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A Thorough Analysis of Natural Polymers as Functional Excipients in Contemporary Pharmaceutical Formulations

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Abstract

Natural polymers' innate biocompatibility, biodegradability, and environmental friendliness have made them attractive functional excipients in contemporary pharmaceutical formulations. This study emphasizes the importance of natural polymers-such as starch, cellulose, alginate, chitosan, gelatin, and xanthan gum-derived from plant, animal, and microbial sources in the creation of cutting-edge drug delivery methods. These polymers have a variety of physicochemical characteristics, including swelling, viscosity, gel-forming capacity, and mucoadhesion, all of which are essential for regulating drug release, boosting stability, and increasing bioavailability. Natural polymers are appealing substitutes for synthetic excipients in pharmaceutical applications because they provide benefits such lower toxicity, sustainability, and cost-effectiveness. The categorization, origins, and functional roles of natural polymers in biological, pharmacological, and environmental applications are also covered in the review. Their use in targeted delivery, hydrogels, nanoparticles, controlled and sustained drug delivery systems, and gene delivery systems is highlighted. Additionally, recent advancements including the invention of stimuli-responsive polymers, chemical modification, and the integration of nanotechnology have significantly enhanced their functionality and broadened their applications. Despite its advantages, challenges like unpredictability, microbial contamination, and regulatory difficulties require standardization and advanced processing techniques. All things considered, natural polymers provide a versatile and durable foundation for the development of innovative drug delivery systems, improving patient compliance and therapeutic outcomes in modern pharmaceutical sciences.

Keywords: Mucoadhesion, biocompatibility, controlled drug delivery, pharmaceutical excipients, natural polymers, and biodegradability

1. Introduction

Excipients are inert ingredients added to pharmaceutical formulations to increase stability, ease medication distribution, and boost dosage form performance. Excipients are essential to the quality, safety, and effectiveness of pharmaceutical medicines even if they lack therapeutic activity. They support a number of formulation activities, including boosting stability, regulating drug release, increasing drug solubility, and streamlining production procedures. Binders, disintegrants, lubricants, stabilizers, emulsifying agents, and film-forming agents are examples of frequently used excipients that have a big impact on the final properties of pharmaceutical formulations. [1, 2, 3, 4] Because of their consistent physicochemical characteristics and ease of production, synthetic polymers have long been used extensively as medicinal excipients. Concerns about long-term safety, environmental effect, and toxicity have been brought up by the growing use of synthetic materials. Since many synthetic polymers come from petroleum-based sources, their biodegradability and biocompatibility may be restricted. Furthermore, some synthetic excipients may accumulate in biological systems or have unfavorable side effects, which is why scientists are looking on safer and more sustainable substitutes. [5, 6]

In the field of pharmaceutical sciences, naturally produced polymers have garnered a lot of interest recently as possible alternatives to synthetic excipients. Natural polymers are macromolecules with distinct physicochemical and biological characteristics that come from plant, animal, or microbial sources. Examples include proteins like collagen and gelatin, as well as polysaccharides like starch, alginate, pectin, and xanthan gum. These materials' functional qualities—such as swelling behavior, gel formation, viscosity increase, and film-forming ability—have led to extensive research into their suitability for a range of medicinal applications. [5, 7, 8]

The outstanding biocompatibility of natural polymers is one of their main benefits. These substances often interact well with biological tissues and provoke few immunological or inflammatory reactions because many of them come from biological sources and mimic elements found naturally in living things. Furthermore, natural polymers are biodegradable, which means that they can be broken down by physiological or enzymatic processes into innocuous byproducts that the body can readily expel. This characteristic reduces long-term toxicity and keeps polymer residues from building up in biological systems. [9, 6, 10] Natural polymers are becoming more and more popular as pharmaceutical excipients due to their safety and affordability. Many natural polymers are economically appealing for large-scale pharmaceutical manufacture because they are non-toxic, renewable, and easily accessible from natural resources. Their eco-friendliness and sustainable origin also complement the growing emphasis on environmentally conscious and green pharmaceutical development worldwide. [11, 12, 13]

The significance of natural polymers in pharmaceutical sciences has increased due to the development of contemporary drug delivery technologies. Mucoadhesive drug delivery systems, hydrogels, nanoparticles, targeted drug delivery platforms, and controlled-release formulations all make extensive use of these polymers. They can control drug release profiles, increase drug stability, and boost bioavailability because to their special physicochemical characteristics. As a result, natural polymers are increasingly being used in cutting-edge pharmaceutical technologies intended to improve patient compliance and therapeutic outcomes. [14, 15, 16] This review's objective is to give a thorough overview of natural polymers that are utilized as functional excipients in contemporary pharmaceutical formulations. In addition to discussing their origins, categorization, physicochemical characteristics, and various functions in drug delivery systems, the article highlights current developments and potential directions for the creation of pharmaceutical formulations based on natural polymers.

