Chitin and chitosan: Structure, properties and applications, some perspective on building preservation

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Abstract. Chitin and chitosan, as the most abundant amino polysaccharides in nature, have characteristics such as high biocompatibility, low toxicity, biodegradability, and acceptable antimicrobial properties. These unique properties led Chitin and Chitosan to pay great attention not only in terms of the abundance of natural resources but also because of their high potential for the preparation of applied materials. Extensive improvements have been made in improving their properties for use in tissue engineering and medication, wound healing and relief agents. This paper tries to show a general perspective on the many applications of these biopolymers. The text ends with the description of the potential application of this material in building preservation.

1 Introduction

Biopolymers are organic polymers synthesized by biological organisms and are caused by bonding between monomer units. The application of biopolymers in geoengineering is not known as a completely new method because organic polymers such as natural bitumen have been used in ancient civilizations. In ancient China, a type of viscous rice was made with sugarcane, lime and river sand, slurry with good resistance and high durability [1].

Among the three most common biopolymers including polynucleotides, polypeptides and polysaccharides, polysaccharides are the most widely used in construction projects [2].

Polysaccharides are carbohydrate polymer chains that are created by binding monosaccharide units. Polysaccharides are abundantly found in nature and act as the ingredients of the structure and skeleton of living organisms (e.g., cellulose and pectin in plants and chitin in animals) or energy-saving materials (e.g., starch in plants and glycogen in animals. The characteristics of biopolymers have led to their widespread use in food, agriculture, and therapeutic applications [3].

Biopolymers act as an adhesive after combining with soil and improve soil resistance, improve erosion resistance and reduce permeability [4]. The use of biopolymers in soil improvement has advantages over other new methods of improvement (such as microbial injection). For example, in this method, we do not need to inject germs and foodstuffs as well

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as time for microbial cultivation and microbial sedimentation process, and this method can be used in fine soils (including clay soils). On the other hand, Biopolymers are readily found in the poultry and many of them are known as harmless and even edible substances. Therefore, these materials can be considered environmentally friendly materials for soil improvement.

Chitin is one of the most abundant biopolymers after cellulose. Chitin is a natural polysaccharide and is found prominently in crustacean shells such as crabs and shrimp, insect cuticles, and the cell walls of fungi. The history of Chitin and Chitosan goes back to the 19th century. For the first time in 1811, a French scientist named Braconid extracted chitin from the fungus. Then, in 1859, Roget acquired Khorasan from the process of detoxification of chitin game in the presence of potassium hydroxide, and finally, its structure was fully discovered in 1950 [5]. Chitin and Chitosan are as natural amino polysaccharides with unique buildings and versatile properties are widely used in medicine and industry. Among their distinctive properties are high biocompatibility, acceptable biodegradability along with low toxicity, as well as their antibacterial and anti-sensitive properties [6-13].

2 Chitin and chitosan structure

Cellulose and chitin are both polysaccharides that play a protective role for plants and animals, respectively, so they produce cellulose plants in the cell walls and insects and chitin crustaceans in their shells [14]. Cellulose and chitin structures are very similar to each other in cellulose hydroxy groups at carbon position no. 2 have been replaced with acetamide groups and in the chitosan case, amine groups have been replaced by hydroxy groups in cellulose (Fig. 1).

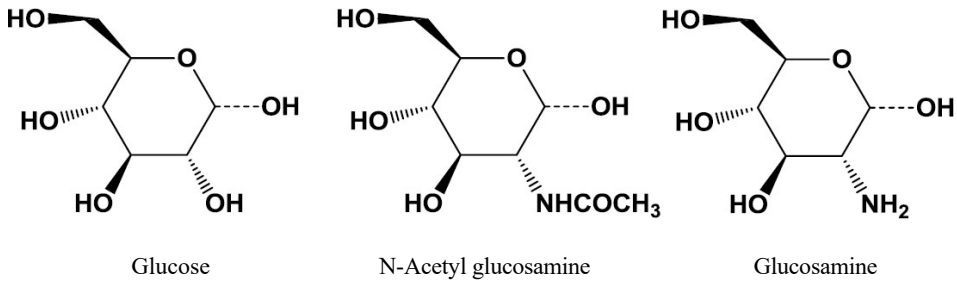

Fig. 1. The structure of the solitary unit of cellulose Acetyl-glucosamine (mono unit of chitin) and glucosamine (mono unit of chitosan(-N))

