World Journal of Pharmaceutical Science and Research
www.wjpsronline.com

Review Article

ISSN: 2583-6579
SJIF Impact Factor: 6.916
Year - 2026
Volume: 5; Issue: 3
Page: 394-405

THIS ARTICLE PRESENTS ON: OVERVIEW OF VARIOUS POLYMERS UTILIZED IN PHARMACEUTICAL DRUG DELIVERY SYSTEMS

Rachana V. More*, Nida N. Mulla, Sanjay K. Bais

Fabtech College of Pharmacy, Sagola, Dist-Solapur Maharashtra, India.

Article Received: 20 January 2026 || Article Revised: 10 February 2026 || Article Accepted: 2 March 2026

***Corresponding Author: Rachana V. More**
Fabtech College of Pharmacy, Sagola, Dist-Solapur Maharashtra, India.
DOI: https://doi.org/10.5281/zenodo.19049477

How to cite this Article: Rachana V. More, Nida N. Mulla, Sanjay K. Bais (2026) THIS ARTICLE PRESENTS ON: OVERVIEW OF VARIOUS POLYMERS UTILIZED IN PHARMACEUTICAL DRUG DELIVERY SYSTEMS. World Journal of Pharmaceutical Science and Research, 5(3), 394-405.

ABSTRACT

The present review highlights the significance of polymeric materials in the pharmaceutical delivery of therapeutic substances. Various dosage formats—such as tablets, transdermal patches, strips, films, semi-solid formulations, and powders — use polymers as essential components. These materials serve as the structural foundation of drug-delivery technologies because they regulate how the drug is released from the formulation. Biodegradable polymers have gained considerable interest since they break down into harmless units and, importantly, allow for a consistent and predictable release rate from controlled-release systems. Natural polymers provide additional benefits due to their availability, safety, and ability to offer defined release kinetics and desirable physicochemical traits, making them suitable candidates for drug-delivery platforms. Because of their inherent suitability bio-origin materials tissues, biodegradable macromolecule have become widely utilized in medical and pharmaceutical fields. In healthcare applications, macro molecule substances are often employed as implantable materials that must function reliably over extended periods. Such advancements help enhance therapeutic efficiency while reducing adverse effects and discomfort for patients. The primary function of a polymer in a release system shield medicine from the biological environment extend its release duration, thereby improving the drug's stability. Drug release from polymeric matrices occurs through mechanisms such as diffusion, polymer erosion, or swelling. This review also covers the features and performance of plant-based and mucoadhesive polymers commonly incorporated into modern drug-delivery technologies.

KEYWORDS: Polymeric materials, formulation aids, artificial polymers, plant-sourced polymers, prolonged release, modified release, adhesive drug delivery.

INTRODUCTION

Contemporary drug-delivery practices have progressed through multiple developmental stages, beginning with the introduction of polymer-based carrier systems designed to control the location and timing of therapeutic release. These advancements enabled the creation of pulsatile delivery platforms, long-acting depot implants, and other systems capable of administering drugs in a spatially and temporally regulated manner. Although conventional dosage forms have historically served as the foundation of medical treatment, the emergence of potent and highly specific biological therapeutics has dramatically increased the need for more intelligent and responsive release technologies. Foundational contributions by researchers such as Heller, Langer, and Peppas emphasized that innovations in chemical engineering are essential for advancing drug-delivery science, recommending that self-adjusting, feedback-controlled mechanisms should become standard features of next-generation platforms. As a result, modern delivery devices must overcome inherent limitations of traditional systems while meeting the rising demand for adaptive, precise, and efficient approaches required for today's powerful bio-therapeutic agents.[1] Several approaches have been explored to achieve prolonged gastric retention, such as incorporating low-density or floating polymers that remain buoyant on the stomach's contents, as well as using mucoadhesive polymers that attach to the gastric mucosa. These strategies help maintain within the staying in the stomach for an extended timeframe, enhancing drug absorption improving therapeutic effectiveness.[2] Although numerous macromolecules—such as hypromellose, carbopol, and chitosan—have been evaluated for gastroretentive applications, achieving consistent and dependable gastric retention continues to be a major challenge. Recent technological progress has introduced advanced approaches, including formulation modifications using combination techniques, vector-assisted drug transport, polymer-based encapsulation systems, and delivery pumps strategically placed within specific regions of the gastrointestinal tract. These innovations strengthen drug-targeting accuracy and improve the overall therapeutic response. Because biodegradable polymers are safe for biological use and naturally break down into non-toxic components, they are now widely incorporated into medical and pharmaceutical applications. In clinical settings, such polymeric materials are frequently engineered as long-acting internal devices that maintain functionality over extended periods, thereby reducing side effects, simplifying treatment, and enhancing patient outcomes. Within pharmaceutical formulations, polymers play several key roles, functioning as binding agents in tablets, modifying viscosity in liquid preparations, and forming protective coatings that influence release profiles, shield drugs from degradation, and improve palatability. Collectively, these materials support essential purposes such as taste masking, controlled or targeted delivery, increased stability, and improved biological performance.

