccharides (absence starch)
4	Ruthenium Test	Observe a little amount of dried mucilage powder under a microscope after mounting it on a glass slide bearing ruthenium red solution	Results in a pink colour	Presence of mucilage

CHARACTERIZATION OF MUCILAGES AND GUMS

1. **Structural:** Gums and mucins are polysaccharides that contain sugar. As a consequence, the existence of the different sugars is verified using chromatography, and their structures are clarified using mass spectroscopy and NMR.
2. **Purity**: The quality of the specified gum and mucilage is evaluated by tests for alkaloids, glycosides, carbohydrates, flavonoids, steroids, amino acids, terpenes, saponins, oils and fats, tannins, and phenols.
3. **Degree of impurity grade**: Analytical methods must be used to test for impurities.
4. **Physico-chemical attributes**: Characteristics to take into account include colour, fragrance, shape, taste, touch, texture, solubility, pH, swelling index, loss on drying, hygroscopic nature, angle of repose, bulk and actual densities, porosity, and surface tension. Additionally, a number of ash values are estimated. Evaluations are made of the microbial load, presence of specific pathogens, and in vitro cytotoxicity. Mucilage and gums have extremely high viscosities. The commercial usage of excipients is greatly influenced by their rheological properties. The behaviour of the sample flow is recognised.
5. **Toxicity**: According to oligosaccharide ester derivatives (OECD) guideline No. 425, the following fixed-dose approach is used to assess the sub-acute poisoning of gums and mucin. Guinea pigs and rats of both sexes are used in a sub-acute toxicity study, which includes determining the LD50 [30].

PHARMACEUTICAL APPLICATIONS OF NATURAL POLYMERS

Natural polymers are most frequently used as adjuvants in pharmaceutical preparations such as thickeners, binders, emulsifiers, suspending agents, disintegrants, stabilizers, gelling agents, film-forming agents in transdermal and periodontal films, buccal tablets, sustaining agents in matrix tablets and coating agents in microcapsules, including those used for peptide delivery. These natural polymers can be utilized to develop formulations for controlled and sustained release that is derived from a variety of sources [31].

- **Binding agent:** Natural polymers such as mucilage have been the subject of numerous investigations and these studies have indicated that natural polymers have better binding capabilities than synthetic polymers, making them suitable as binding agents in formulations [32]. Ex- Paracetamol tablets include Cassia roxbughii seed as a binder [33], Metronidazole

medication include cashew tree gum as a binder [34].

- **Gelling agent:** The formation of gels, a more modern class of dosage forms, involves enclosing large volumes of hydro or hydro-alcoholic liquid inside a network of colloidal stiff fragments that may include inorganic substances like aluminium salts or organic polymers that can be either natural or manufactured [35]. Ex-Locust bean gum

Natural Gel Forming Agents Are Classified as:

a) Polysaccharides: Agar, Gellum gum, Alginic Acid, Cassia tora, Tragacanth, Pectin, Xanthum gum, Sodium Carrageenan, Guar gum
b) Protein: Gelatin, Collagen [36]

Research demonstrates that Trigonella Foenum gracecum polymer has been utilized to create intra-nasal gel using diazepam as the model medication [37].

- **Suspending and Emulsifying agent:** Suspending agent are excipients that enable active medicinal components to stay suspended in the formulation and prevent caking at the bottom of the container. A well-formulated suspension has the ability to be quickly re-suspended with some light shaking or agitation. Gums efficiently stabilize the emulsion by interfacial absorption, which leads to the formation of a condensed film with a high tensile strength that resists droplet coalescence. They prevent the coalescence of the hydrophilic barrier between the oil and water phases by stabilizing the oil/water emulsion by generating robust multimolecular films around each oil globule. By using these substances, the active component will be distributed uniformly throughout the formulation, resulting in both chemical and physical stability. By molecular contact and hydrogen bonding, natural gums improve the moisture retention of the hydration layer around the suspended particle. Ex-Cordia gharaf gum [38].
- **Sustained material to the medication type:** The delivery of medicine can be extended through gums. For sustaining drug release, they have been utilized in tablets, suspensions, and matrix systems. When this polymer comes into the presence of water, it hydrates and creates gel-like substance. Due to the often diffusion-controlled medication release from this gel, it will be extended for a very long period. Ex: Gum guar, Karaya gum, xanthene gum [39].
- **coating material:** Many gums have coating properties that can sustain medication release or prevent it from degrading in the stomach. When the number of coatings increases, drug release decreases. Ex: Grewia Gum [40].
- **Microencapsulation:** The gums can be used to microencapsulate medication particles to sustain the drug release because of their coating capabilities. Ex: gum kondagogu, gum Xanthan, Guar gum [41].