Fig. 2 shows the chemical structures of chitin and chitosan. Chitosan is a derivative of chitin. The number of stainless-steel groups on the polymer chain determines the difference between the two polymers (Fig. 2). A polymer with 100% stainless amine groups is called chitin, and a polymer without amide groups (100% of the amine group) is called chitosan. Contractually, 50% of amide groups are considered as the boundary between chitin and chitosan, i.e. polymer with a degree of detoxification of less than 50% is called chitin, and DD with more than 50% is called chitosan. Chitin in solid-state has three different shapes that are classified as alpha, beta, and gamma. Frequency percentage -α Chitin in nature of two states –γ and -β is greater than two states of chitin. α chitin is extracted from diatoms and squid arms in the cell walls of fungi and crustacean shells such as shrimp, crab, and β chitin. -β and -α is known chitin. Different orientation of polymer chains has caused such a difference in chitins that stainless steel groups play an important role in this formation by creating intra-chain and extra-chain hydrogen bonds between acetyl carbon groups no. If the orientation of all polymer chains is in the same direction, it is called chitin. In this case, chains can have extra-chain hydrogen bonds in addition to intra-chain hydrogen bonds and increase the

strength of the structure. But in the case of β-chitin, the orientation of the chains only allows the formation of hydrogen bonds within the chain. In the case of -γ chitin is the orientation of the chains randomly. (Fig. 3)

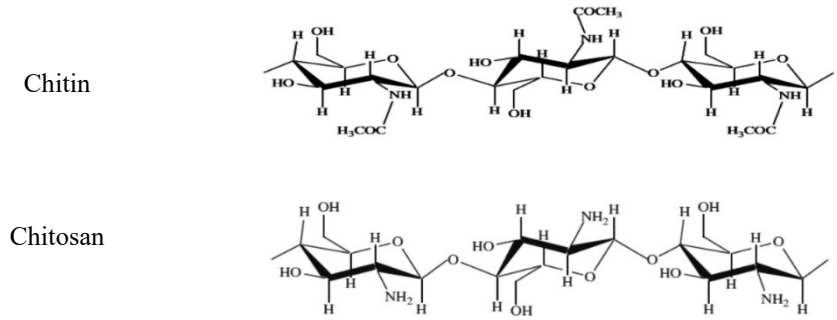

Fig. 2. Structure of chitin and chitosan biopolymers

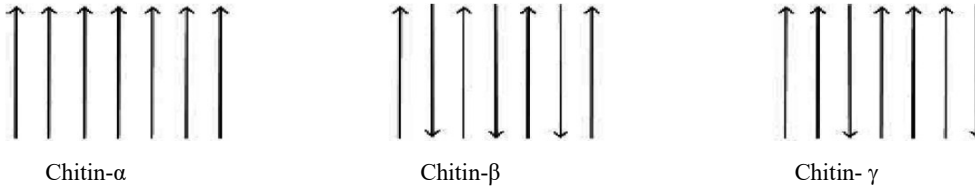

Fig. 3. Three modes of chitin orientation.

3 Chemistry and physical properties of Chitin and Chitosan

The main parameters that have a direct impact on chitin and chitosan properties are molecular weight Mw, degree of deacetylation, and crystallinity rate. But for human applications such as food and medical industry, in addition to the above, purity (ash content produced), moisture content, heavy metals content, and protein content are also determined [7, 13, 15].

4 Biological properties of chitin and chitosan

Chitin and chitosan have attracted a lot of attention, especially in the medical and pharmaceutical industries, one of the most important characteristics that make them suitable for these applications is their high biocompatibility, biodegradability, and non-toxicity. In addition, biological properties such as biodiesel adhesion, anticancer, antimicrobial, inflammation and pain reducer, antioxidant, blood coagulant, and cholesterol-lowering, distinguish them from other biological polymers [16].