2. Function of Polymeric materials in pharmaceutical drug delivery system

- **Medicinal Tablet**

Polymeric materials play several essential roles in pharmaceutical drug-delivery systems, particularly in the formulation of medicinal tablets. For many years, these High-molecular-weight materials are commonly incorporated as essential formulation aids in standard fast-acting oral preparations. They help simplify manufacturing steps and ensure that the active ingredient remains stable throughout storage.[3] Microcrystalline cellulose is widely used employed as a bulking agent preparation of potent, low-dose tablets, serving as an carbohydrate excipient materials. Cellulose and starch derivatives function as disintegrants, as they swell when water reaches the surface, prompting the tablet to or to separate into smaller parts and thereby which enhancing the available surface region of the active ingredient, enhances solubilization Before compression, polymers such as synthetic water-soluble polymer Cellulose ether polymer and hydroxypropyl methylcellulose (hypromellose) serve as binding materials to improve particle cohesion, flow properties, and tablet compaction. In certain cases, a non-functional polymer film coating is applied to the dosage form. Although it does not modify the drug's release profile, this coating helps prevent chemical degradation, masks unpleasant tastes, and improves the appearance of the final product without interfering with therapeutic performance.

- **Capsule**

Many individuals prefer capsules over tablets, particularly when dealing with ingredients that are difficult to compress or when there is a need to mask the unpleasant taste of certain medications. Capsules also help improve the bioavailability of specific therapeutic agents. In fast-dissolving tablet formulations, several polymer-based excipients are used to increase bulk and enhance processing. Historically, animal-derived protein polymer animal-derived protein polymer has served as the main substance used manufacturing soft one hard two capsule shells. However, in recent years, hydroxypropyl methylcellulose (HPMC) has become a widely accepted non-gelatin alternative for producing hard capsules, offering greater stability, improved compatibility with sensitive drugs, and suitability for vegetarian or dietary-restricted patients.[4]

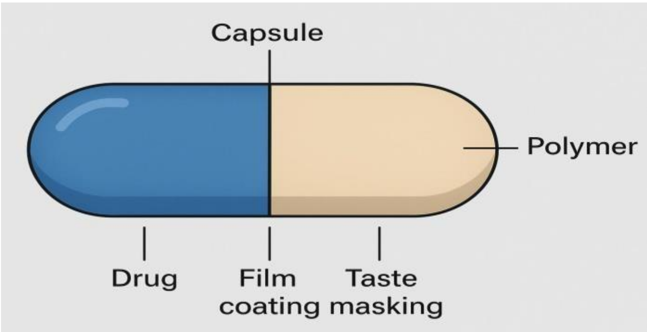


Figure no. 01: Capsule.

- **Extended-delivery drug systems**

Commonly used water-insoluble polymers in ER formulations include ammonium methacrylate copolymers like ethyl cellulose and cellulose ester polyvinyl-derived substances such as polyvinyl acetate.[5] The permeability of Eudragit differs due to the changing fractions Nitrogen-containing cationic groups with exhibiting lower aqueous medium permeability, making it suitable for slower release profiles. Gastro-retentive dosage forms (GRDFs) represent an effective approach for Attaining sustained-release medication patterns by retaining the formulation within the stomach for prolonged durations. These systems are designed to release the drug gradually in situ while remaining in the gastric environment. To achieve gastric retention, multiple strategies have been explored, including use of decrease's density or floating polymers that remain buoyant fluids and bioadhesive to mucosal surfaces that adhere to the gastric mucosa. Polymers such as hydroxypropyl methylcellulose (HPMC), carbopol, and chitosan have been widely investigated; however, ensuring consistent and reliable gastric retention remains a significant challenge.Once the dosage form dissolves within the stomach, the released drug slowly passes into the small intestine, where absorption primarily occurs. Gastro-retentive The system functions especially advantageous for dosage that exhibit optimal absorption gastrointestinal tract. Unlike conventional extended-release systems—which continuously drug amount form travels through entire GI GRDFs maintain the medication in the region of highest absorption for an extended period. This enhances bioavailability, produces a more stable plasma concentration–time profile, and improves overall therapeutic performance.[6] Cellulose(HPMC),carbopol, and chitosan, it is still difficult achieve consistent and dependable

