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A quick overview of chitosan, its sources and applications-A review

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Abstract
Chemical pesticides are highly hazardous to humans and animalsand not very biodegradable, they frequentlypollute water and soil. A sustainable healthy environment needs ‘‘green’’ pesticides. This review describes the chitosan, structurally, chitosan is a straight-chain copolymer composed of D-glucosamine and N-acetyl-D-glucosamine being obtained by the partial deacetylation of chitin, as well as different sources and the conditions of chitosan preparation are also discussed.The chitosan can be isolated from crustacean such as crabs and shrimps as well as insects and fungi.Finally, several selected chemical and biomedical applications are presented, in which chitin and chitosan being recognized as novel biomaterials due to advantage of their biocompatibility and biodegradability.

Keywords: chitosan, overview, sources, applications

Introduction

Chitosan is the second most abundant natural biopolymer derived by deacetylation of chitin, which can be isolated from crustacean such as crabs and shrimps as well as insects and fungus lead to chitosan (Badawy and El-Aswad, 2012) [1]. Chitosan is a nontoxic copolymer consisting of β-(1,4)-2-acetamido-2-deoxy-d-glucopyranosyl and β-(1,4)-2-amino-2-deoxy-d-glucopyranosyl units which possessesuperior properties: antimicrobial, biocompatible and low toxicity which clearly points to an immense potential for future development (Karagozlu and Kim, 2014) [2]. It is a large family of compounds with different charactersaccording to its structure (Noand Meyers, 1997) [3]. The first step of extraction ofchitin is demoralization (removal of calcium carbonate), It is usually done by hot reaction with HCL, HNO3 etc, followed by an deproteinzation (Figure 1). Chitosan is insoluble in water, but soluble in dilute aqueous acidic solutions below its PKa (-6.3). Hydrogen bonds links the chains of thosepolymers in there different automorphic structures, thisshowing polymorpohism and configuration (Reena *et al.*, 2018) [4]. Chitosan is one of the mostabundant, renewable materials in the world. Due to its safety, biocompatibility, antimicrobial, non-toxicity and environmental compatibility, the chitosan hasbeen found to have many applications in biology, wastewater treatment, heavy metal recovery, food, cosmetics, printing, photographic chemistry, dyeing and paper making (No, and Park, 2002) [5].

It's found that chitosan oligosaccharides, with a degree of polymerization (DP) of 6–8, have antitumor activity (Muraki *et al.*, 1993) [6]. The use of chitosan in agriculture has recently become a prominent research topic. We hope that by publishing this review, public will become more aware of the benefits of chitosan and how it might be used in the future.

