



## CHITOSAN NANOPARTICLES THEIR MULTIPURPOSE APPLICATION: A REVIEW

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### ABSTRACT

Cellulose and chitosan being the first two abundant biopolymers in nature offer wide opportunities to be utilized for high-end applications such as water purification. The nano-sized cellulose and nano-sized chitosan present superior adsorption behavior compared to their micro-sized counterparts. This area of research which explores the possible usage of nano-biopolymers is relatively new. The present review article outlines the development history of research in the field of cellulose and chitosan, various methods employed for the functionalization of the biopolymers, current stage of research, and mechanisms involved in adsorption of heavy metals and dyes using nanocellulose and nanochitosan. The significance of research using nano-biopolymers and future prospects are also identified.

**KEYWORDS:** Cellulose and chitosan nanocellulose and nanochitosan.

### INTRODUCTION

The exoskeleton of crustaceans, shell mollusks and to certain extent a few species of fungal cell wall contain chitin and chitosan. Chemically, chitosan is deacetylated derivative of chitin. The greatest advantage of chitin and chitosan are they are biodegradable, non-toxic and less antigenic nature.<sup>[1]</sup> Based on several studies chitin is converted into chitosan and the key four steps involved in the process are deproteinization, demineralization, decoloration and deacetylation.<sup>[2]</sup> Nanotechnology can produce variety of new materials which may have wide functional purposes. The major advantage of nanoparticles is that it provides more surface area and enhanced functional properties. Chitosan and chitosan particles are used to make a wide variety of compositions containing chitosan nanomaterials, nanofibers, films, nanoclay, colloids, composites, gels and other products either alone, in combination with other natural chemical or biological or biochemical compounds.<sup>[3,4]</sup> Chitosan and chitosan nanomaterials have a wide array of applications in biomedical, pharmaceutical, nutraceutical, foods and personal care areas.<sup>[9-11]</sup>

Application of chitosan in foods is gaining interest, specifically after the chitosan derived from shrimp has been recognized as Generally Recognized as Safe (GRAS) for common use in foods by the US Food and Drug Administration in 2011. The role of chitosan particles in foods could be viewed in broad categories based on their functions such as i) Antimicrobial property, ii) Additive property that includes functions such as color stabilization, emulsification, antioxidant

activity and iii) Dietary fiber like property aiding water holding and fat entrapment, thereby imparting health benefit. Due to the multifunctional properties of chitosan, in the last decade the number of patents issued on the processing of chitosan and its derivatives related to the use in food industry has increased.

Antimicrobial function of chitosan is known against wide variety of Gram-positive, Gram-negative bacteria, mould and yeast. The polycationic property of chitosan exhibits antimicrobial activity due to its ability to interact with negatively charged cell membranes of these microbes.<sup>[19]</sup> Both Gram positive and Gram negative bacteria have been found to be affected by chitosan having a minimum inhibitory concentration (MIC) in the range of 100 to 2000 ppm. The variations in the MIC values even for the same species across studies may be due to varying degree of acetylation of chitosan, since acetylation is associated with antimicrobial effect. Similarly, micro and nano chitosan particles have been found to show antifungal activities with MIC values ranging from 10-500 ppm against variety of species. Fungal species such as *Botrytis cinerea* and *Drechstera sorokiana* exhibited very low MIC of 10 ppm while several other fungi such as *Candida albicans*, *Microsporum canis*, *Aspergillus fumigatus*, *Aspergillus parasiticus* have shown higher MIC between 1000 and 2000 ppm, while for *Trichophyton mentagrophytes* and *Byssoschlamys* spp. the MIC values were found about 2000-5000 ppm.<sup>[19]</sup> In addition to the concentration of nanoparticle, size and zeta potential of both low and high molecular weight chitosan tend to influence the inhibitory effect against *C.*