- **Drug release**

There are several uses for polymers in practically every drug delivery method. Because of their adaptability, systems with targeted, sustained, or regulated delivery profiles can be developed.[7]

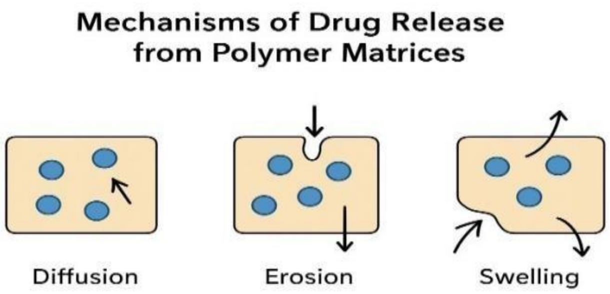


Figure no. 2: Drug Release.

Controlled Diffusion Release

In systems In systems where the drug is released through diffusion active compound moves outward through a polymer membrane or matrix. The diffusion rate depends on properties such as the drug's solubility, the polymer's pore structure, and its molecular weight. For example, ethyl cellulose matrix tablets release the drug slowly as it passes through the fine channels present within the polymer framework.[8]

Controlled Release by Erosion

The encapsulated medication is released when the polymer progressively breaks down or dissolves in erosion-controlled systems. For instance, the medication is gradually released when biodegradable polymers such as PLGA break down into lactic and glycolic acid.[9]

Controlled Release

Of Swelling When biological fluids are present, hydrophilic polymers swell to create a gel layer that allows the drug to diffuse gradually. For instance, in sustained release tablets, HPMC and carbopol swell in aqueous medium to regulate medication release.[10]

Controlled Osmotic Release

In osmotic systems, the drug solution is forced through an orifice by pressure created when water enters through a semi-permeable polymer membrane. For instance, cellulose acetate membranes are used by OROS (Osmotic Pump Systems) to achieve zero-order[11] release kinetics.

Smart (stimulus-responsive) polymers

To precisely regulate medication release, "smart" polymers react The system is designed to respond to fluctuations in pH, temperature, or enzymatic activity in its surroundings. For instance, medications are released in the colon rather than the stomach via pH sensitive Eudragit polymers.[12]

2. Polymers classes

Polymers can be classified in several ways depending on their interaction with water, polymerization process, chemical structure, origin, and biostability.

- **Depending on Water affinity**

Water-repellent polymers

Examples: (PVC)

Hydrophilic (Water-loving) Polymers

Absorb water; may swell

Examples: PEG (Polyethylene glycol), HPMC (Hydroxypropyl methylcellulose)

Hydrogels (PVP)

Can absorb large amounts of water and swell

Examples: Polyvinylpyrrolidone (PVP)

- **Polymers are classified by their synthesis method.**

Chain-growth polymers are produced through the continuous addition of individual monomer units.

Examples: Alkane polymers, polyethylene, polypropylene

Condensation (Step-Growth) Polymers

Formed with elimination of small molecules (H_2O, HCl, etc.)

Examples: Polyesters, polyamides, polystyrene

- **Categorized by polymerization pathway**

Chain-reaction polymerization

Fast growth of chains Free radical, ionic, or coordination-type reactions.

Step Polymerization (Step Expansion)

Monomers react stepwise to form long chains Slower than chain polymerization.

- **As per the structural chemistry**

C–C Backbone macro highly stable

Examples: Polyethylene, polystyrene

Inorganic Polymers

Backbone contains non-carbon atoms

Examples: Silicones (Si–O backbone)

Natural Polymer

Occur naturally in plants/animals

Examples:

Proteins: Collagen, keratin, albumin

Carbohydrates: Cellulose, starch

- **According to their sources**

1. biopolyers Obtained from various biological origin

Examples already listed above

Synthetic Polymer

Examples: Polyesters, polyamides, PVC

➢ **Based on Biostability**

Biostable Polymers

Do NOT degrade inside the body Used for long-term implants

Biodegradable Polymers Break down inside the body.

