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Recent findings and future prospects on the applications of chitosan in various fields

Abstract

Chitin is a natural polysaccharide found in insect exoskeletons, crustaceans, and fungal cell walls, and is the second most abundant biopolymer after cellulose. Through deacetylation, chitin can be converted into chitosan by removing acetyl groups. Due to its low toxicity, biodegradability, and biocompatibility, chitosan is widely investigated as a biomaterial. This article reviews the roles of chitosan, and chitosan-based coatings in medical and pharmaceutical applications, while also addressing their importance in agriculture and food science. Their major applications include serving as carriers for active ingredients such as cosmetic compounds, drug delivery systems, and nanoparticles that improve the effectiveness of agrochemicals. They are also widely applied in pharmaceutical formulations because of their mucoadhesive properties, as well as in tissue engineering for the regeneration of damaged or lost tissues. In addition, chitosan exhibits antimicrobial activity by absorbing metal ions, interacting with bacterial cell walls, and binding to DNA. Other important applications include food preservation and environmentally friendly water treatment through the removal of heavy metals, oils, greases, and other toxic substances. Owing to their notable antifungal and antibacterial properties, these materials have broad potential in the food, environmental, medical, textile, cosmetic, and agricultural industries.

Keywords: biomaterials, drug delivery systems, tissue engineering, antimicrobial activity, food preservation

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Introduction

Chitin is a naturally occurring polysaccharide that constitutes the structural component of insect exoskeletons, crustacean shells, and fungal cell walls. Owing to its biocompatibility, biodegradability, and low toxicity, chitin has attracted considerable attention in biomedical research. In medicine, it has been used as a haemostatic agent in wound-healing applications and incorporated into tissue-engineering scaffolds at both nano- and macroscale levels (Madhumathi et al., 2009). Furthermore, various nanostructured forms of chitin, including nanoparticles and nanofibers, have been extensively investigated for biomedical applications, particularly in drug delivery systems. Beyond the biomedical field, chitin and its derivatives are also applied in papermaking and other industrial sectors.

Due to the limited solubility and processability of chitin, it is often converted into chitosan, a more versatile and functional derivative (Fig. 1).

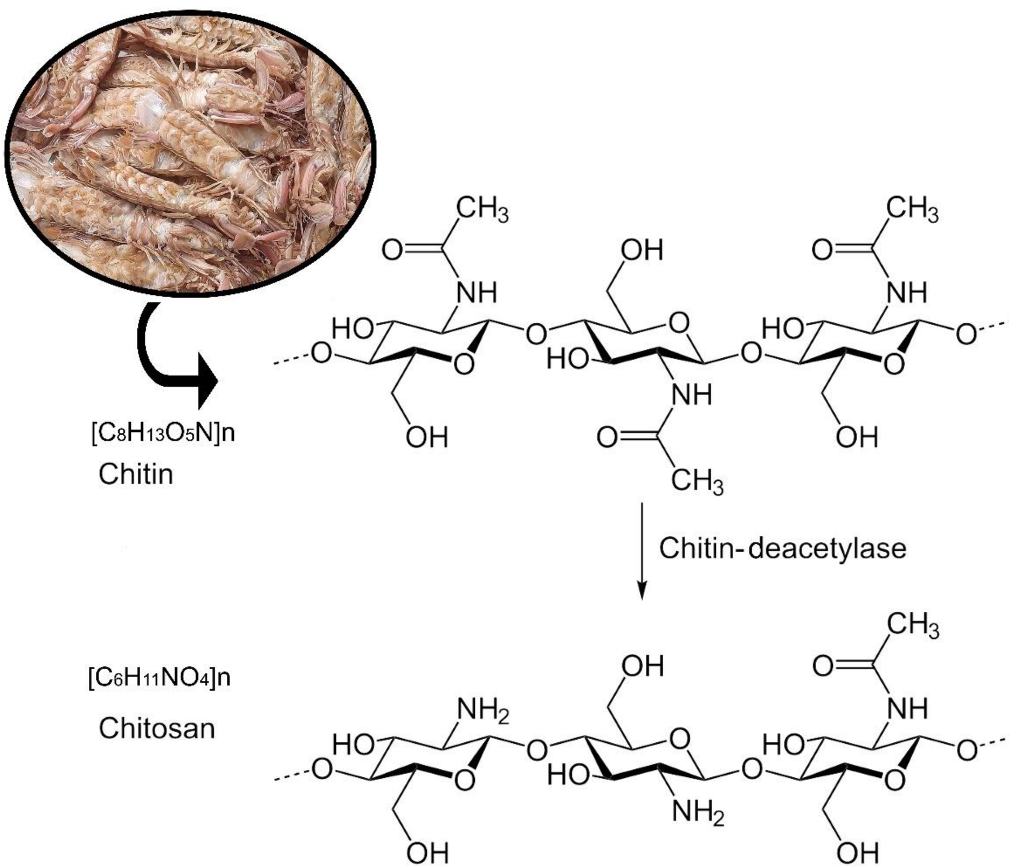

Fig. 1. Chemical formulas of chitin and chitosan

Chitosan is a natural biopolymer widely recognised as an environmentally friendly material with numerous applications in the food, pharmaceutical, agricultural, textile, and cosmetic industries

