Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 12 [8] July 2023 : 420-429

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD

REVIEW ARTICLE **OPEN ACCESS**

A Review on Chitosan - An Eco-Friendly Polymer and its Potential Applications

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ABSTRACT
Chitosan, a helical polysaccharide macromolecule, is the second most prevalent natural biopolymer after cellulose and is a component of the exoskeleton of crustaceans like crabs, shrimp, insects, and other arthropods. Both chitin and chitosan have been found to have remarkable biological qualities like bioresorbable degradation products, hydrophilicity, biocompatibility, cellular binding capability, and acceleration of wound healing, which explains their wide range of applications in the food, cosmetic, biomedical, and pharmaceutical industries. Additionally, chitosan derived from the shells of crustaceans are used for food coating can effectively protect against dehydration, oxidation and microbial contamination. Time-repeated coating with high-quality chitosan can significantly decrease weight loss and extend shelf life of products. This review highlights the extraction and biological applications of chitosan extracted from marine wastes in various fields.
Keywords: Chitosan, antimicrobial, anticancer, Food packaging

Received 23.04.2023 Revised 12.05.2023 Accepted 11.07.2023

INTRODUCTION

Chitosan is a natural biopolymer with bioresorbable degradation products, hydrophilicity, biocompatibility, cellular binding capability, and acceleration of wound healing. Chitosan is a natural polymer that can be used for a variety of things, such as water purification, biomedical products, and food preservation. The living organisms that live in the ocean produce around 10^{12}–10^{14} tons of chitin a year, of which 2.8×10^{10} kg are produced by arthropods in freshwater and 1.3×10^{12} kg in marine environments [1,2]. Developing commercial procedures for chitin extraction would provide enough raw material for commercially competent polymers, given this huge amount of chitin. A large amount of seafood waste is burned, disposed of in landfills, dumped at sea or left to spoil. Unless properly processed, it can adversely affect human health, biodiversity, and the environment [3].

Chitin can be recovered from prawn and crab wastes as a powder, used for drying, folding, and creating products with added value. It has a variety of uses in the food business. The most important idea is that chitosan coatings are used to protect food products from bacterial contaminants and also to extend and improve the shelf life and the quality of the product [4,5,6,7].

CHITOSAN EXTRACTION:

Seafood waste is an additional beneficial chitosan resource with high economic potential and significant added value. The shells are deacetylated into chitosan by a straightforward procedure. Shrimp and crab shells are a valuable source of chitosan which can be used to make chitosan adding value to the food sector. Chitosan derived from seafood waste offers the possibility for significant resource recovery and value addition, also having a high commercial potential for use in a variety of food-related applications [8]. The possible uses of discarded shrimp and crab are attracting more attention. A useful component known as chitosan can be produced from shrimp tail shells, shrimp trash, and crab shells from bay fisheries.

The extraction of chitin can be done through two processes, i.e., chemical and biological. Chemical chitosan extraction is done by following three main steps, that is, demineralization, deproteinization, and de-acetylation. The chitin and chitosan extraction technique, which was carried out using chemical means, was deproteinization of biomass followed by deacetylation of the chitin, yielding the chitosan as residue. Generally, the heterogeneous method treats the chitin by a hot concentrated NaOH solution for several

hours, and the deacetylation is achieved to about 85-99%, with the production of chitosan. Chitin can be extracted from different sources and converted into the highly useful chitosan by varying degrees of deacetylation by using varying concentrations of NaOH [9,10,11].

The extraction procedure starts with the gathering of leftover shrimp and crab shells. Following the collection procedure, the material is processed through a pipeline where it is crushed into the right-sized particles for further processing. Woody biomass and activated carbon may be used as extra resources during this procedure. This procedure results in the extraction of chitin, which is employed in a variety of industries, including the food and biomedical sectors. Depending on the quality of the inputs used for extraction, one plant may be able to produce up to 10 tonnes of chitosan every day once it has been removed from the waste resources. Research shows that using shrimp and crab shells for chitosan manufacturing instead of conventional sources like fish scales increases resource productivity [8,12,13].