*albicans* and *F. solani*. However, only high molecular weight chitosan solution and nanoparticles were able to inhibit the growth of *A. niger*.<sup>[20]</sup> but little is known about the antimicrobial potential of chitosan and chitosan nanoparticles against food spoiling microorganisms. Yeast was completely eliminated following the addition of 0.3 g of chitosan per liter of pasteurized apple-elder flower juice stored at 7°C. The total count and more specifically the lactic acid bacterial counts increased at a slower rate. However, the increase of bacterial count was relatively lower as compared to the increase in the control.<sup>[24]</sup> Chitosan has been used as a clarifying agent in several juices including orange, pomegranate, apple and others. Earlier, use of chitosan in the treatment of fruit juices showed inhibition of yeast but failed to inhibit *E. coli* O157:H7 suggesting that it may increase the food poisoning risk.<sup>[25]</sup> However, Abd and Niamah showed chitosan at a concentration of 0.2 to 1 g/L in apple juice could inhibit growth of some spoilage bacteria, mould and yeast.<sup>[26]</sup> Recent developments in the area of chitosan admixtures, especially arginine-functionalized chitosan showed antibacterial activity against *E. coli* O157 in chicken juice.<sup>[27]</sup>

Chitosan scavenges free radicals or chelate metal ions from the donation of a hydrogen or the lone pairs of electrons and this is considered responsible for the antioxidant ability and free radical scavenging activity of chitosan.<sup>[28]</sup> In addition, the low molecular weight of chitosan and the degree of quaternization appear to contribute to the antioxidant capacity of chitosan. Solubility of chitosan is promoted in the acidic environment of the stomach and this allows chitosan to bind to fatty acids and lipids and it is proposed that greater portion of such lipids bound to chitosan is known to be excreted rather absorbed.<sup>[29]</sup> Several patented formulation of chitosan with other fibers in the form of tablets, capsules and drinkables are available as nutritional supplement. The chitosan fibers have been implicated in management of body weight and in lowering lipid levels.

Chitosan alone may have lower transfection efficiency and to increase the efficiency, Oliveira and colleagues studied diethylethylamine – chitosan derivatives which resulted in condensation of DNA.<sup>[29]</sup> Lu et al. observed that the transfection efficiency of chitosan-graft-polyethylenimine DNA was similar to that of Lipofectamine 2000 in chondrocytes and synoviocytes without affecting cell viability. Due to low cytotoxicity, the authors have suggested that chitosan might be a safe and efficient vector for gene delivery in chondrocytes and synoviocytes. It is thought that chitosan and polyethylenimine complexes protect the DNA from serum degradation.<sup>[30]</sup> Previous study has demonstrated quaternized oligomers to be efficient than oligomeric chitosans and the size of the complexes ranged from 200-500 nm.<sup>[31]</sup> However, it was reported that release of DNA from chitosan could be changed by formulation conditions Li and Birchall tested cationic polymer

chitosan for dispersability and reported higher deposition of chitosan on modified lactose formulation.

### Future Research

Over the years there is a tremendous increase in the use of non-biodegradable materials or plastics derived from petroleum products as food packaging materials. Such uncontrolled use of these materials resulted in the accumulation of plastic waste in the environment and pose serious concerns to the ecosystem. Attempts have also been made from time to time from various parts of the world to address the demand for sustainability and environmental protection by exploring alternative and eco-friendly biomaterials for food packaging industries. Hence, biopolymers are the best suitable alternatives to be exploited and developed into eco-friendly food packaging materials due to their biodegradability and among these, chitosan is most favoured naturally available biopolymer. However, the major disadvantages of using chitosan are its poorer mechanical, thermal and barrier properties as compared to the commonly used non-biodegradable polymers from petroleum. Packing methods employed for such foods is mainly aimed to maintain quality, safety and value of foods. The advancement of nanotechnology has been tremendously helping the progress of the chitosan based materials by the incorporation of newer nanoparticles thereby improving the functional properties of chitosan matrix having tremendous applications in food packaging industry.

