Improving shelf-life of Cavendish Banana Using Chitosan Edible Coating

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Abstract

Chitosan has been widely used as an edible coating for extending the shelf life of fruit. In this research, chitosan was applied to Cavendish banana. The effect of different degree of deacetylation (DD) of chitosan (70%, 80%) in various chitosan concentration (1, 1.5, 2 % w/w) in solution on weight loss and vitamin C loss were investigated. The effect of the presence of emulsifier triethanolamine (TEA) was also examined. Sensory analyses were conducted to monitor the changes in color, texture, and aroma. The results showed that coated banana fruit demonstrated delayed ripening processes compared to the uncoated banana. This also confirmed by the reduction in weight loss as well as in vitamin C loss in comparison to the uncoated banana. Weight loss and vitamin C loss decreased with increasing chitosan concentration and degree of deacetylation of chitosan. The addition of TEA emulsifier was not significantly influence the weight loss and vitamin C loss. In summary, 2% (w/w) chitosan with DD of 80% was proved to be the most suitable coating among the others for reducing the weight loss and vitamin C loss, and desirable sensory analysis.

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Keywords: Banana; chitosan; shelf-life; weight loss; vitamin C loss

1. Introduction

Banana is a quite popular tropical fruit, especially in commercial local trade. It contains a lot of nutrients and minerals which are very beneficial for health. Its vitamin C content which is regarded as a familiar antioxidant is relatively high of up to 15%. Bananas are usually harvested before fully mature for domestic consumption. Usually bananas are stored at room temperature. During storage, banana fruit is easily deteriorated due to the quick ripening...
process\textsuperscript{1,2}.

Recently, there have been many researches on edible coatings and films to diminish crop losses and maintain the quality of fresh fruit for a longer period. Edible coating is one of the methods of extending postharvest shelf-life. Many edible coating techniques to extend the shelf life and prolong freshness of fruits have been developed using polyethylene wax emulsion, bee wax, carnuba, candelilla, chitosan, and paraffin\textsuperscript{3,4,5}. Chitosan [\(\beta\)-(1-4)-2-amino-2-deoxy-D-glycopyranose] is a polysaccharide obtained from alkaline deacetylation process of natural chitin\textsuperscript{6}.

The application of the chitosan–edible coatings is promising to improve the quality and extend shelf-life of fruits since it is able to form an ideal coating on fruits surface to delay the ripening of fruits besides it is regarded as a safe material. Some researchers have suggested that chitosan has a good potential as a coating on fruits such as tomatoes\textsuperscript{7}, strawberry\textsuperscript{8}, apple\textsuperscript{9}, mango\textsuperscript{10}, avocado\textsuperscript{11} and banana fruit\textsuperscript{12}.

As compared with other polysaccharides, chitosan has several important advantages, including biocompatibility, biodegradability, no toxicity and it has antimicrobial properties\textsuperscript{13}. Systemic investigations have been reported on the effects of chitosan on the mechanical properties and barrier characteristic of chitosan based edible coating.

Various studies on chitosan edible coating have been published but there are still very little work deals with the variation degree of deacetylation of chitosan. Therefore, the objective of this study was to study the effects of different DD and concentration of chitosan on weight loss and vitamin C loss. Additionally, the addition of TEA emulsifier in the chitosan solution during coating process was also examined. Sensory analyses were conducted to monitor the changes in appearance color, aroma, and texture.

2. Materials and method

2.1. Plant Material

Cavendish banana of which skin color were more yellow than green and free of visible physical and fungal infection were purchased from the commercial market. Fresh banana were selected for uniform size, shape, and color prior to coating.

2.2. Preparation of chitosan edible coating

Several chitosan with various DD was produced in the laboratory scale via deacetylation process of shrimp waste. Two different DD of chitosans, i.e. 70\% and 80\% were selected for being used as edible coating of banana. The chitosan (CH) with various concentrations (1, 1.5, 2\% w/w) was prepared by dissolving the corresponding amount of chitosan in the solution containing 0.6\% w/w acetic acid. The mixture was heated to 90^\circ C while stirring until more or less homogeneous. If TEA emulsifier was included in the solution, TEA of 0.15\% w/w was added after fifteen minutes stirring at 90^\circ C. The solution was then cooled down to a room temperature and stirring was continued until ten hours in order to achieve emulsion with good stability.

