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Chitin and Chitosan: The Versatile Biopolymers

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Abstract: Chitin is a biopolymer copious in nature. A biopolymer is a degradable biomaterial which is produced by monomers from living organisms. It is a polysaccharide which is synthesized by many types of living organisms such as fungi and insects. As chitin is available in enormous quantity in nature, it has a number of applications in the fields of tissue engineering, drug delivery, wound dressing, cosmetics, food and beverage, agriculture, and waste water treatment. Chitin is non-toxicity, biocompatibility and biodegradability which makes it an eco–friendly and versatile biopolymer. Chitosan, a derivative of chitin, is produced by the deacetylation of chitin, it also has similar uses in various industries. This review focuses on the extraction process of chitin from seafood waste and how chitin and chitosan are applicable in numerous industries.

***Index Terms* - Chitin, chitosan, biopolymer, drug delivery, cosmetics, wound dressing.**

I. INTRODUCTION

A polymer is a natural or synthetic substance or a material which is made up of large molecules or macromolecules. Biopolymers are produced naturally or chemically from biological material or by living organisms through biosynthesis. They are classified into three main classes namely polynucleotides, polypeptides, and polysaccharides. This classification is based on the monomer used and the structure of biopolymer formed. Chitin is classified under polysaccharides. It is naturally available and is inexpensive. When the monomeric units are bonded together by covalent bonds, a large polymeric structure of biopolymer is formed [3]. Chitosan is a cationic polymer produced by deacetylation of chitin. It is found abundantly in crustacean, insect, arthropod exoskeletons, and molluscs [19]. Chitin is one of the most abundant biopolymers available in the world. The word chitin is derived from a Greek word ‘chiton’ which means a coat. For the first time, the word chiton was used by Braconnot in 1811 [15].
Chitin has numerous applications in different industries such as waste water treatment for the removal of metal ions, dyes and pigments as membrane in purification processes; in food industry it is used as a packaging material, as a preservative and as food additive; in agricultural industry for seed and fertilizer coating and for controlled agrochemical release; in pulp and paper industry for surface treatment and photographic paper; in cosmetics and toiletries for moisturizer, body creams and lotions and biomedical applications such as tissue engineering, drug delivery, wound healing and cancer diagnosis [1, 8].

II. STRUCTURE AND PROPERTIES OF CHITIN AND CHITOSAN

Chitin $(C_8 H_{13} O_5 N)_n$ is made up of a long chain polymeric polysaccharide. Biocompatibility, biodegradability, and non-toxicity are some properties of this natural polymer. It has a high molecular weight and it consists of linear repeating units of b-1,4-linked N-acetyl D-glucosamine. Chitin chemically mirrors cellulose, in cellulose the hydroxyl group at carbon - 2 is substituted by acetamido group in chitin. Chitin is white, hard, semi-transparent polymer, nitrogenous polysaccharide, inelastic, it has low chemical reactivity and is insoluble in most organic solvents. It is available in the form of granules, sheets and powders. Pure chitin is inexpensive and commercially available [1,8]. Chitin and chitosan polymers are natural amino polysaccharides which have unique structures, multidimensional properties and wide - ranging applications in enormous industrial areas [5, 7]. Chitin can be easily procured from crab shells, shrimp shells and fungal mycelia. Chitin is obtained by processing crustacean shells. The processing mainly involves the removal of proteins and the dissolution of calcium carbonate which is present in crab shells. The calcium carbonate present in crab shells is in high concentrations. The product derived after processing is deacetylated in sodium hydroxide. This treatment produces deacetylated chitosan [2]. The physiochemical properties of chitosan are that it has high crystallinity, it is insoluble in water and other organic solvents, it is hydrophilic, bio - adhesive and has ionic conductivity [20].

Chitin polymorphism can be seen using X-ray diffraction. α, β, and γ, are the three crystalline structures. These structures differ by the number of chains per cell, degree of hydration, and unit size. α-chitin is the most abundant. It is found in arthropod exoskeletons, where the polymeric chains are antiparallel. In β-chitin is found in animals that show flexibility and resistance, such as squids, where the polymeric chains are parallel. γ-chitin is a mixture of both [11, 13].

