



INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Chitosan: The Versatile Biopolymer for Modern Applications

Author: - Sandhya I. Goyal

Coauthor's name: - Asfiya F. Khan

Vedant B. Giri

Mayuri K. Ghatal

Rohan L. Ghosale

Kunal B. Hadap

Institutional name: - Konkan Gyanpeeth Rahul Dharkar College of Pharmacy and Research Institute

Abstract –

Chitosan was first identified in the mid-1700's but gained little recognition until its crystalline structure was partially clarified in 1934. Found in molds and commercially derived from crustacean's shells, chitosan is now utilized in various sectors, including the food industry. Given the seasonal downturns in the fisheries sectors and the continuously rising demand for high-quality chitosan, alternative sources such as mushrooms and other fungi are being reconsidered. Nevertheless, the crab shells used to produce chitosan are byproducts of the fishing industry. Therefore, producing chitosan from fungi can only be financially viable if waste mycelia generated from the industrial application of fungi as biocatalysts in "white biotechnology" or waste carbon sources, such as those from food processing industries, are utilized as substances for the cultivation of fungi that yield high amounts of chitosan. Chitosan possesses the ability to be modified or to form complexes with various aspects of Chitosan and its applications in different fields, particularly within the food industry.

Chitosan, a biopolymer derived from chitin, has attracted a lot of attention due to its numerous applications in botj commerce and medical. Because of its remarkable properties, such as its antibacterial activity, biodegradability, and biocompatibility, chitosan is used in industry. It is employed in several industries, such as the manufacturing of textiles, food packaging, and wastewater treatment. Chitosan's unique properties make it a valuable material for tissue engineering, wound healing, drug delieivry systems, and other medical applications. Because of its biocompatibility and ability to enhance drug absorption, it is a good choice for pharmaceutical applications. Chitosan's diverse properties present numerous chances for creative advancements in the industrial and medical domains.

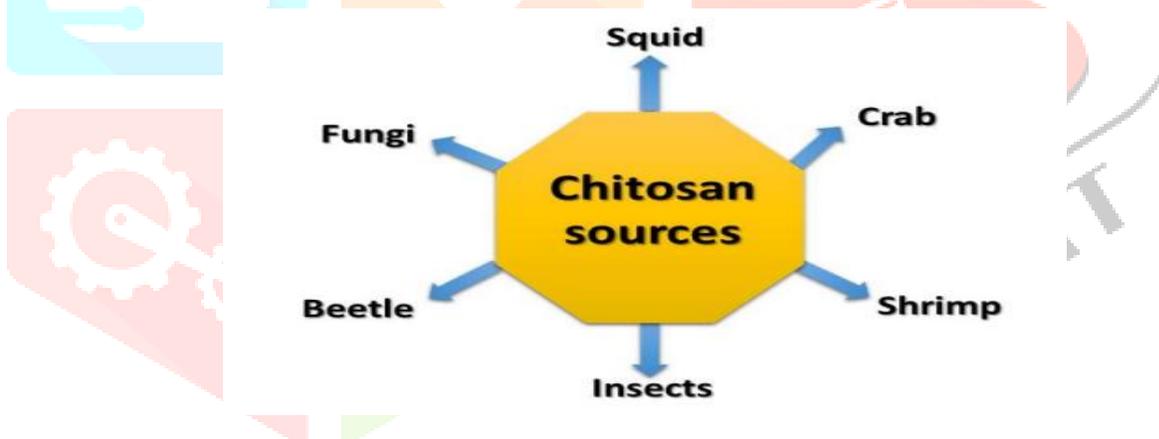
Keywords –

Chitosan, Crustacean Shells, Mushrooms, Fungi< Production< Properties, Applications of Chitosan.

Introduction –**I. Sources:**

Although other species including lobster, crayfish, and oysters have also been utilized prawns and crabs are the most often cited sources in the literature for the raw material used to produce chitosan [1]. Shrimp is one of the most promising and talked-about sources of chitosan among the many others that are accessible, and numerous other species, including insects and beetles have been utilized [2].

