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Review Paper

A Review on Natural Polymers Used in Controlled Drug Delivery System

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ABSTRACT

Polymers serve a critical function as additives in any lozenge configuration. They influence drug liberation and must be resilient, cost-effective, synergistic, and non-hazardous. They are broadly categorized as organic polymers and man-made polymers.Man-made and organic-based compostable polymers have garnered significantly more focus in recent decades owing to their inherent roles in sectors associated with ecological preservation and the maintenance of biological wellness.Compostable materials are utilized in farming, medication containment, and diverse sectors. In modern times, there has been a rise in fascination regarding degradable polymers. Two categories of compostable polymers can be identified: manufactured or organic polymers. Manufactured polymers are broadly employed in clinical inserts and equipment because they can be molded into diverse forms.Organic polymers are primarily complex carbohydrates; therefore, they are biologically compatible and devoid of any adverse reactions. In this section, we have examined various organic polymers, their benefits over manufactured polymers, and the function of organic polymers in engineering innovative drug transport systems. Drug transport systems are often termed medicinal preparations intended for the transport of curative agents. The pharmacodynamic and pharmacokinetic behaviors of healing agents within our anatomy are explicitly connected to their physicochemical characteristics, such as Log P, dissolvability, and blood-protein engagement. Consequently, these variables must be accounted for throughout the preparation design phase.

INTRODUCTION

Natural polymers have surfaced as one of the most extensively delved accoutrements for enhancing the remedial goods of the being medicine motes. Natural polymers are biodegradable, biocompatible and fairly safer when compared to synthetic coffers. The colorful sources of natural

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polymers include shops, creatures and microbes like bacteria and fungi. Carbohydrates have been extensively used in colorful forms. Carbohydrate polymers are being considerably studied for biomedical and pharmaceutical operations

Natural polymers have garnered considerable attention as prospective substances for the purpose of medicine delivery owing to their essential biocompatibility, biodegradability, negligible toxin, and accessible modifiability. They're deduced from natural sources similar as shops, creatures, and microorganisms and offer several advantages over synthetic polymers, similar as low immunogenicity, environmental sustainability, and low- cost Common natural polymers used in medicine delivery include chitosan, alginate, gelatin, collagen, cellulose, and bounce. These polymers can be reused into colorful forms, similar as nanoparticles, microparticles, hydrogels, and flicks, to deliver medicines to specific spots in the body. The face parcels of natural polymer- grounded medicine delivery systems play a pivotal part in determining their efficacity, bioavailability, and toxin. still, the face parcels of natural polymers are frequently delicate to control, leading to limitations in their use in medicine delivery. thus, modifying the face of natural polymers has come an important exploration area in medicine delivery.

Controllable tube treatment is a important fashion for modifying the face parcels of natural polymers. It offers anon-destructive and cost-effective system to conform the face parcels of natural polymers, similar as face chemistry, face morphology, and face energy. The performing tube- treated natural polymer- grounded medicine delivery systems have shown bettered biocompatibility, controlled medicine release, targeted medicine delivery, enhanced cellular uptake, and bettered vulnerable response.

This critical review aims to give a comprehensive overview of the recent developments in the tube revision of natural polymer- grounded medicine delivery systems, including the tube sources, process control, face characterization ways, and face revision strategies. The challenges and arising trends in this field have also been bandied. The study extends a deeper understanding of the eventuality of tube treatment for enhancing the performance of natural polymer- grounded medicine delivery systems and highlights the unborn directions for exploration in this area.