2. Natural Polymer Classification

Macromolecules derived from biological sources, including plants, animals, and microbes, are known as natural polymers. These polymers, which are mostly made up of proteins, polysaccharides, or their derivatives, have drawn a lot of interest in the field of pharmaceutical sciences due to their various functional characteristics, biodegradability, and biocompatibility. Plant-derived polymers, animal-derived polymers, and microbial polymers are the three main groups into which natural polymers utilized in pharmaceutical formulations can be generally divided based on their source and origin. Pharmaceutical uses are determined by the unique physicochemical properties of each class. [7, 11, 17, 18]

2.1 Natural Polymers Derived from Plants

Polymers derived from plants are a common natural material utilized in medicinal compositions. Polysaccharides derived from plant sources, including seeds, fruits, leaves, and plant exudates, make up the majority of their composition. These polymers are widely utilized as medicinal excipients because of their affordability, safety, and availability. Rice, potato, and maize starch is frequently used in tablets as a diluent, disintegrant, and binder. As binders and controlled-release agents, cellulose derivatives such as hydroxypropyl methylcellulose and microcrystalline cellulose are utilized. Guar gum, acacia, and pectin are examples of plant gums and mucilages that serve as stabilizing, thickening, and suspending agents. Brown seaweed alginate is also utilized for controlled medication delivery systems and gel formation. [18, 19, 20, 21, 22] Figure 1 illustrates polymers derived from plant sources, highlighting naturally occurring polysaccharides such as cellulose, starch, and gums that are widely utilized in pharmaceutical and biomedical applications. Figure 2 represents polymers of animal origin, including proteins and polysaccharides such as collagen, gelatin, and chitosan, which are known for their biocompatibility and biodegradability. Figure 3 depicts polymers produced by microbial sources, emphasizing biopolymers such as xanthan gum, dextran, and alginate, synthesized through controlled fermentation processes and valued for their consistency and functional versatility.