The processes involved in the extraction of chitosan could also affect the viscosity of chitosan produced. The deacetylation process in the present study was performed only for two hours, and can have a great impact on the deacetylation extent of the extracted chitosan from the crabs in mud. The extracted chitosan from mud crab shells showed lower water-binding capability than the commercially available chitosan. The extracted and the commercial chitosan showed different peaks in the spectrum as both the chitosan were made from different sources. The mud crab-extracted chitosan was made from the shells of the mud crabs, whereas the commercial chitosan was made from shrimp shells. Chitosan was also prepared from swimming crab shells through the application of various methods like deproteinization and deacetylation [14].

The research output showed that the chitosan yield obtained from the Egyptian shrimp shells was 8.7%, which was significantly higher than that of other waste shrimp shells. The results also indicated that the shell chitin had good solubility and viscosity properties, providing a potential source of low coast chitosan. The extraction process used a strong sodium hydroxide solution to deacetylate the shell material and obtain chitosan's with different degrees of deacetylation. During the deacetylation process, a white precipitate appeared, which contained deacetylated chitin and an oxide product. The degree of deacetylation was determined by measuring the solubility and viscosity of the obtained chitosan in 1% acetic acid solution. This research output showed that it is possible to obtain a high yield of low-cost chitosan from waste shrimp shells, making it an attractive option for many applications [10,15].

Chitin extraction from shellfish involves protein reduction to remove proteins, and demineralization to remove inorganic calcium carbonate from the shells. The major commercial sources of chitin are the shells of crustaceans, such as shrimp, crab, lobster, and krill, which are supplied in bulk quantities by the shellfish processing industry. The most abundant elements found in shells of crustaceans are Ca, Mg, Na, K, and Fe16. Chemical deproteinization using sodium hydroxide results in the partial deacetylation of the chitin, as well as the hydrolysis of the biopolymer, which reduces its molecular weight [16,17,18].

The debris from the crab and prawn was treated with an alkaline deacetylation procedure to extract the chitin. In order to separate the processes of protein deacetylation and deproteinization, hydrochloric acid a potent alkaline solution, was used in the extraction procedure. Following a phase of phosphate buffer treatment, the resultant chitosan was copolymerized with sodium or potassium hydroxide and calcium phosphate to remove the acetyl groups from the polymer chain. The remaining acetyl groups from the polymer chain were then further removed using various strengths of sodium or potassium hydroxide. Chitosan manufactured using this process had an average level of deacetylation between 90 to 95 percent, making it a viable material for a variety of uses. This study also shown that the final phase of amino-oxidation, further reducing or eliminating any remaining acetyl groups from the chitosan molecule, is feasible using various hydrogen peroxide concentrations [10,19].

Lee and his colleagues confirm that calcium oxide deproteinization treatment is expected to efficiently remove proteins and improve chitin extraction yields from the shells of blue crabs and shrimp [20]. Chitosan was extracted from blue crab and shrimp shells using calcium oxide treatment followed by sodium hydroxide treatment, which may enable the skipping of demineralization steps. Removing insoluble particles, such as chitin residues, proteins, polysaccharides, and polysaccharide conjugates, from chitosan material is an additional starting step. Conventional methods indicate that extracting and purifying the chitin from shells of crustaceans involves proteinization and demineralization through heavy bases and acid treatments followed by deacetylation. An alternative method for purifying chitosan made use of the immobilized pepsin. At pH 4.5 and 45°C, deproteinization was carried out at its best. After 160 minutes of incubation, amino acid analysis showed that 53.8–80.4% of the protein in chitosan had been removed, which was more effective than the usual sodium hydroxide deproteinization method. Chitosan's molecular weight dropped when it was deproteinized by immobilized pepsin, however this process was much milder than that of free pepsin [21].