(Yanat, Schroen, 2021). Depending on its molecular weight and degree of deacetylation, chitosan exhibits a broad range of biological activities, including antifungal, antibacterial, anticancer (as a carrier of anti-cancer drugs), and antioxidant properties (Kumar 2000; Jia et al., 2001; Xie et al., 2001). Various chitosan-based materials, such as nanoparticles, capsules, hydrogels, and films, have been developed for applications including food preservation (Chollakup et al., 2020), drug delivery, and bone tissue engineering (LogithKumar et al., 2016). In addition, numerous studies have demonstrated the strong antimicrobial activity of chitosan against several pathogenic microorganisms, including *Fusarium solani* (Mart.) Sacc and *Candida albicans* (C.P. Robin) Berkhout (Panda et al., 2022). Different chemical properties of chitosan are presented in figure 2, while its biological activities are summarised in figure 3.

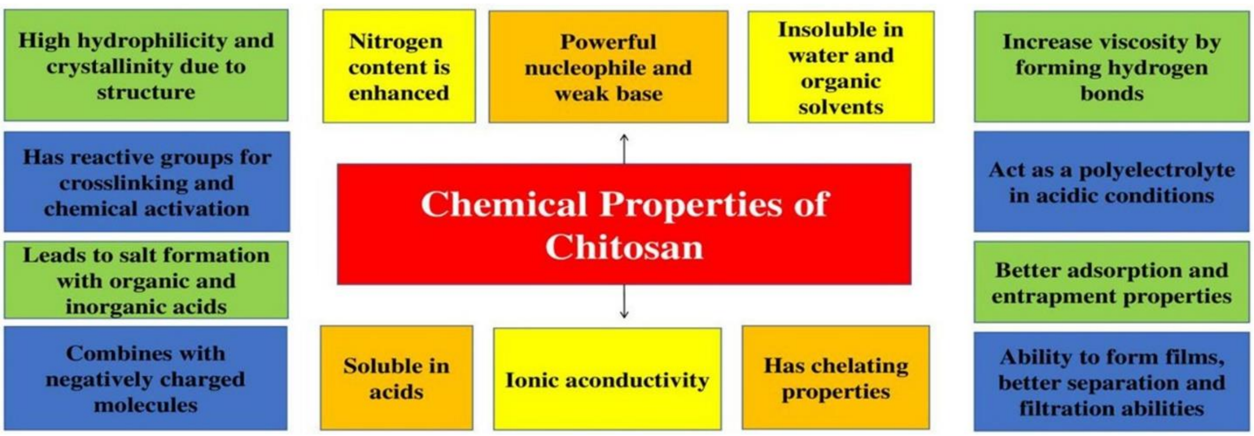

Fig. 2. Chemical properties of chitosan

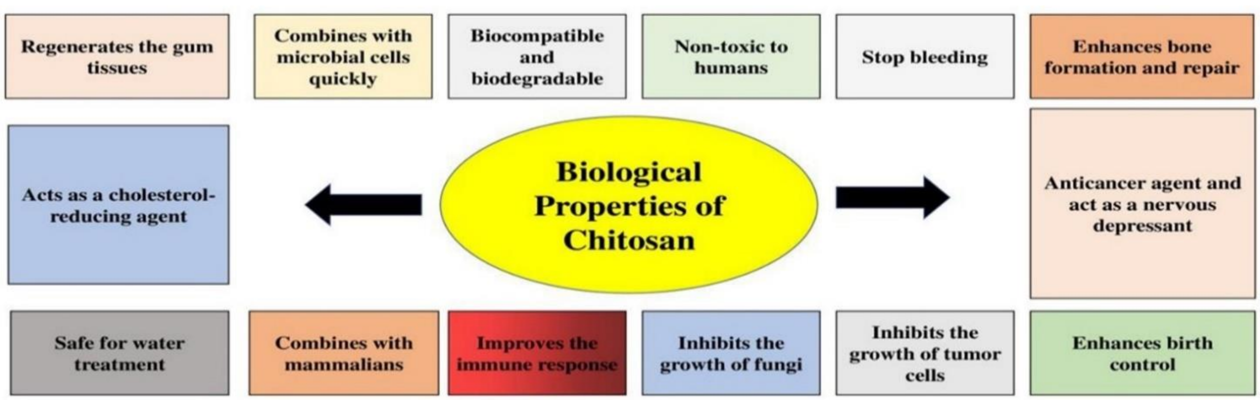

Fig. 3. Biological properties of chitosan

Chitin and chitosan are primarily produced using chemical or biotechnological extraction methods. Chemical extraction, based on the use of strong acids and bases, remains the most widely applied method at both laboratory and industrial scales. Natural sources of chitin and chitosan include crustaceans (such as king crab, lobster, and shrimp), fungi (e.g., *Lactarius vellereus* (Fr.) Fr., *Penicillium chrysogenum* Thom, *Aspergillus niger* Tiegh, and *Mucor rouxii* (Calmette) Wehmer), molluscs (such as squid pens and oyster shells), and insects, including butterflies, wax worms, silkworms, and ladybugs (Yadav et al., 2019). Crustacean shells are the most significant source of chitin. Chitin recovery generally involves demineralisation, deproteinisation, and the removal of lipids and pigments. In addition, several microbial strains, including *Lactobacillus* spp., *Bacillus* spp., *Serratia marcescens* Bizio, and *Pseudomonas* spp., have been utilised in biotechnological production processes.

The present review aims to summarise current knowledge regarding the properties and applications of chitosan, and chitosan-based materials, with particular emphasis on their biomedical, pharmaceutical, agricultural, and food-related applications. Relevant literature was retrieved from databases including Elsevier, PubMed, SciFinder, and Web of Science using the keywords: chitin, chitosan, chitosan coating, oligochitosan, medicinal plants, functional foods, pharmaceutical benefits, drug delivery, and biomaterials. Only English-language articles published up to December 2023 were included. Duplicate and irrelevant records and articles on unclassified studies were excluded.

Chitosan as biostimulants and their practical applications in agricultural and horticultural sciences

Chitosan, a deacetylated derivative of chitin, has attracted considerable attention in agricultural and horticultural sciences due to its biostimulatory, antimicrobial, and stress-mitigating properties. Its application enhances plant physiological performance through multiple biochemical and molecular mechanisms and has been widely explored in both pre- and postharvest systems.