Chitin and chitosan are considered as the materials of huge futuristic potential with colossal possibilities for modifications to set forth desired properties and functions. Research and development work on chitin and chitosan has reached a status of intense activities worldwide. The positive characteristics of good biocompatibility and excellent biodegradability with ecological safety and low toxicity with protean biological activities such as antimicrobial activity and low immunogenicity have provided substantial opportunities for further growth and development. Chitin has become a product of great interest not only as it is an under-utilized resource but also as a new functional biomaterial of copious potential in various fields [5, 7].

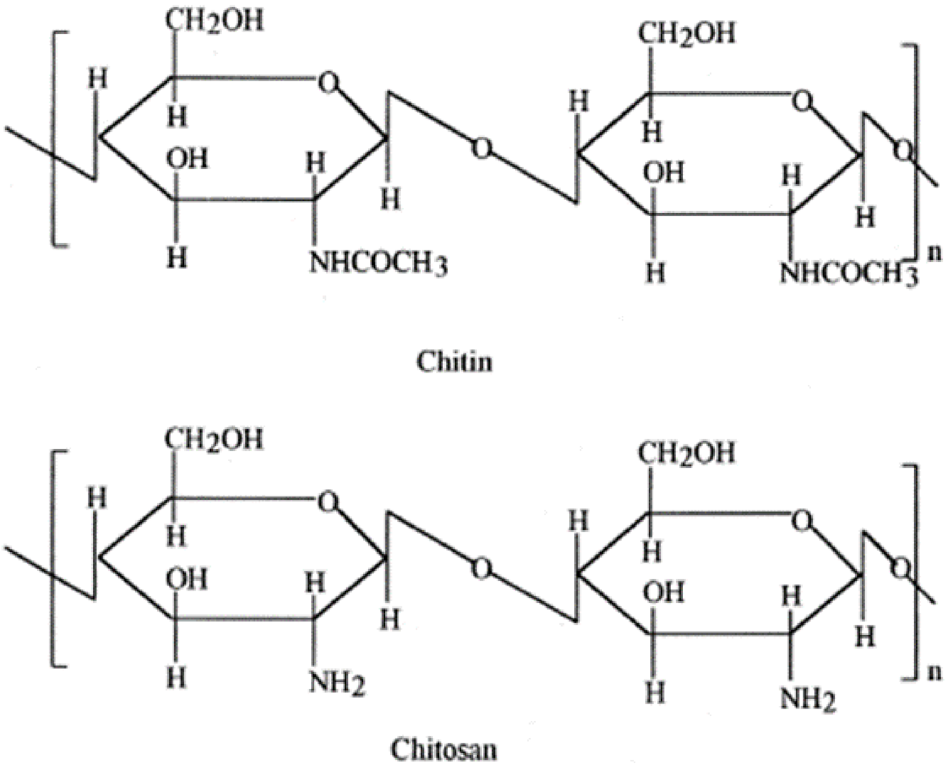

Figure 1 Structure of Chitin and Chitosan [2]

III. EXTRACTION OF CHITIN AND CHITOSAN FROM SEAFOOD WASTE

Chitin is extracted from seafood waste as it is one of the main sources of chitin and chitosan is produced from the deacetylation of chitin. The following two are the main two methods in the extraction of chitin and chitosan.

3.1 Chemical Extraction

A strong alkaline solution is used such as hydrolysis with sodium hydroxide at high temperature and concentration to breakdown polymeric chains. Alkaline solution deproteinization, acid solution demineralization, and discoloration are the three main steps of chemical extraction.

3.1.1 Deproteinization

The chemical bonds between protein and chitin gets disrupted which leads to the depolymerization of the biopolymer. This involves the use of bases and strong acids at high temperature.