Chitosan was extracted from a variety of insects using acid-base extraction and decolorization. Chitin, which is derived from insects, crustaceans, and fungi, is deacetylated to produce chitosan. This process improves chitin's biological properties, especially its antibacterial activity, and makes it more acid soluble [3]. In a different investigation, the fungus *Termitomyces titanicus* biomass was used to extract chitosan and chitin, with the chitin extraction rate reaching 28 or 38.04%. Finally, it is crucial to remember that the production of chitosan and chitin from fungi is not completely risk-free. Several *Zygomycetes* genera are utilized to extract *Rhizopus* and *Absidia* are two examples of these polymers. For example, *Rhizopus oryzae*, can result in pulmonary human mucormycosis, as well as certain species of *Abortio* in domestic animals is caused by *absidia*. Consequently, particular safety precautions had to be used when dealing with this potentially harmful fungus to stop them from spreading [2] [3].



Significant Sources of Chitosan

II. Significance:

Chitosan has recently been widely employed for a range of biological and medical purposes due to its unique properties. Examples of its uses include water purification, materials for wound healing, pharmaceutical excipients or drug carriers, obesity treatment, and scaffolding for tissue engineering [4] [5] [6].

Chitosan has been shown in the literature to primarily serve as a biocompatible dental carrier that accelerates the process of periodontal regeneration, in addition to its previously reported antibacterial, antifungal, and anti-inflammatory properties. [7] [8] [9]

Using immobilized enzymes to catalyze chemo-, regio-, and/or stereoselective chemical reactions is a common and very successful technique. In this regard, it is commonly known that chitosan can be used to immobilize enzymes, either as an encapsulating vehicle or as a carrier for covalent bonding [10].

Chemical structure –

Chitin is the source of the polysaccharide chitosan. The molecular weight of chitin varies from 300 to 1000 kDa, contingent on its origin [21]

Chitosan is a copolymer comprising N-acetyl-D-glucose amine and D-glucose amine. Chitosan, a linear, semi-crystal polymer, has at least 60% deacetylated glucose amine residue. This corresponds to a deacetylated level of 60. Chitin can be deacetylated chemically in very alkaline conditions or enzymatically in the presence of certain enzymes, such as chitin deacetylase. [21]