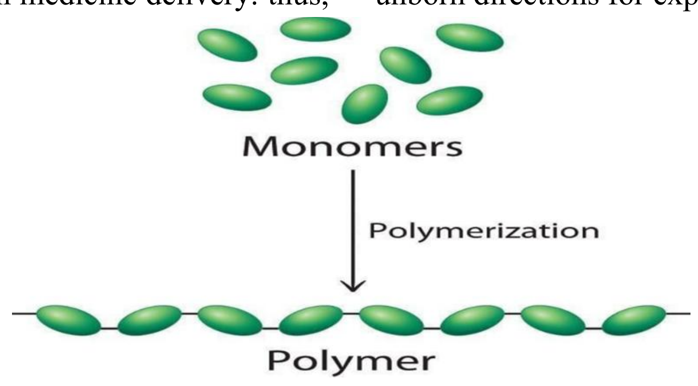

FIGURE 1.POLYMER

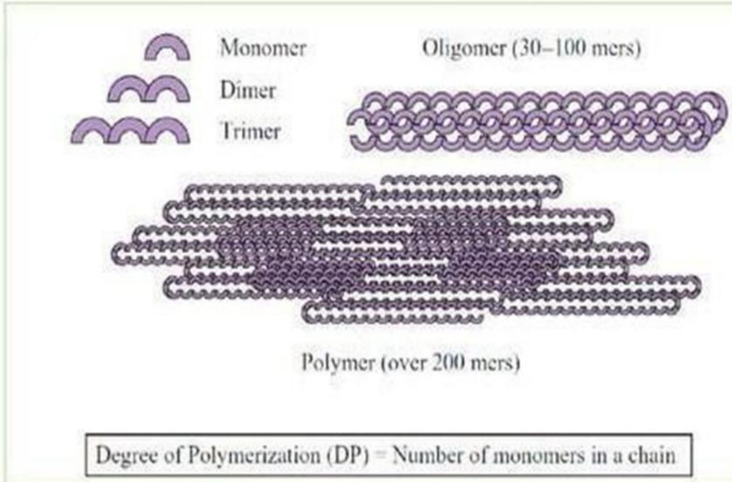

FIGURE 2. POLYMERIZATION

CONTROLLED DRUG DELIVERY SYSTEM

This is the medicine delivery system in which a constant position of a medicine is maintained in blood and towel for an extended period. Pharmacokinetics(PK) angles of tube attention of a medicine versus time for two types of delivery systems, conventional and controlled, are represented in Figure 20. In a conventional delivery system, there's typical gelcap PK for multiple dosing with oral tablets or injections, where the medicine position fluctuates over and below the minimum effective attention. The controlled delivery system, on the other hand, shows zero- order PK with just a single Osefo controlled medicine delivery from a specific expression device. The medicine situations are maintained constantly within the remedial window. Controlled DDS maintain medicine tube situations constantly by releasing the definite cure of the medicine at each time point for apre-determined duration. This helps in reducing the cure and dosing frequence and improves patient compliance. lower medicine exposure to the natural terrain reduces medicine toxin and adverse goods. The overall efficacity of the lozenge form is stoked. In Designing controlled release medicine delivery system, colorful factors and parameters need to be considered. The parameters are astronomically classified as expression related and medicine related. Under expression- related parameters, the biomaterial parcels, route of administration, pharmacokinetics and stability improvement are the major factors. In addition, the medicine- related parameters include medicine binding effectiveness with tube proteins and the capability of the medicine to cross natural walls, and nonsupervisory aspects are also the foremost criteria in designing the lozenge Biomaterial parcels similar as biocompatibility, face chemistry, hydrophilicity, declination, mechanical and rheological parcels need to be studied. In addition, the geste of the biomaterials at colorful pH and temperatures also needs to be assessed. The routes of medicine administration are critical for choosing suitable biomaterial and designing the lozenge form. For case, rectal administration needs the melting point of the biomaterial to be at or above 37 °C or it's answerable at that pH so that the medicine gets released. For certain medicines which are n't stable in harsh conditions, including peptides, proteins, genes(DNA), growth factors and colloidal non- colloidal patches, stability improvement should be done while designing the controlled release carrier. This can be achieved by incorporating the particular medicines in technical carrier systems.

Targeting the medicine to the point where the intended pharmacological exertion is demanded is of utmost significance to help the unwanted medicine goods on other organs. This could be achieved by antibody trailing, attaching ligands and localized delivery. The natural walls are a interference to targeting medicine delivery to certain areas including the brain, bone and testicles. medicines formulated with saturation enhancers and nanocarriers are the druthers that can cross the walls and deliver the medicine to the target point. Suitable beast models need to be established for each kind of delivery system to get the stylish in vitro in vivoco-relationship(IVIVC). This helps to bridge the gap between in vivo beast studies and the clinical study results.