3.1.2 Demineralization

This process is used for the removal of minerals using strong acids. Sulphuric acid, hydrochloric acid, acetic acid, nitric acid, and formic acid are a few acids which are used. Calcium carbonate is decomposed in calcium chloride and carbon dioxide is released. This is the chemical reaction: $2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

3.1.3 Discoloration

This process removes astaxanthin and β-carotene pigments present in the extracted source. Organic or inorganic solvents such as acetone, sodium hypochlorite, and hydrogen peroxide are used for discoloration.

3.2 Biological Extraction

This method uses microorganisms that produce enzymes and organic acids which help in the extraction of chitin. Biological extraction method is cost effective, a cleaner and greener process and produces high quality products. The two biological methods used for chitin extraction are as follows.

3.2.1 Enzymatic Deproteinization

In this method, enzymes are added to breakdown the protein. Mostly protease is used and it reduces environmental degradation. Papain, trypsin, pepsin and pancreatin are used on a large scale.

3.4.2 Fermentation

In this method, hydrolyzed proteins are obtained by proteolytic enzymes produced by the lactic acid bacteria. This process allows the recovery of value-added by-products such as proteins, enzymes and pigments. Fermentation is performed using protease-producing bacteria such as Bacillus subtilis, Pseudomonas aeruginosa, Pseudomonas maltophilia, and Serratia marcescens [2, 14, 19, 21].

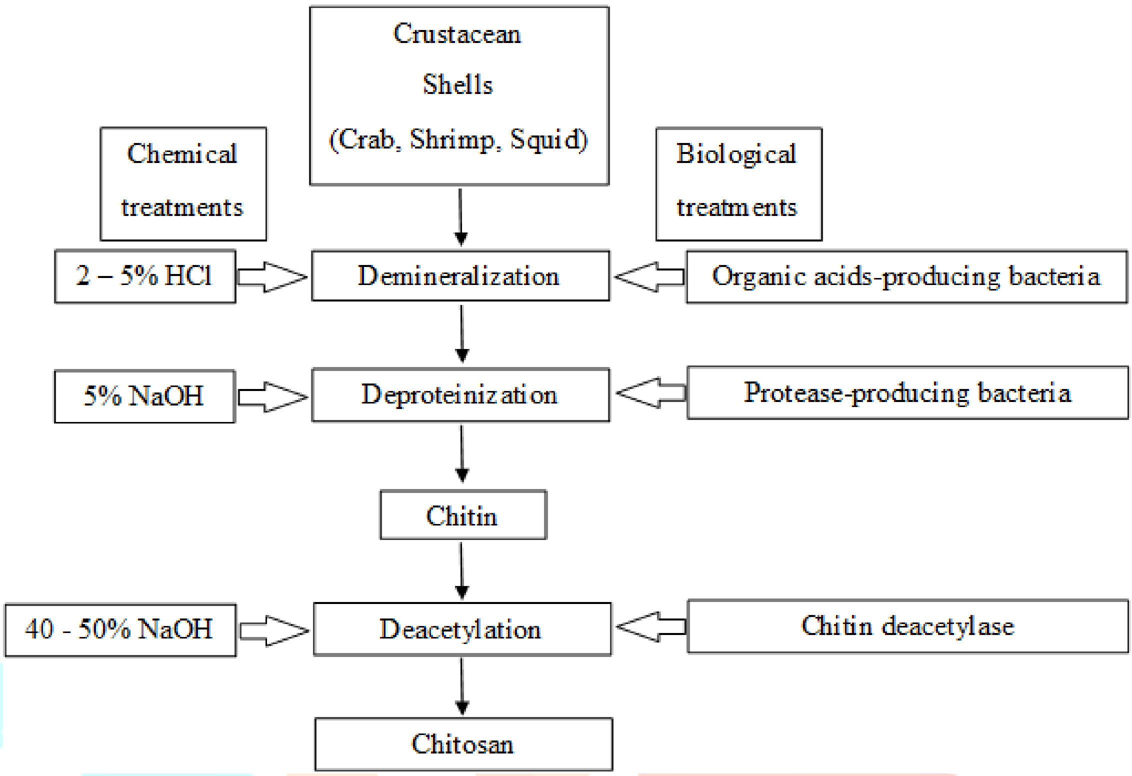

Figure 2 Extraction of Chitin and Chitosan from Seafood Waste [22]