PURPOSE OF ORGANIC POLYMER IN NOVEL MEDICAMENT ADMINISTRATION

1. **Gastrointestinal delivery:** Destroyed by the human colon's bacteria, which promotes the administration of colonic drugs. The mucous adhesive and film-forming properties of the material that coats are good. The development of microspheres for colonic administration [42]. Ex: pectin
2. **Ocular delivery:** Chitosan is appropriate for the development of ocular bandage lenses due to its superior film capacity [43, 44]. Ex: Tamarind gum, gellan gum
3. **Transdermal drug delivery:** Chitosan gel has been used in studies on the delivery of propranolol hydrochloride using a variety of natural polymers with varying cross-link densities as drug release-controlling

membranes. Ex: mucilage of Ficus carica fruit, xanthan gum.

4. **Mucosal delivery:** Organic polymeric material able to utilized to produce bioadhesive dose types because they are protonated in acidic solutions and have a significant affinity for negatively charged cell surfaces [45, 46]. Ex: Karaya gum
5. **Topical delivery:** Since they can produce gels that are relatively stiff and thermally reversible, carrageenans, a class of sulfated polysaccharides that are derived from red sea algae, is used extensively in the industry. Ex: cellulose, agar, and locust bean gum [47, 48].
6. **Gene Delivery:** An isolated natural polymer from a shrimp shell exhibits the capacity to bind with genetic material and solid it to produce nanostructures. These nanostructures are high swiftly absorbed by living tissues [49].

RECENTLY INVESTIGATED SOME NATURAL GUMS AND MUCILAGE

1. **Hakea gum:** The dried exudate from Hakea gibbose plant (Proteaceae). The chemical composition of gum is 12: 43: 32: 5: 8 and includes glucuronic acid, galactose, arabinose, mannose, and xylose. Only a small amount of water may dissolve the leaked gum. Gum was investigated as a mucoadhesive and sustained-release buccal tablet component. These findings show that Hakea gibbosa can function as a bioadhesive polymer in addition to being employed to sustain the release [50, 51].
2. **Cordia mucilage:** Obtained from raw fruits of Cordia obliqua (Boraginaceae). It is possible to cure gonorrhoea with raw gum, and lung diseases can be effectively treated with Cordia mucilage as an expectorant. We studied the ability to bind and emulsifier properties of cordia mucilage. [52].
3. **Ispagol mucilage:** Plantago ovata seeds have an outer covering that may be milled to produce psyllium mucilage (Plantaginaceae). In addition to being investigated for its tablet binding abilities [53], has also been tested for its ability to produce hydrogels by radiation-induced cross-linking for the controlled release of the model drug 5-fluorouracil [54]. Innovative long-term release, swellable, and bioadhesive gastrointestinal medication supply method for ofloxacin were created using psyllium husk and excipients such hydroxypropyl methylcellulose [55].
4. **Bhara gum:** Natural yellowish coloured gum extracted from Terminalia bellerica bark (Combretaceae). The primary chemical components are tannins, primarily ß-sitosterol, gallic acid, ellagic acid, ethyl gallate, galloyl glucose, and chebulaginic acid. A unique sustained-release microencapsulated drug delivery system utilising bhara gum has been created. In the ionic gel formation process utilized to create the microcapsules, famotidine served as the model medication. With the use of microcapsules containing bhara gum, famotidine was released gradually over the course of 10 hours. [56].
5. **Hibiscus mucilage**: Mucilage is extracted from fresh Hibiscus rosa-sinensis leaves (Malvaceae). In the mucilage of Hibiscus rosa-sinensis, chemical components such as L-rhamnose, D-galactose, D galacturonic acid, and D glucuronic acid are present [57]. The creation of tablets with a prolonged release has allegedly employed the mucilage from it [58].
6. **Almond gum:** Prunus amygdalus is a tree from which almond gum is extracted (Rosaceae). Gum comprises L-arabinose, D-mannose, L-galactose, and aldobionic acid. The several compounds that go into making almond gum contain emulsifier, thickener, suspender, adhesion, glaze, and stabilizer capabilities. Almond tree gum was investigated for its capacity for binding

ingredients in tablet formulations. Almond gum increased the drug release as compared to artificial gum concentrations. Uncoated tablet dosage forms formulated with almond gum have been demonstrated to be effective [59].