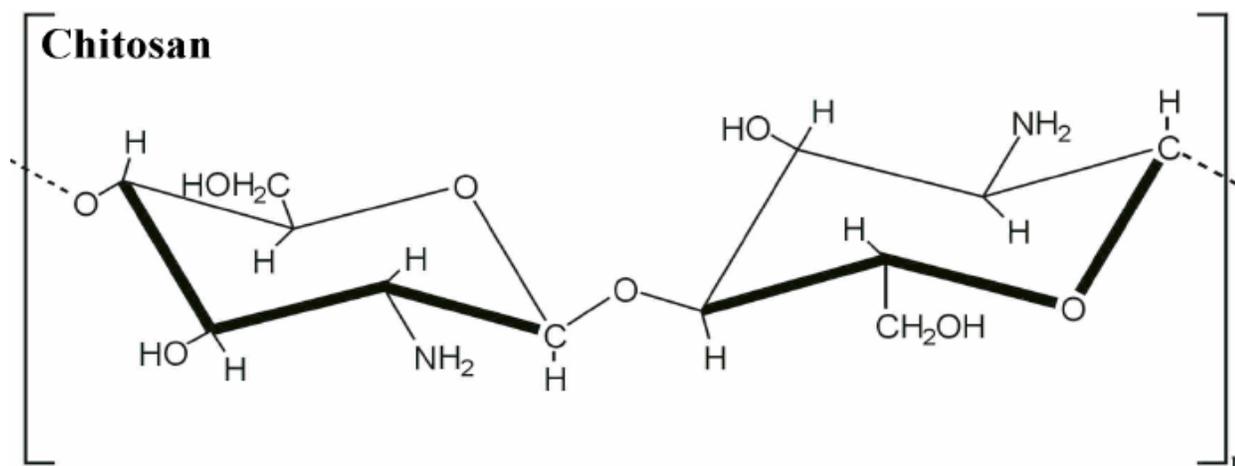


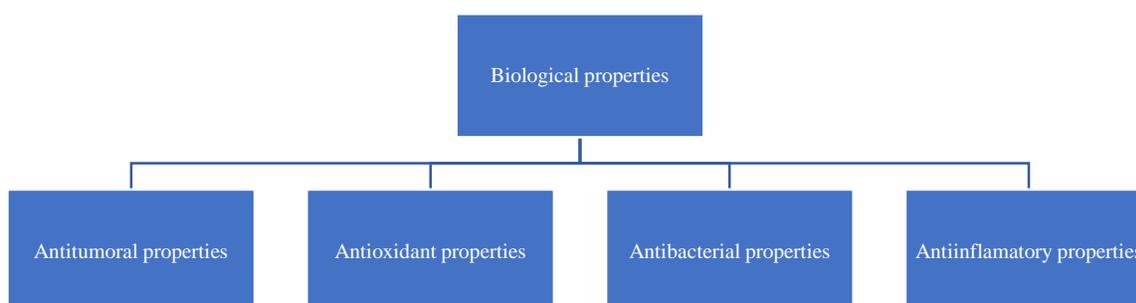
Fig 1: - Chemical structure of chitin

As illustrated in Figure 1, 1-4 linked 2-acetamido-2-deoxy-D-glycopyranose makes up the chemical structure of chitin.

Properties –

I. Biological properties:

Chitin, chitosan, oligosaccharides, and derivatives are therapeutic polymers that have a range of biological activities, including antitumoral, anti-bacterial, antioxidant, and anti-inflammatory qualities. Surprisingly, regulatory agencies still only accept chitosan and chitosan hydrochloride as excipients, not as drugs used to cure diseases.

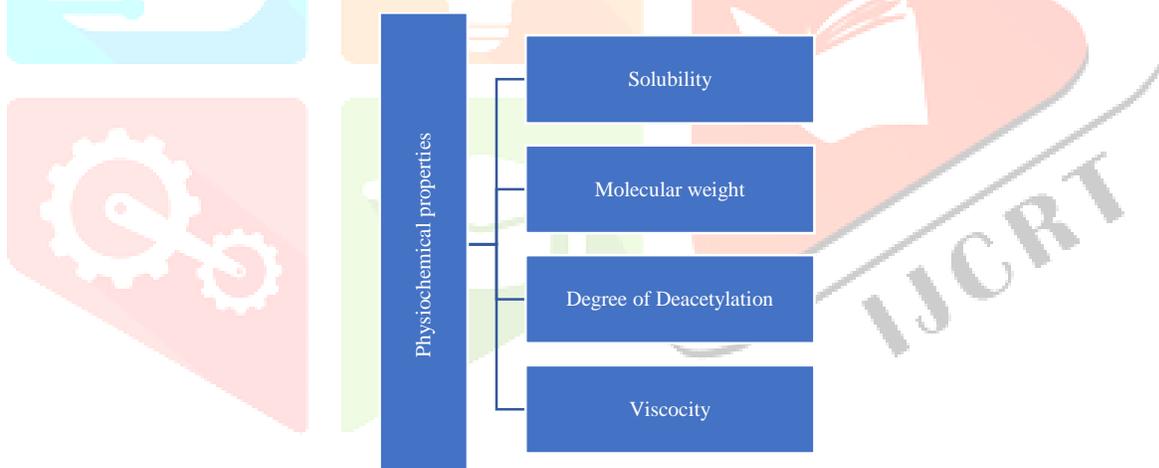


- **Antioxidant properties:** - Because chitosan is made up of several hydroxyl groups and an amino group, it can interact with free radicals and exhibit scavenging capabilities. Some chitosan derivatives, such as N-2 carboxyethyl chitosan and chitosan sulfates, have improved antioxidant properties. [10] [11] [12] [13]

- **Antibacterial properties:** - Antibiotic substitutes are desperately needed since bacterial resistance to antibiotics is a serious public health concern. Chitooligosaccharides, chitosan and its derivatives exhibit antibacterial qualities against a range of microorganisms, including filamentous fungus, bacteria, and yeast [10].
- **Anti-inflammatory properties:** - The inflammatory process is intimately associated with the generation of free radicals. Again, when chitooligosaccharides exhibit higher activity and the molecular weight of the chitosan decreases, this activity seems to be more noticeable. [10] [14].
- **Antitumoral properties:** - Chitosan ranks as the second most plentiful natural polysaccharide, recognized for its remarkable biocompatibility and significant antitumor properties. Due to its biodegradability, biocompatibility, distribution in biological systems, non-toxic nature, and lack of immunogenicity, chitosan has become a popular polymer in the field of pharmacology, particularly in cancer treatment [15].

