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BIO POLYMERS: A POTENTIAL CARRIER FOR PHARMACEUTICAL INDUSTRY

Surita Ghosh

Dr. B. C. Roy College of Pharmacy & Allied Health Sciences, Durgapur - 713212, West Bengal, India.

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Correspondence to Author:
Ms. Surita Ghosh

Assistant Professor,
Dr. B. C. Roy College of Pharmacy & Allied Health Sciences, Durgapur - 713212, West Bengal, India.

E-mail: Suritaghosh3@gmail.com

ABSTRACT: Apart from the API, the excipient plays a crucial role in a formulation because of their versatile application, which enhances different physical and chemical characteristics in a dosage form. At present scenario natural polymers are Considered a leading constituent as an excipient to formulate several innovative approaches for designing the drug delivery system. The components which are obtained from nature is always preferred for our health due to their fewer side effects. Hence, biopolymers have the additional privilege of being incorporated as an excipient in pharmaceutical formulations. Demand for natural polymers is enhancing day by day (increased 7.1% in every year as per scientific data) because of their versatile application in drug delivery systems and multiple utilization of several domains in the biomedical section. Low toxicity, compatibility, sustainability, biodegradability, swelling index, release pattern are the major Parameters of the biopolymers which alter the different pharmacokinetic and pharmacodynamic characteristics of a pharmaceutical dosage form. The major aim of this current review is to impart some knowledge related to the widespread biopolymers. And emphasize the various fundamental applications of biopolymers in the pharmaceutical industry as an excipient and implementation of the biopolymers to design the innovative approaches for drug delivery systems. From this study, it was concluded that biopolymers have been effectively used as an excipient in the manufacturing of dosage forms and play a crucial role as a carrier mediated drug delivery system.

INTRODUCTION: Polymers are those substances in which the monomers (repeating molecular units) are attached with the support of a chemical or covalent bond and form a macromolecule, or a large molecule. Usually, polymers are categorized into three different groups like synthetic, semi-synthetic, and natural polymers [1]. Synthetic polymers are those substances which are integrated by using the chemical processes in research laboratories utilizing different techniques. Polyethene, polystyrene, nylon, synthetic rubber, polyvinyl chloride, Teflon, *etc*. are examples of synthetic polymers. Semi synthetic polymers are the substances which are extracted from natural sources, but they go through some chemical treatment to expand their physical parameters. Rubber, rayon, gun cotton, and different cellulose derivatives like cellulose acetate, cellulose nitrate, *etc*. are examples of semi synthetic polymers. Natural polymers are those components which originate from any type of natural derivative, like animal or plant sources [2].

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In recent years, natural polymers have drawn the main attention of the research scientist due to the enormous implementation of natural polymers in drug delivery systems. Nowadays, natural polymers are considered a key element as an excipient to develop innovative approaches for delivering drugs [3]. The importance of natural polymers is increasing day by day because of their versatile application in drug delivery systems and the multiple utilization of several domains in biomedical sections [4]. Also, the scientists are immensely interested in the natural polymers on account of their remarkable utility beyond the synthetic or semisynthetic polymers. The benefits of natural polymers include that they are stable, nontoxic, compatible, and widely available at an affordable price (cheap) [5]. Natural polymers also have the advantage that they are generally biodegradable in nature; these are known as biopolymers [6]. Now polymer serve as an important role for pharmaceutical industries, and it is treated as a backbone for drug delivery system. It is very essential for controlling the drug discharge rate from a formulation[7].

So, in the modern era, the natural polymer acts as an inert transport system which delivers the API to a specific region or site in our biological system, which is familiar as a targeted drug delivery system. The natural polymer modified the pharmacokinetic and pharmacodynamic parameters, as well as altered the stability and solubility properties, and enhanced the plasma ½ life of a drug molecules [8].

Benefits of Natural Polymers Over Synthetic and Semi-Synthetic Polymers: There are several benefits to using a natural polymer in a polymer-based drug delivery system rather than a synthetic or semisynthetic polymer. Natural polymers enhance the pharmacokinetic behaviours of drug molecules and also improve the distribution properties of drugs in biological systems [9].

Advantages of Natural Polymers:

Biodegradable: Biodegradation takes place in living organisms by enzyme degradation or chemical deterioration processes. Natural polymers do not exhibit any injurious responses to humans or the environment because they are degraded by living organisms, so they are eco-friendly in nature. But synthetic or semi synthetic polymers are composed of various types of chemical components which do not degrade within living organisms, so they are harmful to the surroundings and also to human beings [10].

Non-toxic and Biocompatible: Natural polymers consist of replicate units of monomers, which are generally carbohydrate-based in nature, so they are non-toxic in comparison with synthetic or semi synthetic polymers [11].

Less side Effects and Safety: Natural polymers are extracted from natural origin and do not contain any type of chemical, so they are safe for humans. In the case of synthetic or semi-synthetic polymers, which are formulated by using different types of chemicals and undergo various chemical processes, they are harmful to the environment as well as human beings [3].

