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Environment-friendly Chitosan Nanoparticles and its Application

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ABSTRACT

The shellfish processing industry produces a huge amount of waste which causes environmental problems if discarded. This waste can be effectively utilized to produce valuable byproducts such as chitin and its derivatives including chitosan nanoparticles. When chitin is alkaline deacetylated, a naturally occurring harmless biopolymer called chitosan is created. It is composed of d-glucosamine and N-acetyl-d-glucosamine units connected by (β1–4) glycosidic linkages. The primary limitation preventing chitosan from becoming utilized in living systems is that it is insoluble in water. Promising bio-based and polymeric nanoparticles are chitosan nanoparticles. This material can be prepared using the following techniques: molecular self-assembly, interfacial cross- linkage, ionotropic gelation, coacervation/precipitation, template polymerization, and reverse micelles. Due to its low size, solubility, surface area, and biological characteristics, this material can be used for various applications including antimicrobial agents, wastewater treatment, drug delivery, encapsulation, plant protection, and plant growth-promoting agents, etc.

KEYWORDS

Shrimp shell waste, Polymer, Chitosan nanoparticle, Antibacterial agent.

Introduction

An estimated 6 to 8 million tonnes of garbage originating from crustaceans, which includes crabs, prawns, and lobsters, are discarded globally year (Yan & Chen, 2015). Shrimp shell trash needs to be used properly because it is consumable and damages the environment when disposed of in waterways. Protein, carotene, chitin, minerals, and flavoring chemicals are among its beneficial byproducts (Dayakar et al., 2021; Dayakar et al., 2022). The primary component of crab shells, chitin, is partially deacetylated to provide chitosan, a cationic polymer (Lopez-Leon *et al.,* 2005). When the amount of nitrogen surpasses 7% and the degree of deacetylation goes above 60%, the term "chitosan" is typically used in place of "chitin" (Peter et al., 1986). A random linear polysaccharide, chitosan is mostly made by deacetylating chitin from prawns, crab shells, and squid pens using sodium hydroxide. According to Rinaudo (2006), it is made up of d-glucosamine and N-acetyl-d-glucosamine units joined by one to four glycosidic connections. It finds application in numerous domains such as the biomedical area, agriculture, food industry, genetic engineering, water treatment, paper manufacturing, and pollution management in the environment. Due to their special properties, chitosan nanoparticles may be able to target specific areas in vivo and have a greater affinity for negatively charged biological membranes (Qi *et al.,* 2004). Ohya published the first description of chitosan nanoparticles in 1994. For the intravenous administration of the anticancer medication 5-fluorouracil, they employed chitosan nanoparticles that were created via emulsifying and crosslinking (Grenha, 2012). Since then, a variety of techniques have been used to synthesize chitosan nanoparticles. Currently, there are five methods for producing nanoparticles: the polyelectrolyte complex, ionotropic gelation, microemulsion, emulsification solvent dissemination, and reverse micellar technique. Among them, polyelectrolyte complex and ionotropic gelation are the most often utilized techniques.

Properties of chitosan nanoparticles

- Non-toxic and soluble
- Non-immunogenic
- High charge density
- Antimicrobial property
- Adhesion
- Ability to coagulate
- Biocompatible and biodegradable
- Increased surface area
- Low molecular weight
- Uniformity in size, shape, and white in color

Application of chitosan nanoparticles

Biomedical application

Biocompatible and mucoadhesive, chitosan nanoparticles find application in tissue engineering. These characteristics have the potential to trigger structural remodelling of proteins connected to tight junctions and boost transmucosal permeability, which will facilitate the migration of the nanoparticles along the paracellular pathway. The small particle size increases the ratio of the volume to the surface as well as the specific surface area of chitosan, increasing its bioavailability. To prevent macromolecules in living things from degrading, chitosan nanoparticles can pass through biological barriers. It can also use controlled release to deliver drugs or macromolecules to a specific location (Perera & Rajapakse, 2013). The Chitosan nanoparticle's small size also contributes to its effectiveness in interacting with cell membranes since endocytosis will take up the tiny particles (Ghadi *et al.,* 2014).

Agricultural application

It has been shown that chitosan nanoparticles increase the amount of pigment, photosynthetic rate, rate of nutrient uptake, and other biophysical characteristics of coffee seedlings (Dzung et al., 2011). Chandra and associates (2015) Chitosan nanoparticles have been observed to induce a markedly robust defense response in Camellia sinensis through the upregulation of defense-related enzymes, such as β-1,3-glucose, phenylalanine ammonia-lyase (PAL), the enzyme polyphenol oxidase (PPO), and peroxide (PO).

Food Industry

De Moura *et al*. (2009) created a chitosan nanoparticle-based edible film based on hydroxypropyl methylcellulose. Film comprising carboxymethylcellulose and chitosan nanoparticles has been investigated as a potential material for food and beverage packaging because of its excellent mechanical properties and stability. Chitosan active bio-based film has been reported to be used as a food coating for a variety of foods, such as cheese and meat items such fermented sausages (Wang et al., 2004). Beluga (Huso huso) fish fillets subjected to a food-grade coating consisting of CSNPs infused with fennel essential oils coupled with enhanced atmospheric packing showed minimal amounts of peroxide, total reactive nitrogen, and thiobarbituric acid (Magham et al., 2019). Similar to this, coating Litopenaeus vannamei (white leg shrimp) with CSNPs extended its shelf life by up to 10 days when it was kept at 4 °C (Wang et al., 2015). Jang & Lee (2008) state that chitosan nanoparticles can increase the stability of L-ascorbic acid during heat processing.

Wastewater treatment

Anthraquinone-type acid Green 27 (AG27) dye, arsenate, Pb (II), Cr (VI), Cd (II), and other substances were effectively tested for the adsorptive property of nano-chitosan. The increased porosity and larger circumference per unit mass of chitosan nanofibers make them promising candidates for use as adsorbents. The CSNP-coated membranes continued to support good bacterial growth when compared to noncoated membranes. Multiple tube fermentation (MPN) experiment revealed that the filtered water had the highest level of coliform removal (Rajendran et al., 2015). According to Abdul et al. (2015), aggregates of chitosan zinc oxide nanoparticles could remove 99% of the color in textile effluent.

Antioxidant activity

Chitosan is a proven antioxidant agent. It's capable of chelating metal ions and scavenging free radicals by contributing hydrogen or a single electron. Ion exchange, chelation, and adsorption are just a few of the processes that result from the interaction between chitosan's amino and functional groups of hydroxyl and metal ions. Strong hydrogen bonds and chitosan's semicrystalline structure prevent chitosan from separating from the metal ions. Yen *et al.* (2008), revealed that chitosan could chelate iron and scavenge hydroxyl radicals.

Antimicrobial agent

The most widely accepted mechanism for chitosan nanoparticles' antibacterial action involves their attraction to the negatively charged bacterial cell wall, which disrupts the cell and modifies membrane permeability. This is followed by a connection to DNA replication and eventual cell death.

Conclusion

The properties and uses of chitosan nanoparticles were outlined in this article. Chitosan is an emerging material in the nanotechnology field. Chitosan with its well-known functional properties can be extracted from shrimp shell waste which is available in large amounts from the shrimp processing industry. They have the potential to be encapsulation or immobilization carriers. These unique features offer many potential applications in different areas. Recently, they have been widely used in agriculture, medicine, the food industry, environmental, protection, and biotechnology.

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