2.3. Sample preparation

Bananas were washed with running water and dried naturally at room temperature. Afterwards, they were dipped into chitosan coating solution of various concentrations and degree of deacetylation for 1 minute. The coated samples were stored at room temperature of 30\pm2^\circ C. All sample preparation was done in duplicates. All samples were analyzed per day to study the effect of edible coating on the quality of bananas. The qualities of bananas were observed for several days until they looked overripe.

2.4. Weight loss determination

Weight loss was measured every day and calculated based on the comparison of the weight of the coated sample at its initial condition and its final condition. The percentage of weight loss was calculated by equation:

\[
\text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100\% \tag{1}
\]
2.5. Vitamin C determination

The concentration of vitamin C in banana was determined by a spectrophotometric method\textsuperscript{14, 15}. Ten grams of banana was homogenized in about 100 ml of 4% w/w H\textsubscript{2}C\textsubscript{2}O\textsubscript{4} solution. The mixture was filtered in order to separate the solid residue from the liquid. The liquid was then diluted to a certain volume with H\textsubscript{2}C\textsubscript{2}O\textsubscript{4}. For the calibration process, the standard solutions were prepared from 100 µg.ml\textsuperscript{-1} ascorbic acid solution in a certain volume of 4% w/w H\textsubscript{2}C\textsubscript{2}O\textsubscript{4} was added with 1 ml of 50 µg.ml\textsuperscript{-1} CuSO\textsubscript{4}.5H\textsubscript{2}O solution (pH = 6). The absorbance values were recorded at 249 nm.

2.6. Sensory Analysis

Sensory evaluation was performed by 20 panelists, after seven days of storage at 30±2°C, on samples that had been dipped in 1; 1.5; 2% (w/w) of chitosan (DD: 70%; 80%) in 0.6% acetic acid or dipped in this solution by using triethanolamine as emulsifier. Multiple comparison tests with a six point numerical scale performed to distinguish level of several sensory parameters among chitosan coated samples within the specified DD. The parameters evaluated were color, aroma, and texture. The following numerical scale was used for scoring these attributes: 1. very good, 2. good, 3. slightly good, 4. slightly bad, 5. bad and, 6. very bad.

2.7. Statistical Analysis

The results of sensory tests were analysed using non-parametric statistics of Friedman test as a two way analysis. Multiple comparisons were performed through 95% LSD intervals. The difference was deemed to be significant at p < 0.05.

3. Results and Discussion

3.1. Effect of Chitosan Coating on Weight Loss

The changes in weight loss of chitosan coated bananas during one week storage were depicted in Fig. 1 and Fig. 2. As the banana fruits were easily perishable, the uncoated banana showed to be overripe at day four, thus in this experiment, the storage time was limited to seven days. For the entire duration of the storage the percentage of weight loss in the control sample (uncoated) was higher than in coated samples (p<0.05). The weight loss of control sample was about 22%, whereas the coated banana showed a reduction of weight loss of about 30% during the same period of storage. This confirmed the previous work demonstrating weight loss suppression to about 30% during the same period of storage of chitosan coated banana\textsuperscript{12}. The primary mechanism of weight loss from fresh fruits and vegetables is by vapour-phase diffusion driven by a gradient of water vapour pressure between inside and outside the fruit leading to an enhanced transpiration process.

The varying DD of chitosan affected the weight loss profiles (Fig. 1 vs. Fig. 2). The weight loss of banana coated with chitosan of 70% DD was higher compared to that of banana coated with 80% DD chitosan. The higher the DD value of chitosan, the higher the purity the chitosan. This helped improve the homogeneity of chitosan solution, thus improving the quality of the resulting edible coating. Within the same specified DD of chitosan, the increase of chitosan concentration in the solution caused the decrease in weight loss (Fig. 1 and Fig. 2). The increased of chitosan concentration in the edible coating could increase the barrier to the moisture loss. This seemed plausible since the increase in chitosan concentration would increase the firmness\textsuperscript{12}. The addition of TEA emulsifier TEA to the chitosan coating solution did not significantly affect the weight loss reduction. TEA was expected to improve the wettability of chitosan and increase the chitosan emulsion stability. This might be due to the incompatibility of TEA emulsifier with chitosan. Other additives were probably needed when combined with TEA emulsifier to improve the quality of chitosan coating.
Among various chitosan concentrations, increasing chitosan concentration demonstrated higher weight retention of stored bananas. Figure 3 showed the weight loss profiles of all the samples coated with 2% chitosan of different DD (70%, 80%) both with and without TEA emulsifier as compared with the control sample. It turned out that after seven days of storage, the highest weight loss of 22% was observed in the control sample and the lowest weight loss 10% was found in the sample coated with chitosan 2%, 80% DD, and no TEA emulsifier added (C3*).
In order to clearly compare the effect of 2% chitosan coating on the weight reduction, all experimental data in each sample was linearised to evaluate the rate of weight loss indicated by the slope. The following equations represented the time-related change in weight loss for control (C0) and coated samples with chitosan composition of 2% w/w combined with two different DD of chitosan 70%, 80% (C3, C3*) and TEA emulsifier addition (CT3, CT3*). The linear regression seemed fit to all experimental data in each sample indicated by a relatively good correlation coefficient \(R^2\).