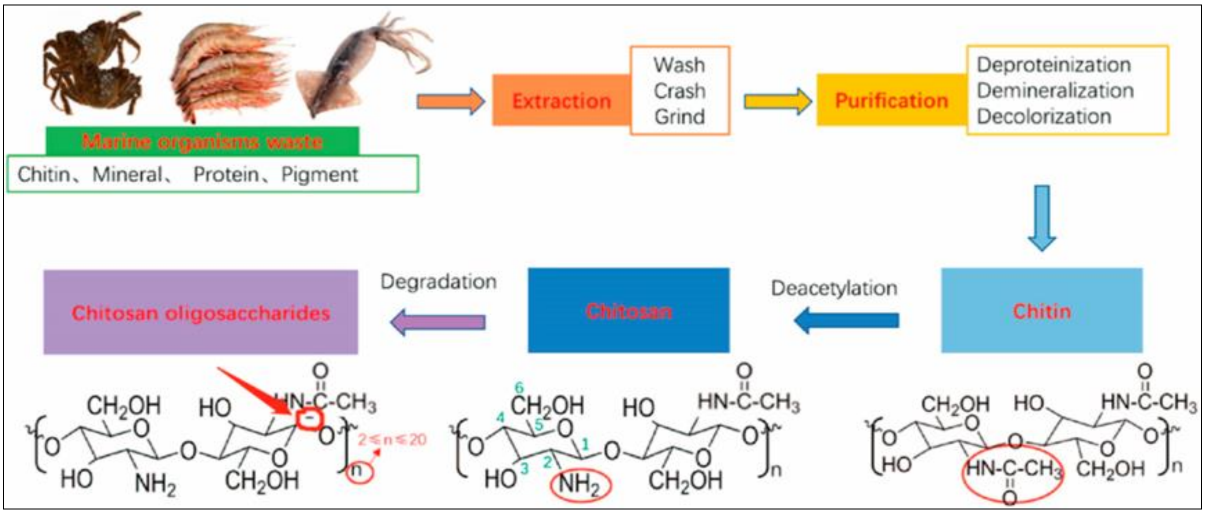

Fig 1: Overview of production and structure of chitosan. According toLi*et al.* (2020)

The Sources of Chitosan

Chitin is a modern and versatile environmentally friendlymaterial (Mahmoud, 2007) [8]. Chitosan is a modified carbohydrate polymer derived industrially by hydrolyzing the aminoacetyl groups of chitin (Elhefian, 2011) [9]. Chitin and chitosan can be found in a variety of species in both the animal and plant kingdoms (Table1). The crustacean waste from crab, shrimp and lobster processingis the most important chitin source for commercial use due to its high chitin content and ready availability (Shahidi and Synowiecki, 1991; Gagné and Simpson, 1993; Puvvada *et al*.,2012) [10, 11, 12]. Chitin is present in crustaceans as part of a complex network of proteins on which calcium carbonate accumulates to form a hard shell. Percot *et al.* (2003) [13] studied the extraction of chitin from shrimp shells using mild conditions. Shrimp waste is the most important chitin source for commercial use. In this study chitin and chitosanwere extracted from *Penaeus semisulcatus* waste collected from a shrimp processing landing centersituated at Arabic Gulf in south of Iran by chemical and microbial methods.Prawn is one of the most promising and highly discussed in different studies, like *Penaeus monodon*commonly known as Giant Tiger Prawn and *Penaeus indica* orIndian prawn (Tarafdar *et al*.,2013) [14]. Paul *et al.* (2014) [15] extracted chitosan from *Fenneropenaeusindicus.* Not onlyshrimps and prawns but some crab like *Sesarma plicatum* also releases chitosan (Sakthivel *et al.*, 2015) [16]. Sumaila *et al*. (2020) [18] uses crab shells in Nigeria to produce chitosan via the three stages of deproteinzation, demineralization and deacetylation using sodium hydroxide and hydrochloric acid under different treatment conditions.

Not only crustacean shells but chitosan can also be isolated from fish scales. Kumari and Rath (2014) [42] and prepared chitosan from chitin obtained from the scales of the fish byusing chemical methods. Furthermore the chitin from fish scales wastes considered the second most abundant natural biopolymer can produce chitosan **(**Firdous and Chakraborty, 2017) [19]. Fish scales are one of those wasteswhich are not only generated from household waste on adaily basis but also from fish industries. Theseindustries generate a huge amount of scales waste per processingwhich usually cause environmental hazard. It is estimated thatthe scales-fish industry produces about 60,000-80,000 tons ofwaste **(**Firdous and Chakraborty, 2017) [19].

There are about 900,000 species in the world of insects, because of their large numbers and the ease of breeding, so insects provide a best choice for extracting chitosan as alternative sources (Tolaimate *et al*.,2003 ; Marei *et al*.,2016). The chitin and chitosan obtained from the house crickets were subjected to physicochemical analysis including elemental analysis and were compared to commercial shrimps it is discovered that the purified chitin and chitosan from crickets exhibit favorable similarities when compared to commercial chitin from shrimp (Ibitoye *et al*., 2018).

