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Review Article

Chitin –and its benefits

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Abstract

Chitin is an important natural resource. Chitin, after wood cellulose, is the most abundant polysaccharide on earth. The annual worldwide production is estimated in approximately 10^{10}-10^{12} ton. Chitin is the fiber in shellfish shell such as crab, lobster and shrimp. It is also found in common foods we eat such as grain, yeast, bananas, and mushrooms. It is produced by arthropods (insects and crustaceans), molluscs and fungi. Crustacean shells are the most important chitin source for commercial use due to its high content and ready availability. Chitin and its derivatives have great economic value because of their numerous applications: food, cosmetics, pharmaceuticals, textile industries, waste water treatment and agriculture.
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Keywords: Chitin, Chitosan, Biomedical uses, Crustacean

Introduction

Chitin is the second most abundant polysaccharide on the planet (Gooday, 1990) and is composed of β (1 → 4) - linked 2-acetamido 2- deoxy- β-D-glucose (N-acetylglucosamine). Chitosan is the name used for low acetyl substituted forms of chitin and is composed primarily of glucosamine, 2-amino-2-deoxy-β-D-glucose, known as (1 → 4)-2-amino-2-deoxy-(D-glucose. Chitosan has three types of reactive functional groups, an amino group as well as both primary and secondary hydroxyl group at the C-2, C-3 and C-6 positions, respectively. Chemical modifications of these groups have provided numerous useful materials in different fields of application (Kurita et al., 1986). Chitin is the major structural component of the exoskeleton of invertebrates and the cell wall of fungi (Tan et al., 1996). Disposal of shell fish processing discards, which amounts to million metric tons, has become a challenge for most of the shell fish producing countries. Therefore, conversion of processing discards into valuable by-products and alternative speciality material has been identified as a timely challenge for research and development. In that sense these biopolymers offer a wide range of unique application including bioconversion for the production of value added food products (Shahidi and Synowiecki., 1991), preservation of foods from microbial deterioration (Chang et al., 1989), formation of biodegradable films (Kittur et al., 1998), recovery of waste materials from food processing discards (Pinotti et al., 1997) and purification of water (Deans et al., 1992).

Unique characteristics of chitin and chitosan

Chitosan has got unique properties, such as biodegradability, bioactivity, biocompatibility, fibre-grade properties, coating ability, and good miscibility with other polymers. The non-toxic, remarkable affinity to proteins, ability to be functionalized and renewable, makes the polymer with broad applications in different fields, such as medicine, agriculture, environmental protection, and food industry.

Physicochemical and biological properties of chitin

Degradability of chitin

Chitin is susceptible to lysozyme, an enzyme responsible for the degradation of chitin (Tomihata and Ikada, 1997). This property of the polymer can be effectively utilized for preparation of temporary scaffold for tissue repair. Chitin and chitosan break down products include oligosaccharides and repeating units of N-acetyl glucosamine, which constitutes the major component of extracellular matrix. There appears much potential for the application of both chitin and chitosan scaffolds for tissue repair which involve the products of degradation in vivo as these are associated with significant biological activity.

Cartilage tissue engineering

Chitin acts as a suitable biomaterial to support cartilage regeneration as its repeating units N-acetylglucosamine is a building block of keratin sulphate and hyaluronate which forms a major component of articular cartilage.

Bone and tendon tissue engineering

The chitin has been used to promote osteogenesis in mesenchymal stem cells by providing substrate for matrix material in bone regeneration. There are reports of chitin's ability to accelerate wound healing (Muzzarelli, 2009) and biological activity of enhancing cell migration (Okamoto et al., 1993) and forming granulation tissue with angiogenesis extending to other vascularised tissue, including bone.

Mechanical properties

Like other polysaccharides, chitin possesses abundant hydroxyl groups that can hydrogen bond to water molecules, resulting in a strong affinity for water. Water binding in turn leads to a lowering of the glass transition temperature, hence, the polymer becomes more rubbery at room temperature. Due to its favourable mechanical properties, chitin has been researched for application that requires good integrity and physical strength, such as surgical sutures and bone substitute materials.

Immunogenicity

Another important aspect to be considered in the application of chitin and chitosan in tissue engineering would be their effect on the immune response. Chitosan possess low immunogenicity and has the ability to acts as an immunoadjuant. They simulate macrophages to produce cytokines and other compounds that confer non-specific host resistance against bacterial and viral infections (Muzzarelli, 2010).

Beneficial effect of chitin and chitosan

A beneficial effect of chitin-chitosan as a food supplement is the reduction of plasma cholesterol and triglycerides due to its ability to bind dietary lipids, thereby reducing intestinal lipid absorption. The hypolipidemic influence of chitosan may also be due to interruption of the enterohepatic bile acid circulation.

Chitosan is used to treat obesity, high cholesterol, and Crohn's disease. It is also used to treat complications like kidney failure, high cholesterol, anaemia, loss of strength, appetite, and insomnia. It is applied to gums to treat inflammation that can lead to tooth loss (periodontitis), or chew gum to prevent "cavities" (dental caries).

- Use of chitin and chitosan as feed additives decreases serum cholesterol and triglyceride levels and increase high density lipoprotein level (Razdan and Pettersson (1994).
- Chitin increases growth of bifidobacteria in intestinal tracts by inhibiting growth of other bacteria.
- Chitosan and chitosan derivative is effective in reducing rancidity and off-flavour development in meat caused by oxidation of unsaturated lipids.
- Wound healing property
- Wound healing is a process for promoting rapid dermal regeneration and accelerated wound healing. Chitosan-based wound dressing reduced scar tissue (fibroplasias) by inhibiting the formation of fibrin in wounds and acts as hemostatic and formed a protective film coating (Lloyd et al.,1998). Being a substrate for lysozyme, chitosan degradation products were internally absorbed, which in turn affected macrophage activity.