\[
\begin{align*}
C0 \text{ (control)} & : y = 3.337x - 2.411 \quad (R^2 = 0.981) \quad (2) \\
C3 & : y = 2.45x - 2.761 \quad (R^2 = 0.971) \quad (3) \\
CT3 & : y = 2.745x - 5.573 \quad (R^2 = 0.971) \quad (4) \\
C3* & : y = 2.001x - 3.593 \quad (R^2 = 0.964) \quad (5) \\
CT3* & : y = 2.177x - 3.284 \quad (R^2 = 0.995) \quad (6)
\end{align*}
\]

The rates of weight loss were decreased according to the sequence as follows: C0, CT3, C3, C3*, C3*. The rates of weight loss of all coated bananas were lower compared to the uncoated sample. Slower rates of weight loss in coated fruits can be attributed to the barrier properties for gas diffusion of stomata, the organelles that regulate the transpiration process and gas exchange between the fruit and the environment\(^{11,16}\). Furthermore, the samples coated with 70% DD of chitosan demonstrated higher rates of weight loss as compared to the corresponding samples coating with 80% DD of chitosan. The addition of TEA emulsifier slightly increased the weight loss rates. Chitosan of 2%, 80% DD, and no TEA emulsifier added (C3*) confirmed to show the slowest rate of weight loss among the other coated samples.

### 3.2. Effect of Chitosan Coating on Vitamin C Loss

The vitamin C contents of bananas were evaluated in order to study the barrier properties of chitosan to oxygen permeability. The effect of coating on vitamin C loss after seven days of storage was presented in Fig. 4.
The samples coated with 70% DD of chitosan demonstrated higher vitamin C losses as compared to the corresponding samples coated with 80% DD of chitosan. It is evident that the coatings with higher DD are the more effective in maintaining the vitamin C content of banana. Furthermore, the addition of TEA emulsifier tended to increase the vitamin C loss confirming that TEA addition was not supportive in enhancing the quality of chitosan coating. In general, the effect of chitosan concentration did not show any tendency which could be due to the variations in raw banana fruits. However, in banana coated with 2% chitosan of 80% DD without TEA (C3*), there was an obvious tendency that vitamin C loss were decreased with increasing chitosan concentration (p<0.05). The sample of C3* maintained the lowest vitamin C loss (11%) during the storage. In the meanwhile the vitamin C loss in uncoated chitosan was about 29.7%. This study showed that the chitosan edible coating with higher DD and higher concentration but prepared without TEA could minimise the vitamin C loss up to about 60% due to the suppressed oxygen permeability.

3.3. Sensory analysis

The uncoated bananas showed unsatisfactory appearance after four days of storage, whereas the coated bananas still demonstrated an acceptable appearance up to seven day storage. For this reason, as the sensory tests were conducted on the seventh day of storage, the uncoated banana as control was not included in the evaluation of sensory tests. The sensory tests would be mainly comparing the chitosan coated bananas to one another.

Based on this sensory test, the limit of acceptability is set at ±3.5. Color and aroma were desirable when chitosan concentration in the coating solution ranged from 1.5 to 2% regardless DD of chitosan indicated by the low numerical scale. In contrast, the coating contained the lowest concentration of chitosan of 1% led to the desirable texture. The addition of TEA emulsifier did not affect the color and aroma acceptance but did significantly affect the texture acceptance though no constant tendency was observed.