III. Physicochemical properties: -

Thousands of d-glucosamine residues are joined by beta 1,4 linkage make up chitin and chitosan. Depending on how much chitin has been deacetylated, chitosan can contain anywhere from 15% to 50% N-acetyl-d-glucosamine units. Because chitin and chitosan include amino groups and range in nitrogen content from 5% to 8%, their biological functions differ. Chitosan is an N-deacetylated derivative of chitin that is produced by converting acetamide groups into primary amino groups. [16][17]



- **Solubility:** - Chitosan dissolves in acidic solvents but does not dissolve in neutral or alkaline ones. Although chitin normally doesn't dissolve in solvents, deacetylation turns it into soluble chitosan, which has a pKa value of 6.5 and contains primary amino groups. [16] [18].
- **Molecular weight:** - Molecular weight significantly influences the physicochemical and biological characteristics of chitosan. The molecular weight of chitosan differs based on its source material and the methods used for its preparation and extraction [16] [19].
- **Degree of Deacetylation:** - Another element that affects chitosan's physicochemical properties functionality, and applications is the degree of deacetylation. The distribution of amino groups along the polymer chain determines the degree of deacetylation. [16] [20].
- **Viscosity:** - The viscosity of chitosan, which is closely correlated with its molecular weight and degree of deacetylation, affects its industrial application. Viscosity rises with

increasing degrees of deacetylation, whereas viscosity decreases with decreasing molecular weight. [16] [10]