APPLICATION OF CHITOSAN

ANTIMICROBIAL ACTIVITY OF CHITOSAN

One of Chitosan's major biological properties is its antimicrobial effects on *Staphylococcus aureus, Candida albicans*, and *Escherichia coli*, among others. According to the research by Gomes *et al.* high antimicrobial activities of chitosan with higher molecular weights could be attributed to pH of mediums where it is found, therefore, lower pH values lead to higher antimicrobial activities of chitosan [22]. This activity is influenced by the percentage of chitosan in a mixture, since collagen does not exhibit antimicrobial activity, as observed in antibiograms. In this study, chitosan used represented 65% DD [Determination of the degree of chitosan deacetylation percentage], thus, achieving 13 mm inhibition zone of *S. aureus* and 10 mm of *E. coli in* antibacterial activity assays [23].

The lower value of the minimum inhibitory concentration and higher value of the inhibition zone are probably due to high solubility of the chitosan in association with collagen, and also to high DD of the chitosan was observed (82%). The collagen hydrolysate-chitosan adhesive films loaded with citronella essential oil showed antimicrobial activities against test microorganisms, but lower than controls. In vitro antibacterial tests with three bacteria strains showed the rabbit collagen glue hydrolysate-chitosan biomaterial suppressed all the three tested microorganisms [24]. Sadeghianmaryan *et al.* designed an Chitosan/Alginate/Hydroxyapatite hybrid scaffolds and investigated for their antibacterial properties for their potential implantation applications [25].

Fish type 1 collagen was extracted from *Spondyliosoma cantharus* and chitosan nanoparticles from shrimp shells were prepared along with the leaves extract of *Lawsonia inermis* L. and the composite was tested for their antimicrobial properties against skin pathogens such as *Candida albicans* and *Staphylococcus aureus*. The composite of chitosan nanoparticles with leaf extract exhibited potential antimicrobial activity against both pathogens showing a higher MIC activity of 20.0 and 22.5 μg/mL against *S. aureus* and *C. albicans*, respectively [26]. In another study, the effect of chitosan extracted from shells of sea crab and *Aspergillus niger* were investigated for antibacterial activity against urinary tract infection pathogens. Chitosan derived from carb shell showed 6 mm of zone of inhibition activity against *E. coli* and 8 mm against *K. pneumoniae* when tested with 20 and 30 μg respectively. The maximum zone of inhibition was recorded when 30 μg of chitosan extracted from crab shell and fungus against all the tested pathogens [27]. Similarly, Mohanasrinivasan *et al.* extracted chitosan from shrimp shell waste and found effective against Xanthomonas sp., plant pathogen associated with citrus canker [28].

Many studies have investigated the potential of chitosan as an edible film to extend the shelf life of food because of its strong antibacterial capabilities. Antibacterial activity was found to be effective against microorganisms that cause fish pathology. According to the study, chitosan's charges, electrostatic forces, and antioxidant capabilities are all crucial for it to work as an antibacterial agent. It was found that chitosan's solubility and other physical traits hinder the substance's antibacterial action. Natural antimicrobials like chitosan are being used more frequently since created natural antibiotics are losing their effectiveness. A potential anti-fungal defence against bacteria and dangerous microorganisms has been proposed for chitosan. Chitosan can be applied to a range of foods, including diseased fruit, to reduce fungal deterioration. Moreover, it effectively combats fungus spores and inhibits germination, preventing the spoiling of fresh fruit. Chitosan is produced using prawn and crab shells, which are biodegradable sources. Chitosan has been intensively researched for its capacity to minimize pathogenic germs and illnesses associated with food-borne outbreaks, with the potential to reduce annual incidence of food-borne illnesses [7,29,30,31].

ANTIOXIDANT ACTIVITY OF CHITOSAN:

The author presents chitosan's physicochemical characteristics, antioxidant capabilities, and possible applications in cosmetics and other oxidative stress-related products. - Vietnamese shrimp waste contains chitosan, a carbohydrate made from shrimp chitin. Investigating chitosan's toxicity, antibacterial activity, and antioxidant potential were the goals of this study. The ability to neutralize free radicals was tested in vitro utilizing the diphenyl-picrylhydrazyl and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radicals [6,32].