All sensory parameters (color, aroma, and texture) were taken into account to evaluate the most organoleptically accepted coated samples. In overall, the C3* sample was the most desirable even though the texture was on the acceptance limit.
Table 1. Sensory evaluation of coated banana on seven days of storage at 30±2°C

| Treatment                    | Color     | Aroma     | Texture   |
|------------------------------|-----------|-----------|-----------|
| Chitosan coating (70% DD)    |           |           |           |
| C3: 1% CH                    | 4.75 ± 0.76xyz | 3.60 ± 0.98dx | 2.90 ± 0.65c |
| C1: 1% CH+TEA                | 4.75 ± 1.99yz | 4.10 ± 1.37xy | 1.80 ± 0.26ab |
| C2: 1.5% CH                  | 4.10 ± 1.36dx | 2.10 ± 0.52bc | 3.60 ± 1.07cdx |
| C2*: 1.5% CH+TEA             | 4.95 ± 2.10y | 5.10 ± 1.37y | 3.50 ± 1.29d |
| C3*: 2% CH                  | 3.95 ± 1.57yx | 4.55 ± 1.03xy | 2.25 ± 0.61bc |
| CT1*: 2% CH+TEA              | 3.20 ± 0.64bc | 4.45 ± 1.28y | 4.35 ± 1.20y |
| CT2*: 2% CH+TEA              | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| CT3*: 2% CH+TEA              | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| Chitosan coating (80% DD)    |           |           |           |
| C3*: 1% CH                  | 1.05 ± 0.42a | 1.85 ± 0.14abc | 3.50 ± 1.10cxy |
| CT3*: 1% CH+TEA             | 2.95 ± 0.93cd | 2.90 ± 0.71bcd | 2.10 ± 0.46b |
| C2*: 1.5% CH                | 4.10 ± 1.36dx | 2.10 ± 0.52bc | 3.60 ± 1.07cdx |
| C2*+ 1.5% CH+TEA             | 2.35 ± 0.64bc | 4.45 ± 1.28y | 4.35 ± 1.20y |
| C1*: 1% CH                  | 4.75 ± 1.99yz | 4.10 ± 1.37xy | 1.80 ± 0.26ab |
| C1+: 1% CH+TEA               | 4.75 ± 0.76xyz | 3.60 ± 0.98dx | 2.90 ± 0.65c |
| Chitosan coating (70% DD)    |           |           |           |
| C3: 1% CH                    | 4.95 ± 2.10y | 5.10 ± 1.37y | 3.50 ± 1.29d |
| C1: 1% CH+TEA                | 3.95 ± 1.57yx | 4.55 ± 1.03xy | 2.25 ± 0.61bc |
| C2: 1.5% CH                  | 3.20 ± 1.50cd | 4.45 ± 1.28y | 4.35 ± 1.20y |
| C2*: 1.5% CH+TEA             | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| C3*: 2% CH                  | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| CT1*: 2% CH+TEA              | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| CT2*: 2% CH+TEA              | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |
| CT3*: 2% CH+TEA              | 3.80 ± 1.39dx | 2.60 ± 0.47bcd | 1.25 ± 0.37ab |

Notes: Data shown are the means of 20 panelists, (C1: 1% CH; CT1: 1% CH+TEA; C2: 1.5% CH; CT2: 1.5% CH+TEA; C3: 2% CH; CT3: 2% CH+TEA); CH referred to chitosan. * indicated 80% DD of chitosan; CT referred to CH with TEA. Different letter (a,b,c,d,x,y,z) indicates significant differences amount formulation (p<0.05); (point numerical scale were: 1. Very good, 2. Good, 3. Slightly good, 4. Slightly bad, 5. Bad and 6. Very bad)

Conclusion

The application of chitosan coating could beneficial in retarding the ripening process of Cavendish banana, maintaining quality and controlling decay of banana. The shelf life of banana fruits could be prolonged up to several days upon the application of chitosan edible coating. In general, chitosan coating could reduce weight loss and delay the vitamin C loss. In overall, the edible coating prepared with 2% chitosan of 80% DD and without the addition of TEA emulsifier was proved to be the most effective coating for banana in terms of weight loss reduction, vitamin C retention, and desirable sensory analysis. This study could be considered as one of the techniques to extend the shelf life of banana by retarding its over-ripeness prior to consumption.

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