Archives of Materials Science and Engineering

Volume 124
Issue 2
December 2023
Pages 71-75

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

DOI: 10.5604/01.3001.0054.3231

Biomedical applications of nanoparticles of chitosan from marine waste

S. Ann Mary [a], R. Sandhiya [a], S. Prince [a], J.M. Venkatraman [a], S. Vignesh [a], G.H. Hikku [b], S. Ramachandran [c,*]

[a] Department of Medical Biotechnology, Faculty of Allied Health Sciences, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603 103, Tamil Nadu, India

[b] Department Medical Bionanotechnology, Faculty of Allied Health Sciences, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603 103, Tamil Nadu, India

[c] Native Medicine and Marine Pharmacology Laboratory, Faculty of Allied Health Sciences, Chettinad Hospital and Research Institute, Chettinad Academy of Research and Education, Kelambakkam-603 103, Tamil Nadu, India

* Corresponding e-mail address: saran_prp@yahoo.com

ORCID identifier: https://orcid.org/0000-0002-8708-9807 (S.R.)

ABSTRACT

Purpose: The review focuses on chitosan nanoparticle synthesis and its biomedical applications. The review briefly explains the biomedical applications of antimicrobials, cancer therapy, gene therapy, and anti-ageing. Notably, the chitosan biological activity can be further increased by coating metal ions such as iron oxide nanoparticles, gold nanoparticles, etc.

Design/methodology/approach: Chitosan is the N-acetyl derivative of chitin, which has the unique properties of biodegradability, non-toxicity, polycationic property and biocompatibility—no reports of ZnO sulphated chitosan nanoparticles being produced for antibacterial. We hope for the conduction of antibacterial research of ZnO sulphated chitosan nanoparticles.

Findings: The study establishes that metal oxide nano-CH, characterised by an expanded size range beyond conventional parameters, exhibits a broad spectrum of biomedical applications. Its commendable biological attributes, encompassing biocompatibility, non-toxicity, and biodegradability, make it a vehicle for drug delivery in medicine.

Research limitations/implications: Nanomedicine is an emerging branch of medicine that applies tools and the basis of nanotechnology for disease prevention, treatment and diagnosis. Moreover, it helps overcome conventional medicine's limitations, including adverse side effects, poor pharmacokinetics and lack of selectivity.

Originality/value: Using chitosan extracted from marine waste presents economic advantages. Furthermore, when coated with metal oxide nanoparticles, it enhances biomedical efficacy. Chitosan is an effective drug delivery vehicle, and its theranostic applications are valuable in the biomedical sector.

Keywords: Chitosan, ZnO, Nanoparticles, Anti-ageing, Tissue engineering, Antimicrobial activity

Reference to this paper should be given in the following way:

S. Ann Mary, R. Sandhiya, S. Prince, J.M. Venkatraman, S. Vignesh, G.H. Hikku, S. Ramachandran, Biomedical applications of nanoparticles of chitosan from marine waste, Archives of Materials Science and Engineering 124/2 (2023) 71-75. DOI: https://doi.org/10.5604/01.3001.0054.3231

BIOMEDICAL AND DENTAL MATERIALS AND ENGINEERING

1. Introduction

Nanotechnology has advanced to the point where it now has a broad range of medical applications. Because of their smaller size, stability at higher temperatures, higher surface-to-volume ratio, and higher reactivity with live cells, nanoparticles with sizes ranging from 1 to 100 nm are highly recommended branches. Nanoparticles have been used in various applications, including gene and medicine delivery, sensor development, fluorescent biological labelling, protein detection, pathogen detection, and DNA structure probing, thanks to the discovery of their distinguishing characteristics. A nanoparticle's outstanding optical capabilities provide an extra quantum effect, making it appropriate for imaging applications. The smaller particles made it easier for them to enter defective cells for targeted delivery. The nanoparticles can be conjugated with various ligands and biomolecules to create targeted medication delivery systems. Aluminium, silver, iron, gold, and titanium oxide are the most commonly utilised and studied metallic nanoparticles [1].

