



Natural polymers: Preparation, applications and benefits

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ABSTRACT

Natural polymers are the major components of all living matter; cheap, available and most importantly eco-friendly. They are widely used in many fields. This research will cover a few types of natural polymers. How can we obtain them, their application, structure and the different way they can be a part of our daily lives without being harmful to our health and environment.

Keywords:

Natural polymers, living matter, daily lives

Introduction

Natural polymers have received attention as economical, readily available and non-toxic materials. They are capable of chemical modifications, potentially biodegradable and with few exceptions, also biocompatible [1]. Biopolymers are available in large quantities from renewable sources, while synthetic polymers are produced from non-renewable resources.

The polysaccharides represent one of the most abundant industrial raw materials and have been the subject of intensive research due to their sustainability, biodegradability and bio-safety [2]. The transition from synthetic polymers, because of the increased cost of solid

waste disposal as well as the prospective menaces from waste incineration, has grown into a need for a permanent ecologically valuable alternative. Thus the development of alternative bio-based materials has presented a great challenge, which has attracted public and scientific interest for the development of biopolymers with the desired physical and chemical properties of conventional synthetic polymers. In living systems, biopolymer scaffolds mechanically resilient yet dynamic support the cells and tissues. Thus complete knowledge of biopolymer networks could help to acquire these unique features of their hierarchical structure combined with internal mechanochemical activity to design functional

materials for the future [2]. We will review here a selection of the most important natural polymers.

Natural Polymers

Natural polymers or biopolymers are renewable biological molecules, which are divided into three main classes: polysaccharides (a polymeric linear-bonded carbohydrate structure), polynucleotides (more than 13 nucleotide monomer structures like RNA and DNA), and polypeptides (short polymers of amino acids) [3]. Biopolymers are produced in the growth cycles of cells of living organisms.

1. Cellulose

Cellulose is the first thermoplastic polymer found in plants. It has the chemical formula $(C_6H_{10}O_5)_n$ where n is the number of repeating units present in cellulose [4]. It is a

polysaccharide that has a linear structure with 100e1000 repeating units of $(1e4)$ β -linked glucose units-Glucose is the glucose unit that has (1-5) OH and CH₂OH groups in the same plane (Fig.1). The D-glucose unit has strong inter- and intermolecular H bonding between the hydroxyl group and the oxygen atom. It acts as a structural component of the primary cell walls in plants [5]. The properties of it which depend on chain length and Dp. Cellulose has poor thermal properties, but excellent chemical properties. It is an odorless and tasteless powder present in crystalline form [6]. It does not show any Tg because it possesses a 100% crystalline structure [7]. Cellulose is a homopolymer with a nontoxic and decomposable behavior. It has excellent tensile and compressive strength due to the presence of a cross-linked structure [8].

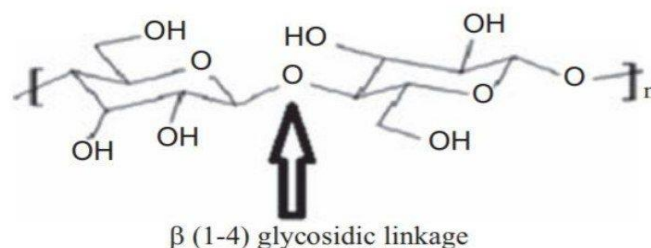


Fig.1. Cellulose structure.

Cellulose derivative preparation and application

Chemical modification of cellulose is performed to improve the properties and to produce cellulose derivatives as carboxymethyl cellulose (CMC), methyl cellulose (MC), hydroxyethylcellulose (HEC), etc which can be tailored for specific industrial applications[9]. That's why we chose a derivative of cellulose for the research.

