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THE APPLICATION OF CHITOSAN IN THE PRESERVATIVE FOR FRUITS AND VEGETABLES AND CONTROL OF POST-HARVEST DISEASES: A REVIEW

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Abstract:

Many post-harvest diseases are caused by wound pathogens, and the complete control of these agents is done through the use of an agent which grows rapidly and is environmental friendly. One of the commonly used agents in regulating post-harvest disease is a polysaccharide called chitosan. Its derivatives are able to form a semipermeable on the surface of the fruit, which can act as a mechanical barrier to protect the fruit from pathogen infection and also to induce host defense responses, and reduce decomposition during storage periods, Chitosan coating as an edible substance has been applied in the preservation of fresh fruit, vegetable or their fresh-cut materials. After coating with chitosan on the surface of post-harvest fruit and vegetable, the respiration rate and weight loss rate are restrained, and higher firmness remains. Meanwhile, the activities of protective enzymes are maintained at a higher level, and the cell membrane can keep relatively intact. Furthermore, chitosan coating has a certain preventive effect against microbes and can reduce decay. Since the storage condition of post-harvest fruit and vegetable is improved, more nutrients are also reserved. Chitosan coating would probably have wide prospects in the preservation of post-harvest fruits and vegetables in the future.

Keywords: Chitosan, Fruits, Vegetables and Post Harvest

INTRODUCTION

Chitin is the second most abundant polysaccharide on earth, after cellulose. This biopolymer, composed of 2-acetamido2-deoxy-b-D-glucose (Nacetylglucosamine) units linked by b(1⟶ 4) linkages is synthesized in great amounts by a large number of living organisms, and forms the exoskeleton of arthropods and insects, the crustacean shells, and the cell walls of fungi and plants (Rinaudo 2006). With the continuous development of science and technology, food safety has received increasing attention (Souza et al., 2020). Due to various influencing factors such as microorganisms and oxygen, there are many restrictions during the storage and preservation process of food (Olaimat and Holley, 2012). Therefore, people have placed higher requirements on the existing food packaging materials not only to extend food shelf life but also to resist oxidation, bacteria, and other food-spoiling factors (Mihindukulasuriya and Lim, 2014). Consequently, the main trend of food packaging materials in this regard focuses on using renewable natural resources and agricultural food industry waste, such as the biopolymer chitosan, methyl furan dicarboxylate material, and polylactic acid (Merino and Alvarez, 2020; Siakenget al.,2019).

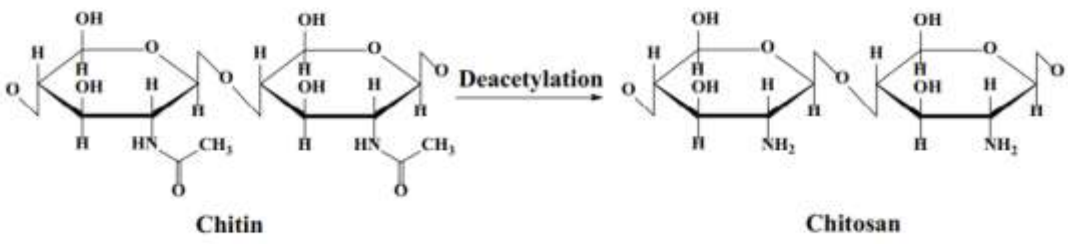

FIGURE 1 The structure of chitin and chitosan

Morin-Crini et al., (2019).

