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Applications of Chitin and Chitosan in Industry and Medical Science: A Review

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Abstract
Chitin can be extracted from the exoskeletons of crustaceans, insects and mollusks and the cell wall of microorganisms. It can be converted into chitosan by deacetylation process. Chitosan shows more versatility than chitin due to its solubility and reactive free amino group (-NH_2). This article helps to understand the importance and characteristics of chitin and chitosan by their various aspects such as properties and medical and industrial applications.

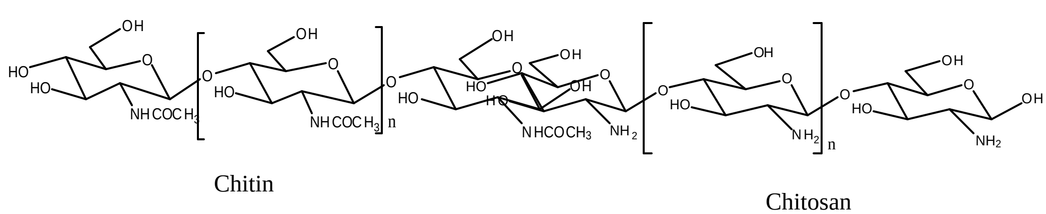
Key words: biomaterial, chitin, chitosan, medical application, biopolymer

Introduction
The meaning of biopolymer is something, that is originated from living beings; made by the combination of many molecules. There are large number of natural polymers considered as biomaterials such as collagen, chitin, silk, alginate, starch and elastin (Correlo *et al*.2005). The problem associated with synthetic polymers such as toxicity and non biodegradability is suppressed by the use of biopolymers. The important characteristic of biopolymer is its ability to degrade by natural enzymes with their immunogenic behavior. The development of biomaterials using natural polymers is an important and promising channel for research.

Chitin is the second most abundant biopolymer found in nature. It is mainly derived from the exoskeletons of crustaceans, insects, mollusks and the cell wall of microorganisms (Muzzarelli 1977). Chitin is a copolymer of N-acetyl-D-glucosamine units linked with â-(1-4) glycosidic bond, where N-acetyl-D-glucosamine units are predominant in the polymeric chain.

Chitosan is the deacetylated derivative of chitin, which is chemically defined as a copolymer of á-(1,4) glucosamine ($C_6H_{11}O_4N)_n$, having different number of N-acetyl groups (Zvezdova 2010). It is white to light red solid powder, insoluble in water but soluble in organic acids.

The structures of chitin and chitosan are presented in Scheme 1.



Scheme1. Polymer chain of chitin and chitosan where *n* stands for the degree of polymerization

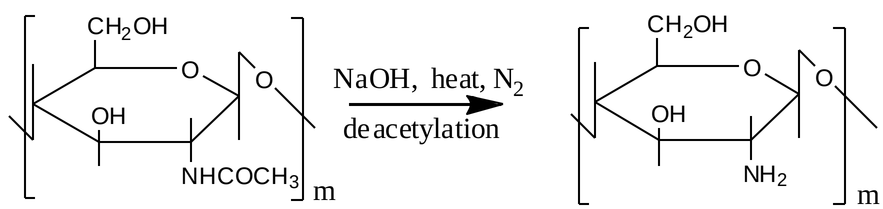
Chitin can be isolated from crustacean shells by chemical process, which was reported by Acosta *et al*. (1995) and Zvezdova (2010). A general scheme is presented in Fig. 1 and involves the following steps.

(a) Demineralization: It involves acid treatment (mainly with HCl) which removes inorganic matters (mainly calcium carbonate).

(b) Deproteinization: It includes the extraction of protein matter in alkaline medium (mainly with NaOH).

(c) Decolourization: It involves bleaching of the product by chemical reagents to achieve colourless product.

The conversion of chitin into chitosan has been shown in Scheme 2.