The future research relating to chitosan and nanochitosan containing materials should be based on the current caveats and pitfalls in using chitosan. There are a few concerns that need to be addressed on top priority to have a wide acceptance of applications of chitosan materials viz. i) quality of the chitosan particles needs to be established ii) oligosaccharide engineering for chitosan applications as food additives needs to be studied in detail, iii) stability of chitosan composites especially used for transfer of biomolecules such as transfection process needs to be improved, since current operating temperature are in a narrow range, iv) improvement in the mechanical, thermal and barrier properties compared to synthetic polymers and v) reduction of inconsistency of raw material specification such as the molecular weight and the acetylation content.

It is a paramount importance that the chemical methods used for preparations of chitosan and its nanoparticle varieties shall be well established, validated and which are scalable at industrial level. Therefore, the simple and low cost production process of chitosan derived nanoparticles having valuable application in human health care management need to be established. Even chemical, physical and other qualities and characteristics of such chitosan derived materials should be well tested and analytically established. Industry supported private and academic research amalgamated with regulatory agencies would accelerate the development of such

naturally available chitosan and chitosan derivatives for human use. These combined efforts to develop chitosan derived products would certainly support environmental sustainability for human health and existence of other living system.

## REFERENCES

1. Benjakul S, Visessanguan W, Tanaka M (2003) Partial purification and characterization of trimethylamine-N-oxide demethylase from lizardfish kidney. *Comp Biochem Physiol B Biochem Mol Biol*, 135: 359-371.
2. Dutta PK, Dutta J, Tripathi VS (2004) Chitin and chitosan: Chemistry, properties and applications. *Journal of Scientific and Industrial Research*, 63: 20-23.
3. No HK, Meyers SP, Prinyawiwatkul W, Xu Z (2007) Applications of chitosan for improvement of quality and shelf life of foods: a review. *J Food Sci.*, 72: R87-100.
4. Singh K, Mishra A (2015) Chitosan nanoparticulate and their applications: A review. *Int J Pharm Bio Sci.*, 6: 557-566.
5. Berthold A, Cremer K, Kreuter J (1996) Preparation and characterization of chitosan microspheres as drug carrier for prednisolone sodium phosphate as model for Anti-Inflammatory Drugs. *Journal of Controlled Release*, 9: 17-25.
6. Mehrotra A, Nagarwal RC, Pandit JK (2011) Lomustine loaded chitosan nanoparticles: characterization and in-vitro cytotoxicity on human lung cancer cell line L132. *Chem Pharm Bull (Tokyo)*, 59: 315-320.
7. Ohya Y, Takei T, Kobayashi H, Ouchi T (1993) Release behaviour of 5-fluorouracil from chitosan-gel microspheres immobilizing 5-fluorouracil derivative coated with polysaccharides and their cell specific recognition. *J Microencapsul*, 10: 1-9.
8. Patil P, Bhoskar M (2014) Optimization and evaluation of spray dried chitosan nanopaparticles containing doxorubicin. *Int J Curr Pharma Res.*, 6: 7-15.
9. Allémann E, Leroux JC, Gurny R, Doelker E (1993) In vitro extended-release properties of drug-loaded poly(DL-lactic acid) nanoparticles produced by a salting-out procedure. *Pharm Res.*, 10: 1732-1737.
10. Du WL, Niu SS, Xu YL, Xu ZR, Fan CL (2009) Antibacterial activity of chitosan tripolyphosphate nanoparticles loaded with various metal ions. *Carbohydrate Polymers*, 75: 385-389.
11. Kim K, Kim JH, Park H, Kim YS, Park K, et al. (2010) Tumor-homing multifunctional nanoparticles for cancer theragnosis: Simultaneous diagnosis, drug delivery and therapeutic monitoring. *J Control Release*, 146: 219-227.
12. Agulló E, Rodríguez MS, Ramos V, Albertengo L (2003) Present and Future Role of Chitin and Chitosan in Food. *Macromolecular Bioscience*, 3: 521-530.
13. Cao R, Liu Q, Yin B, Wu B (2012) Chitosan extends the shelf-life of filleted tilapia (*Oreochromis niloticus*) during refrigerated storage. *Journal of Ocean University of China*, 11: 408-412.
14. Kamil J, Jeon Y, Shahidi F (2002) Antioxidative activity of chitosans of different viscosity in cooked comminuted flesh of herring (*Clupea harengus*). *Food Chemistry*, 79: 69-77.
15. Vargas M, González-Martínez C (2010) Recent patents on food applications of chitosan. *Recent Pat Food Nutr Agric*, 2: 121-128.
16. Jean M, Alameh M, De Jesus D, Thibault M, Lavertu M, et al. (2012) Chitosan-based therapeutic nanoparticles for combination gene therapy and gene silencing of in vitro cell lines relevant to type 2 diabetes. *Eur J Pharm Sci.*, 45: 138-149.
17. de Paula Pansani Oliveira F, DallaPicola IP, Shi Q, Barbosa HF, Tiera VA, et al. (2013) Synthesis and evaluation of diethylethylamine-chitosan for gene delivery: composition effects on the in vitro transfection efficiency. *Nanotechnology*, 24: 055101.
18. Kuang Y, Yuan T, Zhang Z, Li M, Yang Y (2012) Application of ferrirous oxide modified by chitosan in gene delivery. *J Drug Deliv*, 2012; 920764.
19. Goy RC, Britto D, Assis OBG (2009) A review of the antimicrobial activity of chitosan. *Polímeros: Ciencia e Tecnologia*, 19: 1-7.
20. Ing LY, Zin NM, Sarwar A, Katas H (2012) Antifungal activity of chitosan nanoparticles and correlation with their physical properties. *Int J Biomater*, 2012; 632698.
21. Qi L, Xu Z, Jiang X, Hu C, Zou X (2004) Preparation and antibacterial activity of chitosan nanoparticles. *Carbohydr Res.*, 339: 2693-2700.
22. Rabea EI, Badawy ME, Stevens CV, Smagghe G, Steurbaut W (2003) Chitosan as antimicrobial agent: applications and mode of action. *Biomacromolecules*, 4: 1457-1465.
23. Jeon SJ, Oh M, Yeo WS, Galvão KN, Jeong KC (2014) Underlying mechanism of antimicrobial activity of chitosan microparticles and implications for the treatment of infectious diseases. *PLoS One*, 9: e92723.
24. Rhoades J, Roller S (2000) Antimicrobial actions of degraded and native chitosan against spoilage organisms in laboratory media and foods. *Appl Environ Microbiol*, 66: 80-86.
25. Kiskó G, Sharp R, Roller S (2005) Chitosan inactivates spoilage yeasts but enhances survival of *Escherichia coli* O157:H7 in apple juice. *J Appl Microbiol*, 98: 872-880.
26. Abd AJ, Niamah AK (2012) Effect of chitosan on apple juice quality. *International Journal of Agricultural and Food Science*, 2: 153-157.