Fruits and vegetables are an essential part of the human diet They contain nutrients that are essential to human health Over the past decades, eating fruits has evolved from being eaten as a dessert to be a nutritional and medicinal active part of human diets. The consumption of fruit and vegetables on a regular basis is associated with reduced risks of cancer, cardiovascular disease, hypertension, stroke, Alzheimer's disease, asthma, osteoporosis, macular degeneration, cataracts, and some of the functional declines associated with aging (Liu, 2003). Due to the benefits of consuming fruits and vegetables, there is an increase in their demand notwithstanding the problems faced during their cultivation. One major problem faced with the supply of fruits, vegetables and other agricultural crops have to do with the effect of post-harvest diseases caused by pathogenic fungi, bacteria, and viruses (Janissiewicz and Korsten 2002). The use of bioactive compounds such as chitosan to control the post-harvest fungal disease has had much consideration due to impending problems associated with chemical agents, which include an increase in public resistance to fungicide-treated produce, growth in the number of fungicides toler and post-harvest pathogens, and a number of fungicides that are still under observation. In post-harvest studies, chitosan has been described as maintaining the natural standard of fruits and vegetables by reducing respiration rates, ethylene production, and transpiration (Li and Yu 2000; El Ghaouth et al. 1992). Although most post-harvest diseases could be controlled successfully with chemical fungicides, their usage is becoming increasingly restricted due to regulations regarding chemical residue levels. Post-harvest diseases are one of the major causes of fruit loss (Deepmala et al. 2015), which can reach very high values and represent more than 25% of the total production in industrialized countries and 50% above in developing nations (Nunes 2011). Chitosan is the only alkaline natural polysaccharide that has good biological inter-miscibility and biodegradable properties (Liang et al. 2017). Studies have shown that chitosan is most effective in inhibiting microbial growth at concentrations ranging from 0 to 5%. At low concentrations, chitosan easily binds to the cell surface membrane disrupting it and causing cell leakage and subsequently cell death. But high concentration binds to the cell membrane and prevents the leakage of intracellular components (Hosseinnejad and Jafari 2016). Moreover, the higher the chitosan concentration, the greater its antimicrobial activity (Zhang et al. 2014). To date, there exist two main sources of chitosan production which are crustaceans and fungi. Certain fungi such as zygomycetes have been recently been found to be able to produce chitosan, and research has been done with regard to its production. Some studies reported that fungal chitosan exhibited low antimicrobial activity on E. coli, Klebsiella pneumonia and S. aureus as compared to what crustacean them protection against chitosan permeability (Palma-Guerretro et al. 2010). Environmental factors such as moisture, pH and temperature have been shown to affect chitosan antimicrobial activity. In a study, the effect of temperature and pH was investigated for different molecular weight samples of chitosan and results showed that the antimicrobial activity of chitosan increased when the temperature was high and the pH decreased (Chang et al. 2015). From the above-mentioned problems, one could say that the use of chitosan as an antimicrobial agent needs careful understanding since several factors both intrinsic and extrinsic affect its microbial activity.

The aim of this review is to summarize the most recent published and relevant advances in the application of chitosan for fresh horticultural produce, in terms of postharvest disease control, maintenance of overall product quality, use as a health promoting compound, and food safety issues.

Effect of chitosan on fruit and vegetable:

Application of chitosan treatment at the pre-harvest or postharvest stages has been considered as a suitable alternative treatment to replace the use of synthetic fungicides. This can help to prevent postharvest fruit diseases and to extend storage life, while maintaining the overall quality of the different fresh commodities (Bautista-Baños et al., 2006). The susceptibility of fresh produce to postharvest diseases and deterioration of quality attributes increases after harvest and during prolonged storage, as a result of physiological and biochemical changes in the commodities. These changes can favor the development of postharvest pathogens and the incidence of postharvest diseases, which are the major cause of losses through the supply chain. Therefore, the development of decay-control measures that aim to maintain the quality of fruit and vegetables and to provide protection against postharvest diseases after removal from cold storage at the retailer"s market shelf will be beneficial to reduce these postharvest losses On the other hand, postharvest disease control for fresh horticultural produce should begin at the farm, and this involves the cultural practices and fungicide applications used, The adverse effects of synthetic fungicide residues on human health and the environment, and the possibility of the development of fungicide-resistant pathogens, have led to intensified worldwide research efforts to develop alternative control strategies. In addition, the current consumer trend is more towards „green" consumerism, with the desire for fewer synthetic additives in food, together with increased safety, excellent nutritional and overall quality, and improved shelf-life. Furthermore, there is the potential for foodborne outbreaks due to contamination of fruit in the field through dirty irrigation water or treatments, or at postharvest through human handling or improper sanitation (Beuchat, 2002). Postharvest fungal diseases can limit the storage period and shelf life, and thus market life, of fruit and vegetables, which results in serious economic losses worldwide (Palou & Smilanick, 2020; Romanazzi, Smilanick, Feliziani, & Droby, 2016). Edible coatings on fruits and vegetables during storage control moisture transfer, respiration rate, oxidation processes, and extend shelf life. Edible coatings can also give the same effect as modified atmosphere storage by modifying internal gas composition. Active ingredients can be incorporated into the edible coatings and consumed with the food, enhancing safety and nutritional quality (Dhall, 2013). Edible films prevent moisture losses during postharvest storage, swater vapor uptake and water vapor permeability are important parameters to characterize biopolymers that are used in the design and fabrication of edible coatings. It has been shown that water vapor perme ability rate increases with the increase of storage time, molecular weight of chitosan, drying temperature, and with the decrease of storage temperature. Water vapor uptake of chitosan films decreases during storage at room temperature but increases during storage at low temperatures in the freezer and refrigerator thinner chitosan films have lower water vapor permeability (Kerch& Korkhov, 2011).The freshness of fruits and vegetables (F&V) is an important criterion that dictates which product a consumer prefers to buy in the market. Supermarkets face challenges to keep the F&V fresh and offer consumers better quality products. The F&V are biodegradable and prone to microbial attack. Challenges involving natural ripening and the degradation process of the F&V, mainly through an enzymatic reaction, are an important concern for food industries. The F&V are sensitive to decay and perish, due to rapid ripening and softening, which limits their storage, handling, and transport potential (Hu et al., 2017). The F&V are sensitive to decay and perish, due to rapid ripening and softening, which limits their storage, handling and transport potential (Hu et al., 2017). Characteristics that lower the products quality, such as browning, off-flavour development and texture breakdown, are commonly seen on microbiologically spoiled food. Therefore, acceptable methods of preservation are top priority in the food industry. Coating the F&V with bio compat able nonallergic polymers is a good choice for preservation. Inadequate and costly solutions for food preservation has led scientists to create natural preservatives which are safe, effective, and acceptable (Huq et al., 2015). Chitosan coatings delay the rate of respiration, decrease weight loss, and prolong the shelf life of fruits and vegetables during postharvest storage. The impact of chitosan-based edible coatings on shelf life, microbiological quality and biochemical processes during postharvest storage of fruits and vegetables has been described in a number of recent publications. The latest studies that have not been included in the recent reviews on edible coatings for fresh fruits (Dhall, 2013; Shiekh, R.A., Malik, Al-Thabaiti, & Shiekh, 2013) have been reported in this paper.