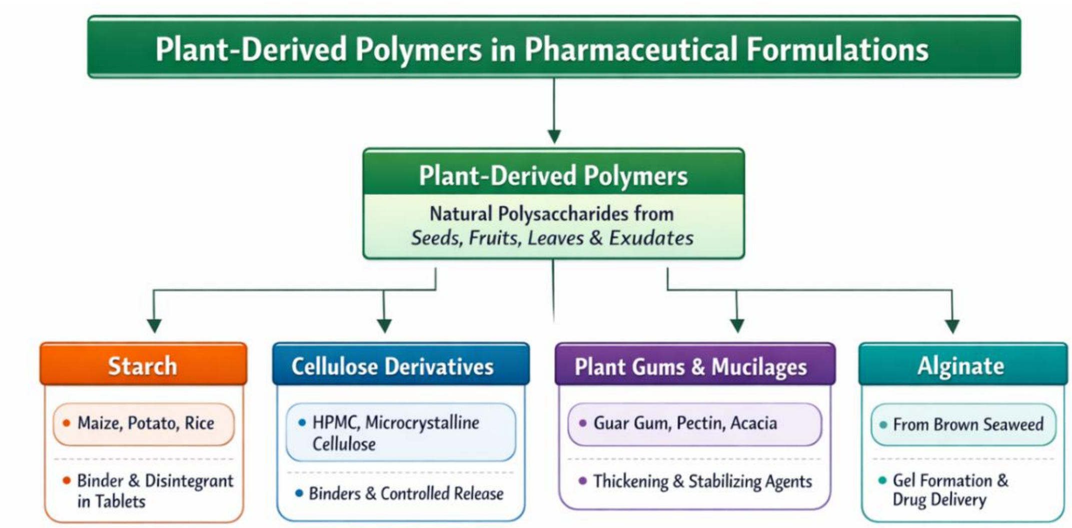

Figure 1: Plant derived polymers

2.2 Natural Polymers Derived from Animals

Important natural materials used in biomedical and pharmacological applications are polymers generated from animals. These polymers have good biocompatibility and biodegradability and are primarily proteins or polysaccharides derived from animal tissues. Because of its mucoadhesive properties and capacity to improve drug absorption, chitosan-which is derived from the chitin found in shrimp and crab shells-is utilized extensively. It is used in mucoadhesive drug delivery systems, nanoparticles, and microspheres. Gelatin is frequently used as a stabilizer and in hard and soft capsules. It is made from collagen found in animal skin and bones. Collagen is utilized in tissue engineering and wound treatments. Nonetheless, immunogenicity, pathogen transmission, and moral dilemmas are among the worries. [23, 24, 6, 25, 26]