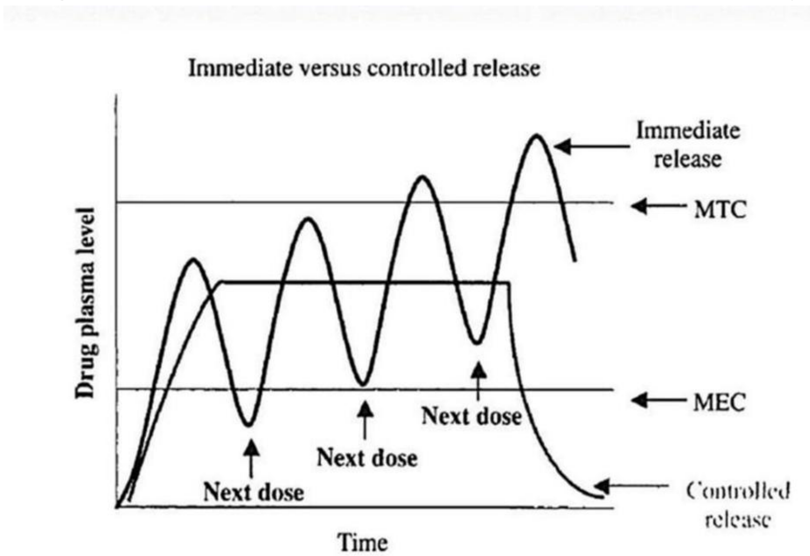

FIGURE 3. THERAPEUTIC OR TOXIC LEVELS AND IMMEDIATE-VERSUS CONTROLLED-RELEASE DOSAGE FORM.

HISTORY

Humanity has utilized polymers for millennia, long before the chemical structures behind them were understood. Early societies relied on natural sources, such as cellulose from wood and cotton, proteins from wool and silk, and natural rubber. Because of their natural durability and pliability, these substances were vital for early human life, serving as the primary components for making garments, equipment, and housing.

The 19th century marked a turning point as scientists began chemically altering natural substances to enhance their performance. A landmark moment occurred in 1839 when Charles Goodyear perfected the vulcanization of rubber, making it significantly more durable and heat-resistant. This period also saw the emergence of semi-synthetic materials like celluloid, bridging the gap between nature and laboratory innovation. Modern polymer science was officially born in the early 20th century through the work of Hermann Staudinger. In the 1920s, he proposed that polymers are “macromolecules”—long, chain-like structures of repeating units held together by covalent bonds. Though his ideas were initially met with skepticism, they eventually became the cornerstone of the industry.By the mid-20th century, a surge in manufacturing led to the mass production of now-ubiquitious synthetics like nylon, polyethylene, and PVC. Today, the field has evolved to focus on sustainability, with researchers developing biodegradable alternatives to address the global challenge of plastic waste.

Polymers in Advanced Medicine

Modern medicine increasingly relies on polymers to create sophisticated drug delivery systems. These technologies are designed to protect medication from degrading in the body, reduce toxic side effects, and ensure the treatment reaches the exact site of a disease.

Targeted Delivery Mechanisms

Polymers act as protective carriers—such as micelles, microcapsules, or lipoproteins—that can be programmed to find specific areas of the body. There are two primary ways this is achieved:

- Passive Targeting: Taking advantage of biological differences, such as the "leaky" blood vessels found in tumors, which allow polymer carriers to accumulate naturally in the diseased tissue.
- Active Targeting: Attaching specific "ligands" to the surface of the polymer carrier. These act like keys that only fit into the receptors of target cells, allowing for highly precise treatment.

Controlled and Pulsatile Release

The timing of a drug's release is just as important as its destination. Polymers enable different release profiles:

- Sustained Release: The polymer slowly degrades or allows the drug to diffuse out at a steady, continuous rate.
- Pulsatile Release: This method mimics the body's natural biological rhythms (like insulin production) by releasing the drug in "pulses" only when triggered by external stimuli like pH changes, light, or temperature shifts.