Chitosan (Ch) was compared to the additives propyl gallate (PG) and gallic acid for its antioxidant effects (GA). The findings demonstrated that compared to PG and GA, Ch has a stronger antioxidant activity. Moreover, it was found that adding Ch to a model diet improved its mechanical recovery and decreased lipid peroxidation. The agar disc diffusion method, which measures the percentage of hemolysis inhibition to evaluate the antioxidant activities of chitosan films with erythrocytes, has been used to characterize the antioxidant capabilities of chitosan films. The microstructure analysis of the produced films showed that they were of high quality and suitable for a variety of uses. In conclusion, superior antioxidant qualities and

the ability to function as a potent barrier film make chitosan FFS a valuable material for food packaging [32,33,34,35,36].

A naturally occurring cationic biopolymer generated from chitin, chitosan demonstrates a number of biological characteristics. It has been discovered that chitosan contains significant bioactive components with a variety of extremely powerful actions. It performs the functions of hemostasis, wound healing, antioxidant healing, and antibacterial activity. Moreover, it can clean water of metals and other toxins, as well as control cancer and immune system activity. It also functions well as a coagulant for ions in microorganisms and as a biopolymer with uses in food packaging [6,38].

The antioxidant properties of water-soluble chitosan derivatives, which were thought to be hydroxyl radical scavengers and had metal-bonding abilities, have been researched by a number of scientists. There are several processes that account for the antioxidant action of chitosan. One of them is free-radical scavenging activity, wherein chitosan can neutralize different free radicals by nitrogen's impact on the C-2 position. It has been suggested that chitosan's ability to act as a free radical scavenger is connected to the fact that free radicals can interact with the hydrogen ions from ammonium ions (NH3) to form stable molecules.

The antioxidant characteristics of chitosan fibres were improved when flavonoids were grafted onto them in comparison to unmodified fibres, although it was discovered that these improvements depended on the flavonoid's antioxidant assay. The antioxidant activity of the construct, however, may differ significantly from the free flavonoid attached due to enzymatic oxidation and grafting to chitosan [37].

The samples' antioxidant capacities are strongly related to their capacities to deactivate reactive oxygen species, scavenge free radicals, chelate pro-oxidative transition metals, and donate electrons and hydrogen. One of the key factors influencing how protein hydrolysates' antioxidant capabilities are thought to be their molecular weight. The correlation coefficients between anti-oxidative activities and the average molecular weight of seven fractions were examined in the current text. The seven fractions' antioxidant activity rapidly decreased as their average molecular weight increased. The linear relationships between antioxidant activities and logarithms of average molecular weight were inferred, and it was discovered that there were significant negative correlations between antioxidant activities and average molecular weight of hydrolysate fractions. The results were consistent with earlier research that found increased DH of hydrolysates to be advantageous for their antioxidant properties. Since shorter and more active peptides make up lower average molecular weight samples, they could act as electron donors and react with free radicals to convert them into more stable compounds and stop chain reactions. Additionally, samples with lower Average molecular weight were more likely to successfully cross the intestinal barrier and carry out their biological roles. The average molecular weight of protein hydrolysates was shown to be the primary factor affecting their capacity to act as antioxidants [38].

Antioxidant effects are shown by chitosan derivatives. 1,2,3-triazole moieties are the most frequently used chitosan derivatives. They have been employed to provide radical scavenging activity in cosmetics and other goods to protect cell nuclei from oxidative stress. A higher level of radical scavenging activity than the original form is achieved by these moieties, which also improve chitosan's scavenging capacity. Due to its strong capacity to scavenge free radicals, the N methylation of 1,2,3-triazole moieties has also been utilized as a component in a number of anti-fungal and anti-phytopathogen products. By interacting with the plasma membrane and lowering the capacity to scavenge free radicals, chitosan derivatives can prevent cells from oxidative damage [33,39,40].

