Synthesis and utilization of chitosan as edible coating material for natural fruit preservation

E Andrijanto*, T Reksa, J Maheda, R Diani and E Wahyu

Departement of Chemical Engineering, Politeknik Negeri Bandung, Jl. Gegerkalong Hilir Ds. Ciparaga, Bandung Barat, 40559, Indonesia

*edi.srimulyono@gmail.com

Abstract. This study is to see the effect of edible coating such as chitosan to prevent fruits from ripening and to extend their shelf-life. Grape and tomato were used as samples and those were treated with chitosan solution at different concentration 1, 2 and 3%. The combination of 3% chitosan solution with polyphenol and ascorbic acid at different concentration were also studied. The shelf-life of the grape and tomato was improved almost 2.5 to 3 times longer using 3% chitosan solution compared to the uncoated grape used as blank. The shelf-life of grape is increased from 6 days to 16 days and tomato is enhanced from 4 days to 18 days by coating it with 3% chitosan solution. The addition of polyphenol to the chitosan solution was slightly extending their shelf-life although it is not very significant. The results proved that the chitosan treatment into grape and tomato enhanced their shelf-life quite significantly and this material has potential to extend the shelf-life for other fruits and it can benefit for farmer.

1. Introduction

Many attempts have been done to find a new method to prevent fruit from deterioration for vegetables and fruits. Chemical treatment to prevent browning using reducing agent has been reported in practice such as citric acid [1], glutathione [2] and oxalic acid [3]. Edible coating such as chitosan has benefit to extend shelf-life of vegetables and fruits to prevent from rotten by coating them through spraying, dipping and forming a film [4]. The use edible coating such as chitosan has been proved becoming one of the best natural preservative coatings for some type of foods for antimicrobial activity, non-toxic, biodegradable and film forming properties. Chitosan has been successfully used to extend shelf-life of fruits and vegetables [5-7].

The mechanism chitosan prolongs of fruits and vegetables by reducing the respiration rate, preventing bacterial attack on the surface of fruits and reducing the water loss. These three mechanism make chitosan has the ability for extending shelf-life many fruits. Using a very minute amount of chitosan film, the quality of fruits is enhanced.

Chitosan is prepared from chitin by de-acetylation reaction which is readily soluble in dilute acidic solution with pH below 6. As the pH increases above 6, amines of chitosan become deprotonated and the polymer loses its charge and becomes insoluble. Degree of deacetylation contribute to the solubility of chitosan. The deacetylation method refers to the work of Choi at al. [8]. Chitosan has chemical structure shown in Figure 1a which is composed of 2-amino-2-deoxy-D-glucose (glucosamine) monomers, which are linked β-1-4-glycosidically, whereas chitin is composed of N-acetyl-glucosamine monomers Figure 1b [9].
The objectives of this study were to investigate the effectiveness of chitosan postharvest treatments for the postharvest fruits such as grape and tomato. In addition, the influence polyphenol and ascorbic acid were also evaluated.

2. Methods

2.1. Chitin preparation
Chitin extraction refers to the work of Acosta at al. [10].

2.2. Chitosan preparation
Chitosan preparation refers to the work of Muzzarelli at al. [11].

2.3. Polyphenol extraction
Extraction of Polyphenols from Dried Tea Leaves to crudely crushed dried tea leaves (30 g) hot water (60 deg C) is added in the ratio 1:20 (with periodical stirring to deactivate enzymes). The boiling mixture’s filtrate is collected (three times). Rotavapour (water bath at 60 °C) is used to concentrate the tea solution. The volume of the concentrate is 245 ml.

2.4. Polyphenol analysis
The polyphenol determination refers to the work of Singleton et al. [12].

2.5. Chitin and chitosan characterization
Characterization is determined using FTIR Thermo Fischer scientific and scanned from 4000 to 800 wave number. The functional group of chitin and chitosan is defined from its fingerprint of each compound.

3. Result and discussion

3.1. Characterization of chitin and chitosan
Figure 2 shows the spectra of chitin and chitosan that are almost identical. However, some differences are observed from the figure. The peak at around 3200-3450 cm⁻¹ indicating the presence of OH vibrations in both compounds. In the infrared spectra, the chitin indicated by the presence of the amide band at 1620 cm⁻¹ and at 1625 cm⁻¹ which shows the carbonyl group. Chitosan showed no amide band in this region or at least very small which is still observed due unfinished of the deacetylation process of chitin to form chitosan. This proves that chitin has been converted into chitosan.
3.2. Chitosan coating

Table 1 shows the results of chitosan solution coating on grape and tomato with the variation of chitosan concentration.

| Fruit | Shel-life (days) | Chitosan concentration |
|-------|------------------|------------------------|
|       | 0%  | 1%  | 2%  | 3%  |
| Grape | 6   | 9   | 15  | 16  |
| Tomato| 4   | 12  | 15  | 18  |

The ability of chitosan to coat the fruit is measured using visual observation until the fruit begins to wrinkle. In this study, a blank is identified as uncoated fruit and used as a standard. The results of the coating effect can be illustrated in table 1. Chitosan coating was used on two kinds of fruits which are grape and tomato. The parameter used was chitosan concentration that was varied from 1%, 2%, and 3% w/v.