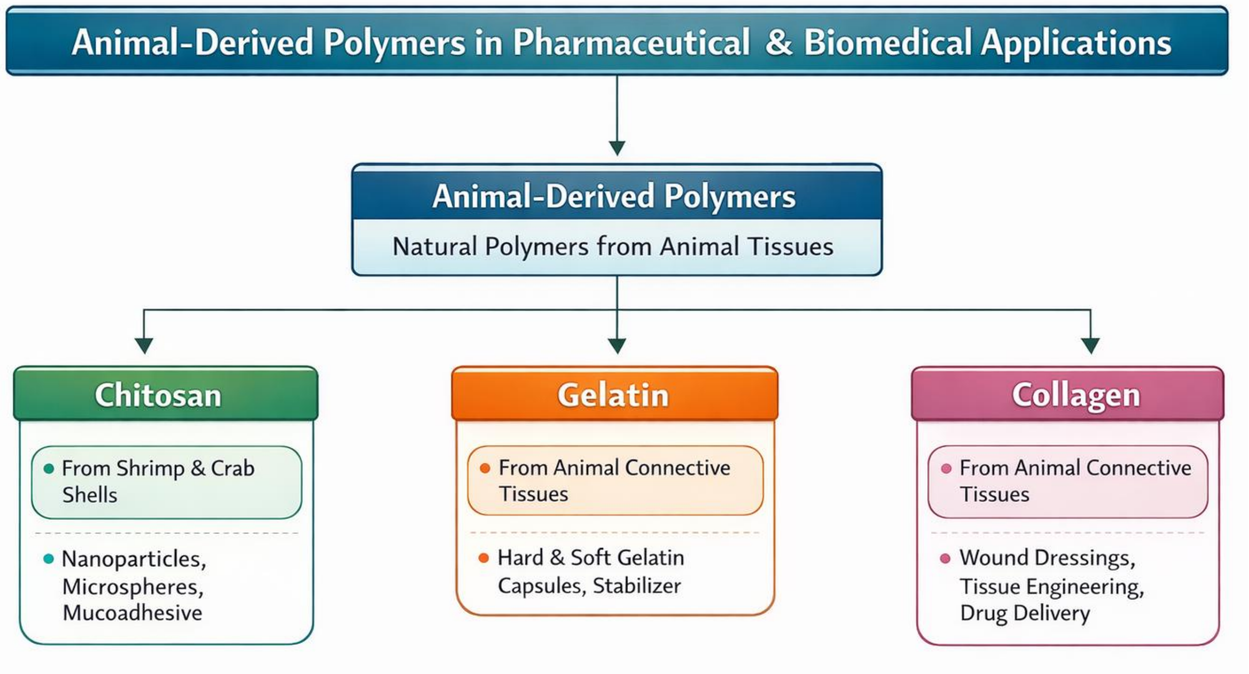

Figure 2: Animal derived polymers

2.3 Microbial Natural Polymers

Natural polymers made by microorganisms like bacteria, fungus, and algae are known as microbial polymers. Because they may be manufactured using controlled fermentation procedures that guarantee uniform quality, purity, and reproducibility, they are being utilized more and more in pharmaceutical applications. [27, 28] The bacteria Xanthomonas campestris produces xanthan gum, one of the most often utilized microbial polymers. High-molecular-weight polysaccharide xanthan gum is renowned for its exceptional viscosity, stability, and tolerance to temperature and pH variations. It is frequently utilized in pharmaceutical suspensions, emulsions, and topical formulations as a stabilizer, thickening agent, and suspending agent. [29] Another important microbial polymer is dextran, produced by bacteria such as *Leuconostoc mesenteroides*. Dextran is a branched polysaccharide widely used in biomedical applications, including plasma volume expanders, drug delivery systems, and controlled-release formulations. [30] Another important microbial polymer with good film-forming capabilities is pullulan, which is made by the fungus Aureobasidium pullulans. It is frequently utilized in oral dissolving films, edible films, and capsule shells. [31] All things considered, microbial polymers offer a number of benefits, such as high purity, reliable physicochemical characteristics, scalable production, and economical synthesis using fermentation technology. [32, 33]

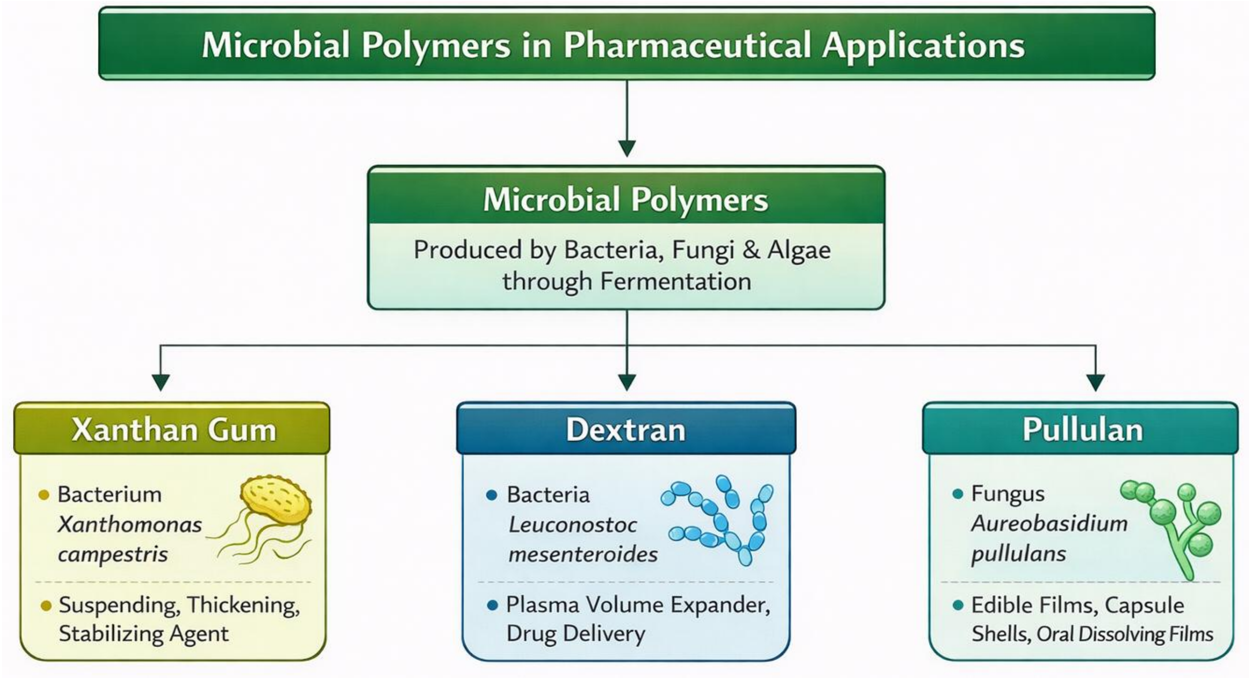

Figure 3: Polymers made by microorganisms

3. Physicochemical Characteristics and Their Impact on Drug Release

Since their physicochemical characteristics dictate how they behave in drug delivery systems, natural polymers are crucial to pharmaceutical formulations. These characteristics affect the dosage form's overall performance, release rate, and drug stability. [34, 14] Table 1 below discusses some of the most significant characteristics influencing medication release and formulation.