ANTICANCER ACTIVITIES OF CHITOSAN:

The anticancer capabilities of chitosan and its derivatives, such as chitosan oligosaccharide (COS) and chitosan Schiff base CSQ/Ag, are covered in this article. With less toxicity than chemotherapy medicines, chitosan and its derivatives exhibit anticancer action through the cellular antioxidant defence system and apoptotic pathways. When SPIONs or carboxymethylated chitosan were added to the chitosan nanoparticles, cell viability was higher in 3D cultures than in 2D cultures. There are many therapeutic uses for chitosan and its many derivatives, including as an anticancer agent. Chitosan's selective antitumour effects on colorectal cancer cells in vitro have been investigated, resulting to the creation of composite chitosan drug nanocarriers. Inhibiting cell growth, triggering apoptosis, and interfering with cell cycle progression are thought to be the ways that chitosan interacts with cancer cell membranes to exhibit excellent anticancer actions. Furthermore, it has been discovered that chitosan nanoparticles exhibit greater efficiency than free medicines and extend retention at the tumour site due to their precise distribution there. The biocompatibility and biodegradability of chitosan nanocomposites employed in cancer therapy need to be investigated further. In many different forms of cancer, chitosan has also been discovered to activate caspase-3/7 activity, inhibiting the cellular antioxidant defence mechanism that might cause the apoptotic death of cancer cells. Moreover, it has been proposed that certain of its

derivatives, including glucosamine and N-acetylglucosamine, may have anticancer effects by preventing angiogenesis or obstructing the actions of enzymes implicated in carcinogenesis [41,42,43].

The potential of chitosan as a cancer treatment has been thoroughly investigated. Dox-encapsulated chitosan nanoparticles had effective cytotoxic effects against cancer cells, according to a 3D cell culture study employing human prostate cancer cells. In a similar vein, it was discovered that in typical 2D grown cells, silver nanoparticles loaded with dox had stronger anti-proliferative action than free medicines. Furthermore, a complete tumour model investigation showed that these chitosan-based drug delivery systems may successfully target and prevent the growth of tumours. Moreover, toxicity studies revealed that these substances were less harmful to healthy cells than the chemotherapy drug 5-fluorouracil (5-FU), indicating the possibility of their usage as potent anti-cancer medications. Overall, the findings of these investigations indicate that chitosan and its derivatives have minimal toxicity towards normal cells and demonstrate promising anticancer effects by targeting and suppressing tumour growth [44,45].

The present study is on a doxycycline-loaded collagen-chitosan composite scaffold to accelerate healing of diabetic wounds. Other types of chitosan composite scaffolds for ACS defects are also being investigated. Porous chitosan composite scaffolds have shown a good development potential for AC defect repair. The intrinsic antioxidant activities of chitosan are essential in tissue engineering. Bioactivities of Chitosan. Chitosan is mostly expressed by its antimicrobial, antitumor, and antioxidant activities. The results of their studies showed that chitosan increases antioxidant and anticancer potential of NPs from Ag [46,47,48].

According to their study's findings, zinc is slowly released by nanoparticles after being used to treat leukaemia cells, and this release of zinc causes target tumour cells to activate their apoptotic pathway. Chitosan nanoparticles cause leukaemia cells, among other tumour cells, to undergo apoptosis by causing oxidative stress by lowering glutathione levels and raising ROS. Chitosan was used to create the first silver nanoparticles, which demonstrated anti-cancer effects on mouse leukemia cells, by Hemmati and colleagues [48]. The mechanical properties of collagen-based and chitosan-based composites were measured as a test for degradation. Materials made from chitosan and collagen could be used as bioactive substances, which could influence the behavior of cells [48,49].

Although collagen and chitosan were proposed individually as ECM materials in vitro, the effects of the composite matrix based on chitosan-collagen are not well studied for the effects of cellular morphology, differentiation, and function. Furthermore, bioactive collagen/chitosan composites can significantly decrease the melanin content, inhibit the tyrosinase activity, and down-regulate mRNA tyrosinase expression. Recent studies also showed that the alteration of collagen/chitosan complexes leads to its higher potential as drug delivery systems for treating advanced cancers [16,49].