2. Chitosan

In 1859, Rouget created chitosan as a deacetylated derivative of a natural chitin polymer. Chitosan is a partly deacetylated polymer comprising N-acetylglucosamine (NAGlc) and N-glucosamine (N-Glc) units (Fig. 1) obtained by alkaline deacetylation of chitin. Chitosan is a biocompatible, biodegradable, and effective biomaterial from non-toxic, renewable resources. Chitosan becomes a polycationic species at lower pH due to the protonation of the amino group. The sulfonation procedure can revive the cationic property, which introduces anionic character. Molecular weights range from 300 to 1000 kDa, with degrees of deacetylation ranging from 30% to 95% depending on the preparation, and their sources can be rotated 180 degrees about one another. Chitin has been extracted from various natural sources, including shrimp [2], crab [3], cuttlebone, fungi, and others.

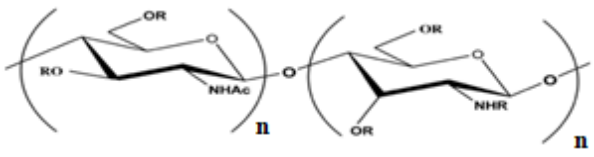

Fig. 1. Structure of chitosan

3. Sources of chitin

Marine organisms are a rich source of unique biopolymers such as chitin (Fig. 2) and potential bioactive compounds with many biological activities. Over the past few decades, marine resources have become an increasingly important source of new bioactive molecules. Chitosan is a partially deacetylated polymer of acetyl glucose amine that is attained after the alkaline deacetylation of chitin [4,5].

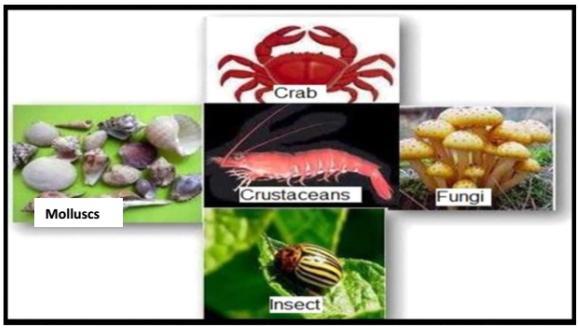

Fig. 2. Sources of chitin

Chemical sensors, electrocatalysts, batteries, electro-luminescence, smart windows, memory devices, and other medical applications all benefit from chitosan nanoparticles. If the nanoparticles are used in biological applications, they must be biocompatible. Biocompatibility refers to the ability of chitosan molecules to remain intact within living tissue while causing no immunological reactions or other negative effects on the tissue's surroundings. Biomedical uses include tissue engineering, medication delivery, bone repair/replacement, antiviral, antimicrobial, anti-oxidant, hemocompatible biomaterials, and dental immunisation. The researchers concluded that excellent tumour-targeting drug delivery is critical for therapeutic success [6] with minimum side effects and great diagnostic picture quality.

4. Extraction of chitosan

The procedure for chemical extraction of chitosan includes the processes of demineralisation, deproteinisation, and deacetylation. Decolourisation is an optional procedure that can be performed to remove the colour, mostly-carotene. Astaxanthin utilises a variety of organic and inorganic solvents, such as hydrogen peroxide, acetone, and sodium hypochlorite (Fig. 3).

100 g of raw samples from marine sources were demineralised for 36 hours at room temperature with 1 per cent HCl dilute and deproteinised for 16 hours with 0.5 N

NaOH solutions in a beaker (2000 ml capacity). The recovered chitin (40 g) was deacetylated for 3 hours in a 50 per cent NaOH (300 ml) solution. Furthermore, extracted CH samples were sulfated with dichlorosulfonic acid and agitated for 4 hours at room temperature. The resultant CH solution was filtered and purified using ion exchange chromatography and dialysed for 48 hours (pH 7.2) against milli-Q water before being lyophilised and stored at room temperature [7].