IV. APPLICATIONS OF CHITIN AND CHITOSAN

3.1 Food Industry

Chitosan is cheaper than other biopolymers available so it is widely used in the food industry for increasing the shelf life, for packaging purposes. The chitosan films restrict the entry of microbes and moisture inside the packed food which enables the food to maintain its quality for a long duration of time. It also acts as a thickener and stabilizer for sauces and binds lipids. When the chitosan films are coated with polysaccharide solution containing Ca^{2+} ions, it prevents the changes that take place in the sensory properties of fruits and vegetable. The Ca^{2+} ions change the permeation rates of CO_2 and O_2 and increase the shelf life of the product [6, 9, 19].

3.2 Agricultural Industry

Mould contamination in agricultural products is determined by chitin. A few studies have proved that chitin treated seeds such as wheat have shown accelerated growth. It also reduces the penetration of insects and pathogenic fungi. The hydrolysed produce of chitin and chitosan can be used as biofertilizers. It also induces fungal microbe - associated molecular pattern (the first layer of multi-layer defence in plants) in variety of plants [1, 6].

3.3 Cosmetic Industry

Chitin and chitosan are fungistatic, fungicidal and have the ability of dissolving in organic acids therefore they can be used in cosmetic products. They also maintain skin moisture, treat acne, improve suppleness of hair, reduce static electricity in hair, tone skin and it is also used for oral health (it is used in toothpaste and chewing gums) [6]. The use of these biopolymers has gained a lot of attention and are being used widely due to the various benefits [4]. They have many applications in creams, lotions, toothpastes, chewing gums, nail enamel, foundation, eye shadow, lipstick, cleansing material, bath agents and nail lacquers. They can also be used as dental fillers for absorbing the fungus that sticks to teeth, to make clean false teeth, to prevent the tooth damage and plaque formation [1, 3].

3.4 Drug Delivery

The main function of proper drug delivery is to deliver the appropriate amount of active agent at a constant or suitable rate. It should also be able to channel the active agent solely to the site of action in the body. The different routes of drug delivery are oral, buccal, periodontal, topical and transdermal, ocular, nasal, pulmonary, rectal, parenteral. The dosage form for all the routes is one the these: hydrogels, nanoparticles, microbeads, microemulsion, compacted granules, microparticles, tablets. The following mechanism is seen during drug delivery: diffusion, swelling, erosion and biodegradation. Controlled - release dosage is used as it increases the safety and reliability of drug therapy [17].

3.5 Antimicrobial Application

The antimicrobial activity of chitosan is that its positively charged amino groups bind to the surface of the bacterial wall or the plasma membrane as they have negative charge. Therefore, there is a change in cell permeability allowing the flow of ions and proteins from the cytoplasm into the extracellular space and causing cell death. High degree of acetylation, high molecular weight and the antibacterial activity helps the changes in cell permeability and blocks the transport of the bacteria. Lower degree of acetylation and lower pH allow antibacterial activity. Other factors influencing the antimicrobial activity of chitosan are the absorbing property of metal ions and their ease of penetrating the cell wall and binding to DNA and inhibiting messenger RNA synthesis. Due to this, chitosan films are used in food packaging to form a protective layer and maintain the food quality [19].

3.6 Biomedical Application

Chitin is found in gels, membranes, beads, scaffolds, nanofibers and microfibers. The various biomedical applications of chitin are surgical sutures as they are biocompatible, dental implants as they are biodegradable, artificial skin, rebuilding of bone, corneal contact lenses, time release drugs for animals and humans, used as encapsulating material and wound healing [6, 10]. The chitin sutures can resist bile, urine and pancreatic juice while other types of sutures do not resist these juices [1].