The use of cellulose and other sustainable biopolymers for various applications suits the needs of a green economy [10]. As the most abundant naturally occurring biopolymer, cellulose has been widely applied in producing many different products that are essential in our modern life. Cellulose consists of long chain

anhydro-D-glucopyranose units (AGU) that are joined together covalently between the equatorial group of C1 carbon atom and C4 carbon atom (β 1,4-glycosidic bonds) [11]. This linear chain can be extended to molecules containing 1000-1500 β -glucose units [12]. However, cellulose has certain inherent drawbacks, such as poor crease resistance, undesired solubility in solvent medium, and lack of thermoplasticity. The controlled chemical or physical surface modification is necessary to improve cellulose properties [13]. Generally, the biosynthesized constitution of natural cellulose cannot be modified in the same ways as those that can be applied to a synthetic polymer [14]. Surface functionalization by introducing exogenous groups into cellulose

molecules is one feasible way to alleviate this problem. This can allow the tailoring of cellulose surface chemistry to facilitate self-assembly, controlled dispersion within a wide range of matrix polymers, and enhance both the particle-particle and particle-matrix bond strengths, without destroying its many desirable intrinsic properties [15]. Cellulose can be converted into a wide range of derivatives by functionalization, thus conferring new applications to cellulose. For drug delivery system, the generated cellulose derivatives would usually form a thick

adsorbed/ protective layer at the oil/ water interface, resulting in the increased viscosity of continuous phase and lowering the creaming rate of the drugs [16].

Preparation of cellulose derivative Sodium Carboxymethyl Cellulose (CMC)

The carboxymethylation process of converting cellulose to sodium carboxymethyl cellulose (CMC) is a typical etherification reaction [17] as shown below :

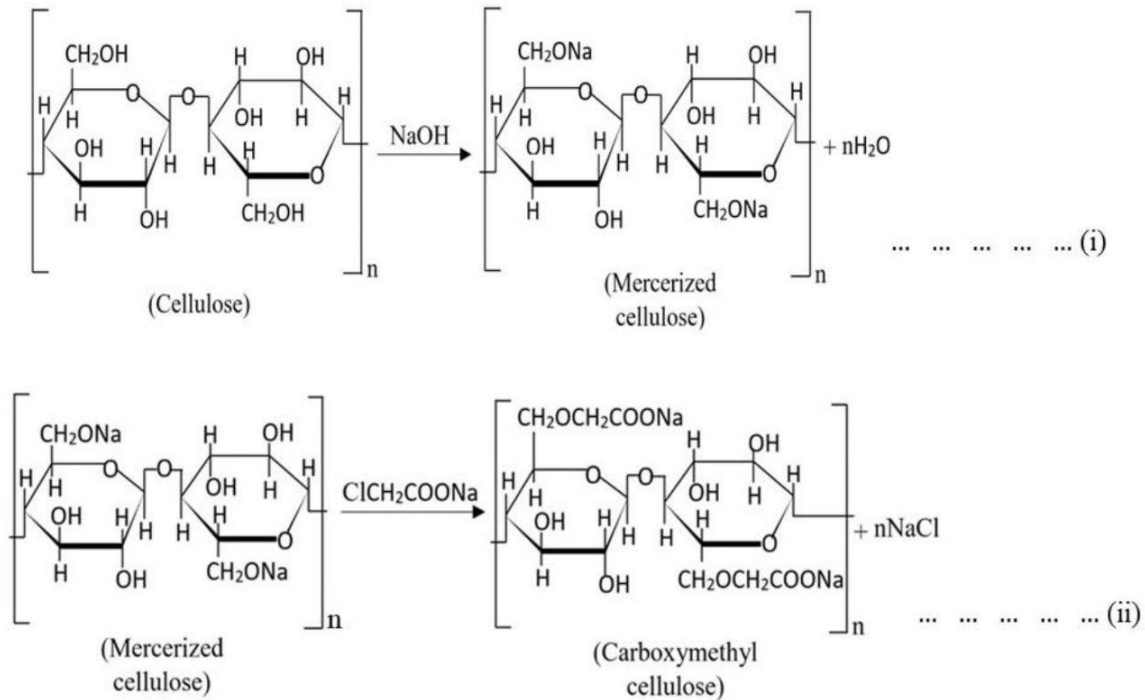


Fig.2.Synthesis of CMC.