Table 1: Properties of natural polymers affecting drug release [35, 36, 37, 14, 38, 39, 40, 41]

Physicochemical Property	Description	Effect on Drug Release / Formulation
Molecular Weight	Natural polymers' mechanical strength, viscosity, and capacity to form matrices are all influenced by their molecular weight. Stronger and denser polymer networks are formed by high molecular weight polymers.	High molecular weight polymers create robust matrices and thicker gels that prolong medication release and slow drug diffusion. Drugs are released more quickly when low molecular weight polymers disintegrate more quickly.
Solubility	The degree to which a polymer dissolves or hydrates in biological fluids depends on its solubility. Gums and polysaccharides are examples of hydrophilic polymers that easily react with water to generate viscous solutions.	Because they dissolve quickly, highly soluble polymers may release the medication quickly. Diffusion barriers created by poorly soluble polymers limit medication release and slow fluid penetration.
Swelling Capacity	The tendency of polymers to absorb water and increase in volume when exposed to watery conditions is known as swelling. When natural polymers come into touch with gastrointestinal fluids, they swell.	Drug diffusion is controlled by swelling, which creates a gel barrier surrounding the dose form. By creating a thicker diffusion barrier and preserving tablet integrity, a higher swelling capacity typically inhibits drug release.
Viscosity	Molecular weight and polymer concentration have an impact on viscosity, which is the resistance of polymer solutions to flow. Viscous gels can be formed by hydrated polymers.	Thicker gel layers made of high-viscosity polymers limit drug diffusion and extend drug release. Faster drug molecule movement and release are made possible by low-viscosity polymers.
Biodegradability	The capacity of polymers to be degraded by biological or enzymatic processes within the	While preventing the body from accumulating polymer residues, the gradual breakdown of

	body is known as biodegradability. Natural polymers are frequently both biocompatible and biodegradable.	the polymer matrix permits controlled and prolonged medication release.
Mucoadhesion	The capacity of some polymers to stick to mucosal tissues—such as the buccal, nasal, or gastrointestinal mucosa—through electrostatic or hydrogen bonding interactions is known as mucoadhesion.	Adhesion to mucosal surfaces increases the drug's residence time at the absorption site, improving bioavailability and allowing for regulated drug delivery.
Gel-Forming Ability	When certain natural polymers are hydrated or subjected to particular ions or pH levels, they can gel and form a three-dimensional polymer network.	Drug delivery is made possible by gel formation, which traps drug molecules inside the polymer matrix and releases them gradually through erosion and diffusion processes.

4. Pharmaceutical, Biomedical and Environmental Applications

Because of their many uses, natural polymers are essential as pharmaceutical excipients. They are essential to contemporary medication formulation because of their capacity to function as stabilizers, disintegrants, binders, and controlled release agents. Natural polymers are anticipated to supplant numerous synthetic excipients in the future due to the increased interest in sustainable and biocompatible materials. However, sophisticated processing and standardization methods are required to handle issues like unpredictability and stability. [42] Tables 2, 3, and 4 illustrate the use of natural polymers in pharmaceutical, biomedical, and environmental applications, respectively.

Table 2: Pharmaceutical Applications [43, 6, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60]

S. No.	Natural Polymer	Source	Pharmaceutical Application	Mechanism / Role	Key Benefit
1	Chitosan	Chitin (crustacean shells)	Drug delivery systems, nanoparticles, mucoadhesive systems	Cationic nature enables interaction with cell membranes and mucosa	Enhanced absorption, targeted delivery
2	Alginate	Brown algae	Controlled release systems, hydrogels, wound dressings	Gel formation in presence of divalent ions	Sustained drug release, biocompatibility
3	Gelatin	Animal collagen	Capsules, microspheres, tissue engineering	Film-forming and biodegradable matrix	Safe, biodegradable carrier
4	Starch	Plants (corn, potato)	Tablets (binder, disintegrant), controlled release	Swelling and gel formation	Cost-effective, biodegradable
5	Cellulose & derivatives	Plant cell walls	Tablet coating, controlled release formulations	Film-forming and matrix-forming properties	Improved stability and release control
6	Pectin	Plant cell walls (fruits)	Colon-targeted drug delivery, *in-situ* nasal gel	Degraded by colonic bacteria	Site-specific drug release
7	Guar gum	Plant seeds	Controlled release, colon delivery	Swelling and enzymatic degradation	Sustained and targeted delivery
8	Dextran	Microbial (bacteria)	Plasma expanders, drug carriers	Water-soluble polysaccharide, forms conjugates	Improved drug stability and circulation
9	Hyaluronic acid	Animal connective tissue	Targeted delivery, ophthalmic and injectable systems	Binds to specific cell receptors (CD44)	Target specificity, biocompatibility
10	Collagen	Animal connective	Tissue engineering, wound	Mimics extracellular	Promotes cell growth