Scheme 2. Schematic representation for the conversion of chitin into chitosan

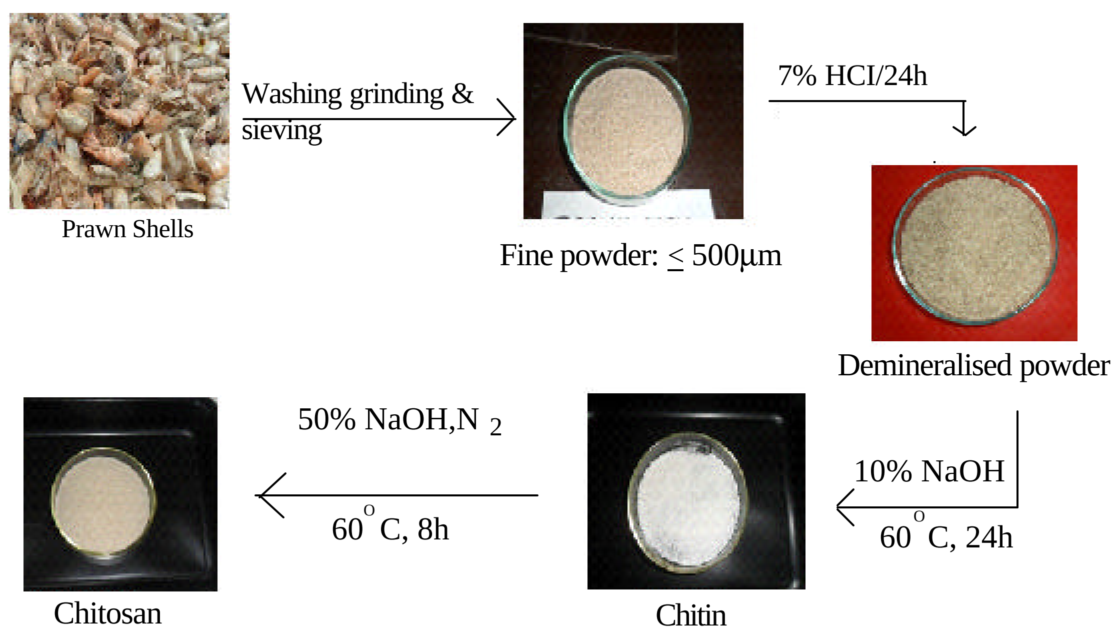


Fig. 1. Photographs showing different steps of isolation of chitosan from prawn shells using method adapted from literature (Zvezdova 2010)

Chitin and chitosan are the naturally abundant and renewable polymers having excellent properties such as biodegradability, biocompatibility, non-toxicity and adsorption (Hudson & Smith 1998). The reaction of chitosan is more versatile than cellulose due to the presence of -NH_2 groups (Dutta *et al.* 2004).

Like cellulose, chitin and chitosan can undergo many reactions such as etherification, esterification and crosslinking (Hon 1996). The main parameter that affects the characteristics of chitosan is its molecular weight (Zhou *et al.* 2003) and degree of deacetylation (representing the proportion of deacetylated units).

Unlike other naturally occurring polysaccharides such as cellulose, dextran, pectin, alginic acid that are either acidic or neutral, chitosan is highly basic in nature. Due to this unique property, chitosan has several functional properties such as polyoxysalt formation, ability to form films, chelate metal ion and optical structural characteristics (Majeti 2000, Hench 1998).

Chemical properties of chitosan

This biopolymer has a number of chemical properties that make it suitable for several biomedical applications. Some of them are listed below (Dutta *et al*. 2004).

1. Chitosan is a linear polyamine.
2. It has reactive amino groups ($-NH_2$).
3. There is availability of reactive hydroxyl groups (-OH).
4. It has chelating ability for many transitional metal ions.

Biological properties of chitosan

Besides the various chemical properties, chitosan shows diverse biological properties which are summarized (Venter *et al*.2006, Younes & Rinaudo 2015) as follows:

1. Biocompatible:
   i. Natural polymer
   ii. Safe and non-toxic
   iii. Biodegradable to normal body constituents
2. Binds to mammalian and microbial cells aggressively
3. Regenerative effect on connective gum tissue
4. Accelerates the formation of osteoblast responsible for bone formation
5. Haemostatic (causes stop bleeding)
6. Fungistatic (inhibiting the growth of fungi)
7. Spermicidal (birth control)
8. Antitumor or Anticancer (inhibiting the growth of tumor or cells)
9. Anticholesteremic (cholesterol lowering agent)
10. Central nervous system depressant (slow down the brain activity)
11. Immunoadjuvant (involved in the improvement of immune response)

Applications of chitin and chitosan

The poor solubility of chitin causes limitation in its applications. Besides these limitations, its various applications have been reported such as raw material for man-made fibers as absorbable sutures and wound dressing materials besides these chitin and chitosan fibers are also used in waste water treatment (Sridhari *et al*. 2000)

Chitin and chitosan have potential applications in hair care. Chitin and acylated chitosan with an organic diacid anhydride are used for skin care. Chitosan can be used in shampoos, hair colorants, styling lotions, hair sprays and hair tonics (Rinaudo 2006). Chitin and chitosan are found to be used in creams as a moisturizer, nail enamel foundation, eye shadow and lipstick cleansing materials and bathing agents. Chitin and chitosan are used in toothpaste, mouthwashes and chewing gum. Chitin is also used as dental filler (Dutta *et al.* 2004).