Ethyl Cellulose

The polymer is obtained by synthesis (etherification) through the substitution of the cellulose hydroxyl groups with ethoxylones. The chemical reaction involves cellulose dissolution in sodium hydroxide aqueous solution, which leads to degradation of the

cellulose's molecular structure. This results in the formation of an alkali cellulose and exposure of the cellulose hydroxyl group for reaction. Afterwards, ethyl chloride gas is added to the reaction medium, leading to bonding with the alkalinized cellulose. EC, sodium chloride, and water are formed [18-20] as shown below :

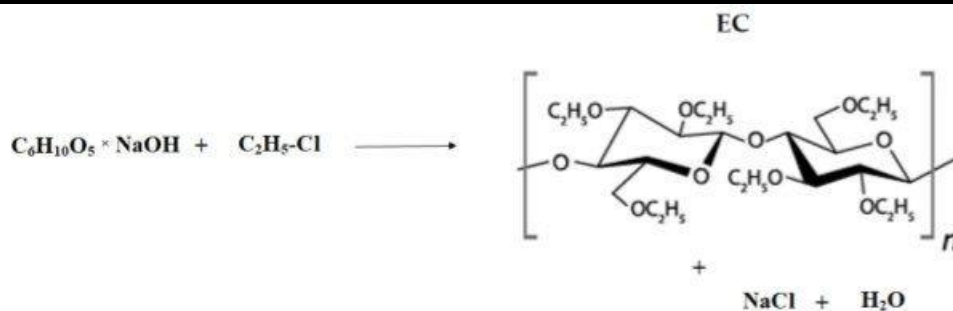


Fig.3. Synthesis of EC.

Application of cellulose derivative Sodium Carboxymethyl Cellulose (CMC)

As excipients for the sustained drug release, it is a low-cost polyanionic and soluble cellulose derivative [21]. The many unique properties of this polymer make it suitable for a wide variety of applications, such as preferred stabilizers, suspending agents, binders and thickeners. A preferred disintegration is the highly polymerized grade of CMC with a small number of carboxymethyl groups [22]. Grades with a low degree of polymerization are poor disintegrating agents irrespective of their degree of substitution.

In bio-medicine, CMC has been used for preventing the over-degradation of superoxide dismutase enzyme (SOD) [23]. CMC can be used for carrying SOD to form hydrogels, thus realizing the sustained release of SOD [24]. The SOD ingredients can be absorbed into the CMC-based matrix, rendering two formulations: hydrogels and conjugates. The characterization of both formulations showed that only 50% of SOD was released after 72 h, indicating a better controlled profile. Barkhordari et al. prepared the CMC-based new pH sensitive nanocomposite beads, by combining the CMC with layered double hydroxides (LDH) [25]. The CMC-LDH bead was further used to intercalate the model drug, Ibuprofen (IBU), through the co-precipitation method. In the vitro tests of drug delivery, the synthesized CMC-LDH-IBU

nanohybrids exhibit a better protection for the IBU against stomach pH and a controlled release in the intestinal tract conditions.

Ethyl Cellulose

For DDS, EC can be used in combination with water-soluble polymers to prepare the coating film for sustained drug release. As a derivative of EC, hydroxyethyl cellulose (HEC) is also non-ionic water-soluble cellulose ether. It is insoluble in organic solvents, but can easily disperse into aqueous mediums to render solutions of variable viscosities and desired properties [26]. It can be used as a film former and suspending agent, for the preparation of drug tablets to control its release profile, especially when a non-ionic material is desired. Remuñán-López et al. described the preparation of EC based bilayercomposites by a casting/solvent evaporation method followed by compression [27]. The mucoadhesive bilayers were composed of an EC backing layer and a drug-chitosan mixture layer with or without an anionic crosslinking polymer (polycarbo phil, sodium alginate, gellan gum). The designed bilayer structure can deliver the drugs, such as nifedipine and propranolol hydrochloride, in a unidirectional fashion to the mucosa. The formulated tablets displayed a controlled swelling and sustained drug release in a phosphate buffer (pH of 6.4).