Anticoagulant activity

Compared to heparin, the sulfated chitosan has been shown to possess high anticoagulant potency. Sulfation was carried out using chlorosulfonic acid in N, N-dimethylformamide at room temperature to avoid degradation of chitosan. Unlike heparin, sulfated chitosan does not show anti-platelet activity, which causes excessive bleeding in patients.

Antimicrobial activity of chitin, chitosan and their derivatives

The growing consumer demand for foods without chemical preservatives has focussed efforts in the discovery of new natural antimicrobials. In this context, the unusual antimicrobial activity of chitin, chitosan and their derivatives against different groups of microorganisms has received considerable attention in recent years (Yalpani, 1992).

The exact mechanism of the antimicrobial action of chitin, chitosan and their derivatives is still unknown, but different mechanisms have been proposed.

- Interaction between positively charged chitosan molecules and negatively charged microbial cell membrane leads to leakage of proteinaceous and other intracellular constituents (Papineau et al., 1991).
- Chitosan acts as chelating agent that selectively binds trace metals and thereby inhibits the production of toxins and microbial growth (Cuero et al., 1991).
- Activates several defence processes in host tissue(ElGhaouth et al.,1992)
- Acts as water binding agent and inhibits various enzymes (Cuero et al., 1991).
- Binding of chitosan with DNA and inhibition of mRNA synthesis occurs via chitosan, penetrating the nuclei of the microorganisms and interfering with the synthesis of mRNA and proteins (Sudharshan et al., 1992).
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Antimicrobial activity against bacteria

Numerous studies have shown the effect of chitosan against different bacteria. According to different findings, *Bacillus cereus* required chitosan concentration of 0.02% for bactericidal effect, while *Escherichia coli* and *Proteus vulgaris* showed minimal growth at 0.005%, and complete inhibition at 0.0075%. Chitosan glutamate and chitosan lactate have bactericidal activity against both gram positive and gram negative bacteria in the range of one to five log cycle reduction within one hour (Wang, 1992).

Antimicrobial activity against Fungi

Use of bioactive substances such as chitosan to control post-harvest fungal disease has attracted much attention due to imminent problems associated with chemical agents, which include development of public resistance to fungicide treated produce, and increasing the number of fungicide tolerant post- harvest pathogens. Results of various studies suggest that coating fruits and vegetables with chitosan or its derivatives has got advantage for long term storage of these foods. Chitosan reduces the growth of numerous fungi, in addition to the formation of gas permeable films, direct interference of fungal growth and activation of several defence processes.

Biomedical uses

Hemostatic agent

Chitosan's property allows it to rapidly clot blood, and has been used as bandages and other hemostatic agents. Chitosan quickly stop bleeding and reduce blood loss, and result in 100% survival of otherwise lethal arterial wounds in swine (Brown et al.,2007). Chitosan hemostatic products reduce blood loss in comparison to gauze dressings and increase patient survival (Anthony E, 2003). Chitosan is hypoallergenic and has natural antibacterial properties, which further support its use in field bandages. The hemostatic agent works by an interaction between the cell membrane of erythrocytes (negative charge) and the protonated chitosan (positive charge) leading to involvement of platelets and rapid thrombus formation.

Drug delivery system

Chitosan's properties also allow it to be used in transdermal drug delivery. This molecule will maintain its structure in a neutral environment, but will solubilize and degrade in an acidic environment. This means chitosan can be used to transport a drug to an acidic environment, where the chitosan packaging will then degrade, releasing the drug to the desired environment. One example of this drug delivery has been the transport of insulin (Agnihotri, 2004).

Industrial application of chitin

Due to its physical and chemical properties, chitosan is being used in a vast array of widely different products and applications, ranging from pharmaceutical and cosmetic products to water treatment and plant protection. These properties depend on the degree of acetylation and molecular weight.

Cosmetics

Chitosan is compatible with lots of biologically active component incorporated in cosmetic products composition. Chitin and chitosan and their derivatives offer uses in three areas of cosmetics: hair care, skin care and oral care.

Water filtration

Chitosan can also be used in water processing engineering as a part of a filtration process. Chitosan causes the fine sediment particles to bind together, and is subsequently removed with the sediment during sand filtration. It also removes phosphorus, heavy minerals, and oils from the water. Chitosan is an important additive in the filtration process. Sand filtration apparently can remove up to 50% of the turbidity alone, while the chitosan with sand filtration removes up to 99% turbidity.

Paper industry

Biodegradable chitin and chitosan can strengthen recycled paper and increase the environmental friendliness of packaging and other products. Hydroxymethyl chitin and other water soluble derivatives are useful end derivatives in paper making. It can be used as biodegradable packaging material for food wrap and other products.

Textile industry

In textile industry, chitin can be used in printing and finishing preparations, while the chitosan is able to remove dyes from dye processing effluents.

Conclusion

In brief, it is very much evident that chitin/chitosan and their modified derivatives exhibit an unlimited application potential for use in a wide range of fields. Even though chitin chitosan and their derivatives have been considered as versatile biopolymers in food applications their potential uses as functional food ingredients have to be studied with broader emphasis. Further basic and application oriented studies are expected to fully utilize the potential of chitin/chitosan for still additional uses and for the benefit of the society.

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