Plant physiological and biochemical responses

Chitosan induces the production of hydrogen peroxide (H_2O_2), which acts as a signalling molecule in plant stress responses. It also enhances the activity of key antioxidant enzymes, including peroxidases (POX), superoxide dismutase (SOD), and catalase (CAT), contributing to the detoxification of reactive oxygen species (ROS) and improved stress tolerance.

In grapevine, chitosan activates multiple defence pathways, including phytoalexin production, phosphorylation of mitogen-activated protein kinases (MAPKs), and increased activity of chitinases and glucanases. It also upregulates defence-related genes, enhancing resistance against *Erysiphe necator* Schwein, *Botrytis cinerea* Pers., and *Plasmopara viticola* (Berk. & M.A. Curtis) Berl. & De Toni, which cause powdery mildew, grey mould, and downy mildew, respectively (Loron et al., 2023). Irradiated chitosan has further demonstrated effectiveness in controlling grapevine diseases, particularly downy mildew (Meynaud et al., 2023).

Effects on plant growth and stress tolerance

Chitosan application has been widely reported to improve seed germination, seedling vigour, and plant growth across numerous crops. It enhances antioxidant capacity, photosynthetic performance, and the accumulation of phenolic compounds under abiotic stress conditions.

In vegetable crops, chitosan increased germination and growth in artichoke (*Cynara scolymus* L.) and reduced fungal infections (Ziani et al., 2010). In basil (*Ocimum basilicum* L.), it alleviated drought stress and improved antioxidant activity, photosynthetic efficiency, and phenolic content. Similarly, in bean (*Phaseolus vulgaris* L.), chitosan enhanced leaf area development and increased chlorophyll and carotenoid levels, resulting in higher yield (Pereira et al., 2017).

In bell pepper (*Capsicum annuum* L. var. *grossum*), chitosan improved germination, seedling emergence under cold stress, and reduced microbial contamination in fresh-cut produce (Sathiyaseelan et al., 2021). Foliar application of thiamine-loaded chitosan nanoparticles enhanced germination and growth in chickpea (*Cicer arietinum* L.) (Muthukrishnan et al., 2019), while in chilli (*Capsicum frutescens* L.), chitosan improved anthracnose control and yield-related traits (Akter et al., 2018).

Chitosan has also been shown to alleviate abiotic stress in several species. In basil, it mitigated drought-induced damage and enhanced antioxidant and phenolic metabolism (Pirbalouti et al., 2017). Similar improvements in morphophysiological and biochemical traits were observed in bitter melon (*Momordica charantia* L.) (Sheikhalipour et al., 2023).

Disease resistance and plant immunity

Chitosan stimulates plant immune responses by enhancing defence-related enzyme activity and phytohormone production. In cucumber (*Cucumis sativus* L.), it induced defence enzymes and hormonal signalling pathways (Zohara et al., 2019). In eggplant (*Solanum melongena* L.), it enhanced nematicidal activity and systemic resistance (Attia et al., 2021).

