Chitin and Chitosan: Marine Biopolymers with Unique Properties and Versatile Applications

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Chitin and Chitosan: Marine Biopolymers with Unique Properties and Versatile Applications

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Abstract: Chitin and chitosan are unique and typical marine polysaccharides waiting for future development and have been attracted the interest of many researchers from various disciplines. Chitin and its derivatives exhibit a variety of physicochemical and biological properties resulting in numerous applications in areas ranging from waste water treatment to agrochemical, environemental and industrial uses. In addition to its lack of toxicity and allergenicity, its biocompatibility, biodegradability and bioactivity make it a very attractive substance for diverse applications as a biomaterial in the pharmaceutical and medical fields. In the present study, chitin and chitosan properties will be reviewed and their potentialities as promising biomaterials also will be discussed.

Key words: Chitin · Chitosan · Biomaterial · Properties · Applications

INTRODUCTION

Chitin is a β (1-4) polymer of N-acetyl-D-glucosamine and the major structural component of the exoskeleton of invertebrates, cuticles of insects and the cell walls of fungi. It is considered to be an important renewable source and the second most abundant biopolymer on earth after cellulose. It is approximately produced at levels more than 1011 tons annually in the aquatic biosphere. For example, copepods, a single subclass of marine zooplankton alone produce billions of tons of chitin annually [1]. The first discovery of chitin was in mushrooms by Henri Bracannot (1811), a French botanist and director of botanical gardens at the academy of science in Nancy. In 1823, chitin was isolated from insects and was got its name when another French scientist, A. Odier named it "chitine" which simply means "tunic" or "coverage" in Greek [2]. In 1859, C. Roughet a chemist discovered that chitin could be transferred into water soluble form through some chemical reactions. After that in 1870, this modified chitin was named chitosan [3]. Despite the early discovery of chitin, researches about it became more intensive only in the last 20 years, this can be attributed to the fact that chitin in its pure form is water insoluble; however, its uses are extended considerably after chemical treatment. In the present study, chitin and chitosan properties will be reviewed and their potentialities as promising biomaterials also will be discussed.

Chitin/Chitosan Structure: Chitin is a linear, highly crystalline homo polymer of β-1, 4 N- acetyl glucosamine (GlcNAc). Earlier, it was designated "animal cellulose" because it is structurally similar to cellulose except that hydroxyl groups had been replaced with acetamide groups at the C-2 position Figure (1). Chitin consists of β-1, 4–linked N-acetyl glucosamine residues that are arranged in antiparallel (α), parallel (β) or mixed (γ) strands, with the (α) configuration being the most abundant. In most organisms chitin is cross linked to other structural components, such as proteins and glucans [4] except for β chitin of some centric diatom (chitan) such as *Thalassiosira fluviatilis* produce radiating spines that are fully acetylated and the purist form of chitin known in nature and unlinked with other extracellular components[5].

Chitin/Chitosan Occurrence and Potential Sources: Chitin occurs in a wide variety of species, from ciliates, amoebae, chrysophytes, some algae, yeasts and fungi to the lower animals like crustaceans, worms, insects and mollusks. Vertebrates, plants and prokaryotes do not contain chitin [6].

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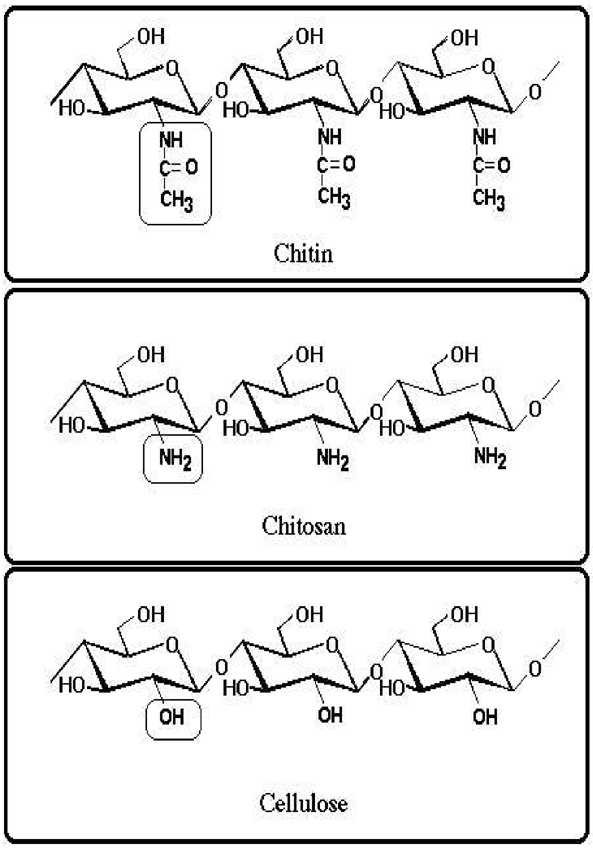

Fig. 1: Structure of chitin, chitosan and cellulose

However Goody 1995 [7] reported the presence of chitin in many Streptomycete spores and stalks of prosthecate bacteria. Shells of arthropods contain 20-55% chitin on a dry weight basis. From a practical view point, shells of crustaceans such as crabs and shrimps are very available wastes from seafood processing industries. They can be used for the commercial production of chitin. Prawn, krill, squilla, lobster, cray fish, jelly fish, cuttlefish (squid), oysters, clams, insects and fungi are other potential sources for chitin production. Chitosan exists naturally only in a few species of fungi like zygomycetes and mucorales such as Absidia coerulae [8], but practically chitosan prepared by chitin deacetylation [9].