7. **Copal gum:** Naturally originate resin extracted from the Bursera bipinnata plant (Burseraceae). Agathic acid, sandaracopimaric acid, ciscommunic acid, transcommunic acid, polycommunic acid, monomethyl ester of agathalic acid, agatholic acid, and acetoxy agatholic acid are all contained in copal resin [60]. Copal gum has been investigated as a film-forming agent and matrix-forming substance for sustained drug delivery. It can also be used as a coating material for sustained release and colon-targeted drug delivery [61].
8. **Phoenix mucilage:** Phoenix dactylifera dried fruit produces mucilage (Palmaceae). Between 44 to 88 percent of the fruit is composed of carbohydrates, the majority of which are reducing sugars like fructose, sucrose, mannose, glucose, and maltose. There are also trace amounts of polysaccharides such pectin (0.5–3.9%), starch, and cellulose. Mucilage from date palms has been effectively assessed for its binding abilities [62].
9. **Albizia gum:** The sticky substance is extracted out of the Albizia zygia tree (Leguminosae) carved stem. With some ß-1-6-linked D-galactose units, it is composed of ß-1–3-linked D-galactose units. As a natural emulsifier for food and medicines, Albizia gum has been investigated as a potential candidate for gum Arabic [63, 64]. These gums were investigated as coating materials in compression-coated tablets, which the intestinal microbiota destroyed and released the drug through [65].
10. **Terminalia gum:** The Terminalia randii tree induces terminalia gum exudates from the incised trunk (Combretaceae). Haemorrhoids, diarrhoea, dysentery, and wounds are all treated using extracts from Terminalia randii stem and bark. The effectiveness of gum exudates from Terminalia randii as a binding agent has been studied [66].
11. **Neem gum:** Azadirachta indica plants serve as the source of neem gum (Meliaceae). Mannose, glucosamine, arabinose, galactose, fucose, xylose, and glucose are all sugars found in gum. Neem gum has undergone research into its sustained release and binding abilities [67, 68].
12. **Grewia gum:** The inner bark of the edible plant Grewia mollis is processed to produce a polysaccharide found in Grewia gum (Tiliaceae). The gum mostly consists of the monosaccharide's glucose and rhamnose, as well as the sugar acid galacturonic acid [69]. For its binding and compressive properties, studies on Grewia gum have been conducted [70]. The ability of this gum to build matrixes has also been studied. In this investigation, direct compression was used to compress and assess tablets containing various amounts of Grewia gum. According to in vitro drug release experiments, Grewia gum can delay the release of cimetidine from tablets for up to 12 hours. The release of cimetidine from tablets and the film-forming property were both delayed by the interaction of Grewia gum and HPMC [71].
13. **Mimosa scabrella gum:** Mimosa scabrella seeds are processed to extract gum (Mimosaceae). Gum can be very hydrating and contains mannose:20–30% galactomannan: galactose ratio of 1:1:1. Studies have been carried out on Mimosa scabrella gum for its controlled-release matrix-forming property. In this study, it was observed that drug release decreased with the increase in polymer concentration, and 25% w/w of gum showed an excessive sustained release effect. The release mechanism was a combination of diffusion and relaxation [72].