These features promote the application of NP-based collagen biopolymers in medical fields, such as targeted controlled drug delivery, cell targeting, and tissue engineering. Collagen-CHS-based films/membranes are important biomaterials used in antibiotic delivery, wound healing, cancer therapy, transdermal delivery, cardiac diseases, tissue engineering. Collagen-based biomaterials or composites are becoming an important DDS because of specific hole sizes for the active drugs or main loading, efficient fibrillary networks, enzymatic degradation, long-term in vivo stability, biocompatibility, low antigenicity, greatly reduced toxicity, and safety characteristics. Porous chitosan-gelatine scaffold has more than 94% porosity. Doxycycline loaded collagen-chitosan scaffolds were applied to the cross-linking process to carry out cross-linking, a buffer MES was prepared first, taking.488 grams of MES and 15 ml water, out of this, 20 ml MES buffer was taken out, and transferred individually to the beaker. Subsequently, the excision wound was treated with cross-linked Doxycycline loaded collagen-chitosan scaffolds along with primary dressings and monitored for 21 days [46,50,51].

According to one research, silver nanoparticles were incorporated into chitosan-based nanoparticles. In mice, the Ehrlich ascites tumour cells were successfully combated by these nanoparticles. In addition, a number of studies have used chitosan nanoparticles to test the anti-cancer effects of cancer cell lines on mouse leukaemia cells and human breast cancer cell lines. These research' findings indicate that when exposed to chitosan nanoparticles, cell viability and apoptosis are increased in comparison to control groups. Also, when applied to a bearing mouse model of human breast cancer, Fe3O4-CMC genistein nanoparticles demonstrated self-assembled micro particles. This study also showed that over time, these particles had an anticancer effect on the breast cancer cell line by dramatically slowing its growth rate in comparison to the control group [43,45,48].

The nanoparticles were demonstrated to enhance uptake of the direct anticancer medicines, which lowered toxicity while maintaining therapeutic efficacy, and to raise fluorescence intensity five-fold when exposed to cancer cells. These particles also contained the targeting ligand FA-231, which was used to target the receptor on human breast cancer cells. Because of this, the research demonstrated that the nanoparticles exhibited a particular affinity for tumour cells as opposed to healthy cells and had a lower toxicity profile than conventional anticancer medications [41,48].

The impact of various chitosan hydrogel properties, such as swelling and stability, on cell viability and proliferation is examined by Debnath and his coworkers (2015). Chitosan hydrogel can improve cell viability and proliferation in vitro, notably for stem cells, according to the results. The study also showed that chitosan hydrogels have a great deal of potential to act as an advantageous matrix for cell development and differentiation [52].

The researchers also stated that the chitosan nanoparticles' size and shape are influenced by the amount of AUNPs present, which also has an impact on the cytotoxicity and rate of drug release. A further finding of the study was that chitosan nanoparticles (LCNPs) of various sizes had varying effects on the proliferation of MCF-7 cells, with LCNPs at 8 h being the most efficient at inhibiting cell viability. Furthermore, the clonogenic experiment showed that, at 8 hours, LCNPs dramatically decreased cell survival in an L132 cancer cell line. Finally, surface Plasmon resonance was employed to research the impact of shape and surface chemistry on anti-proliferative activity. The outcomes demonstrated that LCNPs with higher radical content had superior anti-proliferative action compared to those with lower radical content. Overall, this research has shed fresh light on the application of chitosan nanoparticles to the treatment of cancer cells and has offered helpful data for the investigation of drug delivery [53,54].

Hydrogels were created and put to the test in 24-hour cultures of CCD 1106 KerTR cells, a human keratinocyte cell line generated from epidermal cells, to test this. Cells that were metabolically active were discovered in the hydrogels that had been created during the study. Moreover, experiment results demonstrated that using these modified hydrogels can prolong cell viability maintenance when compared to using a standard substrate. XTT and MTT assays in serum-free media were used to further evaluate the cytotoxicity of both modified and unmodified hydrogel matrices in comparison to various kinds of chitosan samples [52,55].