Chitin/Chitosan Properties

Chitin/Chitosan Physic-chemical Properties:

- Color and appearance: chitin is colorless to off-white, hard, inelastic, nitrogenous polysaccharide[10].
- Degree of polymerization (DP): ranging between 2000 and 4000
- Degree of deacetylation (DDA): The degrees of deacetylation in chitin usually range from 5-15% and in chitosan from 70-95%, the higher degree of acetylation (DA) of chitin the lower solubility in common solvents. [11].
- Crystallinity: is the hydrogen bounding formed between the arranged strands of chitin, the higher crystallinity the more stability for chitin molecules and the degree of crystallinity is a function of the degree of deacetylation. [12].
- Molecular weight: the chitin molecular weight average range from 1.03×106 to 2.5×106 Dalton but the conversion of chitin to chitosan by deacetylation reduce it to 1 105 to 5×105 [13].
- Solubility: chitin is hydrophobic (water insoluble) as well as in most organic solvents. In contrast chitosan is soluble in dilute organic acids at low pH [14].
- Chemical reactivity: because they have amino and hydroxyl groups which they easily substituted with other groups.
- Processability: chitin can easily processed into gels, beads, powders, fibers, membranes, cotton, flakes, sponges, colloids, films, spins.
- Stability: they are remarkably stable in concentrated alkaline solutions even at high temperatures.
- Chelating activity: because they are high basic polysaccharide.

Chitin/Chitosan Biological Properties:

- Biodegradability: eco-friendly and non toxic or allergic
- Biocompatibility: they have no antigenic properties and thus are perfectly compatible not only with animal but also with plant tissues.
- Bioactivity: bacteriostatic, haemostatic, immunologic, analgesic, cicatrizant, anti-ulcer, anticoliac-diseases, anti-inflammatory, hypourouricemic, hypocholesteroloemic, free radical scavenging activity, anticoagulant, anti-gastritis, anti-thrombogenic, antiviral, antibacterial, antifungal, anti-tumor, spermicidal, ……etc [16,17,18].

Chitin/Chitosan Applications: Chitin/chitosan compounds had potential and versatile uses in the biomedical, agricultural, environmental and Industrial fields. These applications are summarized in Table (1).

Table 1: Application fields of chitin / chitosan and their derivatives

Field of application	Examples	References
Medecine /veterinary	Artificial skin and blood vessels, surgical sutures, orthopedics, contact lenses, haemodyalis, treatment of renal failure, tumors, leukemia, hypoinsulinoemia, wound healing, bone regeneration accelerator, control of AIDS virus, burns treatment.	[,20,21,22, 23,g]
Dentistry	Dental surgery and therapy, dental materials, dental creams, dental plague inhibitor.	[24,25,26]
Pharmacology and para-pharmaceuticals	Drug delivery, excipient, decrease toxicity, sustained drug release, cottons, sponges, bandages, plasters, films, fibers, wetting agent.	[19,27,28,29,30,31]
Dietetique	Anti fats, hypocholesterolaemic, dietary fiber, weight loss, no caloric value.	[b,e,l,32,33,34]
Cosmetics/toiletries	Hydrating agent, moisturizer, bath lotion, face, hand and body creams, skin and hair products (skin creams, shampoos, lacquers, varnishes, soap etc), oral care, fragrances and men toiletries.	[27,35,g]
Biotechnology	Immobilization of cells and enzymes, matrix for affinity and gel permeation chromatography, cell culture, substrates for enzymes, biosensor construction, membranes permeability control and reverse osmosis.	[,19,36,37,38,39, 40]
Genetic engineering	Gene carrier and DNA vaccine delivery, protects DNA from DNAase degradation.	[41,42,43,44,45]
Agriculture	Seed and fruit coating, fertilizer, biopesticide and fungicide, growth enhancers, stimulator for the plant hormones responsible for root formation, stem growth and fruit development.	[27,46,i]
Food industry and feed additives	Food preservative, antioxidant, emulsifier, thickener, stabilizer, cryoprotectant, clarifier, viscosifier, gelling agent, flavor extender, livestock and fish-feed additive.	[m,46,27,1914,]
Environment pollution control	Eco-friendly, treatment of industrial, nuclear and food processing wastes, flocculation, precipitation and capturing of pollutants from sewage, decontamination and removal of hazardous pollutant from marine environment.	[g,h, 4]
Water treatment	Chelation of metal ions, pesticides, phenols, dyes, DTT, PCBs, proteins, amino acids, detoxifying water from oil and greases, determination of lead in water samples.	[27,47,48]
Paper manufacture and photography	Filter for water purification, biodegradable packaging for food and agricultural products, surface treatment, paper sizing and finishing, water resistant paper, wrapping and toilet paper, card board, hard sheets, paper improvement agent, chromatography paper, printing, fixing agent for colour photography, filling agent, colour film	[b,c,d]
Textile industry	Wool finishing, dyeing improvement, textile preservative and deodorant agent, textile printing and antimicrobial finishing, flocculants, dyes removal from textile waste water.	[49,50,51,52]
Wood industry	Wood adhesive, preservative, protector, fungicide, improvement of wood quality, remediation of waste wood.	[53,54,a]
Cement industry	Water proofing and water repellent.	[g]
Miscellaneous industries	Leather, plastics, cigarettes and solid state batteries.	[55]

a,b,c,d,e,f,g,h…: web sites references cited at the end of this paper

CONCLUSION

Chitin and chitosan are unique and typical marine biomaterial waiting for future development.

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