SIGNIFICANCE

Various drug delivery and targeting systems are currently being developed to minimize drug degradation and loss. These technologies aim to reduce harmful side effects while increasing bioavailability and ensuring that a higher fraction of the medication accumulates in the intended area.

Commonly utilized drug carriers include:

- Polymeric systems: Soluble polymers and microparticles made from insoluble or biodegradable natural and synthetic polymers.
- Vesicular carriers: Liposomes, micelles, microcapsules, and lipoproteins.
- Biological entities: Whole cells and "cell ghosts" (engineered cell membranes).

These carriers can be engineered to be slow-degrading or stimuli-responsive (sensitive to pH or temperature changes). They can also be functionalized for specific targeting by conjugating them with antibodies that recognize unique markers in the target zone.

Mechanisms of Targeting

Targeting refers to the precision with which a drug-loaded system is directed to a specific site. There are two primary strategies for reaching these locations:

- Passive Targeting: This relies on natural physiological processes. For example, chemotherapeutic agents often accumulate preferentially in solid tumors due to the enhanced vascular permeability of tumor tissues compared to healthy tissue.
- Active Targeting: This involves modifying the surface of drug carriers with ligands that are recognized by specific receptors on the target cells. Since ligand-receptor interactions are highly selective, this method allows for much more accurate localized delivery.

Controlled Release and Biodegradation

The success of a pharmaceutical formulation depends heavily on controlled release and subsequent biodegradation. The primary release mechanisms include:

- Desorption of drugs bound to the surface.

- Diffusion through the carrier matrix or the walls of nanocapsules.
- Erosion of the carrier matrix.

A combined erosion-diffusion process.

The method of administration is often as important as the drug itself. Sustained (continuous) release involves polymers that dispense medication at a steady rate via diffusion or gradual degradation. Conversely, pulsatile release is often the preferred method, as it mimics the body's natural rhythmic production of hormones like insulin. This is achieved using "smart" polymers that release the drug only when triggered by external stimuli, such as light, temperature, or pH shifts.