Commercial Benefits: Natural polymers are more economical because their manufacturing costs are lower compared to synthetic or semi-synthetic polymers.

Easily Available: Biopolymers are originated from plant or animal origin, which are effortlessly obtainable in nature, and the sources are renewable**.** The cultivation of different plants is promoted by the government in developed countries, from which natural polymers are obtained (like tragacanth, guar gum, *etc* [12].

Eco-friendly Processing: Natural polymers are easily collected from various natural sources throughout the year in different seasons in sufficient quantities. The formulation process is also eco-friendly and simple compared to the synthetic polymer formulation.

Better Acceptance and Patient Tolerance: Natural polymers have better acceptability in comparison with synthetic and semisynthetic polymers. Some polymers are originated from natural, edible sources. So, this are more acceptable to the patient [9].

Characteristics of Natural Polymers: Natural polymers exhibit different properties depending on their chemical, physiochemical, and mechanical characteristics.

Chemical Property: Polymers contain repeated molecular units, which are known as monomers. If one monomer is repeatedly present in a polymer, this is known as a homopolymer, and the arrangement of the different monomer units within a polymeric chain is known as a copolymer [13].

Basically, a polymer is the repetition unit of a monomer in a single or branch chain. They are interacting with each other through different forces of attraction. The intermolecular force between the polymeric chain is insistent by means of the polymer's monomer units and the attractive force present in the polymer chain. Generally, polymers consist of an extended chain, so the attraction, or intermolecular force, is enhanced between the molecules. The branch chain also creates hydrogen bonding, or ionic bonding, with its own chain. If any amide group or carbonyl group is present in a polymer, hydrogen bonding takes place [14].

Mechanical Property: The mechanical property describes a polymer's ability to withstand different tensile strengths. The tensile strength and melting point are increased if a well-built intermolecular force or a strong hydrogen bond are present within the polymeric chain. Bond distortion in nature describes the elasticity property of a natural polymer. The rate of movement of drug particles throughout the polymeric bed is related to the transportation property, which is recognized as per the diffusion behaviour of a natural polymer.

Transport Property: Transport property is very important in the case of polymers because it is associated with diffusivity (which means the speed of the molecules throughout the polymer matrix). The transport property of a polymer is directly connected to the various applications of polymers like films and membranes [15].

Classification of Natural Polymers: Natural polymers perhaps classified into three major groups according to their source of origin. Such as,

Plants' Sources of Origin: They are extracted from any type of plant source. e.g., gum acacia, gum tragacanth, pectin, agar, starch, *etc*.

Animals' Sources of Origin: They are isolated or extracted from any animal source. E.g., chitosan, albumin, gelatine, collagen, etc.

Microbes' Sources of Origin: They are derived from any type of microbe, like bacteria, fungi, molds, algae, etc., e.g., dextran, xanthan, pullulan, carrageenan, *etc* [3].

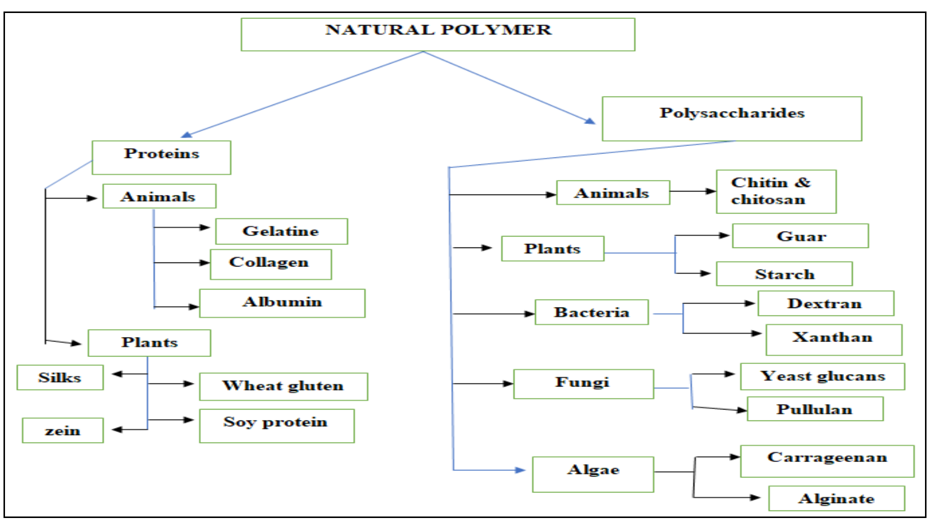
According to its chemical composition, the biological polymer could be categorized into two main groups. Such as

Natural Polymers Consist of Proteins: Under this classification, the main composition of the natural polymer is protein.

The amount of protein is higher in comparison with other chemical group, which is also present in natural polymers. Other than protein, there are many groups present, like gliadin, glutenin, carbohydrates, *etc*., e.g., soy protein, white gluten, zein, collagen, *etc* [9].

Natural Polymers Consist of Polysaccharides: This classification is established on the presence of polysaccharides in the natural polymer.

The major chemical component is polysaccharides, along with different chemical groups. e.g., starch, pectin, cellulose, agar, chitosan, *etc* [10].



