

Review Article

Antiviral and Antinematodal potentials of chitosan: Review

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Abstract

For many years, chemical pesticides have been performed to control different pests and diseases and this may be due to their broad spectrum of action, easy of application and the relatively low cost. But these chemicals have environmental risks, thus alternative control agents are needed. Chitosan is one of the novel suggested solutions to reduce the economic losses associated with chemical pesticides. Chitosan is naturally-occurring compound, as well as safe and biodegradable which obtained from certain natural sources. Chitosan have unique properties which help to control viruses, bacteria, fungi, insects, plant nematodes and other pests locally and systemically.

Introduction

Chitin and/or chitosan molecules are largely used as safe and environmental-friendly tools to ameliorate crop productivity and conservation of agronomic commodities [1]. In particular, chitosan involved in the production of drugs, cosmetics, biotechnological items, and food have achieved better results using these particular molecules. However, in recent years, the use of modified biopolymer molecules based on chitin and/or chitosan has magnificent advantages for many users [2].

Chitosan has a broad spectrum of unique biological activities especially against viral infections in plants [2,3]. The ability of chitosan and/or its derivatives to suppress viral infections is mediated by its effect on the plant and is most probably determined by its ability to cause plant resistance to infection, in addition to desirable changes in the metabolism of plants and fruits, as well as improving germination and crop yields [4].

Chitosan, which imitates the phytopathogen contact, is known to induce a broad spectrum of defense responses in various plant species [5]. Chitosan and derivatives are not – toxic agent and act as a powerful elicitor for plant responses towards plant diseases locally and systemically to alert healthy parts of the plant [6]. Therefore, in this review we just aimed to throw a light on the importance of chitosan or its derivatives in plant protection fields especially against plant virus and plant parasitic nematodes.

More Information

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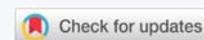
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Chitosan processing

The raw material of chitosan (Figure 1) is chitin (Figure 2) which is a biodegradable polymer produced from crab or shrimp shells [7-9]. Recently, chitin or chitosan produced from mycelia of Zygomycetes fungi as alternative sources (Krishnaveni and Ragunathan, 2015 and Khalil, 2016) [9]. The treatment of crustacean shells with alkali solution (NaOH) is mainly remove proteins and this process called Deproteinization, while to remove CaCO₃ (Demineralization) from crustacean shells it will treat with acidic solution (HCL), moreover, to eliminate pigments (Decoloration) it was done by using NaOH or potassium permanganate or hydrogen peroxide or sodium hypochlorite [9-13]. After chitin production (Figure 3), the purity must be tested because any remaining impurities might cause problems related to produce products. The using of NaOH again produce chitosan and this treatment is expected to produce 70% of deacetylated chitosan [14].

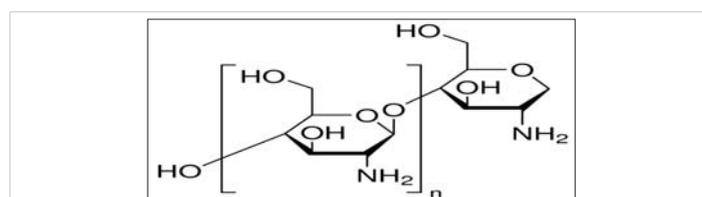


Figure 1: Chitosan.

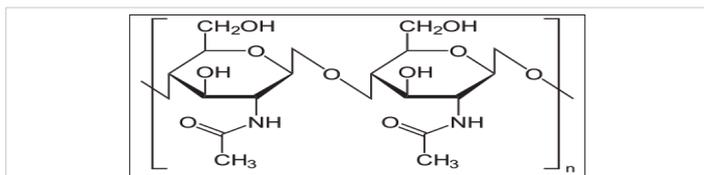


Figure 2: Chitin.

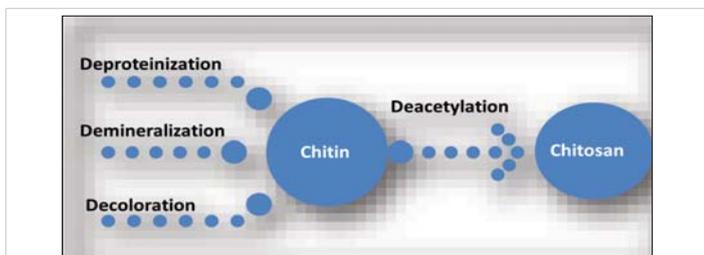


Figure 3: The processes of chitosan production from crustacean shells.