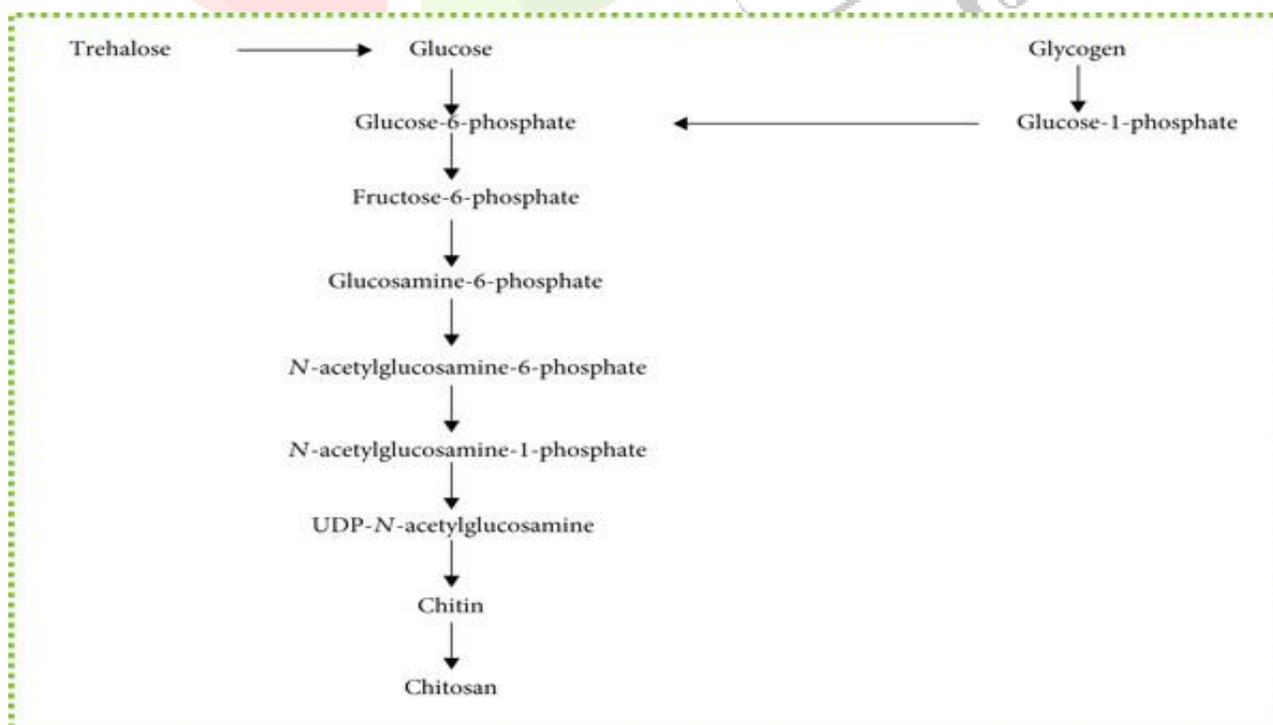
Methods of extraction –

The chitin polymer is typically deacetylated to extract chitosan. The exoskeletons of crustaceans, crabs, and shrimp, as well as the cell walls of fungi, are typically the primary sources of chitin. Rouget initially reported it in 1859 after obtaining deacetylated chitin by boiling it in a strong KOH solution. Through the deacetylation process, chitin has been transformed into chitosan using a variety of techniques. Through the use of certain enzymes, chitin can be hydrolyzed biologically to produce chitosan. Some acetyl groups are still present in the chemical structure of CS. Because each repeating unit of chitosan has an amine group as well as primary and secondary hydroxyl groups, chitosan is chemically more active than chitin [28] [29] [30]

The mechanical and other physicochemical characteristics of chitosan can be changed by chemically modifying these reactive groups. It is more reactive than chitin because of the hydroxyl and amine groups in its chain. New chitosan derivatives can be created by altering these functional groups through various chemical processes [27].

Hexokinase produces glucose-6-phosphate (G6P) in the first step from glucose, which can be acquired free or by hydrolyzing trehalose using trehalase. If glycogen is the starting material, glycogen phosphorylase will depolymerize to produce glucose-1-phosphate, which will then undergo isomerization via phosphoglucomutase. G6P will be the result. Phosphoisoisomerase forms G6P and then transforms it into fructose-6-phosphate. Following this, fructose-6-phosphate undergoes amination and acetylation to become N-acetyl-d-glucosamine-6-phosphate [16]

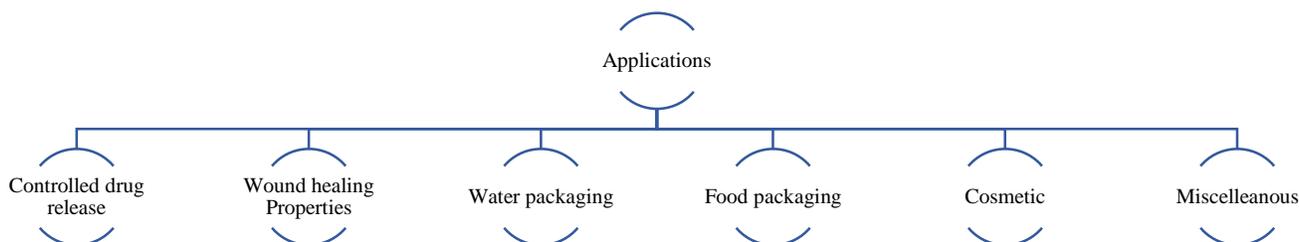
GlcNAc-6-P is isomerized to 1-phospho-N-acetyl-d-glucosamine by phospho-N-acetyl glucosamine mutase. N-acetyl glucosamine (uridine-5'-triphosphate) is produced by further interconversion of uridine triphosphate to uridine-5'-diphosphate (UDP). Then, when chitin synthase is present, UDP N-acetylglucosamine is converted to chitin [16]



The linear chains come together on their own to create microfibrils of different lengths and widths. Some fungi's cell walls contain the chitin deacetylase enzyme (EC 3.5.1.41), which catalyzes the conversion of chitin to chitosan [16].

Three primary processes are typically involved in the extraction and purification of chitosan from crustaceans: demineralization, deproteinization, and deacetylation.[16].