Examples: PLA, PGA

Non-Biodegradable Polymers

Remain intact, do not break down

Example: PVC

- **Utilizing Polymers in Various Drug delivery Methods**

There are several uses for polymers in practically every drug delivery method. Because their adaptability, systems with targeted, sustained, or regulated delivery profiles can be developed.[13]

Systems for Oral Drug Delivery

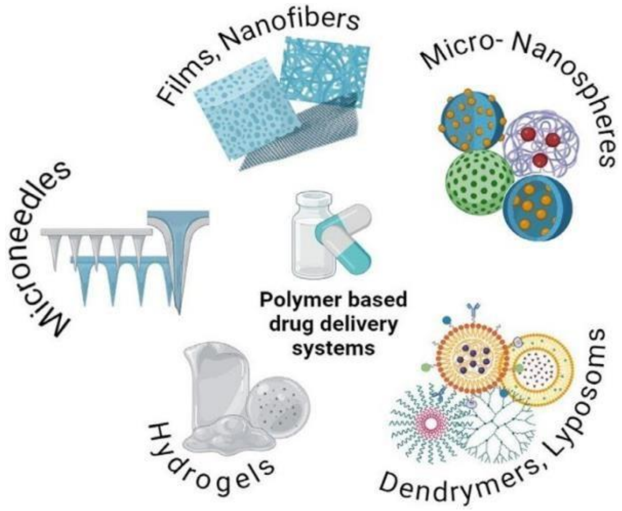


Figure no. 3: system for oral drug delivery.

The more popular practical mode of adsorption is oral. Tablets, capsules, Formulations designed for sustained or controlled drug release over time.are made from polymers such HPMC, ethyl cellulose, and carbopol. For instance, metformin pills' HPMC matrices guarantee sustained glucose control. To stay in the stomach longer, floating pills contain polymers like PVA and sodium alginate (gastroretentive systems).[14]

Drug Delivery Systems

For the Eyes Rapid tear outflow poses a challenge to ocular systems. The viscosity and contact time of ocular formulations are improved by polymers such chitosan, carbopol, and hydroxypropyl cellulose. For instance, carbopol is used by timolol eye drops to prolong their therapeutic impact.[15]

Systems for Parenteral Drug Delivery

Biodegradable polymers (PLGA, PLA) are utilised in parenteral systems to create implants or injectable microspheres with continuous release. For instance, PLGA is used in Leuprolide Acetate Microspheres (Lupron Depot®) to provide sustained distribution for one month.[16]

Targeted and Managed Medication

Administration Nanoparticles and liposomes for site-specific delivery, like tumour targeting, are made from polymers like PEG and PLGA. As an illustration, PEGylated liposomal doxorubicin (Doxil®) enhances tumour targeting while lowering adverse effects.[17]

Table 1: Examples of Polymer-Based Drug Delivery Systems.

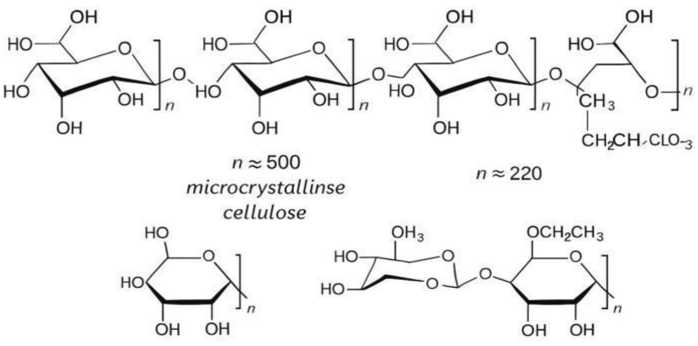
Route	Polymer Used	Example/Use
Oral	HPMC, Ethyl cellulose	Controlled release tablets
Transdermal	PVA, Eudragit	Nicotine patch
Ocular	Carbopol, HPC	Eye gels
Nasal	Chitosan	Peptide delivery
Parenteral	PLGA, PLA	Injectable microspheres
Targeted	PEG, PLGA	Nanoparticles liposomes

- **Natural Plant Polymers Applied in Pharmaceutical Delivery**

Macromolecule a crucial the polymers play a significant role in creating controlled-release drug delivery formulations and are widely incorporated into solid, liquid, and semi-solid formulations. Bio-derived and man-made polymers are widely incorporated extensively explored pharmaceutical use inexpensive, Easily accessible, biocompatible materials capable of undergoing alteration, generally, and highly biocompatible.[18]