CLASSIFICATION OF POLYMERS

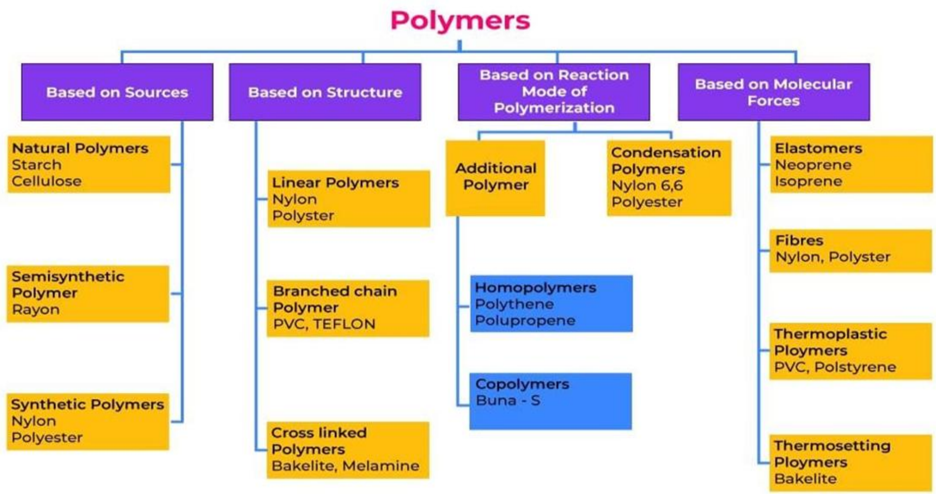

FIGURE 4. CLASSIFICATION OF POLYMERS

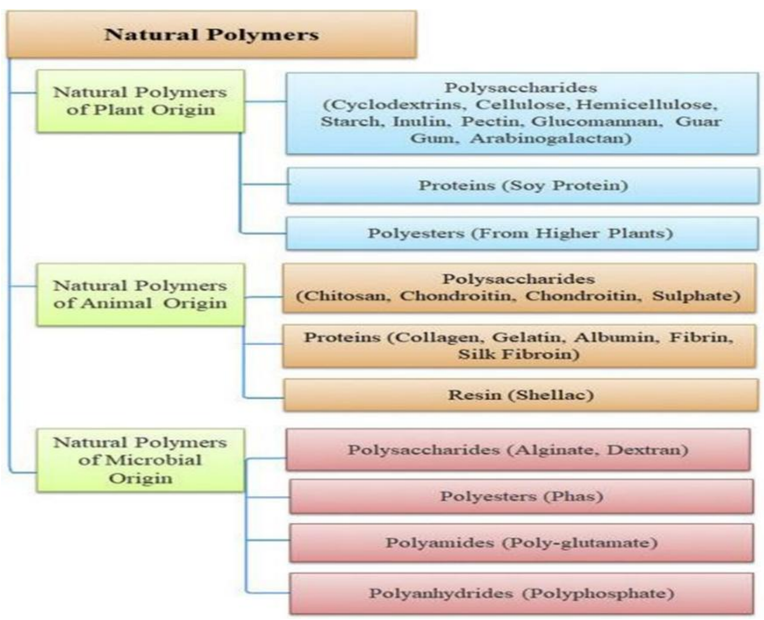

FIGURE 5. CLASSIFICATION OF NATURAL POLYMERS

NATURAL POLYMER

Natural polymers serve as the fundamental building blocks of life. This group includes essential substances such as cellulose, starch, proteins, silk, hair, chitin, and natural rubber. In the natural world, these macromolecules perform various critical tasks:

- Structural Support: Cellulose provides the rigid framework for plant cell walls.

- Energy Storage: Starch acts as a primary energy reserve in plants.
- Protection: Chitin forms the durable exoskeletons of many organisms.
- Elasticity: Natural rubber provides unique flexibility and resilience.
- Biochemical Regulation: Proteins and enzymes drive essential metabolic processes.

Unlike their synthetic counterparts, natural polymers are inherently sustainable. They are derived from renewable resources and are biodegradable, non-toxic, and environmentally compatible, as they can be broken down by microorganisms into harmless, simple substances.

Chemical and Industrial Significance

From a chemical standpoint, natural polymers are defined by their long-chain molecular structures and high molecular weights. Their complex three-dimensional arrangements provide them with unique physical and chemical properties. Because of their inherent strength, rigidity, elasticity, and biocompatibility, they are invaluable across several industries, including textiles, papermaking, food processing, pharmaceuticals, and biotechnology.

Ultimately, natural polymers are biologically synthesized macromolecules that are vital to life. Due to their non-toxic nature and widespread availability, they serve as highly effective and sustainable alternatives to synthetic materials in modern applications.