Some Common Natural Polymers in the Pharmaceutical Industry:

Locust Bean gum: This polymer originates from *Ceratonia siliqua* Linn, associated with the family Leguminosae. It is also referred to as carob bean gum because it is excreted from the brown pod of the locust bean plant. This gum is pulverized, and it is prepared by grinding the seeds (endosperm) of the brown pod collected from the locust tree [16]. This polymer is a natural carbohydrate that contains galactose and mannose in a 1:4 ratio. The major component of locust gum is a neutral galactomannan polymer composed of 1,4-linked D-mannopyranosyl groups with a D-galactopyranosyl unit substituted on C6 of every fourth or fifth chain unit. It is a neutral polymer, and the solubility and consistency of locust gum are a little bit changed in the pH vallue 3–11 [17].

Uses:

- It is extensively exploited in pharmaceutical formulations as a stabilizing agent, binder, flocculating agent, and thickening agent.
- It is also applied to formulated the propranolol hydrochloride-controlled delivery system to prevent first-pass metabolism.
- Locust gum is also employed to prepare matrix tablets with and without a cross-linking agent.
- Diclofenac sodium mini-matrix tablets for sustained release can be formulate by locust gum polymer.
- TIMERx® is an economically accessible tablet formulated by using locust and xanthan gum, which exhibited *in-vitro* & *in-vivo* extended delivery [18].

Karaya gum: It is the dehydrated mucilaginous discharge derived from the tree *Sterculia urens roxb* under the family Sterculiaceae. It's also recognized by Indian Tragacanth, Sterculia, Karaya, or Bassora tragacanth gum and is available in Pakistan, India, and some places in Africa. Karaya gum is a fractionally acetylated polymer of rhamnose, glucuronic acid, and galactose. It consists of a major amount of D-glucuronic acid with D-galacturonic acid residue with branched heteropolysaccharide. No methoxy groups are present in this polymer [19]. The gum is producing a viscous consistency when absorbing water, though it is commercially less soluble. It absorbed water very quickly and expanded many times of its initial volume. Karaya varies from tragacanth in such it has no starch & stains pink when used with ruthenium red solution [20, 21].

Uses:

- In the pharmaceutical field, karaya gum is broadly used as a suspending, stabilizing, thickening, and mucoadhesive agent.
- It is applied as a dental adhesive, bulk laxative, and matrix-forming agent.
- Other than the pharmaceutical industry, it is also applied in the paper, food, and textile sectors. using karaya gum and hydroxypropyl methylcellulose (HPMC) as polymers [1, 21].
- Karaya gum is used to prepare gastric drifting medication for a sustained-release drug delivery system by preparing a matrix system to deliver the drug for eight hours.

Rosin: It is also recognized by the Greek name pitch, or colophony, derived from the plants Pinus palustris (pine) and conifers. The major sources of this polymer are *Pinus soxburghii, Pinus longifolium, and Pinus toeda*. It is a non-evaporated component prepared by vaporizing volatile components with the help of heat, which is provided to the fresh liquid resin. Rosin is collected from oleoresin, and it is a biopolymer with a molecular weight of 400 DA. The major components are abietic and pimaric acids, which are present in resin, and a certain number of Non acidic components and esters are also present in this polymer [1, 4, 5].

Uses:

- Rosin considered as a polymer in various drug delivery techniques because of its physico-chemical properties and ease of accessibility.
- Rosin is a good film-forming biopolymer (due to the existence of esters), which is extensively utilized to formulate different kinds of controlled and sustained-release drug delivery techniques. This polymer was also applied to produce the film of the enteric coating tablet.

- It is also used to prepare transdermal dosage forms.
- It was recorded that rosin had been utilised to formulate the micro encapsules.
- When it was combined with dibutyl phthalate and polyvinyl pyrrolidone, it fabricated a smooth film that enhanced the tensile strength and elongation properties.
- Rosin has been utilised to develop a sustained-release microsphere of diclofenac sodium [4, 5, 23].

Honey Locust gum: This polymer is obtained from the plant *Gleditsia triacanthos*, which belongs to the family Leguminosae. Honey locust gum is collected from the seeds, which contain fat, proteins, fibers, and carbohydrates. 88% D-galacto-D-mannoglycan, 1% cellulose, 4% pentan, 1% ash, and 6% proteins are present in this polymer. Plant seed galactomannan is created of a 1-4 linked D-mannan backbone and a 1-6 linked galactomannan. Honey locust gum is not freely soluble in cold water; for achieving maximum viscosity, solubilization and hydration are mandatory [5, 17, 24, 25].

Uses:

- Pharmaceutically, it is applied to form different types of sustained-release devices.
- Loctus gum is used to prepare a matrix tablet of theophylline, which sustains the drug delivery of theophylline in a controlled manner [17, 24, 25].