14. **Olibanum gum:** The dried, gummy exudate produced from the Boswellia serrate plant is olibanum gum (Burseraceae). Its three primary origins-Aden/Somalia, Eritrea, and India-determine its composition and chemical properties. It comprises around 5-9% oil content, 13–17% resin acids, 20–30% polysaccharides, and 40–60% boswellic acid [73]. Recent investigations have indicated that the anti-inflammatory gum olibanum has a favourable effect on rheumatism. An investigation on olibanum gum sustained release matrix-forming, binding was performed [74]. The emulsification solvent evaporation technique was used to manufacture olibanum resin-coated microcapsules [75].
15. **Chinee apple mucilage:** Ziziphus mauritiana, a member of the Rhamnaceae family of tropical fruit trees, is also known as Indian jujube, Indian plum, Chinese date, Chinee apple, beriberi, and dunks. Proteins, amino acids, alkaloids, terpenoids, fibers, flavonoids, tannins, glycosides, and phenolic compounds are the chemical constituents of Z. mauritiana leaves [76]. Tablet formulations may benefit from the usage of Ziziphus mauritina as a possible natural binder [77].
16. **Cocculus mucilage:** Cocculus hirsute leaves are employed to extract mucilage (Menispermaceae). Mucilage includes polysaccharides and a gelatinous substance. On the skin, leaves are used as an emollient and demulcent. The gelling property of the mucilage was investigated. This study involved comparisons. To make the gel, flurbiprofen was employed as a model medicine. Marketed flurbiprofen gel and gel made from Cocculus hirsute leaf powder were compared, and both gel's potential to reduce inflammation has been evaluated. It was determined that the amount of medication released from the test gel preparation and its anti-inflammatory activity was greater than those of the commercial gel [78, 79].
17. **Fenugreek mucilage:** Trigonella foenum-graceum seeds are used to obtain mucilage (Leguminosae). Its seeds have a high mucilage content and do not dissolve in water; instead, they create a sticky, tacky mass that swells when exposed to liquids [80]. Mannose, galactose, and xylose can be found in gum. When hypromellose and fenugreek mucilage were of the same content, it was found that the mucilage from fenugreek was more effective in delaying release [81].
18. **Abelmoschus gum:** The fresh fruits of the plant Abelmoschus esculentus are used to extract the okra gum (Malvaceae). Okra polysaccharide comprises the main polysaccharide component, which varies greatly in the molar ratios of galactose, galacturonic acid, and rhamnose and with certain fractions of glucose, mannose, arabinose, and xylose [82]. Okra pod mucilage has been investigated for safety and significance as a suspending agent [83]. The extracted mucilage has been examined for its disintegration ability and determined to be non-toxic. It was utilized to formulate a suspension of paracetamol. Abelmoschus esculentus gum is used as a polymer in the development of a floating dosage form for the gastrointestinal system. Okra polysaccharide serves as both the carrier and a microbially triggered ingredient in the formulation of colon-targeted tablets. The results lead to the conclusion that the medicine might potentially be transported practically intact by the okra polysaccharide under investigation to the colon, where anaerobic microorganisms cause the drug to degrade [84].
19. **Damar gum:** The natural gum is extracted by tapping Shorea wiesneri trees

(Dipterocarpaceae). It ranges in color from white to yellow. It contains about 40% resin (resin that dissolves in alcohol), 22% beta-resin, 23% dammarol acid, and 2.5% water. Investigation on the sustained release matrix-forming ability of gum damar has been performed. Drug delivery was sustained for more than 10 hours, according to the matrix drug release [85]. The gum's ability to microencapsulate was also assessed. Increases in particle size, encapsulation effectiveness, and drug release rate were seen with increasing gum: drug ratios. Due to its powerful binding abilities, it has also been employed for water-resistant coating in the pharmaceutical, and dentistry sectors [86].