It has also demonstrated antiviral and antifungal effects, reducing Bean yellow mosaic virus (BYMV) severity in faba bean (*Vicia faba* L.) (Sofy et al., 2020), suppressing ginger rhizome rot (*Zingiber officinale* Roscoe), and contributing to the control of *Ralstonia solanacearum* Smith in tomato (*Solanum lycopersicum* L.) (Algam et al., 2010). In sweet potato, chitosan reduced the growth of *Ceratocystis fimbriata* Ellis & Halst. and altered fatty acid composition (Xing et al., 2018).

Postharvest applications and food preservation

At the postharvest level, chitosan-based nanoparticles and coatings are widely used to extend shelf life, improve food quality, and reduce microbial spoilage. These systems also enhance formulation efficiency while reducing environmental toxicity (Gumelar et al., 2020).

Edible films and coatings based on chitosan have been shown to improve preservation in a wide range of products. Chitosan–glycerol films enhance strawberry storage, while gelatin/chitosan films with nanocarriers improve stability of apple cubes. Chitosan coatings exhibit antioxidant properties in cashew nuts (Rambabu et al., 2019), and chitosan/gelatin films with silver nanoparticles improve antimicrobial and oxidative stability in grapes (Kumar et al., 2018).

Additional studies report delayed ripening and extended shelf life in tomatoes, mangoes, papayas, lettuce, green chilies, blueberries, and mushrooms using chitosan-based packaging systems (Priyadarshi et al., 2018a; Vilvert et al., 2022). Chitosan nanoparticles also improve fruit quality and shelf life in banana (*Musa acuminata* Colla), while combinations with procyanidins, plant extracts, and photoactivated compounds enhance postharvest quality and reduce spoilage in berries and strawberries (Mannozzi et al., 2018; Luksiene, Buchovec, 2019).

Nanotechnology and advanced formulations

Chitosan-based nanomaterials and composites further expand its agricultural applications.

Chitosan nanoparticles improve seed germination and disease resistance, for example by enhancing defence enzyme activity and lignin accumulation in tomato, and by increasing resistance to anthracnose in chilli using silver nanocomposites (Gowda, Sriram, 2023). Chitosan–selenium nanoparticles improve drought tolerance in bermudagrass and salinity tolerance in bitter melon (Hao et al., 2023; Sheikhalipour et al., 2021).

In experiment with wheat, nano-chitin whiskers enhance grain protein content, yield, and micronutrient accumulation while improving resistance to *Fusarium* spp. (Xue et al., 2018; Liang et al., 2018). Similarly, chitosan-based complexes with bioactive compounds such as harpin, thiamine, tripolyphosphate, and salicylic acid enhance plant growth and disease resistance in tomato, pepper, chickpea, lettuce, and maize (Nadendla et al., 2018; Sathiyabama et al., 2019; Martin-Saldaña et al., 2018; Kumaraswamy et al., 2019).

Chitosan applications in food, pharmaceutical, medicinal and environmental fields

Chitosan is a versatile biopolymer widely applied in pharmaceutical, agricultural, cosmetic, textile, and biomedical fields, including drug delivery systems, food packaging, water treatment, and tissue engineering. Its broad applicability results from its cost-effectiveness, biocompatibility, biodegradability, non-toxic nature, and excellent film-forming and mechanical properties.

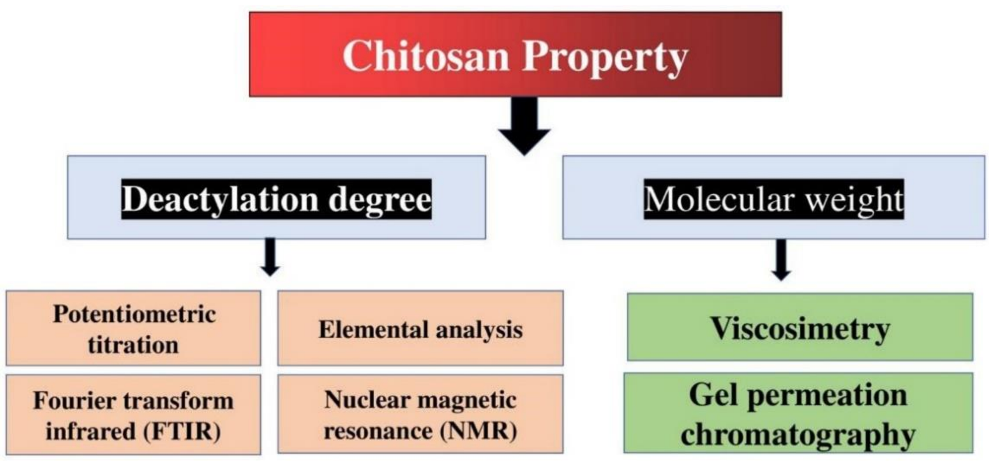

Fig. 3. Different methods to evaluate the average molecular weight and the deacetylation degree of chitosan