Chitin that found also in the cell wall of microorganisms. Firdous and Chakraborty (2017) [19] mentioned that chitosan can also be extracted from bacteria and fungi by an enzyme called chitosanases present within the species. Various strains of *Aspergillus Niger*, *Salmonella typhi*, *Salmonella paratyphi*-A, *Escherichia coli*, *Proteus vulgaris*, and *Pseudomonas aeruginosa* were obtainedfor chitosan production (Kumaresapillai *et al*., 2010) [23]. Kaur *et al.* (2012) [24] isolated *Bacillus* sp. And *Serratia* sp.bacteria showed chitosandegrading ability with a yield of 16% and 10% respectively. These strains release chitosan because theyshow chitin deacetylase activity and contain chitosanaseenzyme. The strains used in this work arepromising sources of chitin and these strains can be adapted byindustries for producing a good quality and economically cheapchitosan.

Table 1: The amount of chitin in some different organisms (According to Kurita (2006))

Organism	W (chitin)%
Crab	72.1
Paralithodes (king crab)	35.0
*Crangon*and *Pandalus* (shrimp)	17–40
Nephro (lobster)	69.8
Clam	6.1
Bombyx (silk worm)	44.2
Penicillium notatum	18.5
Penicillium chrysogenum	20.1
Mucor rouxii	44.5
Lactarius vellereus	19.0

Applications of Chitosan

Over the past several years, chitosan has received increasing interest in its chemistry, dentistry, medicine, textiles, veterinary medicine, biotechnology, cosmetics and environmental science sapplications (Figure 2) (Chawla *et al*., 2015) [26].

Despite various restrictions, chitosan has the potential to be used in a variety of food processing and other domains. The gel-forming ability, high adsorption capacity, biodegradability, and antibacterial properties of chitosan are due to its polyelectrolyte nature and the presence of reactive functional groups, which are critical for its commercial applications. (Chawla *et al*., 2015) [26].

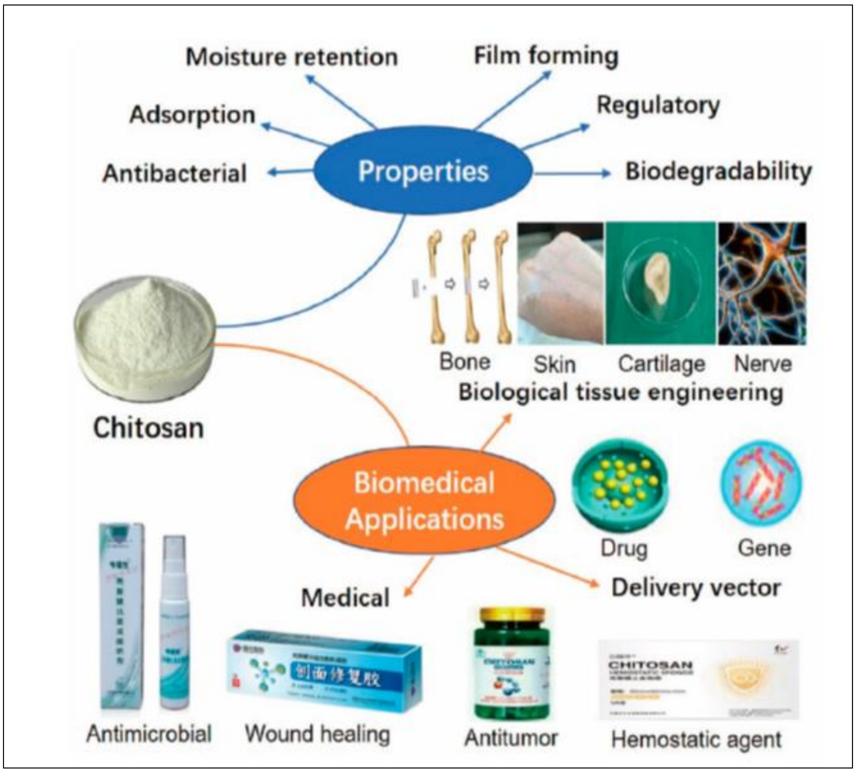

Fig 2: Some Applications of chitosan

Duan *et al*. (2007) [28] reported that Chitosan–lysozyme film is prevent growth of *Escherichia coli*, *Pseudomonasfluorescens*or *Listeria monocytogenes* in pre-inoculated mozzarella cheese. Chitosan is utilized as a food quality enhancer in a variety of countries. In Europe, it is sold as dietary pills to aid weight loss, and in some countries, such as Japan, it is added to a variety of foods (e.g. noodles, potato crisps, biscuits) (Venugopal, 2011) [29].