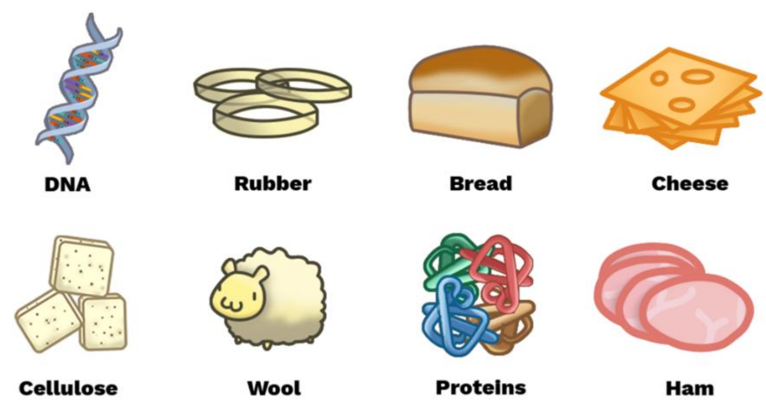

FIGURE 6. EXAMPLES OF NATURAL POLYMER

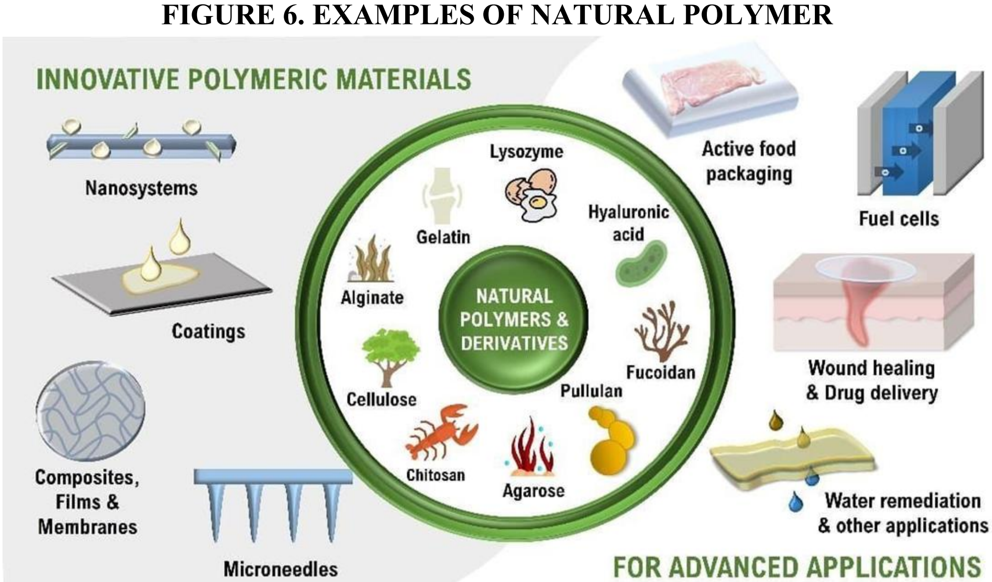

FIGURE 7.NATURAL POLYMERS AND DERIVATIVES

ADVANTAGES

Controlled Drug Release: One of the most significant benefits is the ability to release medication into the body at a specific, predetermined rate. This ensures the therapeutic effect lasts longer and maintains steady levels in the bloodstream.Biocompatibility: Natural polymers (especially polysaccharides) are highly compatible with the human body. They are generally non-toxic and do not trigger adverse side effects or immune rejections.

Biodegradability: Many polymers can break down naturally into harmless substances. This is environmentally friendly and, in medicine, means that implants or drug carriers dissolve on their own without needing surgical removal.

Structural Versatility: Synthetic polymers offer incredible flexibility in manufacturing. They can be engineered into various shapes, sizes, and strengths, which is essential for creating complex medical devices and implants.

Protection of Medication: Polymers act as a shield, protecting drugs from premature degradation. This improves the "bioavailability" of medicine, ensuring it stays potent until it reaches its target.

Precision Targeting: Polymers can be modified to deliver drugs directly to a specific site (like a tumor). This maximizes the treatment's effectiveness while minimizing damage to healthy cells.

Economic Efficiency: Most polymers are cost-effective to produce on a large scale, making them a "profitable" and accessible choice for pharmaceutical and industrial use.

Stability and Compatibility: They are chemically stable and can be mixed with various other ingredients (excipients) without losing their properties or causing negative reactions.

APPLICATION OF NATURAL POLYMERS

In the food industry, natural polymers—primarily proteins and polysaccharides—serve a wide range of functional roles. These materials are essential for thickening and gelling aqueous solutions, stabilizing foams and emulsions, and preventing the unwanted formation of ice or sugar crystals. Additionally, they play a vital role in the controlled release of flavors. In food technology, these proteins and polysaccharides are commonly known as "hydrocolloids." This term refers to a diverse group of long-chain natural polymers that can form viscous dispersions or solid gels when mixed with water.

Key Characteristics of Hydrocolloids:

- Hydrophilic Nature: Because they contain a high number of hydroxyl ($-OH$) groups, these polymers have a strong affinity for water molecules.
- Colloidal State: Their ability to remain dispersed in water in a colloidal state is what gives them the name "hydrophilic colloids" or hydrocolloids.
- Interchangeability: In the context of food science, the terms "hydrocolloid" and "natural polymer" are often used interchangeably. Practical Applications and Market Drivers The primary use of natural polymers in food is to modify texture through thickening and gelling, as well as to stabilize complex mixtures.