General properties and antimicrobial mechanisms

Chitosan exhibits structural similarity to heparin (Zhong et al., 2007) and demonstrates strong antimicrobial activity against a broad range of microorganisms. Its mechanisms of action include disruption of microbial cell membranes, formation of a dense polymer film on the cell surface. Intracellular chitosan that penetrates the cell and reaches the cytoplasm can directly interfere with DNA transcription and, consequently, protein synthesis, particularly in bacteria such as *Escherichia coli* Migula (Zheng, Zhu, 2003; Yan et al., 2021). The main mechanisms of action against pathogenic microorganisms are presented in table 1 – Appendix 1.

The antimicrobial effectiveness of chitosan is influenced by environmental and structural parameters, including pH, molecular weight, degree of deacetylation (DDA), and chemical modifications (Gow et al., 2017; Patale, Patravale, 2011). Methods used to determine molecular weight and degree of deacetylation of chitosan are illustrated in figure 3.

Food packaging and preservation applications

Chitosan is widely used in food packaging and preservation due to its antimicrobial and film-forming properties. It contributes to extended shelf life, improved food quality, and reduced microbial spoilage (Verlee et al., 2017; Xing et al., 2018).

Chitosan-based membranes and coatings are effective in preserving fresh fruits, vegetables, and meat products (Priyadarshi et al., 2018b; Yadav et al., 2021). Functionalised systems such as chitosan–silver colloids exhibit strong antibacterial and antifungal activity against foodborne pathogens (Biao et al., 2017). Similarly, chitosan nanoparticles inhibit the growth of phytopathogenic bacteria, including *Xanthomonas* and *Erwinia* species (Oh et al., 2019).

Chitosan-based edible films and nanocomposites are also effective in delaying ripening and preserving quality in fruits such as strawberries, grapes, tomatoes, mangoes, papayas, lettuce, green chilies, blueberries, and mushrooms (Rambabu et al., 2019; Priyadarshi et al., 2018a).

Chitosan in drug delivery and biomedical applications

Chitosan is extensively investigated in drug delivery systems due to its excellent biocompatibility, biodegradability, and ability to form a wide range of functional structures, including films, nanoparticles, hydrogels, microspheres, fibres, microneedles, liposomes, and nanocomposites (Yilgor et al., 2009; Gull et al., 2020; Ma et al., 2020; Kalalinia et al., 2021). These properties enable controlled drug release, improved stability of active compounds, and enhanced therapeutic efficiency. It is also widely applied in wound healing systems, where chitosan-based nonwoven mats, hydrogel dressings, and composite membranes loaded with antibiotics or bioactive compounds support tissue regeneration and accelerate healing through sustained and localized drug delivery (Han et al., 2014; Mishra et al., 2017; Hu et al., 2017).

The pharmaceutical potential of chitosan is further expanded through chemical modification. Key derivatives include *N*-carboxymethyl chitosan, hydrophobic chitosan, methoxyphenyl-modified chitosan, highly cationic chitosan, polyurethane-based chitosan, hydroxyalkyl chitosan, and cyclodextrin-linked chitosan, all of which improve solubility, stability, and bioactivity, thereby broadening biomedical applicability (Desai et al., 2023). Recent advances have focused on the development of targeted and anticancer delivery systems, such as zinc-chitosan nanoparticles for leukaemia treatment and polymeric chitosan-based systems for the controlled delivery of camptothecin and timolol maleate (Saravanakumar et al., 2018; Min et al., 2008).

An important characteristic of chitin- and chitosan-based materials in biomedical applications is their immunomodulatory activity. Chitin has been reported to play a significant role in the recruitment of innate immune cells involved in helminth immunity and allergic responses (Reese et al., 2007). In addition, interactions between chitin and keratinocytes are important in regulating epidermal immune responses, particularly in the context of microbial exposure associated with skin allergies (Koller et al., 2011).The medicinal properties and health benefits of chitosan and its nanocomposites are summarised in table 2 – Appendix 1.

Environmental applications

Chitosan and its derivatives are effective adsorbents for removing pollutants from water systems, including antibiotics, dyes, and emerging contaminants. Chitosan-based nanofibers, hydrogels, and magnetic composites have been successfully applied for the removal of tetracycline, ciprofloxacin, methylene blue, malachite green, and other pollutants (Afzal et al., 2018; Danalioglu et al., 2018; Rezaei et al., 2017; Rostamian et al., 2022).

Recent studies have also demonstrated the potential of chitosan for *in situ* aggregation and removal of nanoplastics from water systems, further highlighting its environmental remediation capabilities (Djajadi et al., 2024).