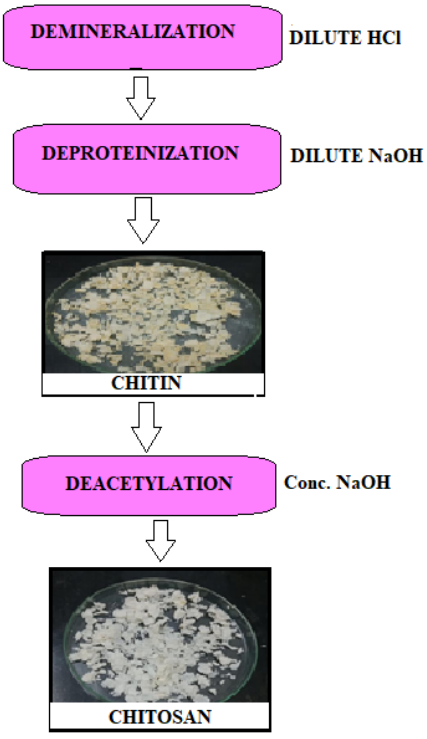

Fig. 3. Flow chart of extraction of chitin and chitosan

5. Synthesis of chitosan nanoparticles (Nano-CH)

Chitosan was dissolved at 0.5% (w/v) over 1% (v/v) HOAc, and pH 4.6–4.8 was achieved utilising 10 N NaOH. Nano-CH emerged spontaneously once 1mL of an aqueous sodium tripolyphosphate (TPP) solution (0.25%, w/v) was introduced to a 3 ml chitosan solution under magnetic stirring. Nanoparticle purification is done under the centrifugal force at 9000 g for 30 min. Supernatants can be discarded from the tube; the chitosan nanoparticles were simultaneously cleaned with deionised water so that excess sodium hydroxide was removed and kept for freeze-drying (Figs. 4,5) [8].

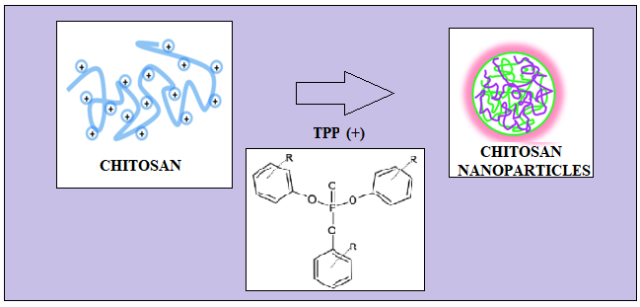

Fig. 4. Synthesis of chitosan nanoparticles

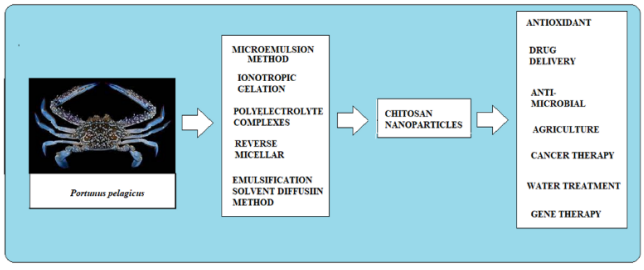

Fig. 5. Methods to synthesise nano-CH and its applications

6. Medical application of nano-CH

6.1. Cancer therapy

The investigation methodology was presented to construct and target the system with Herceptin-conjugated gemcitabine loaded in chitosan nanoparticles (HER 2- Gem – CS-NPs) to treat pancreatic cancer [9]. Superior antiproliferative activity had been seen, and even an elevation in S phase arrest ultimately leads to apoptotic cell death. The report demonstrates whether HER2- Gem- NPs can administer gemcitabine to pancreatic cancer patients in an efficient and targeted strategy.

Peptide-modified polylactic acid-co-glycolic acid-chitosan nanoparticle-arginine-glycine-aspartic acid (PLGA-CSNP-RGD) has seen to be a possible drug delivery method for cisplatin and has been shown to have a comparable cytotoxic response in lung cancer cells while sparing normal cells and lung fibroblast. Despite being a well-known anti-angiogenic therapy, its RGD peptide-integrin V3 receptor interaction could also be used for cell-specific objectives [10,11].