Dissolving of chitosan

Normally chitosan is insoluble in water, but soluble in some aqueous acidic solutions. The most widespread solvent to dissolve chitosan is 1% acetic acid (as a reference) at a pH near 4. Also, chitosan is soluble in 1% hydrochloric acid and dilute nitric acid, but is insoluble in sulfuric and phosphoric acids. Acetic acid solution with high concentration at elevated temperature can provide depolymerization of chitosan [15]. There are many important factors that have vital effects on chitosan solubility. These factors can include temperature, alkali concentration, time of deacetylation, prior treatments applied to chitin isolation, ratio of chitin to alkali solution, particle size, etc. [16].

General uses of chitosan

Chitosan significantly has found applications in various fields such as cosmetics, paper, textile and food processing industries, medicine, agriculture, photography, chromatographic separations, wastewater treatment, and solid state batteries [17]. The versatility chitosan in various fields is due to its enviable properties such as biodegradability, biocompatibility, functional groups, low toxicity, renewability, large molecular weight, particle size, density, viscosity, etc. [17]. Chitosan has been recognized as a promising adsorbent [18].

Agricultural applications of chitosan

Chitin and/or chitosan has fungistatic or fungicidal activity against many plant fungal diseases. In soil applications, chitosan was successfully reduced the incidence of *Fusarium* wilt in several plant species [19-21]. Similarly, chitosan proved efficacy against *Cylindrocladium floridanum* [22], *Alternaria solani* [23] and *Aspergillus flavus* infections [24].

Otherwise, chitosan or its derivatives prevents the growth of several pathogenic bacteria including *Xanthomonas* [25], *Pseudomonas syringae* [26], *Agrobacterium tumefaciens* and *Erwinia carotovora* [11]. However, the antimicrobial activity

of chitosan seems to be higher against fungi than bacteria [27], and among bacteria often been higher against Gram-positive than Gram-negative ones.

The chitinase and chitosanase activity in seeds protected by films of chitin and its derivatives has also been reported by Zargar, et al. [28]. The antimicrobial properties of chitosan and its outstanding film-creating aptitude have been exploited in the post-harvest preservation of fruits and vegetables. Covering fruits and vegetables with a chitosan film grants them antimicrobial protection and enhanced shelf life [29].

Therefore, using of chitin or chitosan in agriculture has four main directions: (1) plant protection against pests and diseases, as well as in preened post-harvest, (2) as microbial biocide (bio-agent) and increase the antagonist microorganism action, (3) support of beneficial plant microorganism symbiotic relationships and (4) plant growth regulation and development. Moreover, biogenic elicitors of natural oligosaccharide are the key of signal molecules in plants [30]. They occur *in vivo* upon the destruction of cell walls as a result of trauma or phytopathogen invasion and trigger a cascade of local and systemic responses preventing further reproduction of a fungus, bacterium, or virus [31,32].

The antiviral activity of chitosan

Different studies clarified that chitosan prevents the plant viral infection [1,19,33]. Because deamination at the site of polymer chain breakage causes the formation of a new 2, 5-anhydromannose structure, which led to suggest that it is precisely this terminal residue that determines the high activity of deaminated derivatives [34]. Also, the anionic derivatives of chitosan such as chitosan 6-O-sulfate-N-succinate, carboxymethyl chitosan and chitosan sulfate were recorded the lowest activity. Thus, the polycationic properties of chitosan are probably important to its antiviral activity not only toward phage infections but also toward viral infections of plants [34-36]. However, chitosan recorded structurally changes in the particles of phage and damage in their integrity [1]. Chitosan recorded decrement in the number of tobacco mosaic virus particles (Hu, et al. 2009).