Integrated applications and concluding remarks

Chitosan can be chemically modified through reactions involving hydroxyl and amino groups, including carboxylation, etherification, acylation, and epoxide ring-opening reactions (Prabakaran et al., 2024). These modifications enhance its solubility, stability, and functional properties, enabling a wide range of industrial and biomedical applications. The multifunctionality of chitosan enables its integration into complex systems across food, pharmaceutical, and biomedical industries. Chitosan-based systems are used in drug delivery, wound healing, food preservation, environmental remediation, and antimicrobial coatings.

Conclusions and future remarks

Chitosan is a multifunctional biopolymer with a broad range of applications across biomedical, pharmaceutical, agricultural, environmental, and food-related fields. In medicine and pharmacy, it is widely investigated in drug delivery systems, wound healing, surgical materials, dental applications, artificial tissues, and antimicrobial and anticancer therapies Its future role in tissue engineering may include the development of scaffolds for tissue and bone regeneration, as well as new applications in bioartificial organs and regenerative medicine.

In addition to biomedical uses, chitosan is applied in cosmetics for skin and hair care products, and in agriculture for seed coating, plant growth promotion, soil improvement, pesticide removal, and postharvest food preservation. In environmental engineering, it is an effective material for wastewater treatment, particularly in the removal of heavy metals, dyes, pesticides, and other organic and inorganic pollutants. It is also used in food and feed industries as a stabilizing agent, dietary fiber source, and functional additive that can influence lipid metabolism and product quality.

The functional versatility of chitosan is closely related to its unique physicochemical properties, including its polycationic nature, film-forming ability, biocompatibility, biodegradability, non-toxicity, and strong adsorption and chelating capacity. It is a linear aminopolysaccharide with reactive amino and hydroxyl groups, enabling chemical modifications such as substitution reactions, chain modification, and depolymerization through chemical, physical, or enzymatic processes. These modifications allow tuning of its solubility, molecular weight, and biological activity.

Recent research trends indicate a growing interest in chitosan-based materials, particularly in nanocomposites and drug delivery systems, as evidenced by the increasing number of scientific publications. Chitosan-based carriers enable controlled and sustained drug release, supporting more efficient therapeutic delivery and maintaining stable drug concentrations within the therapeutic window.

Future research should focus on the development of advanced chitosan-based nanocomposites and smart delivery systems for biomedical applications. Particular attention should be given to targeted therapies involving musculoskeletal, dermatological, neurological, and vascular systems, as well as further optimization of chitosan derivatives for improved efficacy and functionality.

Conflict of interest

The authors declare no conflict of interest related to this article.

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Appendix 1

Tab. 1. Different mechanism of action of chitosan against pathogen microorganisms

Mechanism	**Key points**	**Reference**
Disrupting the cell membrane/cell wall	It is happened by electrostatic interactions between the negatively charged cell membrane, and the positively charged chitosan molecule.	Tao et al. (2021)
	The amino groups of the polymer chain can induce to antimicrobial activity, and giving chitosan a positive charge.	Szymanska, Winnicka (2015)
	The antibacterial activity against both Gram-negative bacteria, and Gram-positive bacteria can be increased by application of positive charges to chitosan through heterogeneous quaternization.	Palma-Guerrero et al. (2010)
Interaction with Microbial DNA	Interaction between microbial DNA and chitosan hydrolysis products can influence protein synthesis via inhibiting mRNA.	Archana et al. (2015)
	In the cases of low molecular weight chitosans, the ability to penetrate a cell 's membrane and to enter in the cell was found.	Mansilla et al. (2013)
Chelation of nutrients by chitosan	Because of chelating properties of chitosan, it can chelate essential nutrients and metal ions which are beneficial for growth of the microbial cell.	Kakei, Shahbazi (2016)
Formation of a dense polymer film on the cell surface	High molecular weight chitosan can form and deposit a dense polymer film on the surface of the cell.	Champer et al. (2013)

Tab. 2. Medicinal properties and health benefits of chitosan and chitosan-based nanocomposite