For more than a decade, they have been used as a safe compound in drug formulations and can also be used as an effective substance in binding hard and soft tissues together due to their adhesion properties. Low-grade chitosan films from detoxification are very suitable for wound healing. They cling to the surface of the tissue, increasing the creatinine side, followed by the production of cutaneous tissue. Proper understanding of chitin and chitosan structure can give us a lot of help in controlling the properties of this species of biopolymers. For example, controlling the degradability of chitin and chitosan depending on their application and type of use is very important. Their degradability rate increases by reducing the degree of detoxification and reducing the length of the polymer chain. Conversely, bio-adhesion of biopolymers is increased by increasing the degree of detoxification and increasing the length

of the polymer chain, due to the increase in the interaction of chitosan amine groups with cells.

5 Preparation of chitosan gel from shrimp skin lesions

Shrimp skin will be used to make chitosan. The preparation method is as follows. First, the skin of the prawns is completely cleaned, and the contents inside them are drained. Then wash with water and dry for two days. After this step, the bark of the prawns will be crushed and ready for the next step. The next step is to put the crushed skin in 7% HCl solution 24 hours at ambient temperature. After this stage, the solution's materials will be thoroughly washed with water and placed at an ambient temperature of 10% NaOH for 24 hours and subsequently washed and finally stored in ethanol for 24 hours. Up to this point, what is achieved is chitin, which is converted to chitosan due to DE acetylation. For this purpose, Caitlin 50% NaOH solution at 110° C will be sprayed on the magnetic mixer for one hour. Then washed with distilled water and placed at 50° C for 12 hours for drying [17-18].

The final product of this stage is chitosan. After obtaining the chitosan, according to the required chitosan concentration to add to the soil, the chitosan dissolved in acetic acid solution to obtain chitosan gel. The preparation process of chitosan gel is from shrimp skin lesions in figure 4.

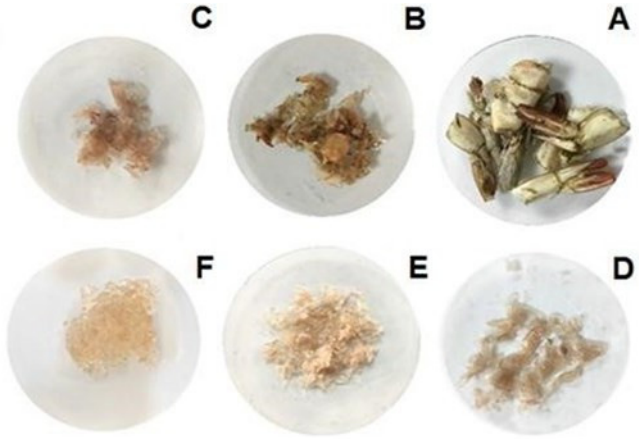

Fig. 4. Steps to prepare chitosan gel from shrimp skin lesions.

6 Chitin and Chitosan Applications

The low solubility of chitin is the most important limiting factor for biopolymers' consumption. Despite this limitation, many applications of chitin and its derivatives have been reported so far. Therefore, chitosan due to the presence of free amine groups along the polymer chain and the ability to form good chelate and solubility in weak acids such as acetic acid has a suitable position among polysaccharides. Fibers made of chitin and chitosan are very effective for the preparation of absorbable suture yarns as well as fabrics for wound healing. It is claimed that fabrics made from these fibers can be used to treat wastewater from heavy metal ions. Chitin and chitosan have found a very good place in industry and medicine compared to other polysaccharides due to their very suitable chemical and physical properties as well as unique biological properties, which are mentioned in some cases.

6.1 Industrial applications

6.1.1 Wastewater treatment and water engineering

Due to its polycationic nature, chitosan can act as a clotting agent and can also act as a killing agent that traps heavy metal ions [18]. In 2008, a complete report on the use of chitosan for dye removal from aqueous solutions has been published. Weltroswki and his colleagues were able to remove metal ions from wastewater using chitosan derivatives in an acidic environment [19].