Tamarind gum**:** *Tamarindus indica*, a member of the Leguminoseae family, is a biopolymer also known as Tamarind Kernel Powder (TKP). is present in the albumen of the kernel of the tamarind tree. It is polysaccharide in nature and consists of glucosyl, xylosyl, and galactosyl in a 3:2:1 ratio. Xyloglucan is present in this polymer, which is an important 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." Tamarind gum is not soluble in organic solvents, but it has an extremely viscous consistency with a wide pH tolerance and gelling capacity when placed in hot water [5, 26, 27, 28].

Uses:

- In the pharmaceutical industry, it is used as a thickening, stabilizing, binding, and gelling agent.
- This polymer has a large drug-retention capacity and tremendous thermal strength. For this reason, it was utilized as an excipient for a hydrophilic drug delivery system.
- This polymer is mucoadhesive, biocompatible, and non-carcinogenic in nature.
- Furthermore, it is employed for the preparation of hydrogels and spheroids.
- By using this polymer, different types of nasal preparation and mucoadhesive dosage forms for ocular purposes are prepared [5, 26, 27, 28].

Carrageenans: This natural polymer is obtained from seaweed, Irish moss, or carrageen. The source of this polymer is *Chondrus crispus*, belonging to the family Rhodophyceae**.** Water or aqueous alkali is used to extract the carrageenans, and they are retrieved by alcoholic precipitation followed by the freeze drying or drum-drying method. Carrageenans are sulfated polysaccharides consisting of anhydrogalactose and galactose. This polymer produces a gel-like or viscous consistency in the occurrence of proteins because of the formation of a complex among the amino acids and the carrageenans. Generally, carrageenan is classified into three different types [1, 4, 29].

Uses:

- Carrageenans are used as additives for preparing different types of liquid dosage forms, like antacids and emulsions.
- It acts as a suspending, emulsifying, and thickening agent in the pharmaceutical field.
- Carrageenans increase homogeneity in colloidal suspensions and give a stable form of an insoluble drug through emulsion preparation.
- It is a very good alternative to gelatine for preparing capsules.
- Different types of cosmetics, like creams, toothpaste, and lotions, are also prepared by using carrageenans.

- Some studies indicate that carrageenans are appropriate for the manufacturing of controlled-release tablets.
- Carragenans were also used to formulate hydrogel beads for controlling drug delivery, which increased the thermostability of the hydrogel matrix [1, 4, 30, 31, 32].

Okra gum: Okra gum is also recognised as Abelmoschus gum, collected from the plant *Abelmoschus esculentus*, which associate with family Malvaceae. This polymer is excavated from the fresh fruit, which is commonly known as laddish finger, a popular and easily available vegetable in India. Okra gum is polysaccharide in nature, composing L-galacturonic acid, D-galactose, and L-rhamnose acid, with some parts of glucose, mannose, xylose, and arabinose [5, 33].

Uses:

- ✓ In the pharmaceutical domain, it is utilised as a suspending agent and binding agent for tablet preparation. Okra gum is a bioadhesive, film-forming agent, and controlled-release polymer.
- ✓ Okra gum is also used as a binding agent for the preparation of paracetamol tablets.
- ✓ Okra polymer is implemented to prepare a floating delivery system which prolongs the gastric retention time [5, 33, 34, 35].

***Dillenia indica*:** This natural polysaccharide originated from the fruit of *Dillenia indica* Linnaeus, which comes under the family Dilleniaceae. It is also recognized by the elephant apple. It is widely available in India, particularly in Assam and the northeast.

In Assam, this fruit is used to prepare different types of pickles, sauces, jams, and jellies [36]. Water was utilized as a major solvent for the extraction process of the mucilage from the Dillenia fruit, and acetone was used to precipitate the mucilage [37].

Dillenia indica is a polysaccharide in nature which contains glycosides, steroids, flavonoids, and reduces sugar. Different chemical components like 3, 5, and 7-trihydroxy-3', 4'-dimethoxy flavone, betulinic acid, β-sitosterol, and stigmasterol are also present in this mucilage. *Dillenia indica* is also a very good source for pectin [38].

Uses:

- *Diallinia mucilage* is a promising excipient in the pharmaceutical domain. The dillenia mucilage has a very good mucoadhesive property, which was utilized to formulate a nasal gel containing domperidone and oxytocin [39, 40, 41].
- *Dillenia indica* is also applied as a polymer in prepared controlled-release formulations. Sharma *et al.* (2014 prepared a microsphere by using *Dillenia indica.* The prepared microsphere had excellent mucoadhesive properties, adhering for 3.5 hours [42].
- This polymer is also implemented as a sustain-release polymer for microsphere formulation [43].

Fenugreek Mucilage: This mucilage is acquired from the seed of *Trigonella foenum-graceum*, generally recognized as fenugreek, an herbaceous plant belonging to the family Leguminous. Fenugreek seeds consist of a high amount of mucilage, but this mucilage fails to dissolve in water. It has a viscous, tacky consistency with fluids. The fenugreek seed also swells up and becomes slippery when interact to fluids [44, 45]. Different types of sugar, like fructose, galactose, lactose, and mannose, are present in fenugreek mucilage. Other than sugar, proteins and amino acids like alanine, arginine, aspartate, cysteine, etc. are also present in this mucilage. The presence of different chemical groups like steroids, terpenoids, flavonoids, tannins, coumarins, alkaloids, and saponins is identified from the aqueous extraction of fenugreek mucilage [46, 47].