Cellulose

The main polysaccharides present in plant cell The primary components of plant cell walls include cellulose, hemicelluloses, and pectin are often pharmaceuticals as excipients tablet fillers. Microcrystalline cellulose is an advanced form of Frequently employed as either an adhesive agent or a filler in tablet formulations. in tablet production, suitable for both direct compression and wet granulation. It is made by partially breaking down high-grade Fibrous cellulose exposed to HCl solution to obtain particles that lack structure. Research also indicates that HPMC forms a sturdier gel matrix than PEO, giving it greater stability and better performance inside the gastrointestinal tract by resisting destructive forces during drug release.[19]



a) *powedered cellulose (n ≈ 500) or microcrystalline cellulose*

Figure 4: Chemical structure of a) powdered cellulose ($n \approx 500$) or microcrystalline cellulose ($n \approx 220$) and b) hydroxyl propy

Pectin

Pectin refers to a group of intricate carbohydrate polymers that naturally occur in the structural layers of expanding. The located and middle lamella and within the secondary walls of tissues such as woody xylem and fiber cells. Due to its versatile physicochemical properties, pectin has gained significant importance as a pharmaceutical additive. It has been incorporated into numerous formulation designs, including the film layer targeted medicine administration [20] systems in combination combined ethyl cellulose, as well as in microsphere and particulate carriers intended for ophthalmic drug administration.

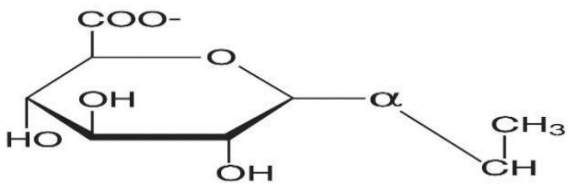


Figure no 5: Molecular composition of pectin.

Insulin

“Inulin resists digestion in the stomach and small intestine,of the GIT tract and therefore reaches the colon, where It is broken down by the bacteria present in the colon. When combined with Eudragit® RS, highly polymerised inulin has been utilised to produce degradable films specifically intended for colonic delivery, capable of withstanding gastric and intestinal conditions. Another investigation prepared film formulations containing inulin along with different grades of Eudragit polymers. The study revealed that a blend Ammonia methacrylate copolymers, Eudragit RS and RL demonstrated enhanced expansion and permeability in environments compared to parts of the gastrointestinal tract.

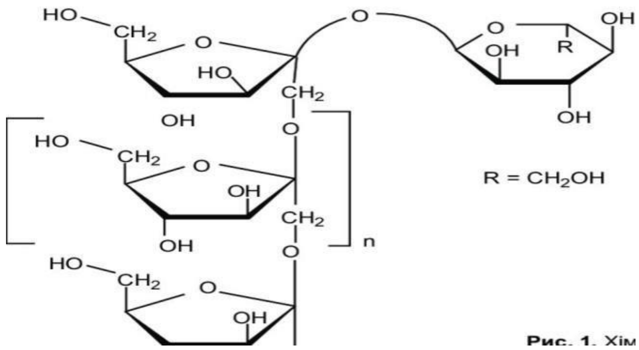


Fig. 6: Three-Dimensional Structure of Insulin Peptide Hormone.

Natural anionic polysaccharides

Seaweed-derived alginic polymers have been extensively studied for their ability to stabilize emulsions in various formulations thickening and despersion stabilizer-binding materials. Their ability to form gels arises from the interaction of guluronic acid units with multivalent ions as calcium or aluminum. This ionic interchain linking results in the absorption of strong gel networks that can be engineered into various dosage formation.

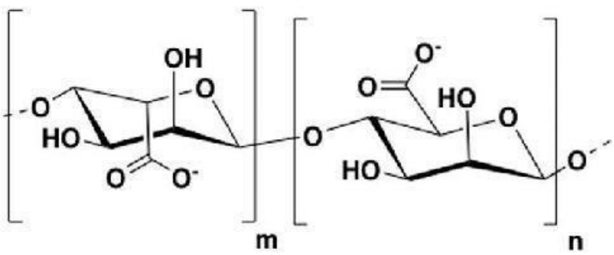


Figure 7: Chemical Structures of Natural Anionic Polysaccharides.