The effectiveness of chitosan solution and nanoparticles in killing mouse HSCs was examined in the study whose findings are summarized in this article. The study discovered that the molecular weight of the chitosan had no discernible effect on the viability of the cells and that both chitosan solution and nanoparticles had a small but significant cytotoxicity on the cells. - When compared to aqueous nanoparticles without ori, the drug-loaded nanoparticles had considerably higher anticancer efficacy. For HepG2 and MCF-7 cells, as well as mice HSCs, the cytotoxicity was assessed using the MTT assay. It was discovered that the activity of ori solutions declined in a concentration-time dependent way, and that this did not rule out interference from other polymers. The study's findings also showed that, as compared to control groups, chitosan solution had higher anticancer activity. Both HepG2 and MCF-7 cells showed the same cytotoxic impact that was reported. Additionally, at all concentrations, the blank nanoparticles had the lowest levels of cell survival. As a result, prepared cytotoxic effects were chosen based on csnps concentrations. When comparing the smallest particle size with the greatest csnps concentration, no discernible toxicity was found, proving that particle size had no bearing on cell viability. While different chitosan concentrations did not influence the overall viability (74.42%), chitosan molecular weight also had no impact on cell viability. Chitosan was employed in this investigation at a maximum concentration of 1000 mg/np, and its particle size was found to be 35 nm, with a molecular weight of 300 kDa.As a result, this study came to the conclusion that chitosan nanoparticles have a great safety record and may be used as a therapeutic agent to treat cancer cells [56,57].

CHITOSAN AS FOOD COATING MATERIAL

Chitosan has a variety of potential applications, including food packaging and biocompatibility. Industrial applications of chitosan extracted from crab and prawn wastes have recently become more popular. *Crangon crangon* shrimp waste is one of the main sources of chitin utilized to extract chitosan. The Omani shrimp shell was used to optimize isolation and antibacterial properties. Microwave technique was used to maximize resource productivity. Deproteination and deacetylation conditions were based on the method proposed by Bajaj *et al*. which involved a series of treatments with acetic acid, hydrochloric acid, sodium hydroxide and ethanol [58]. Chitosan is a natural polymer with a wide range of useful qualities, including mucoadhesive, antifungal, and antibacterial capabilities. The fish sector could utilize chitosan on a massive scale. Due to its biocompatibility and toxicity, it can be utilized as a coating or packaging material to preserve food as well as for drug delivery systems and medical equipment. Moreover, marine organism waste can be utilized to extract chitin, the precursor to chitosan, which has demonstrated antibacterial qualities that can be used for food coating. Crustaceans, arthropods, and some insects have chitin and its derivative chitosan in their exoskeletons. N-acetylglucosamine is a polysaccharide found in chitin, which is the second most prevalent biopolymer on the planet after cellulose. Animal feed processing, bio converters for energy production, and the management of organic waste are among the industrial uses for chitin that is produced from crab and prawn waste. Due to its antitumor efficacy, chitosan derived from crab or prawn

wastes can also be employed in cancer therapy in addition to these uses. This activity has been linked to both the molecular weight and degree of chitosan deacetylation [8,12,59].

The extraction procedure used on the crustacean shell waste allowed for the synthesis of chitin and chitosan with added value. According to the study, 90% of the chitosan from crab shell waste was found to be deacetylated at 90°C. This shows that the extracted chitosan had better pKa values for chitosan because it had more amine groups than raw chitin. Due to its potential use in the food industry, the extraction process for manufacturing value-added products from crustacean shells, such as crab and prawn shells, has been intensively explored. As it increases the number of amine groups on the extracted product that are readily available for usage in various industrial applications, the demineralization-deacetylation process is a crucial stage in this extraction procedure [8,60,61].

The biocompatible nature of chitosan makes it perfect for use in food packaging. Due to its accessibility, affordability, and wealth of qualities including UV protection, the usage of prawn shell waste as a raw material in the production of chitosan has gained prominence. Chitosan can also be made from chitin that has been chemically synthesized as a starting material. Chitin protein fibrils are used to create the biodegradable polymer which can be further used for a variety of things, including medicine delivery systems, water treatment, and food packaging. Chitosan serves as the innermost circle and structural representation of the packaged product when used as a packaging material. Also, because of its film-forming qualities, it can be used in more recent generations of films [12,59,62].