6.1.2 Paper making and packaging industries

Its biodegradability and high environmental compatibility have caused chitin and chitosan to be used in packaging industries as well as recyclable papers. Chitosan can be easily used in paper mills due to its high structural similarity with cellulose [20].

6.1.3 Textile industry

Natural fibers such as cellulose and protein are more vulnerable to bacteria than man-made fibers. Therefore, the use of antibacterial agents to prevent or delay the growth of bacteria is very necessary and as a standard principle in the preparation of textiles, is of great importance [21].

As a result, chitosan, as a non-toxic, biodegradable, and environmentally friendly natural biopolymer, is a suitable option for use in the textile industry, in addition, to the antibacterial properties of this sample of fibers have led to their use in sportswear today. Ladies, children, and delicate clothes used, beautiful, odourless, and anti-allergic [22].

6.1.4 Cosmetics

Organic acids are commonly used as a conditioner in cosmetics. A polyamine saccharide like chitosan can be easily gelled in neutral and acidic environments. But unlike most hydrogels that have anionic properties; chitosan has cationic properties. This feature makes it useful as a skin and hair protector. Chitosan is compatible with many compounds used in cosmetics and absorbs or reduces the effect of many ultraviolet rays. Two important properties of chitin, chitosan, and their derivatives have made it a good candidate for skin protection. Future. A) Are positive in terms of electric charge B) Their molecular weight is generally high and they cannot penetrate the skin. Therefore, they are used as a moisturizer. They are also used in nail sieves, creams, eye shadows, and so on [23].

6.1.5 Food industry

Chitosan has been used as a food additive since 1995 and 1983 in countries such as Korea and Japan, respectively [24]. Increasing consumer demand for high-quality and biologically healthy foods along with their relative abundance has led many researchers and industrial centres to focus on this biopolymer. Chitosan is more effective as a food additive as well as a component of packaging materials, not only in preventing the growth of microorganisms in food but also in improving its quality.

Chitosan is used in the food industry in the following areas: cholesterol-lowering, as a preservative, thickener and stabilizer of sauces, antibacterial materials as well as coatings for fruits for long-term storage.

6.2 Agriculture

Increasing consumer demand for fresh and chemical-free products Organic products, as well as the general desire to find an alternative and low-cost method of storing agricultural products and reducing pathogens during planting and harvesting, have resulted in natural antimicrobial compounds. Hence chitosan due to its antimicrobial properties against a wide range of bacteria, viruses and fungi; It is able to protect plant tissue against pathogens [25-26]. search at the University of Washington has shown that chitosan, as a coating for wheat grains, increases crop yields, and the results of this study have so far been used for other crops. Chitosan can also be used as a controlled release agent for compounds such as pesticides, herbicides, and nutrient compounds for plant growth such as copper, iron, and manganese [27].

6.3 Medical application

Chitin with the chemical structure N-acetyl-D-β glucosamine has many applications in cosmetics, medicine, water treatment. chitin applications in medicine include: preventing the increase of harmful LDL cholesterol, increasing useful HDL cholesterol, healing wounds (similar to antibiotics), preventing tooth breakdown and mass, controlling blood pressure, increasing calcium, strengthening bones, and dozens of other applications. Chitin is a crystalline material and sometimes naturally radiant, and is insoluble like cellulose in ordinary solvents such as water. Chitosan is obtained from chitin de-styling. In the reaction of chitin with concentrated sodium hydroxide solution, acylamino groups (-ACNH) are converted into amino agents ($-NH_2$), and chitosan is obtained (Fig. 5)