3.7 Biopharmaceutical Application

Chitin and chitosan are used in the production of mucoadhesive delivery systems as they have characteristics such as anti - toxicity, biocompatibility, antimicrobial activity and adequate permeation. Chitosan - based nanoparticles are used for drug administration as they have particular features required for a drug - loading vehicle. Chitosan is non-toxic, non - allergenic, biocompatible and biodegradable and the derivatives of chitosan are anticoagulants. Anticoagulants have highest growth rate and can treat a wide range of illnesses. The commercial application of chitosan is its use as a hemostatic functional system [19].

3.8 Tissue Engineering

Tissue engineering has improved the human life. This technique involves regeneration of damaged or dead tissues using biomaterials which help in cell growth and proliferation. The characteristics of a biomaterials used in tissue engineering are:

1. presence of interconnected pores
2. controlled biodegradability
3. modifiable chemical surface
4. mechanical properties similar to the site of implantation
5. insignificant toxicity
6. ease of obtaining desirable shapes and sizes

All these characteristics are available in chitin and chitosan, which makes them the best biopolymer suited for tissue engineering [16, 19].

3.9 Wound Dressing

Various derivatives of chitin and chitosan in the form of hydrogels, fibers, membranes, scaffolds and sponges have been discovered as biomaterials for wound dressing. They have good properties like biocompatibility, high durability, low toxicity, anti-bacterial activity and liquid adsorption. A few other polymers such as alginate, hyaluronic acid, polyvinyl alcohol, glutamic acid, polyethylene glycol diacrylate and 2-hydroxyethyl methacrylate help in improving the wound healing properties of chitin-based membranes. The a – chitin silver composite scaffolds are anti - bacterial against Escherichia coli and Staphylococcus aureus. The b – chitin silver composites are bactericidal against Escherichia coli and Staphylococcus aureus and have other properties such as antibacterial, blood clotting, swelling, cell attachment and cytotoxicity [1, 12].

3.10 Wastewater Treatment

Chitin and chitosan are used for waste water treatment as these molecules are natural and eco – friendly coagulants or flocculants. They help remove metal ions, synthetic polymers, clarify drinking water and reduce odour [6]. Chitosan is a cationic polymer, in acidic media it facilitates dissolution of metal ions and enables ion – exchange with anionic molecules. Polyvinyl alcohol-chitosan and PEG-chitosan composites have been proved to eliminate nitrate ions. Chitosan - based nanomaterials are known to adsorb or remove dye molecules. Here, the hydroxyl groups are exploited in dye adsorption while the amine groups remain as the most active group and they influence other biopolymeric activities [20].