Chitosan alsohas wide applications in medicine, it is found that chitosan oligosaccharides, with a degree of polymerization (DP) of 6–8, have antitumor activity (Muraki *et al*.,1993) [6]. Also, hemodialysis membranes, drug delivery, wound dressing, anticholestestermic agents (Rinaudo, 2008; Anitha *et al*., 2014) [30, 31]. As well as, biomedical products such as artificial skin or packaging, contact lens and system of controlled liberation of medicines (capsules and microcapsules) (Younes and Rinaudo, 2015; Jasim, 2021) [32, 17].

Chitosan shows antimicrobial activity such as antifungal and antibacterial property (Al-Kabee, 2014) [36]. Chitosan acts as fungistatic rather than fungicidal. The antifungal mechanism is carried out by cell wall morphogenesis with chitosan, thereby interfering the fungal growth as in bacteria. The antifungal activity of chitosan depends upon the concentration of the degree of N-acetylation (DA) and local pH (Avadi *et al*., 2004) [33]. In particular, chitosan can also be used as an antimicrobial film to cover vegetables and fresh fruits (Devlieghere *et al*., 2004) [34]. Another point to note is since chitosan exhibits antivirusand antiphage activities (Rinaudo, 2008) [30].

Chitosan has been largely employed in many areas, such as photography, biotechnology, cosmetics, food processing (Fernanda *et al*., 2019) [35] Chitosan exhibit many different relevant properties as active ingredient in dental, skin, hair and nails care. Moreover, they have optimal properties to vehiculate active ingredients for the cosmeceutical industry (Sionkowska, *et al*., 2017) [37].

Chitosan also, shows insecticidal activity against insects. The use of synthetic insecticides in the control of some pests resulted in potential hazards fordisturbances of the environment, non-target organisms and mammals and pest resistance (Prakash and Rao, 1987) [38]. Therefore, chitosan may serve asa good alternative for broad-spectrum and highlypersistent pesticides because it is non-toxic to humans and vertebrates, biodegradable, and maypossess insecticidal properties (Rabea *et al*, 2003) [39]. The insecticidal activity of chitosan of four molecular weights **(**2.27 × 10^5, 3.60 ×10^5, 5.97 × 10^5**,** and 9.47 × 10^5 g/mol) was investigated against two species of arthropod pests: oleander aphid *Aphis nerii* and cotton leafworm *Spodoptera littoralis*. The results against *A. nerii* indicated that chitosans of 3.60 × 10^5 and5.97 × 10^5 g/mol showed high activity among the different molecular weights in leaf-dip bioassay after 24 hof treatment with 48 and 49% mortalities, respectively (Badawy and El-Aswad, 2012) [1].

At now, there is a need new physiologically active compound s as safe alternatives to harmful insecticides in order to overcome resistance and compatible with integrated pest management practices (Badawy *et al*. 2005) [40]. In addition, the degree of N-acetylation (DA) and molecular weight are important factors that have an impact on properties such as solubility (Kubota and Equchi, 1997) [41] and biological activity (Rabea *et al.*, 2003; Badawy, 2010) [39, 43]. Thus, the free amino groups on chitosan molecule are important formany applications. The activity of chitosan and oligo-chitosan on several plant insects and pathogens were studied. Chitosan was active against lepidopterous and homopterous insects; the mortality was 80%. The insecticidal activity of chitosan to *Plutella xylostella* L. was higher than that to *Spodoptera exigua*. The mortality of six types of aphids was generally 60–80%, and the highest was 99.7% (Zhang and Tan, 2003) [44].

Conclusions

Chitosan has a unique chemical structure and properties that derivatives from crustacean such as crabs and shrimps as well as insects and fungus and uses to several chemistry, dentistry, medicine, textiles, veterinary medicine, biotechnology, cosmetics, pharmaceutical and biomedical and environmental sciences applications.

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