Figure 3 and figure 4 shown the coating of the chitosan on grape and tomato result in increased of fruit shelf-life and it is directly proportional to the concentration of chitosan. The blank was the uncoated fruits which was last for 6 days for grape and 4 days for tomato. The increase of chitosan concentration by 1%, 2%, and 3% gives an increase in fruit shelf-life, where for grape became 9, 15 and 16 days respectively. And the tomato was also increased significantly to 12, 15 and 18 days respectively. The self-life of both fruits at the concentration of 3% are enhanced almost tripled in both grape and tomato.

![Chitin and Chitosan Spectrum](image)

**Figure 2.** FTIR spectrum of chitin and chitosan.

![Graph](image)

**Figure 3.** The effect of chitosan concentration to the shelf-life of grape.
Figure 4. The effect of chitosan concentration to the shelf-life of tomato.

This graph proves the effect of chitosan on fruits which provides protection against the deterioration of grape and tomatoes. This can be explained by the two mechanisms of protection. The first mechanism, chitosan forms a thin film and provides protection against fruit dehydration by reducing water evaporation and at the same time inhibiting the weight loss of fruit. The film protection is also maintaining the occurrence of oxygen in the fruit that causes enzymatic reaction that cause aging and fruit decay. The second mechanism is to inhibit the growth of microbes on the surface of the fruit skin that allows the fruit to decay. This mechanism occurs possibly that the chitosan has the antibacterial activity.

Table 2. The addition polyphenol to the chitosan coating.

| Fruit | Shel-life (days) | Polyphenol concentration (ppm) |
|-------|------------------|-------------------------------|
|       |                  | 0    | 1000 | 2500 | 5000 |
| Grape | 6                | 18   | 19   | 8    |
| Tomato| 4                | 12   | 17   | 8    |

Table 2 shows the results of the mixture of chitosan and polyphenols at various polyphenol concentration from 1000, 2500 to 5000 ppm. While the concentration of the chitosan is kept constant at 3% w/v.

Figure 5. The effect of polyphenol concentration to the grape and tomato shelf-life.

The results of chitosan coating show that the increase of chitosan concentration is proportionally to the shelf-life of the fruits, The higher of the concentration the longer of the shelf-life. For The addition of polyphenols is expected to enhance fruit shelf-life, given that polyphenols also have antioxidant activity.
The concentration of polyphenols added was varied from 1000 ppm, 2500 ppm and 5000 ppm. The chitosan concentration is kept constant at 3% w/v. The results of chitosan coated polyphenols by varying the concentrations can be shown in Table 3 or in the Figure 5 and Figure 6. Figure 5 explains that the increasing of polyphenol concentration resulted the increase of the shelf-life of grape from 6 days (blank) to 18 and 19 days at 1000 ppm and 2500 ppm respectively. However, in further increase in concentration at 5000 ppm, the shelf-life of the grape decreased to 8 days. The cause of lowering shelf-life of the grape is not clearly known. So it is considered that the concentration of 2500 ppm is the optimum concentration.

Figure 5 explains the results on tomato coating have the same trend as the grape, where the effectiveness of adding polyphenols is only up to 2500 ppm and the fruit shelf-life reached 17 days. While the addition of 5000 ppm polyphenols, fruit shelf-life decreased to 8 days. So it can be concluded that the addition of excess polyphenols reduces the self-life and reach optimum level at the addition of 2500 ppm. Similar phenomena happen to grape and tomato while the cause is again not clearly known.

4. Conclusions
The conclusions are that the chitosan is successfully synthesized from chitin and this can be clearly explained that its structure is well confirmed from FTIR spectrum. The chitosan coating on grape and tomato, the shelf-life of the fruits is proportionally related to the chitosan concentration. The higher the chitosan concentration results in higher the shelf-life. The chitosan concentration at 3% achieves 16 days and this number is almost three times higher compared to the blanks which is known as uncoated fruits. This enhancement of shelf-life has the same tendency both for grape and tomato. The addition of polyphenol at 2500 ppm increases slightly the self-life by 2-3 days. In this case, the role of polyphenol is not very significant in increasing the shelf-life of the grape and tomato but it is recommended for further study.

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