27. Lahmer RA, Williams AP, Townsend S, Baker S, Jones DL (2012) Antibacterial action of chitosan-arginine against *Escherichia coli* O157 in chicken juice. *Food Control*, 26: 206-211.
28. Garai P, Gogoi M, Gopal G, Radhakrishnan Y, Nandakumar KS, et al. (2014) The basics and advances of immunomodulators and antigen presentation: a key to development of potent memory response against pathogens. *Expert Opin Biol Ther*, 14: 1383-1397.
29. Gnanadhas DP, Ben Thomas M, Elango M, Raichur AM, Chakravorty D (2013) Chitosan-dextran sulphatanocapsule drug delivery system as an effective therapeutic against intraphagosomal pathogen *Salmonella*. *J Antimicrob Chemother*, 68: 2576-2586.
30. Barreteau H, Delattre C, Michaud P (2006) Production of Oligosaccharides as promising new food additive generation. *Food Technol Biotechnol*, 44: 323-333.
31. Kardas I, Struszczyk MH, Kucharska M, Van den Broek LAM, van Dam JEG, Ciecianska D (2012) Chitin and Chitosan as Functional Biopolymers for Industrial Applications. In: Navard P (ed) *The European Polysaccharide Network of Excellence (EPNOE) Research Initiatives and Results* Springer-Verlag Wien, pp. 329-375.