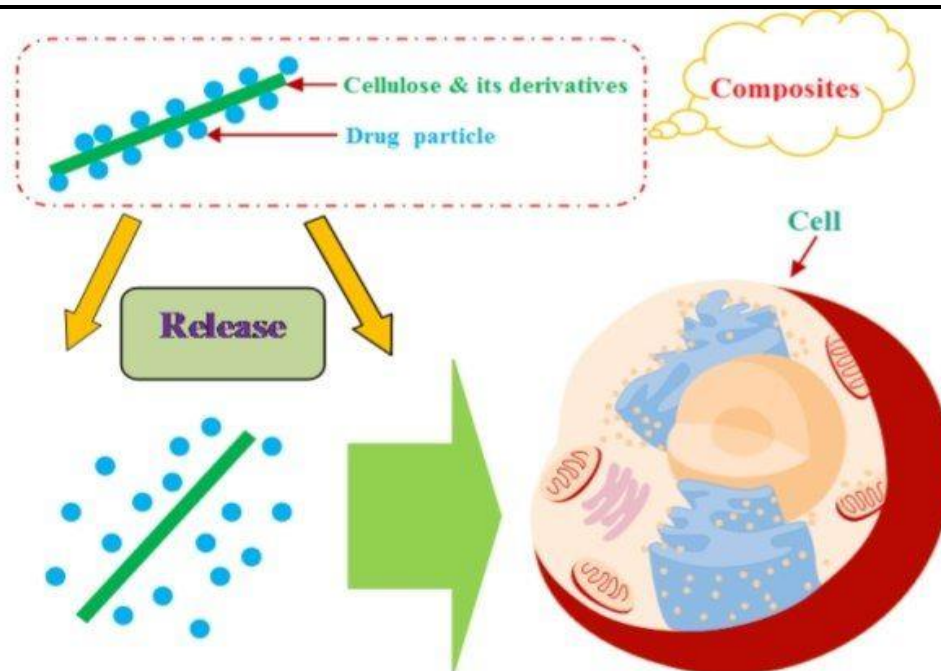


Fig.4.The proposed sustained release mode of HMC-carried drug.

2.Chitosan

Chitosan is the largest nitrogen-based structural polysaccharide and is made up of repeated subunits of modified glucose [28]. It is basically found in insect cells, fish, and many vertebrates. It is a deacetylated derivative of chitin, which is the second most abundant polysaccharide found in nature after cellulose. It has $\beta(1-4)$ anhydroglycosidic bonding, which is

very similar to cellulose, but the properties differ with cellulose. It is insoluble in water or some organic solvents just like cellulose [29]. It is soluble in aqueous solutions of mineral acids and dimethylacetamide [30]. Chitosan has been found to be non-toxic, biodegradable, biofunctional, biocompatible and was reported by several researchers to have strong antimicrobial and antifungal activities[31].