20. **Moringa oleifera gum:** Moringa oleifera stem exudes can be utilized for the extraction of gum (Moringaceae). The gum is a polyuronide composed of arabinose, galactose, and glucuronic acid in the formulation 10:7:2, with traces of rhamnose. Studies were performed on this gum for its gelling, binding, and disintegrating properties [87, 88].
21. **Mastic gum:** The plant Pistacia lentiscus yields a resin that is secreted from its trunk and used for making mastic gum (Anacardiaceae). The main ingredients are camphene, β-pinene, α-pinene, myrcene, linalool, and β-caryophyllene. Gum mastic has been studied as a potential microcapsulating and matrix-forming substance for sustained drug release. Wet and melt granulation processes were used to manufacture the matrix tablets using diclofenac sodium and diltiazem hydrochloride as model drugs. Raise the mastic drug ratio, larger microparticles, better drug loading, and slow drug release. The effectiveness of gum mastic as a matrix-forming agent was enhanced by melt granulation. The results showed that matrix tablets and microparticles for sustained drug release may be successfully made with natural gum [89].
22. **Kondagogu gum:** A naturally occurring polysaccharide known as Kondagogu gum or hupu gum is obtained as an exudate from the tree Cochlospermum religiosum (Bixaceae). The gum contains rhamnose, galacturonic acid, glucuronic acid, b-D galactopyranose, a-D-glucose, b-D-glucose, galactose, arabinose, mannose, and fructose. To identify its capability to float in the GI tract and produce mucoadhesive microcapsules, kondagogu gum has served as the focus point of numerous studies [90, 91].
23. **Mango gum:** Dried polysaccharide exudate extracted from the bark of Mangifera indica (Anacardiaceae). Mango gum has been investigated in several studies examining its binding and sustained release [92]. This gum's ability to disintegrate was also investigated. This gum presence improved the appearance and medication release of the tablets. A poor correlation between the swelling index and disintegration efficiency was also discovered by the study. This gum was used to manufacture mouth-dissolving tablets [93].
24. **Cissus gum:** The stem of the Cissus populnea plant yields cissus gum (Vitaceae). The plant is a tropical species that forms a gel. Hexadecanoic acid, methyl stearate, and octadecanoic acid are the main chemical components. By using the incision method, gum can be isolated from the stems of Cissus populnea, which is a rich source of gum [94]. Cissus gum has been investigated as a controlled-release polymer in the formulation of tramadol matrix tablets. Results of the finding indicated that gum showed controlled drug release comparable to xanthan gum and could be used as a cheaper alternative to synthetic polymers in the formulation of sustained-release tablets [95].

25. **Odina gum:** Lannea coromandelica, also known as the Indian ash tree, is a species of tree (Anacardiaceae). The phenolic and flavonoid components of Coromandelica that are abundant include ellagic acid, quercetin-3-arabinoside, quercetin [31], (2R,3S)- (+)-3′,5-dihydroxy-4,7-dimethoxydihydroflavonol, and physcion. In the formulation of tablets, L. coromandelica gum has a possible role as a binder [96].
26. **Curdlan:** Curdlan is a microbial-based extracellular gum. The root of the name is "Curdle," to define its gelling ability at high temperatures [97, 98]. Curdlan is composed of glucosyl residues bound by 1,3-D-glycosidic linkages, which are present in bacteria, fungi, algae, and advanced plants [99]. Alcaligenes faecalis or Agrobacterium radiobacter are the non-toxicogenic microbes that produce it [100]. Commercial curdlan may contain proteins, nucleic acids, cellular detritus, and other organic acids [101]. The mechanical qualities and texture of noodles, jellies, ice cream, and fish paste products (Ex: Kamaboko) are improved and stabilized by the addition of curdlan gel, a popular food additive. It is also used as a water-holding agent in the processing of meat and dairy products [102]. Leukocyte activation, tumor growth inhibition, immunostimulatory activity, and stimulation of cytokine production in humans have all been related to curdlan in scientific studies [103, 104]. To improve the release profile of the bioactive macromolecules, curdlan hydrogels can play a vital role as a drug delivery vehicle [105].
27. **Ficus carica:** Ficus carica belongs to the Moraceae family. Bioactive substances include phenolic compounds, phytosterols, organic acids, triterpenoids, coumarins, and volatile compounds that were identified in Ficus carica. Mucilage from Ficus carica fruits was used to develop a matrix-type transdermal device for controlling the release of diclofenac sodium [106]. Tramadol hydrochloride transdermal patches were developed using Ficus carica mucilage as a matrix-forming substance for tramadol-controlled release in conjunction with the synthetic polymer polyvinylpyrrolidone. Tramadol hydrochloride permeability could be sustained within the therapeutic range across the porous surface of the mucilage-based patch, according to an in vitro drug permeation investigation. [107].