Uses:

- ❖ Fenugreek mucilage is utilized as an adjuvant in the pharmaceutical domain.
- ❖ It's exploited as a gelling agent, tablet binder, sustaining agent, emollient, and demulcent for different pharmaceutical preparations.
- ❖ It also has mucoadhesive properties [48].
- ❖ Fenugreek mucilage has the potential to be utilized as a suspending agent [49].
- ❖ Fenugreek mucilage acts as a promising super disintegrating agent which showed very good anti-inflammatory action along with diclofenac sodium [50].

- Fenugreek mucilage is also incorporated into the prepared beads. The optimized beads showed better mucoadhesive properties, which controlled the release of metformin over a period of time after oral administration [51].

***Hibiscus mucilage*:** It is collected from the leaves of *Hibiscus rosa-sinensis*, which belongs to the family Malvaceae. This plant is also known as China rose or Chinese hibiscus, which is a popular flowering shrub. Some chemical components, like methyl sterculate, methyl-2-hydroxysterculate, 2-hydroxysterculate malvate, cyclopropanoids, and rosasterol, are present in this shrub. The mucilage that is acquired from the fresh leafage of *Hibiscus rosa sinensis* consists of L-rhamnose, D-galactose, D-galactouronic acid, and D-glucuronic acid [5, 44].

Uses:

- In the pharmaceutical domain, it is applied as an emulsifying agent, disintegrating agent, sustained release agent, suspending agent, etc.
- Commonly, hibiscus leaves are served as traditional medicine to treat constipation, different types of skin diseases, and to reduce the burning sensation [5, 52].
- A dispersible tablet of aceclofenac is also formulated by using hibiscus mucilage, and it is applied as a super disintegrate agent, which shows better results than synthetic super disintegrants like Ac-di-sol [53].
- Hibiscus mucilage can be utilized as a sustained-release polymer [54].

Aloe Mucilage: Aloe mucilage originates from the leaf portions of *Aloe barbadensis Miller*, which associate with the family Liliaceae. The exudate was collected from the cells adjoining the vascular bundles and the central parenchyma tissue of this plant.

This exudate is a yellowish gel in nature and contains 1,8-dihydroxyanthraquinone derivatives together with their glycosides. Some scientists reported that partially acetylated mannan, or else acemannan, is the major polysaccharide, while others confirmed the pectic component as the prime polysaccharide. Arabinan, arabinorhamnogalactan, galactan, galactogalacturan, glucogalactomannan, galactoglucoarabinomannan, and glucuronic acid-containing polysaccharides are also present in the aloe gel. The major active component is aloin, which is a blend of barbaloin, isobarbaloin, aloe emodin, and resins [5, 27, 44].

Uses:

- It has been utilized for the formulation of different topical products like gel, ointment, etc.
- Aloe vera mucilage is very popular in the cosmetic industry.
- It is not only an excipient; aloe mucilage also serves as an anti-inflammatory and anti-diabetic agent [55, 56].
- It is also beneficial for the composition of tablets and capsules.
- It was established that aloe mucilage has the capability to retard drug release and has very good swelling properties [57].

Albizia gum: The major origin of albizia gum is the plant *Albizia zygia*, belonging to the family Leguminosae. The gum is collected from the trunk portion of this tree, and it is round, elongated, and of variable color, ranging from yellow to dark brown. It is composed of β-1-3-linked D-galactose units with a few ß1-6-linked D-galactose units. Albizia gum has the possibility of being a substitute for Arabic gum as a natural emulsifying agent considered in the food and pharmaceutical unit [27, 58].

Uses:

1. In the pharmaceutical domain, it is applied as a binding and suspending agent. This gum is also applied as a coating substance for drug delivery design that target the colon.
2. Albizia and khaya gums were studied as coating substances for direct compression colon-targeted tablets, where paracetamol and indomethacin were used as model drugs.
3. These gums were exploited as a coating material, which was broken down within the colon by microflora and Delivered the drug [59, 60].

Khaya gum: *Khaya senegalensis* & *Khaya grandifoliola*, both associated with the family Meliaceae, are the main sources for Khaya gum.

It is a polysaccharide where galacten is present at the 1, -3 linked β-D galactopyranosyl residues, which are concentrated in the inner chain. Khaya gum is also composed of both D-glucoronic and D-galatoronic acids. Different studies about Khaya gum indicate that it has many similarities to acacia gum. The methylation of the gum also proved that it was similar to acacia gum. Khaya gum is semi-transparent in nature [27, 61].

Uses:

1. In the pharmaceutical domain, it is exploited as a binding agent, suspending agent, and disintegrating agent, and in addition to other polymers, it shows good results for control or sustained release formulations.
2. Khaya gum was able to control the drug delivery for up to 5 hours [62].
3. Khaya gum has a potential binding property to formulate tablets [63].
4. Khaya gum exploited as a suspending agent at 0.2% w/v concentration[64].