Certain studies showed important results about the antiviral impact of chitosan against alfalfa mosaic virus (AMV) on bean [37,38]. It was found that, treatment of the lower surface of a bean leaf with chitosan caused resistance to AMV of its upper surface, the treatment of lower leaves caused resistance in upper leaves, and the treatment of one half of a leaf caused resistance on the other, untreated half. These data suggest that chitosan induces systemic acquired resistance in plants. Chitosan was found to be inhibit the number of local necrosis caused by tobacco mosaic virus especially in low-molecular (Davydova, et al. 2011) and alfalfa mosaic virus [37].

Probably that using chitosan is suppressing the infection



irrespective of the type of the virus. Furthermore, plants carrying a dominant gene of resistance to a certain virus are known to respond to inoculation by the formation of local lesions, and the virus usually cannot move beyond them. Such a response of the plant is called the hypersensitivity response.

Chitosan was found to induce the most important molecular markers of systemic acquired resistance in plants such as salicylic acid which is an essential component of distant signaling [39] and pathogenesis related proteins (PR-proteins) [40], as well as, β -1,3-glucanases and chitinases particularly [5].

The induction of antiviral resistance action may not require the penetration of chitosan into plant cells or the vascular system. However, radiolabeled chitosan oligomers with a polymerization degree of > 6 can't move along plant vessels (Pena-Cortes, et al. 1995). On the other hand, insoluble microcrystalline chitosan was as effective as its soluble analogues in inducing antiviral resistance in bean [38].

Nematicidal activity of chitosan

The availability of chemical nematicides commercially have environmental limitations and high toxic for humans. Hence, it was necessary to find new nematicides derived from natural substances or to develop new strategies for managing PPNs [41].

Currently, chitosan is a novel trend which considered a bioactive polymer and widely applied in agricultural systems. Chitosan has precedence due to its functional properties such as anti-bacterial, anti-fungal, anti-viral, and anti-protozoal activities, as well as non-toxic, easy to modify and biodegradation [42,43].

The nematicidal or nematostatic activity of chitosan were proved in crop protection fields. The nematicidal activity of chitosan and its derivatives hasn't been studied enough. However, there are certain investigations confirmed the activity of chitosan against plant parasitic nematodes [41,44-47].

Chitinous materials (included chitosan) were effective in reducing egg hatching and larvae viability of the root-knot nematodes species such as *Meloidogyne incognita* [46], *Meloidogyne javanica* [45] and *Meloidogyne arenaria* [1], in addition to cyst nematode; *Heterodera glycines* [48].

The molecular weight and concentration of chitosan are considered specified factors for nematicidal activity. Khalil and Badawy [46] were succeeded to prove that low molecular weight of chitosan was more effective than high molecular weight as a natural nematicide. Also, it was found that chitosan combined with some agricultural wastes e.g. mentha, *Brassica*, onion, groundnut, urad, coconut and corn cob was more effective against *Meloidogyne incognita*, on eggplant than chitosan alone Asif, et al. 2017. All treatments decreased egg masses, eggs and soil population per 250 g soil.

In spite of the action of chitosan in reducing plant disease are currently not fully understood, but several investigations have shown that chitosan can induce plant resistance to several pathogens by restricting pathogen growth and/or by eliciting several defense mechanisms [19]. There are many reports on combined applications of chitin/chitosan with biotic or abiotic agents. Combining the use of chitin or chitosan with bio-control agents might result in synergistic, additive or antagonistic effects against root-knot nematodes. Also, addition of chitin or chitosan to the soil enhanced the population of chitinolytic microorganisms (relating to the enzyme converting chitin (a polysaccharide) into chitobiose (a disaccharide) that ruin the eggs and cuticles of young nematodes which have chitin in their composition [49].

The indirect effect of chitosan was proved by Asif, et al. 2017 who found that chlorophyll, carotenoid, phenolic content, peroxidase and catalase were induced with chitosan alone or in combination with the agricultural wastes. While, Radwan, et al. [12] reported that chitosan displayed elicitor activity by inducing local and systemic resistance mechanisms of tomato plants against the root-knot nematode, *M. incognita*.

Finally it could be concluded that chitosan is effective tool against plant virus and nematodes with environmental friendly properties. Also, chitosan is considered to be a promising antimicrobial agent owing to its antibacterial and antifungal activities.

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