6.2. Anti-microbial activity

According to their research findings, chlorhexidine-NPs Cs loaded membranes or chlorhexidine-NPs Cs in exposed

collagen membranes could be valuable in regeneration operations due to antimicrobial effect at small dosage [12]. Chitosan was revealed to have a considerable antifungal impact when transformed into nanoparticles. In conclusion, chitosan nanoparticles are thought to have the potential to be a safe and effective natural antifungal agent [13]. Encapsulating foscarnet into possibly long-circulating nanoparticles could result in a longer blood residence and in vivo exposure of infected cells to the medication, thus lessening harmful effects. However, because of the mucoadhesive qualities of chitosan, the previous mucosal epithelium could make both the oral and topical channels for foscarnet distribution more effective [8].

6.3. Gene therapy

In their studies, they have concluded that FA (folate) linked chitosan nanoparticles can act as a promising non-viral gene therapy for cancer and other inflammatory disease such as rheumatoid arthritis, where the FA receptors are over-expressed in cell membranes [15] (Fig. 6).

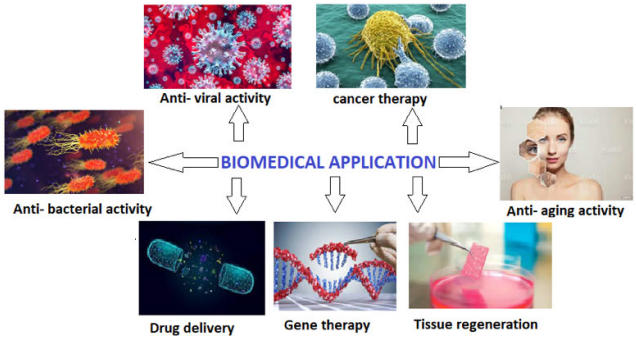

Fig. 6. Biomedical application nano-CH

7. Conclusions

The review looks at how Nano-CHs are created and how they can be used in biomedicine. The paper finds that nano-CH, rather than being in the traditional size range, offers a wide range of biomedical applications. Severs' biological qualities of biocompatibility, non-toxicity, and biodegradability set it apart as an important drug delivery vehicle. Chitosan and its derivative-based nanoparticles can be employed for antibacterial activity, anti-ageing properties, gene therapy, and pharmaceutical delivery in medical and non-medical industries. Antibacterial ZnO sulphated chitosan nanoparticles have not been reported to be produced.

Acknowledgements

The author (SR) is grateful to the Department of Biotechnology, Government of India, for providing funds (BT/PR15676/AAQ/03/794/2016) with related facilities.

Additional information

The work presented in the paper was presented in "Two Days Virtual National Meet on Nano Interface Science (NIS-2021)", Chettinad Academy of Research & Education, Chennai, India, 2021.

References

[1] H. Yabu, Fabrication of nanostructured composite microspheres based on the self-assembly of polymers and functional nanomaterials, Particle and Particle Systems Characterization 36/9 (2019) 1900178. DOI: https://doi.org/10.1002/ppsc.201900178

[2] M.D. Teli, J. Sheikh, Extraction of chitosan from shrimp shells waste and application in antibacterial finishing of bamboo rayon, International Journal of Biological Macromolecules 50/5 (2012) 1195-1200. DOI: https://doi.org/10.1016/j.ijbiomac.2012.04.003

[3] M.-T. Yen, J.-H. Yang, J.-L. Mau, Antioxidant properties of chitosan from crab shells, Carbohydrate Polymers 74/4 (2008) 840-844. DOI: https://doi.org/10.1016/j.carbpol.2008.05.003

[4] V. Manigandan, J. Nataraj, R. Karthik, T. Manivasagam, R. Saravanan, A.J. Thenmozhi, M.M. Essa, G.J. Guillemin, Low molecular weight sulfated chitosan: neuroprotective effect on rotenone-induced in vitro Parkinson's disease, Neurotoxicity Research 35/3 (2019) 505-515. DOI: https://doi.org/10.1007/s12640-018-9978-z