Gum damar: It is derived from the plant *Shoreawiesneri*, which belongs to the family Dipterocarpaceae. Generally, it is whitish to yellowish in color. The major chemical component of gum damar is resin. It is composed of 40% alpha resin, which dissolves in alcohol, and 22% beta resin. Dammarolic acid is also exhibit in gum damar [27].

Uses:

- In the pharmaceutical domain, it is mainly used as an emulsifier, stabilizer, and binding agent for the manufacturing of dosages.
- It produces a water-resistant coating, which is very popular for forming dental accessories.
- Gum damar has the potential property to formulate a sustain-release matrix [65].
- Damar gum has a very good film-forming capacity for coating purposes [66].
- Gum damar can be utilised to formulate microparticles which use a microencapsulating agent for sustained delivery [67].

Hakea gum: It is the dried exudate collected from the plant *Hakea gibbose*, which belongs to the family Proteaceae. Hakea gum is composed of L-arabinose and D-galactose linked, as in gums that are acidic arabinogalactans. Glucuronic acid, arabinose, mannose, galactose, and xylose are the different sugars that are also present in the Hakea gum in a 12:43:32:5:8 ratio. Hakea gum is partially soluble in water [27, 68, 58].

Uses:

- Hakea gum is applied as a sustained-release & bioadhesive material in the development of buccal tablets [68].
- Hakea gum was implemented to formulate a buccal tablet of chlorpheniramine maleate [69].
- It was also perceived that hakea gum has potential properties for sustaining the delivery of drug molecules and also has bio adhesive and mucoadhesive properties [70].

Hupu gum: Hupu gum is also recognise as Kondagugu gum,is a natural polysaccharide obtained from the plant *Cochlospermum gossypium*, which associated with the family Bixaceae. Hupu gum is fabricated with sugars like galactose, arabinose, rhamnose, mannose-D glucose, D-glucouronic acid, and D-galactouronic acid. Tannin, protein, uronic acid, and some soluble fibers are also present on Hupu gum [27, 58, 71].

Uses:

1. Hupu gam is utilize for the medication of diarrhoea, dysentery, cough, pharyngitis, etc.
2. In the pharmaceutical industry, it is utilized as an excipient, which is applied as a substitute for gum tragacanth.
3. Hupu gum is utilized as a sustained-release polymer which can formulate a gastric floating delivery system.
4. It has very good emulsifying properties, even at very low concentrations [72].
5. Kondagogu gum used as a mucoadhesive polymer to formulate microspheres has potential mucoadhesive properties [73].

Tara gum: The source of tara gum is the endosperm part of the seed of *Caesalpinia spinosa*, which belongs to the family Fabaceaeor Leguminosae.

It is a natural polysaccharide that mainly consists of galactomannan, which is a dietary fibre. The major chemical composition is comparable to the main constituents of loctus bean gum and guar gum, which consist of a linear main chain of (1-4)-β-D-mannopyranose units with α-D-galactopyranose units attached by (1-6) linkages. Galactose and mannose are present in tara gum in a 1:3 ratio. Generally, tara gum is extremely viscous in nature, and it produces a very viscous solution even at very low (1%) concentrations [5, 27, 58].

Uses:

- In the pharmaceutical domain, it is utilized as an emulsifying component, a thickening agent, and a stabilizer in various formulations.
- Tara gum is also applied to formulate controlled-release emulsions and tablets.
- Tara gum is implemented as a controlled-released polymer which formulates a matrix tablet of ambroxol hydrochloride[74].
- Fernandes et al. (2021 demonstrated the application of tara gumin toothpaste for delivery of fluoride [75].

Moi gum: *Lannea coromandelica*, which is also recognized as an Indian ash tree belonging to the family Ancardiaceae, is the primary source of Moi gum. The aforementioned gum is acquired from various parts of these plants, including the leaves, fruits, stems, and bark. Generally, the color of fresh gum becomes yellowish white, but after drying, it changes into a dark color. Moi gum is a type of arabino-galactan, which is similar to gum Arabic. The major chemical constituent is D-galactose, which is present in 69.5%; 2.5% L-rhamnose; 11% L-arabinose; 17% 4-o-methyle uronic acid; and 1.38% protein, which is furthermore present in moi gum. Arabino-3,6-galactan is produced after the hydrolysis of the moi gum and mucilage [58, 76].

Uses:

- ✓ Although moi gum is not extensively used in the pharmaceutical field, researchers have conducted a number of studies to evaluate its properties.
- ✓ Moi gum is utilized as a microencapsulating agent to formulate polymers which sustain the drug released [77].

***Leucaena leucocephata* gum:** *Leucaena leucocephata* is the main source of this gum, which belongs to the family Fabaceae. The gum is present on the seeds and leaves of these plants. Mimosine is a toxic and non-protein component which is present in the seeds, bark, and leaves of Leucaena plants. Tanin and oxalic acid are exhibit in the seed. Generally, 25% gum is present on the seed, which is colourless to reddish brown in color. The pH of this gum is 4.2, which is acidic in nature. *Leucaena leucocephata* gum is moderately soluble in water but practically insoluble in semi-polar solvents like chloroform, acetone, ethanol, etc., but in the presence of water, this gum swells up to five times its original size. The viscosity is dependent on the concentration; it will increase with the concentration of gum [27, 78].