Application-



- **Controlled drug release:** - The combination of chitosan and alginate demonstrated an extended drug-release property when used as a pharmaceutical excipient for directly crushed tablets. Drycoated tablets made with an ion-complex of chitosan and alginate have a lengthy induction period for drug release [22].
- **Wound healing properties:** - The chitosan membrane demonstrated high oxygen permeability, reduced evaporative water loss, and enhanced fluid drainage capabilities while successfully preventing exogenous microbe invasion. A wound that had such a membrane applied to it was hemostatic and rapidly healed [22].
- **Water packaging:** - Chitosan composites are useful for eliminating a variety of organic and inorganic contaminants from water systems, including oil, phenol, dyes like methylene blue, and antibiotics like ofloxacin. They also enhance the quality of Water is beneficial [23] [24]
- **Food packing:** - Chitosan is used in food packaging to prolong the shelf life of packed food items and stop germs from growing, because of its antibacterial properties [23] [25]
- **Cosmetic:** - Studies shows, there are advantages for skin, hair, nail, and dental care products, chitosan is a desirable ingredient in modern cosmetic production because to its biodegradability, non-toxicity, biocompatibility, and bioactivity [23] [26].
- **Miscellaneous:** - Chitosan hydrolysates, which are produced by hydrolyzing high-molecular-weight chitosan using the Fenton reaction, have been demonstrated in a study to be effective agents that block or create tight complexes with fine dust in the air that contain certain solid particles and unidentified microorganism species [27].

Challenges and Limitations –

There is an unique quality, due to which chitosan is even used extensively in a variety of biotechnology, pharmaceutical, wastewater treatment, cosmetic, food, and agricultural fields. However, its poor solubility and subpar mechanical qualities are two major factors that restrict its use in the biomedical field. However, by making various changes, the solubility can be enhanced, leading to the formation of new derivatives with better physicochemical characteristics and a wider variety of uses [28] [31]

Future perspectives –

Numerous potential applications for chitosan in drug delivery have been discovered. Nano particles based on chitosan are easily, highly biocompatible, and adaptable drug delivery vehicles. Over the past 20 years, many studies on chitosan, its nanocomposites, and their use in drug delivery systems have been published. Nonetheless, a systemic approach to safety issues of chitosan-based biomaterials and their production processes, toxicity in vitro and in vivo, and drug delivery system selectively needs to be carefully investigated. [28]

Conclusion –

Chitosan is found in many species, and crustacean by-products, such as lobster cephalothorax, that contains at least 20% chitin can be used to make chitosan industrially. It goes without saying that when selecting an appropriate chitosan manufacturing method, the strategy that yields chitosan with stronger bioactivities manufacturing method, the strategy that yields chitosan with stronger bioactivities- that is, products with lower DA value and lower MW- should be used [32]

Accordingly, this investigation has concluded that unconventional chemical methods, such as replacing NaOH and KOH accelerating the reactions with microwave or ultrasound, may be more effective than biological methods for the industrial production of chitosan. It is advised that these unorthodox chemical pathways be further developed before industry considers and adopts them [32]

REFERENCES

- [1] S. (Gabriel) Kou, L. M. Peters, and M. R. Mucalo, “Chitosan: A review of sources and preparation methods,” *International Journal of Biological Macromolecules*, vol. 169, pp. 85–94, Feb. 2021, doi: <https://doi.org/10.1016/j.ijbiomac.2020.12.005>.
- [2] Hadia HEMMAMI, Ilham BEN AMOR, Asma BEN AMOR, Soumeia ZEGHOUD, S. AHMED, and Ali Alnazza ALHAMAD, “Chitosan, Its Derivatives, Sources, Preparation Methods, and Applications: A Review,” *Journal of the turkish chemical society, section a: chemistry*, vol. 11, no. 1, pp. 341–354, Dec. 2023, doi: <https://doi.org/10.18596/jotcsa.1336313>.
- [3] Ilham Ben Amor, Touhami Lanez, Salah Eddine Laouini, A. G. Abdelaziz, and A. Barhoum, “Influence of chitosan source and degree of deacetylation on antibacterial activity and adsorption of AZO dye from water,” *Biomass Conversion and Biorefinery*, Jan. 2023, doi: <https://doi.org/10.1007/s13399-023-03741-9>.
- [4] R. C. F. Cheung, T. B. Ng, J. H. Wong, and W. Y. Chan, “Chitosan: An Update on Potential Biomedical and Pharmaceutical Applications,” *Marine Drugs*, vol. 13, no. 8, pp. 5156–5186, Aug. 2015, doi: <https://doi.org/10.3390/md13085156>.
- [5] O. Skaugrud and E. Onsoyen, “Metal Recovery Using Chitosan,” *Europepmc.org*, 2016. <https://europepmc.org/article/med/1366969> (accessed Mar. 29, 2025)
- [6] T. Chandy and C. P. Sharma, “Chitosan-as a Biomaterial,” *Biomaterials, Artificial Cells and Artificial Organs*, vol. 18, no. 1, pp. 1–24, Jan. 1990, doi: <https://doi.org/10.3109/10731199009117286>.