[5] P. Ramasamy, N. Subhapradha, T. Thinesh, J. Selvin, K.M. Selvan, V. Shanmugam, A. Shanmugam, Characterization of bioactive chitosan and sulfated chitosan from Doryteuthis singhalensis (Ortmann, 1891), International Journal of Biological Macromolecules 99 (2017) 682-691. DOI: https://doi.org/10.1016/j.ijbiomac.2017.03.041

[6] T. Wang, Q. Xu, Y. Wu, A. Zeng, M. Li, H. Gao, Quaternized chitosan (QCS)/poly (aspartic acid) nanoparticles as a protein drug-delivery system, Carbohydrate Research 344/7 (2009) 908-914. DOI: https://doi.org/10.1016/j.carres.2009.02.018

[7] R. Karthik, V. Manigandan, R. Saravanan, R.P. Rajesh, B. Chandrika, Structural characterization and in vitro biomedical activities of sulfated chitosan from Sepia pharaonis, International Journal of Biological Macromolecules 81 (2016) 319-328. DOI: https://doi.org/10.1016/j.ijbiomac.2015.12.030
[8] L. Qi, Z. Xu, Lead sorption from aqueous solutions on chitosan nanoparticles, Colloids and Surfaces A: Physicochemical and Engineering Aspects 251/1-3 (2004) 183-190. DOI: https://doi.org/10.1016/j.colsurfa.2004.10.010
[9] G. Arya, M. Vandana, S. Acharya, S.K. Sahoo, Enhanced antiproliferative activity of Herceptin (HER2)-conjugated gemcitabine-loaded chitosan nanoparticle in pancreatic cancer therapy, Nanomedicine: Nano-technology, Biology and Medicine 7/6 (2011) 859-870. DOI: https://doi.org/10.1016/j.nano.2011.03.009
[10] A. Babu, N. Amreddy, R. Muralidharan, G. Pathuri, H. Gali, A. Chen, Y.D. Zhao, A. Munshi, R. Ramesh, Chemodrug delivery using integrin-targeted PLGA-Chitosan nanoparticle for lung cancer therapy, Scientific Reports 7/1 (2017) 14674. DOI: https://doi.org/10.1038/s41598-017-15012-5
[11] A. Babu, R. Ramesh, Multifaceted applications of chitosan in cancer drug delivery and therapy, Marine Drugs 15/4 (2017) 96. DOI: https://doi.org/10.3390/md15040096
[12] U.S. Barreras, F.T. Méndez, R.E. Martínez, C.S. Valencia, P.R. Rodríguez, J.P. Rodríguez, Chitosan nanoparticles enhance the antibacterial activity of chlorhexidine in collagen membranes used for periapical guided tissue regeneration, Materials Science and Engineering: C 58 (2016) 1182-1187. DOI: https://doi.org/10.1016/j.msec.2015.09.085
[13] M.-C. Chen, M.-H. Ling, K.-Y. Lai, E. Pramudityo, Chitosan microneedle patches for sustained transdermal delivery of macromolecules, Biomacromolecules 13/12 (2012) 4022-4031. DOI: https://doi.org/10.1021/bm301293d
[14] M.C. Bonferoni, G. Sandri, E. Dellera, S. Rossi, F. Ferrari, M. Mori, C. Caramella, Ionic polymeric micelles based on chitosan and fatty acids and intended for wound healing. Comparison of linoleic and oleic acid, European Journal of Pharmaceutics and Biopharmaceutics 87/1 (2014) 101-106. DOI: https://doi.org/10.1016/j.ejpb.2013.12.018
[15] S. Mansouri, Y. Cuie, F. Winnik, Q. Shi, P. Lavigne, M. Benderdour, E. Beaumont, J.C. Fernandes, Characterization of folate-chitosan-DNA nanoparticles for gene therapy, Biomaterials 27/9 (2006) 2060-2065. DOI: https://doi.org/10.1016/j.biomaterials.2005.09.020