Chitosan act as chelating agent and heavy metals trapper (Khor & Lim 2003). Chitosan N-benzyl sulphonate derivatives are used as sorbents for the removal of metal ions in acidic medium and chitosan can also be used to remove the color from dye house effluents as reported by Weltroswki *et al.* (1996). Chitin and chitosan are also found to be used effectively to remove arsenic from contaminated drinking water as well as to remove petroleum products from waste water (Saha & Sarkar 2013).

Chitosan is non-toxic therefore it is used in food industry. Microcrystalline chitin (MCC) is used as flavouring and colouring agent, shelf life as well as dietary fibre in baked food (Jianglian & Shaoying 2013).

Chitin treated seeds (wheat) have shown the growth accelerating and growth enhancing effects. The addition of chitin to the soil reduces the root knot worm infestations and supression of fungal pathogens (Dutta *et al.* 2004).

Tissue engineering is the development and manipulation of laboratory-grown cells, tissues or organs that would replace or support the function of defective or injured parts of the body (Khor & Lim 2003, Vankatesam & Kim 2010). The special attention on chitosan has been paid for the repair of articular cartilage. Microporous chitosan/calcium phosphate composite scaffolds have been synthsized and characterized for tissue engineering. They reported that chitosan provides a scaffold form and calcium phosphates encourages osteoblast attachement and strengthens the scaffold (Zhang & Zhang 2001, Elzein *et al*. 2002).

Chitosan show good effect on wound dressing/wound healing process. Chitin can also be used as a coating on normal biomedical materials. Standard silk and catgut sutures coated with regenerated chitin or chitosan show wound healing activities slightly lower than the chitin fibre (Murakami *et al. 2010*).

Chitin and chitosan are inexpensive and non hazardious. They can be used for the prepartion of dosage forms in commercial drugs (Andrady & Xu 1997) such as spread dry chitosan acetate and ethyl cellulose can be used as new compression coats for 5-aminosalicylic acid (ASA) tablets was reported by Nunthanid *et al.* (2009). Chitin/chitosan controlled delivery systems are in developing stage. It is being used for a wide variety of reagents in several environments. (Surini *et al*. 2003).

Gene therapy is a treatment of human disorders by introducing the genetic material into specific target cells of a patient where the production of the encoded protein occurs (Corsi *et al.* 2003).

The development of efficient and safe gene carrier systems that are capable of transferring DNA in the cells is a major goal of the gene therapy. Several literature survey show that chitosan is a suitable material for efficient non-viral gene therapy (Jayakumar *et al*. 2010).

Besides many good characteristics, chitosan has growth-inhibition effect on tumor cells (Carreno-Gomez & Duncan 1997). The ligand-targated approach is expected to deliver drugs to tumor tissues selectively with high efficiency. Although *in vivo* studies of targated chitosan nanoparticles are currently limited, results from *in vitro* studies have demonstrated their promise for applications in cancer treatment and diagnosis (Hang 2010).

As chitosan shows antimicrobial activity so its film have shown great promise for their applicaton in food preservation. The antimicrobial activity limits or prevents microbial growth by extending the interval period and reducing the growth rate or decreasing live counts of microorganisms (Han 2000) which support the chitosan film for its potentiality in the packaging of food items and food preservation.

Gavhane *et al*. (2013) reported wide biomedical applications of chitin and chitosan, however, he also highlighted some limitations such as allergy and constipation. Furhermore people with intestinal malasorption syndroms should not use chitosan. Its adverse effects on the growth of children and on the outcome of pregnancy was also reported. However, application of chitin and chitosan have faced some limitation with high viscosity and low solubility at neutral pH (Kim & Dewapriya 2014).

Conclusion

Some of the prospects of chitosan in biomedical field have been highlighted and looking potential direction for future research. Furthermore, chitin and chitosan possess various natural biological activities and have a considerable potential to be utilized in a number of medical and industrial applications.

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