Pharmaceutical benefits	Chitosan derivatives and chitosan-based nanocomposite	References
Anti-aging activity	Chitosan oligosaccharide restored redox balance in LPS-induced oxidative stress.	Runarsson et al. (2007)
Anti-bacterial activity	It has shown antibacterial effects and it could inhibit the growth of *Escherichia coli* and *Staphylococcus aureus*.	Manzur et al. (2024)
	Thiazolium chitosan showed antibacterial effects against *L. innocua*, *S. epidermidis*, and *S. aureus*.	Munoz-Nunez et al. (2023)
	Quaternized *N*-aryl chitosan has shown antibacterial impacts against *Staphylococcs aureus*.	Sajomsang et al. (2009)
Antibiofilm activity	Chitosan and chitosan derivatives in numerous structural forms showed antibiofilm impacts against microbial biofilm.	Su et al. (2017)
Anti-cancer activity	Chitosan nanocomposite film coated on the screen-printed electrode showed stability, sensitivity and reproducibility as well as immuno sensor and cancer biomarkers.	Suresh et al. (2017)
	Methyl methacrylate-modified chitosan enhanced transfection rate in mammalian cancer.	Jaiswal et al. (2019)
	Chitosan-based nanoparticle has high potential in treatment of breast cancer due to its antioxidant activity.	Herdiana et al. (2023)
Anti-diabetes	Scutellarin-loaded amphiphilic chitosan derivatives (Chit-DC-VB12) can be used for treatment of diabetes induced retinopathy.	Wang et al. (2017)
	Insulin-loaded thiolated *N*-triethyl chitosan NPS is the appropriate option for diabetes.	Rahbarian et al. (2018)
Anti-fungal activity	It has shown high anti-fungal activity against *Penicillium italicum*, and *Penicillium digitatum* which makes it appropriate for application in fruits preservation.	Alves et al. (2019)
Anti-hepatic activity	Both low molecular and high molecular weight chitosan noticeably regulated cholesterol homeostasis and ameliorated the hypercholesterolemia through the inhibition and activation of hepatic and intestinal cholesterol-modulators.	Sumiyoshi, Kimura (2006)
Anti-HIV activity	WMQ-chitosan oligomers and QMW-chitosan oligomers inhibit HIV-induced cytopathic impacts by	Karagozlu et al. (2014)

	exerting their effects on HIV entry stage.	
	Chitosan-thioglycolic acid-conjugated nanoparticles loaded with the anti-HIV drug has shown high effectiveness in treatment of HIV.	Meng et al. (2014)
Anti-inflammatory activity	Six novel N,N,O tridentate water soluble hydrazide based O-carboxymethyl chitosan Schiff base derivatives shown high anti-inflammatory and antioxidant activity.	Manimohan et al. (2020)
	Golden and silver-based chitosan nanocomposites showed anti-inflammatory and antioxidant effects, which can be used as wound dressing.	Katas et al. (2018)
	Rifaximin-chitosan NPs showed anti-inflammatory property against inflammatory bowel disease.	Kumar, Newton (2017)
	Carboxymethyl chitosan was proved to have anti-inflammatory impacts in mice.	Yang et al. (2016)
Anti-microbial activity	It has high antimicrobial and antioxidant properties which make it suitable for the preservation of vegetables and fruits.	Riseh et al. (2024) Al-Zahrani et al. (2021)
	It has shown antimicrobial activities against *Escherichia coli*, *Aspergillus niger*, *Saccharomyces cerevisiae*, and *Colletotrichum gloeosporioides*.	Rojas et al. (2023)
	The chitosan-silver nanocomposites and chitosan oligosaccharides have been used because of antimicrobial effects against different Gram-negative and Gram-positive bacteria.	Tamer et al. (2023)
Anti-oxidant activity	*In vitro* oxygen radicals scavenging activity in chitosan and its derivatives has been reported.	Park et al. (2003)
Anti-tumor activity	The increase in secretion of interleukin-1 and 2 of chitosan can induce to anti-tumor effects such as infiltration of cytolytic T-lymphocytes.	Tokoro et al. (1988)
	Carboxymethylated chitosan could protect the peripheral nerves and suppressed the apoptosis of cultured Schwann cells.	He et al. (2014)
Antiviral activity	Chitosan with a molecular weight below 10 kDa has been found to have antiviral impacts against different influenza virus sub-types.	Karadeniz (2023)
	Chitosan can prevent viral infection by inducing a hypersensitive, which can limit the multiplication virulent phages, neutralizing the infectivity of	Munoz et al. (2013)