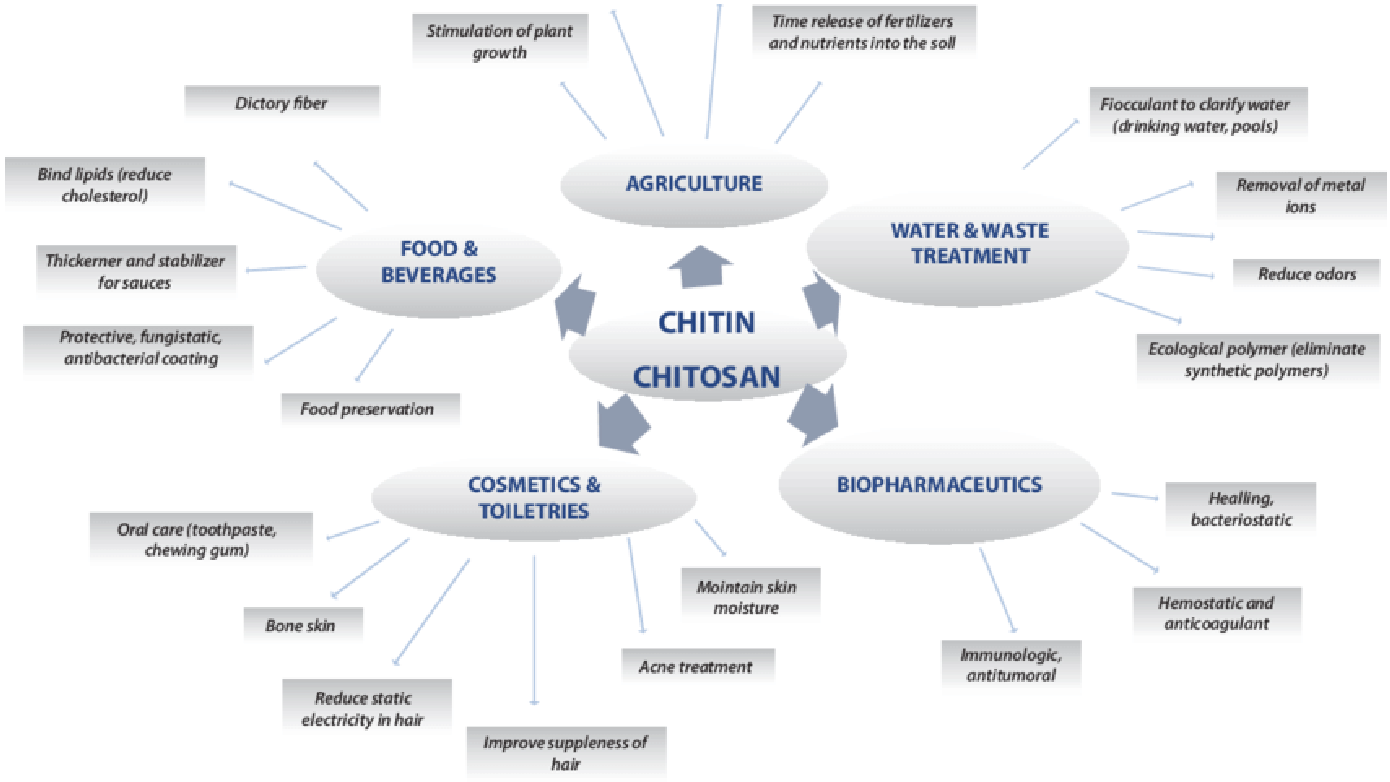

Figure 3 Applications of Chitin and Chitosan [23]

V. CONCLUSION

Chitin and chitosan are two astonishing biopolymers existing in the shells of crustaceans, exoskeletons of insects and in the cell walls of fungi. Because of their structure and properties, industrially they have many applications but, due to environmental conditions, sometimes the quality or quantity of chitin and chitosan may vary, it can be monitored using statistical data [18]. As these biopolymers are a bio-waste, they use energy-efficient methods and are cost effective. Chitin and chitosan are seen to be perfect renewable agents for pure or processes form with antimicrobial particles and natural compounds with multifunctional applications. As such materials are required in the various field of biotechnology and research, the demand for chitin and chitosan will surely increase. Researchers will soon be more attracted to this mesmerizing biopolymer. With more research a very promising future for the future generation can be seen in chitin and chitosan as a biomaterial [19].