		tissue	healing	matrix	and regeneration
11	Isabgol husk	Seed husk of *Plantago ovata*	Bulk laxative, controlled drug delivery, disintegrant, suspending agent	Swells in presence of water forming a mucilaginous gel; increases intestinal bulk and promotes peristalsis; also acts as a hydrophilic matrix for drug release	Natural, safe laxative; improves bowel movement; biodegradable and biocompatible; useful in sustained drug release formulations
12	Gellan Gum	Produced by bacterium *Sphingomonas elodea* (microbial polysaccharide)	Controlled drug delivery, in situ gelling systems (ophthalmic, nasal	Forms gels in the presence of cations (ion-activated gelation); undergoes sol–gel transition	Excellent gelling ability at low concentration

Table 3: Biomedical Applications [43, 6, 44, 45, 46]

Application Area	Role of Natural Polymers	Examples	Key Benefit
Drug Delivery Systems	Carrier for drugs and biomolecules	Alginate, Chitosan, Gelatin	Controlled release, protection of drugs
Tissue Engineering	Scaffold formation	Collagen, Gelatin, Hyaluronic acid	Supports cell growth and tissue regeneration
Wound Healing	Dressing materials, hydrogels	Chitosan, Alginate	Promotes healing, maintains moisture
Regenerative Medicine	Structural and functional repair	Collagen, Fibrin	Mimics natural tissue structure
Stem Cell Applications	Cell encapsulation and support	Alginate, Hyaluronic acid	Enhances cell proliferation and differentiation
Nanocarriers	Drug/gene delivery vehicles	Natural polymer nanoparticles	Improved bioavailability and targeting

Table 4: Environmental Applications [43, 6, 44, 45, 46]

Application Area	Role of Natural Polymers	Examples	Key Benefit
Bioplastics	Alternative to synthetic plastics	Starch, Polyhydroxyalkanoates	Biodegradable, reduces plastic pollution
Food Packaging	Eco-friendly packaging materials	Polysaccharides, Proteins	Sustainable and safe packaging
Water Treatment	Removal of pollutants/heavy metals	Chitosan, Cellulose derivatives	Adsorption of contaminants
Agriculture	Soil conditioning, controlled release fertilizers	Natural polymer composites	Improves soil quality, reduces chemical use
Environmental Remediation	Degradation of pollutants	Biopolymers	Eco-friendly cleanup processes

5. Natural Polymers in Advanced Drug Delivery Systems

Because of their low toxicity, biocompatibility, and biodegradability, natural polymers are essential to advanced drug delivery systems (ADDS). The article emphasizes the widespread usage of polymers such hyaluronic acid, chitosan, polysaccharides, and arginine-based polymers to improve the effectiveness of medication delivery. Natural polymers provide hydrogels or matrix systems that control drug release through swelling and diffusion mechanisms, making controlled and sustained drug delivery one of the main uses. This lessens the frequency of dose and helps maintain steady medication levels. In targeted drug delivery, natural polymers are also crucial. By interacting with cell membranes, polymers such as chitosan and substances high in arginine enhance drug absorption at certain locations. Particularly in the treatment of cancer, this focused strategy improves therapeutic efficacy and minimizes adverse effects. Drug delivery methods based on nanoparticles are another important use. Natural polymer-based nanoparticles enhance solubility and bioavailability while encasing medications and shielding them from deterioration. Additionally, these systems are able to pass through biological barriers like the blood-brain barrier. Cationic natural polymers combine with DNA or RNA in gene delivery systems to produce complexes that shield them from enzymatic breakdown and promote cellular uptake. They are therefore promising gene therapy carriers. Additionally, natural polymers have mucoadhesive qualities that enable medication formulations to stick to mucosal surfaces such as buccal or nasal tissues. This increases absorption and extends the duration of medication residence. They are also utilized in biomimetic drug delivery systems, which improve circulation time and targeting efficiency by imitating natural biological processes. Table 4 lists the use of natural polymers in sophisticated drug delivery systems. [61, 62]