Romanazzi *et al.* (2018) Chitosan-coated fruits are becoming more and more common as an edible covering. The natural polymer chitosan, which is generated from the shells of crustaceans and mollusks, has many uses in food packaging. Chitosan can be used to cover citrus fruits, peach fruits, strawberry fruits, and fresh strawberries to lengthen shelf life and improve quality. Chitosan coatings prevent the growth of germs and fungus, providing antimicrobial active packaging for the production of olive oil [31].

Through developing an edible film on the food's surface, the chitosan-based edible active coatings help preserve the food. This prolongs its shelf life by helping to prevent it from microbial attack and food degradation. Chitosan also possesses anti-oxidant qualities that aid in preserving food quality for a longer time. Many studies of chitosan's impact on various meals have led experts to the conclusion that it is a useful technique for raising food quality and extending shelf life [7,31,63].

Many researchers have noted the potential of chitosan as a coating film due to its functional properties and mechanical properties which can increase the storage life of food products. The application of chitosan on food coatings has shown to have a wide range of antibacterial benefits, preserving the quality and shelf life of food products for longer periods [7,64]. This coating technique is used to protect certain food products from bacterial development and extend the shelf life of perishable produces. Chitosan coatings can be applied on bread to increase hardness, while other non-perishable foods such as fruits and vegetables are coated with a layer of chitosan mixed with lysozyme enzyme and pseudomonas fluorescens to inhibit molds. The coating formed by chitosan provides excellent protection against microbial growth which aids in increasing the shelf life of food products [7,65].

The single chitosan coating technique is one of the most popular methods used to coat food items. This technique has been found to provide the greatest antibacterial effect against microbes which are present on food surfaces. Other treatment includes, heat treatment, hypobaric treatment and gas fumigation. Gas fumigation uses CO_2 for food sanitation before they are packaged. Chitosan has been extensively studied for its bacterial inhibitory properties and its application on food coating has also been tested in vitro experiments. It can be used as an edible coating on complex food items such as carrot sticks and other fruits and vegetables to increase their shelf life and maintain their quality during packaging. Chitosan is usually combined with organic acids like lactic acid, citric acid or acetic acid in order to make it more effective against bacteria. This combination increases the solubility of chitosan and its positive charge density. The antimicrobial activity of chitosan has been tested on cut papaya, and it has been found to have effective antifungal activity [4,63,64,66].

CONCLUSION

As a helical polysaccharide macromolecule, chitosan is one of the most prevalent natural biopolymers after cellulose, and has been found to have remarkable biological properties, including bioresorbable degradation products, hydrophilicity, and biocompatibility, which are used in a wide variety of industries, including food, cosmetics, biomedicine, and pharmaceuticals. It has been proven that chitosan exhibits broad spectrum antibacterial activity in biological activities such as antimicrobial activities. Various encapsulation methods, including peptides and growth factors, anti-inflammatory compounds, and antibiotic compounds, have also been used with chitosan in the delivery of drugs. Besides its biological properties, chitosan is also utilized in several applications in agriculture, including seed coating, fertilizers, metal removal from wastewater, material science, and the recovery of solid waste from food processing

waste. Considering its benefits for biomedical and food products, chitosan may be used in a lot of applications in the future.

ACKNOWLEDGEMENT
The authors thank the Management and the Principal, Dwaraka Doss Goverdhan Doss Vaishnav College, Arumbakkam, Chennai for providing the necessary support to carry out this work.

CONFLICT OF INTEREST
The authors declare no conflict of interests.

AUTHOR'S CONTRIBUTION
All authors have equal have made equal contributions

FUNDING
Nil

ETHICS STATEMENT AND INFORMED CONSENT
Does not apply.

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CITATION OF THIS ARTICLE

Nithya. M. S, Swetha. J, Sowmya Radha. S, Santhi Rasappan, and Balakumaran M.D. A Review on Chitosan - An Eco-Friendly Polymer and its Potential Applications. Bull. Env. Pharmacol. Life Sci., Vol 12 [8] July 2023: 420-429