- [7] A. Paradowska-Stolarz, M. Mikulewicz, J. Laskowska, B. Karolewicz, and A. Owczarek, "The Importance of Chitosan Coatings in Dentistry," *Marine drugs*, vol. 21, no. 12, pp. 613–613, Nov. 2023, doi: <https://doi.org/10.3390/md21120613>.
- [8] A. Aryaei, A. H. Jayatissa, and A. C. Jayasuriya, "Nano and micro mechanical properties of uncross-linked and cross-linked chitosan films," *Journal of the Mechanical Behavior of Biomedical Materials*, vol. 5, no. 1, pp. 82–89, Jan. 2012, doi: <https://doi.org/10.1016/j.jmbbm.2011.08.006>.
- [9] R. Adamski and D. Siuta, "Mechanical, Structural, and Biological Properties of Chitosan/Hydroxyapatite/Silica Composites for Bone Tissue Engineering," *Molecules*, vol. 26, no. 7, p. 1976, Mar. 2021, doi: <https://doi.org/10.3390/molecules26071976>.
- [10] I. Aranaz *et al.*, "Chitosan: An Overview of Its Properties and Applications," *Polymers*, vol. 13, no. 19, p. 3256, Sep. 2021, doi: <https://doi.org/10.3390/polym13193256>.
- [11] G. KOGAN *et al.*, "Antioxidant and antimutagenic activity of -(2-carboxyethyl)chitosan," *Toxicology and Applied Pharmacology*, vol. 201, no. 3, pp. 303–310, Dec. 2004, doi: <https://doi.org/10.1016/j.taap.2004.05.009>.
- [12] R. Xing *et al.*, "Antioxidant activity of differently regioselective chitosan sulfates in vitro," *Bioorganic & Medicinal Chemistry*, vol. 13, no. 4, pp. 1387–1392, Feb. 2005, doi: <https://doi.org/10.1016/j.bmc.2004.11.002>.
- [13] J. Zhou *et al.*, "Advances in the preparation and assessment of the biological activities of chitosan oligosaccharides with different structural characteristics," *Food & Function*, 2021, doi: <https://doi.org/10.1039/d0fo02768e>.
- [14] S.-H. Chang, Y.-Y. Lin, G.-J. Wu, C.-H. Huang, and G.-J. Tsai, "Effect of chitosan molecular weight on anti-inflammatory activity in the RAW 264.7 macrophage model," *International Journal of Biological Macromolecules*, vol. 131, pp. 167–175, Feb. 2019, doi: <https://doi.org/10.1016/j.ijbiomac.2019.02.066>.
- [15] J. Ding and Y. Guo, "Recent Advances in Chitosan and its Derivatives in Cancer Treatment," *Frontiers in Pharmacology*, vol. 13, Apr. 2022, doi: <https://doi.org/10.3389/fphar.2022.888740>.
- [16] D. Alemu, E. Getachew, and A. K. Mondal, "Study on the Physicochemical Properties of Chitosan and Their Applications in the Biomedical Sector," *International Journal of Polymer Science*, vol. 2023, p. e5025341, Jul. 2023, doi: <https://doi.org/10.1155/2023/5025341>.
- [17] R. Singh, K. Shitiz, and A. Singh, "Chitin and chitosan: biopolymers for wound management," *International Wound Journal*, vol. 14, no. 6, pp. 1276–1289, Aug. 2017, doi: <https://doi.org/10.1111/iwj.12797>.
- [18]
V. Zargar, M. Asghari, and A. Dashti, "A Review on Chitin and Chitosan Polymers: Structure, Chemistry, Solubility, Derivatives, and Applications," *ChemBioEng Reviews*, vol. 2, no. 3, pp. 204–226, Apr. 2015, doi: <https://doi.org/10.1002/cben.201400025>.
- [19]
M. M. Abo Elsoud and E. M. El Kady, "Current trends in fungal biosynthesis of chitin and chitosan," *Bulletin of the National Research Centre*, vol. 43, no. 1, Apr. 2019, doi: <https://doi.org/10.1186/s42269-019-0105-y>.
- [20]
Matica, Aachmann, Tøndervik, Sletta, and Ostafe, "Chitosan as a Wound Dressing Starting Material: Antimicrobial Properties and Mode of Action," *International Journal of Molecular Sciences*, vol. 20, no. 23, p. 5889, Nov. 2019, doi: <https://doi.org/10.3390/ijms20235889>.