Uses:

- ❖ The seed gum of *Leucaena leucocephata* is applied as a suspending, emulsifying, disintegrating, and binding agent in the pharmaceutical domain.
- ❖ It’s used as an emulsifying agent, which showed better emulsifying properties compared to gum acacia [79].
- ❖ Verma et al. 2007 formulated a tablet applying ibuprofen as a standard drug for evaluating the disintegrating properties of Leucaena leucocephata gum [80].
- ❖ Other than the excipient, Leucaena leucocephata gum also has medicinal properties. This gum is very effective for treating stomach upset and as a contraceptive agent.
- ❖ The extract substance of the seeds has anti-diabetic, anti-microbial, and antioxidant properties [81].

Bhara gum: The bark portion of *Terminalia bellerica*, associated with the family Combretaceae, is the primary source of the bhara gum. Generally, it is yellowish in color.

Tannins are the major chemical compounds which are present in bhara gum in addition to ellagic acid, gallic acid, ß-sitosterol, ethyl gallate, chebulaginic acid, galloyl glucose, etc [82].

Uses:

- ✓ Bhara gum is utilized in the cosmetic industry as an emulsifier, demulcent, and purgative agent.
- ✓ Bhara gum is implemented as a sustained-release polymer which sustains drug delivery for 10 hours [83].

***Delonix regia* gum:** *Delonix regia* gum is procured from the seed part of the plant *Deloxia regia* in the family Leguminosae. It is also recognized by the flamboyant flame tree, flame tree, flame of the forest etc., but in India it is popular by the name of Gulmohor. The color of this gum is yellowish or reddish brown. Generally, this gum is thick and viscous in nature. *Delonix regia* gum is an inherent polysaccharide composed of protein, fiber, and crude fat. This gum is water-soluble in nature [84, 85].

Uses:

1. In the pharmaceutical sector, it is applied as a binding and disintegration agent for the manufacturing of tablets.
2. In higher concentrations, it is exploited as a polymer in order to develop sustained-release formulations [86].
3. *Delonix regia* gum also has the binding capacity to formulate tablets, and in lower concentrations, it is balanced between binding and disintegration properties when the fastest disintegration is required [87].
4. *Delonix regia* gum has the potential to be applied a suspending agent [88].
5. Adetogun *et al.* 2007 established that *Delonix regia* gum may be applied as a binding agent as a substitute for tragacanth and gum acacia [89].

Almond gum: It is procured from the wood *Prunus amygdalus* or *Amygdalus communis,* which belongs to the family Rosaceae. This gum is a clear extrusion from the injured parts of the trunk and branches of the sweet almond tree. This gum is typically white, red, or yellow in color and is water-soluble. Almond gums contain aldobionic acid, L-galactose, L-arabinose, D-mannose, and other sugars, but galactose and arabinose are the primary sugars found in almond gum. Protein, fat, and different minerals like sodium, potassium, magnesium, calcium, and iron are present in this gum. Furthermore, it is water-soluble in nature [58, 90, 91].

Uses:

1. In the pharmaceutical sector, almond gum is applied as a suspending, emulsifying, thickening, adhesive, and stabilizing agent.
2. This gum is also applied as a controlled and sustained-release polymer
3. Almond gum was used to formulate the indomethacin sustained-release matrix tablet, which had potential for increasing therapeutic activity as well as reducing the dosing frequency [92].
4. As per the study, 2% w/v almond gum binder showed the optimal result as a binding component in tablets [93].

***Cassia tora* mucilage:** The source of this gum is the seeds of *Cassia tora*, belonging to the family Caesalpiniaceae. *Cassia tora* mucilage is popularly known by the name of charota. It is translucent, amorphous, and soluble in water. Generally, Cassia toramucilage is soluble in cold water, but it forms a colloidal dispersion in warm water and is insoluble in acetone, ethanol, methanol, etc. The major chemicals are polysaccharides like glucomannon and galactomannon, and different chemicals like cinnamaldehyde, tannins, coumarins, mannitol, and resins are also present in *Cassia tora* gum. Some essential oils like eugenol, pinene, etc. and volatile oils like cassia oil are present in cassia tora gum [58, 94, 95].

Uses:

- ❖ This mucilage has the potential properties of a suspending and binding agent. Several studies were done to evaluate this property and reported that cassia tora gum works as a binding and suspending agent in pharmaceutical preparations [58].

- *Cassia tora* acts as an economic binding agent with an 8% w/v concentration, and in this specific concentration, it was almost equivalent to the 8% w/v guar gum mucilage [96].
- *Cassia tora* also used as super disintegrating agent to formulate orodispersible tablet of Rosuvastatin [97].
- Tora mucilage's suspending ability is evaluated by comparing it to that of tragacanth, gum acacia, and gelatine. After evaluation, the degree of susceptibility can be arranged in the following order: Cassia tora> Tragacanth gum> Acacia gum> Gelatine [58].