Table 2: Pharmaceutical implications of natural mucilage and gums

Common Name	Botanical Name and Family	Pharmaceutical utiliztion
Cassia tora [108, 109]	Cassia tora (Leguminaceae)	Binder
Leucaena seed gum [110, 111]	Leucaena leucocephata (Fabaceae)	Emulsifier, suspending agent, disintegrate, binding agent in tablets
Cashew gum [109, 112]	Anacardium occidentale (Anacardiaceae)	Suspending agent
Gum Ghatti [108, 109]	Anogeissus latifolia (Combretaceae)	Suspending agent, emulsifier, binder
Bavchi mucilage [113]	Ocimum canum (Gigarginaceae)	Suspending agent, emulsifying agent
Sodium alginate [114, 115]	Macrocytis pyrifera (Lessoniaceae)	Gelation for dental films, suspending agent, nanoparticles, microencapsulation, stabilizer
Persian Gum [116, 117]	Amygdalus scoparia Spach (Rosaceae)	Emulsifying and stabilizing agent
Aloe Mucilage [118]	Aloe barbadensis (Liliaceae)	Sustained release agent, gelling agent

Asario mucilage [119]	Lepidum sativum (Brassicaceae)	Emulsifying, suspending agent, controlled release tablet
Konjac glucomannan gum [120]	Amorphophallus konjac (Araceae)	Gelling properties
Acacia [108, 109]	Acacia Senegal (Leguminosae)	Osmotic medicinal administration
Gellan gum [121, 122]	Pseudomonas elodea	Floating in-situ gelling, beads, ophthalmic drug delivery
Tamarind gum [109, 123]	Tamarindus indica (Leguminaceae)	Mucoadhesive drug delivery for ocular spheroids, nasal drug delivery, hydrogels
Mucuna gum [124]	Mucuna flagillepes (Papillionaceae)	Microspheres
Cactus mucilage [125]	Opuntia ficus-indica (Cactaceae)	Gel forming property in long-term delivery of medication
Ocimum seed mucilage [126]	Ocimum americanum (Lamiaceae)	Disintegrating property
Pectin [108, 109]	Citrus azurantium (Rutaceae)	Colon drug delivery, hydrogel transdermal delivery, iontophoresis, microparticulate delivery, floating beads
Jack fruit gum [127]	Artocarpus heterophyllus (Moraceae)	Tablet binder
Galbanum gum [128]	Ferula gummosa (Apiaceae)	Binding agent
Tara gum [129]	Caesalpinia spinosa (Fabaceae)	Controlled release carrier
Katira gum [129]	Cochlospermum religiosum (Bixaceae)	Gelling agent
Satavari mucilage [130]	Asparagus racemosus (Apocynaceae)	Binder, sustaining agent in tablets

CONCLUSION

This review article emphasizes the relevant details and recent developments in the utilization of natural plant gums and mucilage. Since naturally occurring polymers have been used thoroughly over the past few centuries, it is obvious that they have been used in a variety of formulations where they can be used as emulsifying, suspending, binding, and gelling agents. As a result, it is possible to conclude from the review that in the pharmaceutical industries, polymeric material contributes a significant function. The development of novel medication administration technologies, biotechnological applications, and alternate delivery methods, however, requires the development of additional nature-based sources along with the modification of existing natural components. As additives in the creation of medication types for efficient medication administration, numerous polymer compounds of plant genesis have been utilized effectively, and further ones have been investigated. In matrix-based release-controlled dosage forms like beads, tiny particles, tablets, and cross-linked hydrogels, certain polysaccharides derived from plants, including alginate, carrageenan, arabic gum, konjac glucomannan, gum guar, and locust bean gum are demonstrated outstanding possibilities as carrier transporters. This review leads us to the conclusion that natural polymers can be an

excellent replacement and helps in improving the side effects of synthetic polymers. There are lots of avenues for research on more recent mucilage and gums extracted from plants, which might be utilized as an innovative natural polymer for the creation of various medication delivery systems in the pharmaceutical sector in the future. In order to generate more effective medication supply systems, thus, there will undoubtedly be a demand for natural gums and their variations.

ACKNOWLEDGMENT

The authors are expressing sincere thanks to the entire scientist whose reference are utilized here for helping to improve the knowledge of entire population.

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HOW TO CITE: Yukti Mahajan*, Dev Raj Sharma, Pravin Kumar, Mahender Singh Ashawat, Natural Polymers as Excipient in Formulation of Novel Drug Delivery System, Int. J. in Pharm. Sci., 2023, Vol 1, Issue 8, 50-71. https://doi.org/10.5281/zenodo.8229107