Beyond texture, these polymers contribute to:

- Preservation: Extending shelf life by controlling moisture.
- Health and Nutrition: Serving as dietary fibers or fat replacers. Current market data highlights the significant volume and economic value of these materials. The growth of natural polymers as food additives is largely driven by consumer demand for "clean label" ingredients and the increasing need for functional, health-conscious food formulations.

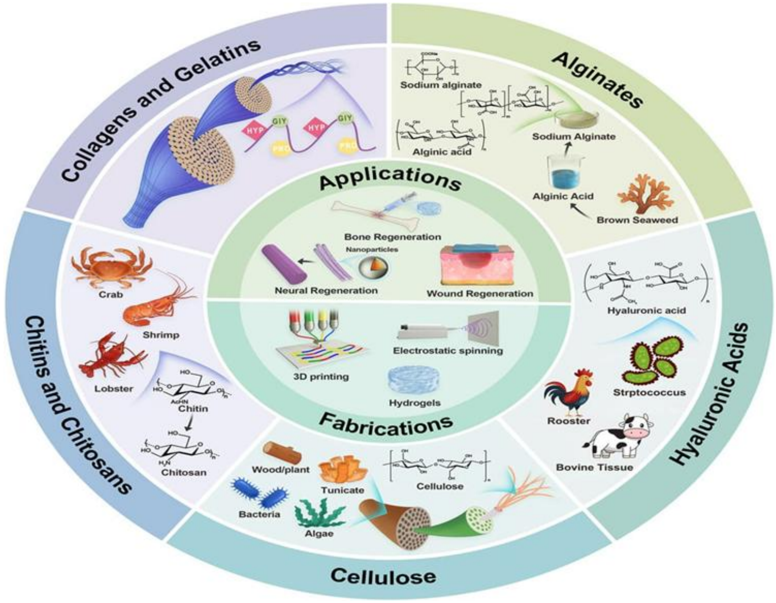

FIGURE 8. APPLICATION OF NATURAL POLYMER

CHALLENGES AND LIMITATIONS

Natural polymers are well-recognized and extensively researched, particularly for their use in biomaterials and medical devices. The market for these materials has massive growth potential, driven by an aging global population and an increasing worldwide focus on healthcare and preventative medicine.

However, a significant gap remains: despite the vast amount of research, very few medical products made from natural polymers are successfully manufactured and commercialized on a large scale. This review explores why there is a "missing link" between academic study and industrial production. If thousands of research papers on biopolymers are published every year, why are these products not reaching the market?

Analyzing the Production Bottlenecks

To understand this disparity, we analyze three critical processes in biomaterial manufacturing:

- 3D Printing: The challenges of maintaining structural integrity and biological activity during fabrication.
- Drying: The difficulty of removing solvents without damaging the delicate polymer matrix.
- Sterilization: The struggle to eliminate contaminants without altering the chemical or physical properties of the natural material.

We focus on the primary technical hurdles and "bottlenecks" that occur during the scale-up of these processes. Our findings suggest that while material science is advanced, there is a lack of integration with chemical and materials engineering.

CONCLUSION

This article summarizes in a comprehensive manner numerous of the recent specialized exploration accomplishments in natural polymers. It discusses the colorful attempts reporting on working this problem from the point of view of the chemistry and the structure of natural polymers, pressing the downsides and advantages of each system and offer. Grounded on considerations of structure- property relations, it's possible to gain filaments with advanced strength by making use of their nanostructures and/ or mesophase parcels of natural polymers .This is a unique book with benefactions from the experts of biomaterial area exploration. it covers all motifs related to natural biomaterials similar as natural rubber, cellulose, chitin, bounce, hemicellulose, lignin, alginates, soy protein, casein and their bio nanocomposites and operations. It's a useful reference for scientists, academicians, exploration scholars and biotechnologists. This review is based on the several research reports and their outcomes have been cited here in a concise manner .I wish to cordially thank all of the contributing authors for their excellent reviews that convey the latest information on natural polymers used in promising materials for the controlled drug delivery, gene therapy, and tissue engineering scaffolds, pharmaceutical and biopharmaceutical and biomedical engineering

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