Table 4: Natural polymers in advanced drug delivery systems [61, 62, 63, 64]

S. No.	Application Area	Natural Polymers Mentioned	Mechanism / Role	Key Outcome / Advantage
1	Controlled & Sustained Drug Delivery	Polysaccharides, Chitosan	Swelling, gel formation, controlled diffusion of drug	Maintains therapeutic drug levels, reduces dosing frequency
2	Targeted Drug Delivery	Arginine derivatives, Chitosan	Electrostatic interaction with cell membranes, receptor-mediated targeting	Site-specific delivery with reduced side effects
3	Nanoparticle Drug Delivery	Chitosan, Polysaccharides	Encapsulation of drugs into nanocarriers	Improved bioavailability and protection from degradation
4	Gene Delivery Systems	Arginine-based polymers, Chitosan	Formation of complexes with DNA/RNA (cationic interaction)	Enhanced cellular uptake and protection of genetic material
5	Mucoadhesive Drug Delivery	Chitosan	Adhesion to mucosal surfaces via ionic interaction	Increased residence time and improved absorption
6	Biomimetic / Bio-inspired Delivery Systems	Natural biopolymers (general)	Mimic biological systems (cells/pathogens) for drug transport	Prolonged circulation and immune evasion
7	Cancer Drug Delivery	Biocompatible natural polymers (e.g., chitosan-based systems)	Carrier systems for anticancer drugs like doxorubicin	Targeted tumor delivery with reduced toxicity
8	Drug Delivery Across Biological Barriers	Polysaccharide-based nanocarriers	Carrier-mediated transport across barriers (e.g., blood–brain barrier)	Improved drug delivery to difficult sites like brain
9	Hydrogel-Based Delivery Systems	Natural polymer hydrogels	Formation of biodegradable gel matrices	Safe and controlled release in implants and localized delivery
10	Hybrid Drug Delivery Systems	Natural + synthetic polymer combinations	Combine biocompatibility (natural) + stability (synthetic)	Enhanced mechanical strength and delivery efficiency

6. Recent Advances and Innovations

Significant progress has been made in the extraction, modification, and use of natural polymers in biomedical and environmental domains, according to recent studies. The biodegradability, biocompatibility, and sustainability of natural polymers like polysaccharides, proteins, and biopolyesters are drawing more and more attention. [65, 66, 5] The creation of polymers produced from trash and biomass is one significant development. These days, alternative raw materials for the synthesis of polymers include renewable feedstocks and agro-industrial wastes. By reducing reliance on fossil fuels and promoting a circular economy, this strategy improves the sustainability of polymer production. [66, 67] Modification of natural polymers using chemical and physical methods is another significant innovation. Mechanical strength, thermal stability, and functional qualities are improved via procedures like blending, grafting, and cross-linking. Natural polymers may now compete with synthetic polymers in cutting-edge applications including packaging, tissue engineering, and drug delivery thanks to these alterations. [66, 68]

Another significant development is the development of stimuli-responsive (smart) natural polymers. These polymers allow for targeted and regulated drug administration by reacting to environmental stimuli like pH, temperature, or ionic strength. In precision medicine, where site-specific and controlled medication release is crucial, these devices are especially helpful. [69, 66]

Additionally, the usefulness of natural polymers has been greatly improved by the integration of nanotechnology. The creation of natural polymer-based nanocarriers, nanocomposites, and nanosystems enhances medication encapsulation, bioavailability, and targeted delivery. These nanoscale systems are frequently used in biomedical applications, such as regenerative medicine and anticancer therapy. [70, 71] The creation of films, membranes, coatings, and hydrogels based on biopolymers is another noteworthy discovery. Wound healing, tissue engineering, food packaging, and environmental remediation are just a few of the many uses for these materials. Their performance in biomedical applications is improved by their capacity to imitate biological structures and interact with living tissues. [71, 72] Their performance has also been enhanced by the creation of hybrid and multifunctional materials that combine natural polymers with additional materials (such as synthetic polymers or nanoparticles). These hybrid systems' improved mechanical characteristics, stability, and multifunctionality increase their potential uses in cutting-edge technology. [66, 73]