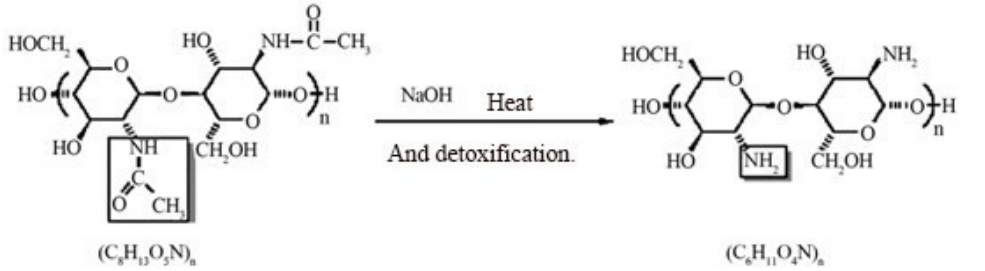

Fig. 5. Chemical structures of catechins and chitosan [28].

The intrinsic biological properties of chitosan, such as biocompatibility, biodegradability, cell adhesion, antimicrobial and antifungal properties and acceleration to wound healing, make it a suitable option for various medical applications [11, 29].

They also use chitosan in medical science to produce the following: surgical stitches, dental implants, artificial skin construction, lens making in ophthalmology, and time-lapse control of drug release in human bodies.

6.4 Civil engineering

Since the beginning of human civilization, geotechnical engineering has helped humans use soil to achieve their goals. The Sumerians used bitumen as an adhesive to increase the strength and durability of earth walls. The discovery of natural Pozzolanic materials such as volcanic ash led to the creation of more durable structures. After the Industrial revolution, conventional Portland cement was used as the most widely used material not only in construction but also in soil stabilization and reinforcement.

Currently, three methods are used to strengthen adobe structures:
1) mechanical strength,
2) physical strength,
3) chemical strength.

Due to the high volume of these structures and the principles of restoration, special attention should always be paid to the principle of reversibility and cost-effectiveness.

Chitosan has had a variety of applications in the field of civil engineering. Biopolymers such as Xanthan gum and chitosan are widely used in the production of viscosity modifier in cement-based materials. It is possible to modify the properties of cement-based materials using nanotechnology science and the production of nanoparticles such as nano chitosan and nano cellulose. Although the use of chitosan in high-performance lubricants has advantages in terms of structure and environmental protection, reforms should be made to the chemical structure of chitosan to achieve the desired characteristics and this requires finding an economical and efficient method for chemical modification of the chitosan structure. Recent research has shown the role of chitosan in increasing the compressive and tensile strength of concrete. In fact, by delaying cement hydration, chitosan delays the initial concrete clamping time and acts as a suitable lubricant [30]. Chitosan has been widely used in industrial wastewater treatment. Chitin and Chitosan can treat effluent from a high-efficiency oil refinery. Chitosan has also been used to absorb heavy metals from water and soil. Chitosan can disinfect groundwater contaminated with copper and phosphorus ions. Chitosan-coated sand particles have also been used to purify contaminated groundwater [24].

6.5 Perspectives in building preservation

Chitosan, being a partially deacetylated product of chitin, is a linear copolymer of β-(1-4)-2-amido-2-deoxy-D- glucan (glucosamine) and β-(1-4)-2-acetamido-deoxy-D-glucan (N-acetylglucosamine), presenting a three- dimensional helical configuration stabilized through hydrogen couples amongst formed monomers. Due to its functional characteristics, chitin and chitosan are excellent candidates as aggregates in concrete mixtures and as a coating for reinforcing steel (RS) to avoid or diminish the corrosion and resulting products in the RC. Shrimp waste, which is generally responsible for an environmental problem, could become a solution for corrosion problems in existing structures.

Furthermore, chitosan as an environmentally friendly polymer can be used as a coating agent for future buildings in order to protect buildings against harsh environments.

7 Conclusion

Chitin and chitosan, as natural amino polysaccharides, due to their unique structure, multidimensional properties, and high performance, have attracted much attention in the industry, especially in medicine and pharmacy. In addition, chemical modifications of these polymers improve their solubility in aqueous media or organic solvents, which increases biological activity as well as their use in medicine has increased. This article seeks to inform the audience about the structure, and characteristics and increase the various uses of chitin and chitosan, especially in various field of civil engineering, like soil and construction materials treatment and stabilization.

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