	phage particles, and reduce the survival of phage bacterium cells.	
Anti-Covid-19	Chitosan and genipin nano/micro spheres have shown antiviral activity against HCoV-NL63 and HCoV-OC43.	Gopal et al. (2023)
	Chitosan and it derivatives could inhibit Covid-19 viral binding with host cells.	Kalathiya et al. (2020)
	It inhibited Covid-19 viral binding with host cells.	Alitongbieke et al. (2020) Itani et al. (2020)
Blood vessel	It can inhibit the anti-coagulant activity and vascular smooth muscle cells.	Chupa et al. (2000) Xue, Greisler (2003)
	It can be used in blood vessel tissue engineering as hemostatic factor for vascular grafts.	Madihally, Matthew (1999)
Cardiovascular and hematological diseases	Application of 5 chitosan in the diet decreased serum cholesterol and atherogenesis inhibition in apolipoprotein E-deficient mouse model.	Ormrod et al. (1998)
	It could down-regulate the markers which have roles in obesity such as leptin.	Bahijri et al. (2017)
Drug delivery	It has shown high antioxidant capacity, promoted hemocompatibility, and enhance antiproliferative activity against cancer cells.	Karthikeyan et al. (2020)
Hair care products	Application of collagen, hyaluronic acid, and chitosan can induce to the improvement of the general appearance, mechanical properties, and condition of hair.	Sionkowska et al. (2017)
Hemocompatibility	It has hemostatic characteristics which is important in wound healing.	Okamoto et al. (2003)
Infectious disease	Chitin obtained from demosponges *Ianthella flabelliformis* was used as drug delivery material for antibiotic drug including decamethoxine.	Kovalchuk et al. (2019)
	In vitro and *in vivo* models revealed that chitosan could decrease *Cryptosporidium parvum* multiplication, and *Cryptosporidium parvum* oocyst viability, respectively.	Mammeri et al. (2018) Ahmed et al. (2019)
Miscellaneous diseases	ACE-inhibitory biopeptides encapsulated in chitosan NPs can be used in hypertension.	Auwal et al. (2017)
	Rifampicin-loaded octanoyl chitosan NPs can be used for tuberculosis.	Petkar et al. (2018)
Mucoadhesivity	It has ability to adsorb molecules which have no affinity for mucus.	Bugnicourt, Ladavière (2016)
	Chitosan can increase adhesivity of polymers, which is important to open the tight epithelial junctions.	Yamamoto et al. (2005)

Neurological diseases	Rotigotine-loaded chitosan NPS for parkinson ˑs disease.	Tzeyung et al. (2019)
	Olanzapine-loaded chitosan NPs for antipsychotic.	Joysa Ruby, Pandey (2016)
Ophthalmology	It can be used in this field because of its optical clarity, mechanical stability, immunologically compatibility, tear strength, wettability, elongation capacity, tensile strength and biodegradability.	Hudson, Jenkins (2002)
Oral hygiene products	Chitosan-based modification is extensively used in varnish, mouthwashes, and toothpastes.	Schluter et al. (2014)
Renal diseases	Gallic acid together with chitosan can decrease the formation of calcium oxalate crystal which showed antioxidant impacts.	Queiroz et al. (2019)
Skin diseases and wound healing	Chitosan-bioactive glass could cause the best level of skin wound healing through tissue regeneration by enhancing collagen deposition, and promoting epithetical cell formation.	Jayaramudu et al. (2019)
	It can significantly improve tissue growth.	Guerle-Cavero et al. (2021)
Tissue engineering	Cell growth and proliferation in tracheal cartilage, nerve	Smirnova et al. (2019)
	Decellularized extracellular matrix/gelatin/and chitosan, EDC/NHS can be used in skin tissue engineering.	Xu et al. (2021)
	Carboxymethyl chitosan/oxidized dextran/sodium alginate can be used in skin tissue engineering because of high antibacterial and hemostasis activity.	Xie et al. (2022)

Najnowsze odkrycia i perspektywy zastosowań chitozanu w różnych dziedzinach

Streszczenie

Chityna jest naturalnym polisacharydem występującym w egzoszkieletach owadów, skorupiaków oraz ścianach komórkowych grzybów i stanowi drugi najpowszechniejszy biopolimer po celulozie. W wyniku deacetylacji chityna może zostać przekształcona w chitozan poprzez usunięcie grup acetylowych. Ze względu na niską toksyczność, biodegradowalność i biokompatybilność chitozan jest szeroko stosowany jako biomateriał. Niniejszy artykuł przeglądowy omawia rolę chitozanu oraz powłok na bazie chitozanu w zastosowaniach medycznych i farmaceutycznych, a także ich znaczenie w rolnictwie i naukach o żywności. Do głównych zastosowań należą nośniki substancji aktywnych, takich jak związki kosmetyczne, systemy dostarczania leków oraz nanocząstki zwiększające skuteczność agrochemikaliów. Są one również szeroko stosowane w farmacji ze względu na właściwości mukoadhezyjne, a także w inżynierii tkankowej w procesach regeneracji uszkodzonych lub utraconych tkanek. Ponadto chitozan wykazuje aktywność przeciwdrobnoustrojową poprzez wiązanie jonów metali, interakcję ze ścianą komórkową bakterii oraz wiązanie DNA. Do innych istotnych zastosowań należą konserwacja żywności oraz przyjazne środowisku oczyszczanie wody poprzez usuwanie metali ciężkich, olejów, tłuszczów i innych substancji toksycznych. Dzięki swoim właściwościom przeciwgrzybiczym i przeciwbakteryjnym materiały te mają szeroki potencjał zastosowań w przemyśle spożywczym, środowiskowym, medycznym, tekstylnym, kosmetycznym i rolnictwie.

Słowa kluczowe: biomateriały, systemy dostarczania leków, inżynieria tkankowa, aktywność przeciwdrobnoustrojowa, konserwacja żywności.

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