7. Regulatory and Safety Considerations

7.1. Regulatory Framework

Natural polymers that are employed as drug delivery vehicles or pharmaceutical excipients must adhere to strict regulations set by organizations like the US FDA, EMA, and CDSCO (India). Many commonly used polymers (such as cellulose, starch, and alginate) are categorized as Generally Recognized As Safe (GRAS), which aids their regulatory acceptability. These polymers are frequently assessed in accordance with excipient guidelines. [74, 75] Identification and characterization, purity and impurity profiling, microbiological limits, contamination control, and batch-to-batch consistency are all common components of regulatory review. Because their composition is dependent on biological sources, climate, and extraction techniques, natural polymers present a significant problem due to their intrinsic variability. Compared to synthetic polymers, this unpredictability makes standardization and regulatory clearance more difficult. [76, 77, 78] Furthermore, in order to guarantee safety and reproducibility, regulatory rules for natural products place a strong emphasis on accurate documentation of source materials, processing techniques, and quality control procedures. [77, 7]]

7.2. Safety Evaluation Requirements

(a) Biocompatibility and Toxicity

Because they are quickly digested by the body and share structural similarities with biological macromolecules, natural polymers are typically regarded as safe. [76, 77] Nevertheless, acute and chronic toxicity tests, cytotoxicity and genotoxicity testing, and immunogenicity assessment are still required to prove safety. According to recent research, many polymers derived from plants or seeds have high safety profiles and low toxicity when tested in accordance with OECD norms. [80, 6]

(b) Degradation and Metabolite Safety

The biodegradation behavior of natural polymers is one of the main safety issues. The safety of the degradation products must also be evaluated, even though they break down into simpler molecules. Degradation should produce non-toxic, readily removed metabolites; the rate of degradation must be regulated to meet therapeutic requirements, and intermediate intermediates (such as oligomers) must be assessed for toxicity. The polymer and its breakdown products must be safe for human use and the environment, according to regulatory bodies. [81, 82]

(c) Microbial Contamination

Because of their biological origin, natural polymers are very vulnerable to microbial contamination. Particularly for oral and parenteral preparations, this is a significant regulatory concern. Microbial limit tests, sterilization and preservation methods, and good manufacturing practices (GMP) are important safety precautions. When polymers are extracted from microbial or plant sources in uncontrolled settings, the risk of contamination increases. [76, 77, 83]

(d) Presence of Impurities and Heavy Metals

Impurities including pesticides, heavy metals absorbed from soil, and leftover proteins can be found in natural polymers. Pharmacopeial standards set acceptable limits for these pollutants. Because plants may absorb metals from the environment, heavy metal contamination is especially dangerous. [76, 77, 84]

7.3. Environmental and Ecotoxicological Safety

Natural polymers are frequently marketed as eco-friendly substitutes for manufactured polymers. They are appropriate for sustainable pharmaceutical development since their biodegradability lessens their long-term environmental impact. Regulatory agencies, however, are increasingly requiring life-cycle analysis for sustainability, assessment of environmental exposure during manufacturing and disposal, and study of the ecotoxicity of degradation products. Since degradation is not always instantaneous and may result in intermediate chemicals, even biodegradable polymers need to have their effects on ecosystems assessed. [82, 85, 86]

Conclusion

Because of their low toxicity, biocompatibility, and biodegradability, natural polymers have become useful functional excipients in contemporary pharmaceutical formulations. These polymers, which come from plant, animal, and microbial sources, have a variety of physicochemical characteristics that allow them to be used as stabilizers, binders, and controlled-release agents in drug delivery systems. Their use in cutting-edge systems including hydrogels, nanoparticles, and targeted delivery platforms has greatly enhanced patient compliance, drug stability, and efficacy. Furthermore, natural polymers promote environmentally friendly and sustainable pharmaceutical development, which is in line with the current worldwide tendencies toward green chemistry. However, issues like microbiological contamination, variability, and regulatory concerns need to be handled with appropriate standardization and quality control procedures. All things considered, natural polymers offer a promising substitute for artificial excipients and are anticipated to become more significant in the creation of novel, secure, and efficient pharmaceutical formulations in the future.

Authors Contributions:

Author's name	Contribution
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Mahesh Prasad	Conceptualization
Shashi Shankar	Literature Search & Data Collection
Anant Prakash Pandey	Literature Search & Data Collection
Abhishek Kumar Singh	Literature Search & Data Collection
Shiv Kumar Srivastava	Writing – Original Draft

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