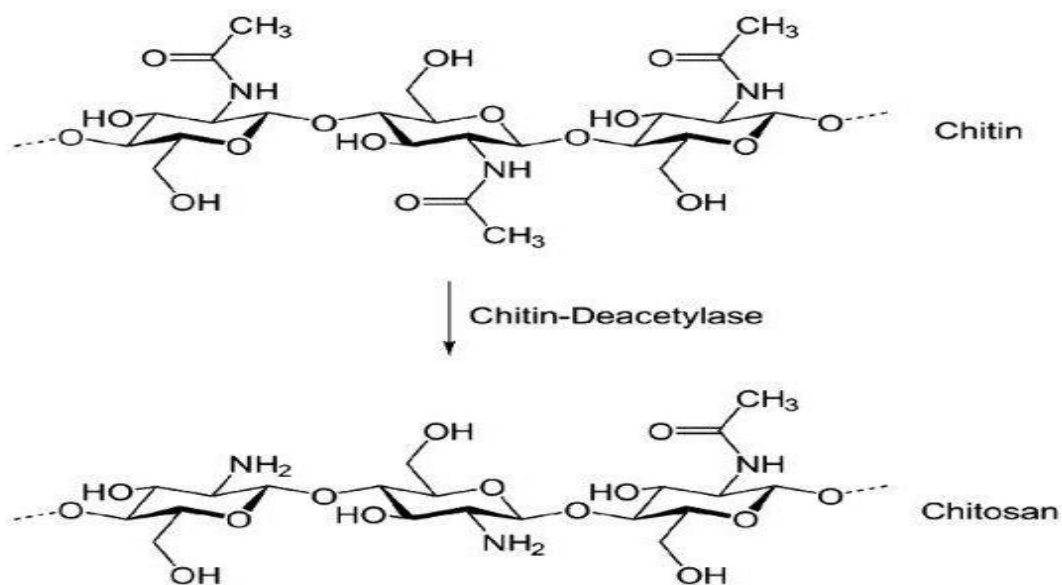


Fig.5.Chaitosan synthesis.

Chitosan-based films preparation

It has been demonstrated that chitosan films may be cast upon pectin films to give clear laminated films having dynamic mechanical properties similar to those of pectin films alone[32]. In addition, plasticizers and/or starch may be added to either the chitosan or pectin solutions used for films preparation. Moreover, pectin-chitosan blends may also be utilized. In accordance with the reported results, it is possible to produce novel films comprising pectin and chitosan layers, where the layers optionally comprise plasticizer and/or starch[33].

Application of chitosan based-films

The modern food industry is facing challenges and requires specific approaches to surmount theme. One of these challenges is related to the packaging of food products with a short shelf life period. Although the use of conventional packaging materials such as plastics and their derivatives is effective for food preservation, they create serious environmental problems that continue to present the food industry as a source of pollution and social concerns. Chitosan can be one of the solutions to solve it. an Edible bio-based films have been investigated for their abilities to avoid moisture loss or water absorption by the food matrix,

oxygen penetration to the food material, aromas loss and solute transports[34].

Until now, the edible and biodegradable bio-based films are always not meant to totally replace the conventional packaging materials[35]. However, the use of active bio-based films as packaging materials is still one of the most promising ways for effective methods of maintaining food quality. One of the most perspective active bio-film is the one based on chitosan combined with different materials such as plant and animal proteins, polysaccharides and antimicrobial peptides (bacitracin) such as nisin and diverging which is a new class bacitracin produced by *Carnobacterium divergens* [36]. Chitosan films have been successfully used as a packaging material for the quality preservation of a variety of foods [37].

3.Collagen

Collagen is the most abundant biopolymer in living organisms. It is an insoluble fibrous protein consisting of three polypeptide chains wound around each other, found in the extracellular matrix, and is the dominant protein in connective tissues. It helps to form bone structure, construction of cartilage, and connective tissues. It can be extracted from various animal species and the major source of collagen is cattle bones and bovine skin [38].

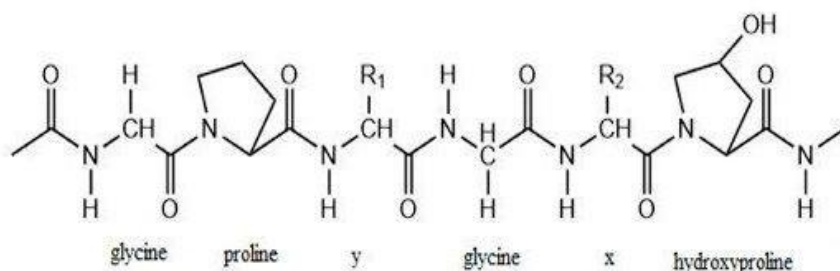


Fig.6. Structure of Collagen type I.

Preparation

Chemical and enzymatic hydrolyses are commonly used methods for the preparation of collagen. Chemical hydrolysis is the most common method, but enzymatic processes have advantages over chemical processes such as high nutritional value, improved functionality, lower waste generation, and less time, but they

are more expensive [39,40]. The isolated collagen molecules are about 280 nm long, with a molar mass of 360,000 Da, and they are stabilized by hydrogen bonds and intermolecular bonds [41]. The removal of crosslinking bonds, intra and intercovalent bonds, is an important step during isolation of collagen, and these bonds are formed due to the

residues of lysine and hydroxylysine, ester bonds, and other bonds with saccharides [40]. The noncollagenous substances can be removed by a mild chemical pretreatment process.