The recent publications related to the effect of chitosan-based coatings on the changes of ascorbic acid content in fruit and vegetables during postharvest storage Synthesis of vitamin C in strawberries and loss of vitamin C in cherries were observed during refrigerated storage. The coating with chitosan inhibits vitamin C synthesis in strawberries and promotes vitamin C synthesis in cherries (Kerch et al., 2011). A chitosan coating delayed the changes in ascorbic acid content of three sweet cherry cultivar (*Prunus avium* L., namely cvs. "Ferrovia," "Lapins," "Della Recca") treated with a 0.5% chitosan coating, stored at 2 C for 14 days (Petriccione, et al., 2015). It has been also reported that vitamin C decreased during storage particularly in coated with chitosan carrot sticks (Simoeset al, 2013). Combined action of pure oxygen pretreatment and chitosan coating containing 0.03% rosemary extracts maintained vitamin C content and sensory attributes in fresh-cut pears (Xiao, Zhu, Luo, Song, & Deng, 2010).Changes in the total polyphenol content of the chitosan-coated sweet cherry fruits were delayed (Petriccione et al., 2015). It has been also reported that content of total phenolics markedly increased in coated carrot sticks stored under moderate O2 and CO2 levels (Simoes et al., 2013). Total phenolic content of chitosan coated samples of carrot shreds stored in macro perforated packs were higher compared to control (Pushkala, Parvathy, & Srividya, 2012). Combined action of pure oxygen pretreatment and chitosan coating containing 0.03% rosemary extracts maintained higher polyphenols content and sensory attributes in fresh-cut pears (Xiao et al., 2010). It has been also reported that strawberries treated with chitosan maintained better fruit quality with higher levels of phenolics (Wang & Gao, 2013). The edible chitosan coatings maintain higher concentration of total phenolics in carambola (Averrhoa carambola L.) fruit during storage (Gol et al., 2015).Browning in fruits during storage is primarily attributed to polyphenol oxidase (PPO) activity (Shiekh et al., 2013). PPO and peroxidase reduce the anthocyanin and other polyphenols' content, leading to lower antioxidant activity of fruits. Nanochitosans showed a significant suppression on the PPO and peroxidase activity in strawberries during storage, while a high rate of increase of their activities was observed in control strawberry (Eshghi et al., 2014). The activities of PPO and peroxidase were markedly lowered in treated litchi fruits and increased activities of SOD, CAT, contents of ascorbic acid and glutathione were observed in pulp of treated fruit, thus leading to lowered contents of hydrogen peroxide and MDA. Liu and coworkers (Liu et al., 2014) reported that plums treated with the ascorbic acid and chitosan combination exhibited a significantly lower PPO activity and significantly higher SOD, CAT and peroxidase activities throughout the storage period. Strawberries sprayed with chitosan at full bloom or at the green-fruit or whitening fruit stages have shown decreased incidence of gray mold and Rhizopus rot infections using natural inocula of B. cinerea and Rhizopus stolonifer, as seen after 10 days of storage at 0 °C followed by 4 days under market-simulation conditions. The disease control with 1% chitosan was more effective than the currently used chemical fungicides: procymidone (40 g hl-1 a.i.) used at the full bloom and green fruit stages; and pyrimethanil used at the whitening fruit stage (Romanazzi et al., 2000). Preharvest spraying with 0.2%, 0.4% and 0.6% chitosan decreased postharvest gray mold and maintained the kept quality of strawberries during storage at 3 °C and 13 °C. Here, the incidence of disease decreased with increased chitosan concentration (Reddy et al., 2000). Sweet cherries treated 7 days before harvest date with 0.1%, 0.5% and 1% chitosan showed decreased incidence of gray mold and brown rot after 2 weeks of storage at 0 °C followed by 7 days of shelf life, as compared to the untreated controls (Romanazzi et al., 1999). At the highest chitosan concentration (1%), the disease reduction was not different with respect to that seen after application of tebuconazole. Similar results were obtained when 1% chitosan was applied 3 days before harvest, as it reduced the incidence of postharvest disease in sweet cherries to the same level as the commercially applied synthetic fungicide fenhexamid (Feliziani et al., 2013).Chitosan-salicylic acid complex coating increased the endogenous salicylic acid concentrations and antioxidant enzyme activities including superoxide dismutase, catalase, ascorbate peroxidase, and glutathione reductase in cucumber during storage (Zhang, &Yang, 2015). It has been observed that the production of superoxide free radicals and MDA were significantly decreased in the plums treated with a combination of chitosan and ascorbic acid (Liu, Yuan Chen, Li, & Liu, 2014).