Marine polysaccharides gum

Extensive research has been carried out on alginates because of their usefulness in stabilizing emulsions, improving suspension, binding tablet ingredients, and aiding tablet breakup. Gel formation occurs when guluronic acid blocks of the alginate chain interact with ions of higher valency—particularly calcium or aluminum. Through this cross-linking process, durable gel structures are produced, which can be further developed into various pharmaceutical forms, including matrix systems, thin films, bead-like particles, pellets, as well as micro- and nano-sized delivery units.

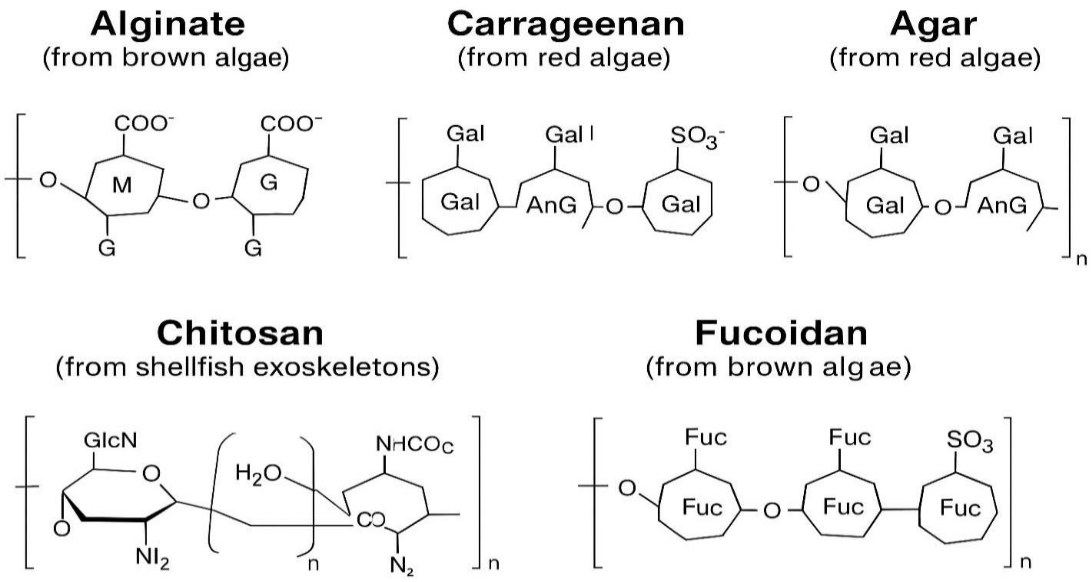


Figure 8: Chemical Structures of Marine Polysaccharide Gums.

Gum cluster bean plant

Cluster bean gum is increasingly recognized as an affordable and adaptable polymeric excipient in controlled-release oral drug delivery systems due to its susceptibility to enzymatic degradation. present colon, particularly suitable for targeted colonic drug release. Additionally, guar gum functions as an emulsion stabilizer, Serves as a cohesive excipient in tablets and as a viscosity-enhancing agent in formulations in topical formulations such as creams and lotions.[21]

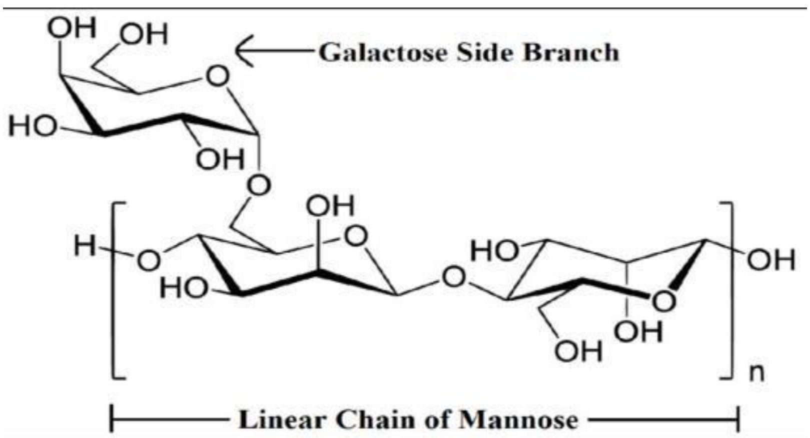


Figure 9: The main backbone consists of β-1, 4-linked D-mannose units.