Application of collagen Pharmaceutical industries

Collagen is used in pharmaceutical industries as microparticles, injectable dispersions, shields in ophthalmology sponges, drug delivery system. Its application in the pharmaceutical as well as biomedical field is due to its characteristics such as weak antigenicity, cell attachment ability, biodegradability and biocompatibility [42].

Tissue engineering

Collagen type I is considered to be the gold standard for this field due to its high biocompatibility. It is used as the basic matrix for cell culture system. Biomaterials based on collagen are widely used in tissue engineering such as injectable matrices, scaffolds intended for bone regeneration etc. These biomaterials are produced mainly from fibril-forming collagen which includes type I,II,III,V,XI [43].

4. Gum Arabic

When a plant suffers injury by insect, bacterial, or fungal attack, it often exudes a viscous, sticky

fluid that tends to seal the wounds. These exudates are mostly polysaccharides and are usually highly branched. Gum arabic, also known as acacia gum, is the hardened sap of Acacia trees. Gum arabic consists of a complex mixture of glycoproteins and polysaccharides, and is soluble in water. The chemical structure of gum arabic is depicted in (Fig.7). Properties such as the gum's origin, odor, color, moisture, and ash determine the quality of gum arabic [44].

Application of Gum Arabic

Gum arabic is one of the most important gums and is used in confectionery and medicaments. On complete hydrolysis, it yields L-arabinose, L-rhamnose, D-galactose, and D-glucuronic acid[45].

Gum arabic has various industrial applications, ranging from pharmaceutical to textile. In the textile industry, it is often used for its stabilizing and binding effects, as well as its role in the viscous control of ink in the dyeing processes. It has been reported that the application of gum arabic for sizing and finishing of textile fabrics also increases the yarn tensile strength. It has also been used as a thickening agent in printing pastes for knitted cellulose fabrics [45,46].

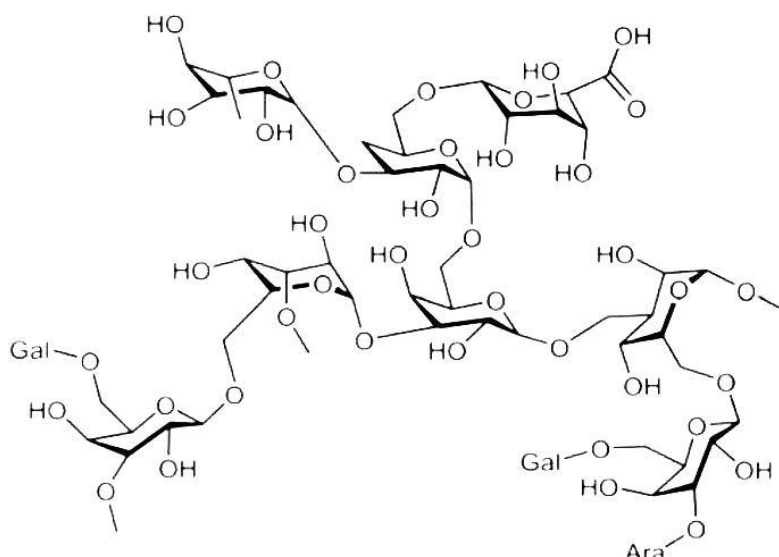


Fig.7.Generic structure of Gum Arabic.

Conclusion

As a conclusion natural polymers has much to offer in food and medical industry so much benefit and less pollution to our environment, chitosan seems to be highly promising for the future improvement of food quality and preservation during processing and storage of different food materials. cellulose has unique optical, mechanical, and rheological properties and is easy to be chemically modified and reconfigured for drug delivery as well as collagen and Gum Arabic.

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