Chitosan uses to control postharvest diseases:

Use of chitosan for postharvest disease control in temperate fruit was investigated in the 1990s in many studies. These studies concerned the application of chitosan in general or focused in a group of chitosans, such as oligochitosan that are characterized by low molecular weigh, table grapes, as small bunches dipped in 0.5% and 1% chitosan solutions, and thereafter artificially inoculated with a B. cinerea conidial suspension (by spraying), and stored at low (0 °C) or room (20 °C) temperatures. The chitosan treatment decreased the spread of gray mold infection from one berry to the other berries (nesting) (Romanazzi et al., 2002). Li and Yu (2001) reported that 0.5% and 0.1% chitosan significantly reduced the incidence of brown rot caused by Monilinia fructicola in peach stored at 23 °C, compared to the untreated fruit. Treatments with chitosan and oligochitosan reduced disease incidence caused by Alternaria kikuchiana and Physalospora piricola and inhibited lesion expansion of the pear fruit stored at 25 °C. These disease-control effects of chitosan and oligochitosan were concentration dependent and weakened over the incubation time. Indeed, at the lowest chitosan concentration, its effectiveness was the lowest for disease control especially after 5 days of storage at ambient temperatures, compared to the beginning of storage (Meng et al., 2010a). In some trials chitosan was combined with oleic acid. Coatings based on chitosan either without or with oleic acid at different percentages delayed the appearance of natural fungal infections in comparison to uncoated strawberries. When oleic acid was added to the chitosan coating, there were fewer signs of fungal infection during strawberry storage, especially when the coatings contained the higher levels of oleic acid, which enhanced the antimicrobial properties of chitosan (Vargas et al., 2006). The postharvest application of chitosan has been combined with physical means for the control of postharvest decay of fruit and vegetables, such as UV-C irradiation, hypobaric treatment, and heat curing, Shao et al. (2012) studied the effects of heat-treatment at 38 °C for 4 days before and after coating apples with 1% chitosan. As well as complete control of blue mold and gray mold on these artificially inoculated apples during storage, chitosan coating followed by heat treatment improved the quality of the stored fruit. Moreover, the presence of chitosan coating prevented the occurrence of heat damage on the fruit surface (Shao et al., 2012). In another investigation, the development of postharvest brown rot on peaches and nectarines was controlled through the heating of fruit to 50 °C for 2 h under 85% relative humidity, which eradicated pre-existing Monilinia spp. infections that came from the field, with the application of 1% chitosan at 20 °C then protecting the fruit during handling in the packaging houses and until consumer use (Casals et al., 2012). In some other studies the most suitable acids were tested for the dissolving of chitosan powder, and it was shown that practical grade chitosan should be dissolved in an acid solution to activate its antimicrobial and eliciting properties. Chitosan dissolved in 10 different acids (as 1% solutions of acetic, L-ascorbic, formic, L-glutamic, hydrochloric, lactic, maleic, malic, phosphoric, and succinic acids) was effective in reducing gray mold incidence on single table grape berries (Romanazzi et al., 2009).