REFERENCES

[1] Barikani, M., Oliaei, E., Seddiqi, H., & Honarkar, H. (2014). Preparation and application of chitin and its derivatives: a review. Iranian Polymer Journal, 23(4), 307-326.
[2] Kumar, M. N. R. (2000). A review of chitin and chitosan applications. Reactive and functional polymers, 46(1), 1-27.
[3] Morganti, P., & Coltelli, M. B. (2019). A new carrier for advanced cosmeceuticals. Cosmetics, 6(1), 10.
[4] Danti, S., Trombi, L., Fusco, A., Azimi, B., Lazzeri, A., Morganti, P., ... & Donnarumma, G. (2019). Chitin nanofibrils and nanolignin as functional agents in skin regeneration. International journal of molecular sciences, 20(11), 2669.
[5] Krajewska, B. (2004). Application of chitin-and chitosan-based materials for enzyme immobilizations: a review. Enzyme and microbial technology, 35(2-3), 126-139.
[6] Rinaudo, M. (2006). Chitin and chitosan: Properties and applications. Progress in polymer science, 31(7), 603-632.
[7] Pillai, C. K., Paul, W., & Sharma, C. P. (2009). Chitin and chitosan polymers: Chemistry, solubility and fiber formation. Progress in polymer science, 34(7), 641-678.
[8] Zhong, Y., Cai, J., & Zhang, L. N. (2020). A review of chitin solvents and their dissolution mechanisms. Chinese Journal of Polymer Science, 1-14.
[9] Yu, Z., Ji, Y., Bourg, V., Bilgen, M., & Meredith, J. C. (2020). Chitin-and cellulose-based sustainable barrier materials: a review. Emergent Materials, 1-18.
[10] Morganti, P., Febo, P., Cardillo, M., Donnarumma, G., & Baroni, A. (2017). Chitin nanofibril and nanolignin: Natural polymers of biomedical interest. J. Clin. Cosmet. Dermatol, 1(1).
[11] Morganti, P., Morganti, G., & Coltelli, M. B. (2019). Chitin nanomaterials and nanocomposites for tissue repair. In Marine-Derived Biomaterials for Tissue Engineering Applications (pp. 523-544). Springer, Singapore.
[12] Shabunin, A. S., Yudin, V. E., Dobrovolskaya, I. P., Zinovyev, E. V., Zubov, V., Ivan'kova, E. M., & Morganti, P. (2019). Composite wound dressing based on chitin/chitosan nanofibers: processing and biomedical applications. Cosmetics, 6(1), 16.
[13] Maevskaia, E. N., Shabunin, A. S., Dresvyanina, E. N., Dobrovol'skaya, I. P., Yudin, V. E., Paneyah, M. B., ... & Morganti, P. (2020). Influence of the introduced chitin nanofibrils on biomedical properties of chitosan-based materials. Nanomaterials, 10(5), 945.
[14] El Knidri, H., Belaabed, R., Addaou, A., Laajeb, A., & Lahsini, A. (2018). Extraction, chemical modification and characterization of chitin and chitosan. International journal of biological macromolecules, 120, 1181-1189.
[15] Crini, G. (2019). Historical review on chitin and chitosan biopolymers. Environmental Chemistry Letters, 17(4), 1623-1643.

[16] Tao, F., Cheng, Y., Shi, X., Zheng, H., Du, Y., Xiang, W., & Deng, H. (2020). Applications of chitin and chitosan nanofibers in bone regenerative engineering. Carbohydrate polymers, 230, 115658.

[17] Parhi, R. (2020). Drug delivery applications of chitin and chitosan: a review. Environmental Chemistry Letters, 18(3), 577-594.

[18] Elsoud, M. M. A., & El Kady, E. M. (2019). Current trends in fungal biosynthesis of chitin and chitosan. Bulletin of the National Research Centre, 43(1), 1-12.

[19] Santos, V. P., Marques, N. S., Maia, P. C., Lima, M. A. B. D., Franco, L. D. O., & Campos-Takaki, G. M. D. (2020). Seafood waste as attractive source of chitin and chitosan production and their applications. International journal of molecular sciences, 21(12), 4290.

[20] Nasrollahzadeh, M., Sajjadi, M., Iravani, S., & Varma, R. S. (2020). Starch, cellulose, pectin, gum, alginate, chitin and chitosan derived (nano) materials for sustainable water treatment: A review. Carbohydrate Polymers, 116986.

[21] Elieh-Ali-Komi, D., & Hamblin, M. R. (2016). Chitin and chitosan: production and application of versatile biomedical nanomaterials. International journal of advanced research, 4(3), 411.

[22] Qavami, N., Naghdi, B., & Mehregan, M. (2017). Overview on Chitosan as a valuable ingredient and biostimulant in pharmaceutical industries and agricultural products. Trakia Journal of Sciences, 15(1), 83.

[23] Orrego, C. E., & Salgado, N. (2014). Green logistics in chitin/chitosan industry. Appl Agroindustries, 1400000, 1200000.