- **The pharmaceutical drug delivery system's polymers**

➢ **Colophony**

As a naturally occurring coating biomaterial, rosin and its modified forms have been widely investigated for roles such as tablet film coating and microencapsulation in pharmaceutical preparations. Beyond medical use, it is incorporated into dental protective coatings, gum bases, and various cosmetic items.[22] Microcapsules of spherical shape can be generated from rosin using a phase-separation process involving solvent evaporation. When combined with polyvinyl pyrrolidone and 30% w/w dibutyl phthalate, rosin produces a smooth, flexible film with superior stretching capability and mechanical strength.

➢ **Chitosan and Chitin**

Chitina natural mucopolysacharide, consists of repeating 2-Acetamido-2-deoxyglucopyranoseunits and hydrolyzed by the enzyme . When chitin undergoes acetylation, it yields chitosan linear polymer containing This structure consists of alternating β-(1→4)-linked D-glucosamine and N-acetyl-D-glucosamine monomer units in a random arrangement. A key and feature that makes chitosan valuable in drug-deli erythromycin systems is its ability to gain a positive charge in acidic environments, and which occurs due to protonation of its amino groups. In contrast, at neutral or alkaline pH, chitosan becomes uncharged and therefore remains insoluble.[23]

➢ **Zein**

Zein, a protein that dissolves in alcohol, originates from the endosperm of maize and is commonly recovered as a byproduct during corn processing. For decades, it has been applied as an edible protective layer in both pharmaceutical dosage forms and food products. Due to its strong film-forming properties, zein offers an economical natural alternative to the Man-made and chemically modified natural polymers are used in rapid-release formulations. Film layer commonly employed-extrusion-based drug delivery formulations.[24]

➢ **Collagen**

This protein plays a central role in maintaining the structural integrity of body tissues. Research has highlighted its potential in developing bioprosthetic implants, restoring damaged organs through tissue engineering, supporting multiple surgical techniques, enhancing cosmetic products, and functioning as a carrier in therapeutic delivery systems[25].

➢ **Polysaccharides**

In green plants, starch serves as the chief energy-storage carbohydrate, accumulating primarily within seeds and underground plant organs. It is present as starch granules, whose distinctive dimensions, forms, and amylose-to-amylopectin ratios vary according to the species. Many types of starch are pharmaceutically approved, including those derived from potatoes, wheat, rice, and corn. To enable oral delivery of protein-based or peptide drugs, researchers have formulated microcapsules containing both proteins and protease inhibitors. These mixed-wall Starch–BSA microcapsules were synthesized through interfacial polymerization using terephthaloyl chloride as the cross-linking agent.

- **Polycaprolactone**

Polycaprolactone (PCL) is a biodegradable aliphatic polyester This polymer exhibits a very low glass transition temperature around −60 °C and a melting point near 60 °C, and it is prepared via ring-opening polymerization of ε-caprolactone typically using stannous octanoate as a catalyst. One of its major industrial uses is in the manufacture of specialty polyurethanes. Incorporation of PCL into polyurethane formulations enhances their resistance to moisture,[26] oils, a variety of solvents, and chlorinated environments.

- **Polymeric orthoesters**

These polymers have been refined through multiple stages of synthetic development to allow polymerization at ambient temperatures without producing any condensation-related byproducts. They contain hydrolytically cleavable bonds that are hydrophobic and weak under acidic conditions but stable in alkaline environments. Their breakdown occurs mainly The polymer degrades via surface erosion, and the degradation rate can be adjusted by incorporating acidic or alkaline excipients into the formulation.[27]

CONCLUSION

In modern pharmaceutics, polymers serve as indispensable components due to their adaptable characteristics and wide functional range. They make it possible to design formulations that deliver drugs in controlled, extended, targeted, or environment-responsive manners. Natural and man-made polymers—like chitosan, HPMC, PLGA, and PEG—have contributed significantly to improving the potency, stability, and absorption of numerous therapeutic agents. Furthermore, the development of smart, degradable, and nanoscale polymeric materials has reshaped drug delivery by enabling precision targeting and stimulus-activated release, ultimately enhancing treatment effectiveness while minimizing unwanted reactions.

With continuous innovation in polymer technology and material sciences, new pathways are emerging for individualized treatments, including 3D-printed medications, nano-delivery carriers, and responsive implantable systems. Consequently, polymers will remain central to creating advanced drug delivery platforms that ensure safe, efficient, and user-friendly therapeutic solutions.