Coating with chitosan 1% led to superior titratable acidity, and decayed fruits percentage while coating with 2% chitosan led to a significant superiority in fruit total soluble solids, sugars percentage, total soluble solids /acidity, fruit firmness, vitamin C, carotene pigment, and reduced fruit weight loss.and The interaction between 2% chitosan and the matured fruits increased fruits total sugar, total soluble solids/acidity, vitamin C and carotene content and reduced fruits weight loss, and the interaction between 1% chitosan of the ripened fruits reduced decayed fruits, while the interaction between chitosan 2% and ripened fruits increased total soluble solids, titratable acidity and fruit firmness (Lateef, 2022) when used Coating with Chitosan and Polyethylene on “Royal” Apricot Fruit Quality and Storability. According to Bal (2018), chitosan coating proved efficient in lowering weight loss and degradation rate. Both cultivars showed a similar pattern in weight loss and decay rate. When the two cultivars were compared, 'Giant' had more weight. Chitosan was used to counteract weight loss since it has a beneficial effect on respiration. Furthermore, Chitosan coating resulted in the retention of a higher titrable acid content and firmness in both cultivars. The coating had no effect on total soluble solids or ascorbic acid concentration, indicating that Chitosan treatment is a viable technique for retaining organoleptic qualities and extending postharvest life. In a different study, Younas et al., (2014) found that fortified chitosan- coated apricots had better weight and moisture loss management, total soluble solids content, and acidity control than the control treatment. According to Gayed et al., (2017), chitosan was effective in minimizing weight loss % and decay (percent), as well as maintaining maximum firmness and lengthening shelf life, in a study about the effect of pre-harvest sprays of calcium chloride and chitosan, separately and in combination, on quality attributes and storability of peach fruits stored at 0 1 °C. Chitosan was found to be beneficial in preventing post-harvest fungal infections and preserving the quality of pomegranate fruit (Munhuweyi et al., 2017).Chitosan coating lowers water loss, nutritional loss, and pathogen growth, all of which contribute to fruit degradation. When strawberry fruits were treated with chitosan, ribosomal proteins were downregulated, according to a recent study (Ban et al., 2018). Katiyar et al., (2020) showed that chitosan coated sweet cherries held at 20 °C lost the least weight, 8.85 percent, compared to 16.18 percent in the control treatment stored at 4 °C. The control group (0.657 %) had the lowest titratable acidity value at 4°C, whereas the Chitosan-2 coated sweet cherries (0.600 percent) had the highest at 20°C. (Culi et al., 2020) found that adding 0.05 percent chitosan to apricots (*Prunus armeniaca* L.) during storage at 2 °C for 70 days reduced deterioration, fruit softening, color change, and a decrease in total soluble solid and titratable acidity content .Monjazeb et al., (2020) discovered that a chitosan coating can increase the firmness and stability of apricots while also aiding weight loss. Another study traced into the efficiency of chitosan coating treatment for controlling weight loss and maintaining apricot fruit quality, Fruits were coated with 0.25, 0.5, and 0.75 percent chitosan and stored for twenty-five days at 0 °C and 80 % relative humidity. Over time, weight loss from all treated and untreated fruits increased. In compared to untreated samples, the weight loss of chitosan-coated apples was higher. In the storage of coated and uncoated fruits, there was no significant difference in total soluble solids (TSS), titratable acidity (TA), TSS/TA, and vitamin C.

CONCLUSION:

Coating with chitosan, led to an extension of the life of the fruits and vegetables, and enormous numbers of papers published demonstrate that chitosan, as a one-of-a-kind product available in big quantities, has a promising future in the development of sustainable agricultural practices as well as food production and preservation. Given the ever-increasing global demand for food, ongoing climate change, and farmland consumption, chitosan appears to be a promising tool for cultivation under stress conditions, allowing the cultivation of varieties with interesting organoleptic properties but severe fruit-bearing duration problems

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