- [21] Varaprasad Bobbarala, *Concepts, Compounds and the Alternatives of Antibacterials*. 2015. doi: <https://doi.org/10.5772/59522>.
- [22] D. Sahoo, S. Sahoo, P. Mohanty, S. Sasmal, and P. L. Nayak, "Chitosan: a New Versatile Biopolymer for Various Applications," *Designed Monomers and Polymers*, vol. 12, no. 5, pp. 377–404, Jan. 2009, doi: <https://doi.org/10.1163/138577209x12486896623418>.
- [23] Milad Ghezelsifloo and A. Dehghani, "Application of Chitosan in Industry and Medicine: A Mini-Review," *Qeios*, Mar. 2024, doi: <https://doi.org/10.32388/x1t0p3>.
- [24] A. K. Rana, Vijai Kumar Gupta, P. Hart, F. Scarpa, and Vijay Kumar Thakur, "Sustainable MXene-chitosan/chitin composites for Interdisciplinary applications in water purification, bio-medical, bio-sensing and electronic fields," *Materials Today Sustainability*, vol. 25, pp. 100671–100671, Mar. 2024, doi: <https://doi.org/10.1016/j.mtsust.2024.100671>.
- [25] P. Cazón and M. Vázquez, "Applications of Chitosan as Food Packaging Materials," *Sustainable Agriculture Reviews* 36, pp. 81–123, 2019, doi: https://doi.org/10.1007/978-3-030-16581-9_3.
- [26] "Cosmetics and Cosmeceutical Applications of Chitin, Chitosan and Their Derivatives," *Docta.ucm.es*, 2024. <https://docta.ucm.es/entities/publication/dcl1a7e80-af38-414c-b0b3-5fb593ba9198> (accessed Mar. 29, 2025).
- [27] S. Fatullayeva, D. Tagiyev, N. Zeynalov, S. Mammadova, and E. Aliyeva, "Recent advances of chitosan-based polymers in biomedical applications and environmental protection," *Journal of Polymer Research*, vol. 29, no. 7, Jun. 2022, doi: <https://doi.org/10.1007/s10965-022-03121-3>.
- [28] M. Yadav, B. Kaushik, G. K. Rao, C. M. Srivastava, and D. Vaya, "Advances and challenges in the use of chitosan and its derivatives in biomedical fields: A review," *Carbohydrate Polymer Technologies and Applications*, vol. 5, p. 100323, Jun. 2023, doi: <https://doi.org/10.1016/j.carpta.2023.100323>.
- [29] E. E. Kady, "Chitin, Chitosan and Glucan, Properties and Applications," *World Journal of Agriculture and Soil Science*, vol. 3, no. 1, Aug. 2019, doi: <https://doi.org/10.33552/wjass.2019.03.000553>.
- [30] S. Kumari and R. Kishor, "Chitin and chitosan: origin, properties, and applications," *Handbook of Chitin and Chitosan*, vol. 1, pp. 1–33, Jan. 2020, doi: <https://doi.org/10.1016/B978-0-12-817970-3.00001-8>.
- [31] O. F. Abdel Gawad, "Graft modification of carboxymethyl chitosan with styrene and its biological applications," *Beni-Suef University Journal of Basic and Applied Sciences*, vol. 9, no. 1, Jan. 2020, doi: <https://doi.org/10.1186/s43088-019-0019-7>.
- [32] M. S. Kou (Gabriel) and D. L. Pet, "ORCID," *orcid.org*. <https://orcid.org/0000-0002-2934-0186>