TABLE 1: RECENT ADVANCEMENT OF BIOPOLYMER IN PHARMACEUTICAL DOSAGE FORM DESIGN

Name of biopolymer	Application in dosage form design
Locust Bean gum	Antibacterial Wound Dressing Film[98].Super disintegrating agent in Oro dispersible tablet [99]. Fast disintegrating tablet[100]. Matrix Tablet[101,] Hydrogel [102], Mucoadhesive Buccal Tablets[103], Niosome loaded Hydrogel for topical apllication[104,] Nanoparticls[105],
Karaya gum	Floating drug delivery system[22], Sustain release matrix tablet[101], Vaginal Film [106], Hydrogel[107], Mucoadhesive tablet[108], Microparticles[109], Effervescent Floating Matrix Tablets[110],
Honey locust gum	Microspheres [111], Sustain release matrix tablet[25], Microparticle [112].
Tamarind gum	Nanoparticles[113,114], Hydrogel[115,116,] Coating materials for gauze[117], Ocular delivery[118,119], Microcapsules [120], Mucoadhesive Tablet[121], Emulsifier in nanoemulsion[122], Disintegrating agent[123,]
Moringa gum	Nanogel[124], Encapsulating Agent [125,126], Nanoparticles[127], Hydrogel[128], Nanometric carrier, [129], colon specific drug delivery system [130], Binding agent for tablet formulation[131],
Okra gum	Nanoliposom[132], Nanoparticles [133, 134, 135], Mucoadhesive Tablet[136], Binding agent[137], Film formingagent[138].
Dillienia indica gum	Nasal Gel[39,40,41,] Microparticles[42,43], Microbeads[139], Nanoparticles [140,141], Buccal patches[142.]
Fenugreek mucilage	Matrix tablet [48], Suspending agent [49], Super disintegrating agent [50], Mucoadhesive beads [51], Hydrogel [143], Buccal Patches[144], Bio adhesive tablet for sustain release[145], Nanoparticulate system for ocular drug delivery system[146].
Hibiscus mucilage	Disintegrating agent[53, 147], Wound healing activity [148], Mucoadhesive Beads [149], Sustain release matrix tablet[150],
Aloe Mucilage	Matrix tablet[57], Hydrogel[151,152], Microencapsulating agent[153], Binding agent[154], Bioactive Film[155],
Albizia gum	Coating Materials for tablet[59, 60], Oral Dissolvable Films[156], Microbeads[157], Binding agent [158],
Khaya gum	Binding agent[63], Suspending agent[64], Oral Dissolvable Films[156], Colon targeted drug delivery system (Tablet)[158], Matrix tablet[159]
Gum damar	Film forming agen[66], Microencapsulating agent[67], Sustain release tablet[160], Nanocapsules[161], Sustained release matrix[162],
Hakea gum	Sustain release and mucoadhesive property[70],
Hupugum	Mucoadhesive Microcapsules[73], Microcrystals[163], Solid mixture of poorly water soluble drug[164], Colon targeted drug delivery system[165],
Tara gum	Controlled delivery matrix[74], Toothpaste[75], Thickening agent in emulsion preparation[166], Microencapsulating agent[167], Nanocrystal film[168],
Moi gum	Microsphere [77],
Leucaena leucocephatagum	Emulsifying agent[79], disintegrating agent[80], Sustain release carrier[169],
Bharagum	Microsphere [83]
Delonix regia gum	Binding agent for formulation of tablet[86,88], Suspending agent[87], Mucoadhesive nanostructure lipid carrier[170], sustained release tablet[171], pH and time dependent colon targeted drug delivery system[172],
Almond Gum	Sustain release matrix tablet[92], Binding agent for tablet [93], Bio composite Film[173], Sustained release pellets [174], Nanoparticles [175].
Cassia tora mucilage	Binding agent[96], encapsulating agent[176].

CONCLUSION: In the last few decades, natural polymers have drawn huge attention from research scientist due to their tremendous implementation in drug delivery approach. In the present scenario, natural polymers are considered essential ingredients which play a critical role in developing different innovative approaches for delivering the drug into the targeted area. Biopolymers are more acceptable because of their numerous advantages over synthetic and semi-synthetic polymers. But the selection of a natural polymer is an important criterion for incorporating it into the drug delivery approach. In the polymer and drug interaction study, the degradation pattern of the polymer is also playing a crucial role in selecting a polymer as the carrier of a drug delivery technique. From the above discussion, it can be concluded that several natural polymers have a diverse role in the pharma industry in different prospects as well as drug delivery systems. It was established that natural polymers have been efficiently utilized as an excipient in the manufacturing of dosage forms and play a crucial role as a carrier-mediated drug delivery system. Numerous polysaccharides obtained from plant origins have been prospective criteria as carriers for sustained or controlled-release drug delivery systems. So, there will be a huge scope for research scientists to develop innovative approaches by using Biopolymers as carriers to deliver the drug in a controlled or sustained manner.

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