REFERENCE

1. Heller J, Langer R. Design of controlled release systems for drug delivery and chemical engineering approaches. Adv Drug Deliv Rev, 1990; 4(2): 1–15.
2. Streubel A, Siepmann J, Bodmeier R. Gastroretentive drug delivery systems. Expert Opin Drug Deliv, 2006; 3(2): 217–33.
3. Thoorens G, Krieg F, Leclercq B, Carlin B, Evrard B. Microcrystalline cellulose, a direct compression binder in a quality by design environment — a review. Int J Pharm, 2014; 473(1–2): 64–72.
4. Ku MS, Li W, Dulin W, Donahue F, Cade D, Benameur H. Application of hydroxypropyl methylcellulose (HPMC) in capsules. Drug Dev Ind Pharm, 2011; 37(7): 735-45.
5. Gupta P, Thakur N, Jain R, Banweer J, Jain S. Osmotic pumps: A review. Int J Compr Pharm, 2011; 2(8): 1-8.
6. Awasthi R, Kulkarni GT. Decades of research in drug targeting to the upper gastrointestinal tract using gastroretentive drug delivery systems: a systematic review. Expert Opin Drug Deliv, 2016; 13(5): 621-39.
7. Li X, Jasti B. Design of Controlled Release Drug Delivery Systems. New York: McGraw-Hill; 2006.
8. Siepmann J, Siepmann F. Mathematical modeling of drug delivery. Int J Pharm. 2012; 453(1): 12-24.

9. Makadia HK, Siegel SJ. Poly lactic-co-glycolic acid (PLGA) as biodegradable controlled drug delivery carrier. Polymers. 2011; 3(3): 1377-97.
10. Colombo P, Bettini R, Santi P, De Ascentiis A, Peppas NA. Swellable matrices for controlled drug delivery. J Control Release, 2000; 64(1-3): 43-51.
11. Verma RK, Krishna DM, Garg S. Formulation aspects in the development of osmotically controlled oral drug delivery systems. J Control Release, 2002; 79(1-3): 7-27.
12. Chourasia MK, Jain SK. Pharmaceutical approaches to colon targeted drug delivery systems. J Pharm Sci., 2003; 6(1): 33-66.
13. Li X, Jasti B. Design of Controlled Release Drug Delivery Systems. New York: McGraw-Hill; 2006.
14. Streubel A, Siepmann J, Bodmeier R. Gastroretentive drug delivery systems. Expert Opin Drug Deliv, 2006; 3(2): 217-33.
15. Saettone MF, Salminen L. Ocular inserts for controlled drug delivery. Pharmaceutics, 1995; 11(1): 103–15.
16. Cleland JL, Daugherty A, Mrsny R. Emerging protein delivery systems. Curr Opin Biotechnol, 2001; 12(2): 212-9
17. Barenholz Y. Doxil®—the first FDA-approved nano-drug. J Control Release, 2012; 160(2): 117-34.
18. Singh R, Shah SH. Role of polymers in drug delivery. Int J Pharm Sci Rev Res, 2011; 7(2): 1-10.
19. Colombo P, Bettini R, Santi P, De Ascentiis A, Peppas NA. Analysis of the swelling and release mechanisms from drug delivery systems with emphasis on HPMC matrices. J Control Release, 1995; 34(3): 157-168.
20. Van den Mooter G, Maris B, Samyn C, Augustijns P, Kinget R. Inulin-Eudragit matrices for colonic drug delivery. J Pharm Sci, 1999; 88(8): 799-807.
21. Mandal S, Mandal SD. Guar gum in drug delivery applications. Int J Biol Macromol, 2014; 67: 748-756.
22. Sinko PJ, Singh Y. Martin’s Physical Pharmacy and Pharmaceutical Sciences. 7th ed. Philadelphia: Lippincott Williams & Wilkins; 2011.
23. Rinaudo M. Chitin and chitosan: properties and applications. Prog Polym Sci, 2006; 31(7): 603–632.
24. Shukla R, Cheryan M. Zein: the industrial protein from corn. Ind Crops Prod, 2001; 13(3): 171–192.
25. Lynn AK, Yannas IV, Bonfield W. Antigenicity and immunogenicity of collagen. J Biomed Mater Res B., 2004; 71(2): 343–354.
26. Woodruff MA, Hutmacher DW. The return of PCL—applications in biomaterials. Prog Polym Sci., 2010; 35(10): 1217–1256.
27. Heller J, Barr J. Poly (ortho esters): synthesis, characterization, and applications. Adv Drug Deliv Rev., 2002; 54(7): 855–865.