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Effects of *Aloe Vera* Gel Coatings on the Postharvest Quality of Honeydew Melons (*Cucumis melo* L.) Stored Under Atmospheric Condition

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Abstract

Honeydew melon (*Cucumis melo* L.) is a highly nutritious fruit, but its climacteric respiration property leads to rapid quality degradation, a short shelf-life, and low marketability. The objective of this study was to evaluate the effects of *Aloe vera* gel coating on postharvest quality of honeydew melon cv. Ngan Huy under atmospheric conditions. The fresh fruits were completely immersed into *Aloe vera* gel solutions at different concentrations of 30%, 40%, 50%, 60%, and 70% at room temperature for 5 minutes. Tween 80 0.05%, CMC 1%, and glycerol 2% were added in the coating solutions. Thirty-six fruits were used in each treatment. The weight loss, firmness, respiration, and ethylene production rates, total soluble solids (TSS) and vitamin C content, and the rate of fruit spoilage were measured during storage to determine the efficacy of the *Aloe vera* gel in maintaining the postharvest quality of the honeydew melon fruits and protecting them from deterioration. Uncoated fruits exhibited significantly greater changes ($P<0.05$) in weight loss, firmness, respiration, ethylene production rates, TSS, and vitamin C content compared to coated fruits. Fruits coated with 60% or 70% *Aloe vera* gel exhibited the smallest changes ($P<0.05$) in all the tested parameters. Based on the changes of the overall quality characteristics, application of an edible coating with 60% or 70% of *Aloe vera* gel were considered to be the most suitable practice to maintain the quality of honeydew melon.

Keywords

Aloe vera gel, coating, fresh fruit, honeydew melon, postharvest quality

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Introduction

Honeydew melon (*Cucumis melo* L.) is a popular fruit in Vietnam because of its nutritional benefits and delicious flavor. Besides the economic value locally, honeydew melons grown with VietGAP guidelines also have high potential for export. However, honeydew melon is a climacteric fruit that continues to ripen after harvest, and shows a typical rise in respiration and ethylene production (Miccolis and Saltveit, 1995). The changes in respiration rate, fruit texture, and other physiological and biochemical attributes during ripening lead to rapid quality degradation, a short shelf-life, and low marketability for honeydew melons. The rapid rate of perishability of honeydew melon requires postharvest technologies that control the respiration rate and other physiological and biochemical changes. Several techniques have been developed to preserve the quality of horticultural products such as temperature control, modification of the atmosphere composition in storage rooms, and the application of chemical treatments. Edible coatings appear to be a promising approach to prolonging the storage life and maintaining the postharvest quality of fresh produce due to the same effect as modified atmosphere packaging (MAP) in modifying the internal gas composition (Park, 1999). This should also meet the demand of customers to have safe food without any “chemical” treatments.

Edible coatings can be developed from proteins, polysaccharides, and lipids individually or in combination (Kester and Fennema, 1988). Recently, much interest has increased in using edible coatings based on *Aloe vera* gel for fruits and vegetables. Composed mostly of polysaccharides, the *Aloe vera* gel provides a barrier to moisture and oxygen, which then can decrease the deterioration of fruits and vegetables. *Aloe vera* gel-based edible coatings have been shown to prevent loss of moisture and firmness, control respiration rate and maturation development, delay oxidative browning, and reduce microorganism proliferation in fruits such as grapes (Valverde *et al.*, 2005), cherries (Martínez-Romero *et al.*, 2006), papayas (Marpudi *et al.*, 2011), and oranges (Arowora *et al.*, 2013). *Aloe vera* gel also shows strong antifungal and antimicrobial activity against certain bacterial and fungal pathogens such as *Aspergillus niger*, *A. flavus*, *Alternaria alternata*, *Penicillium digitatum*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Sitara *et al.*, 2011; Devi *et al.*, 2012). In Vietnam, research using an edible coating for fruits and vegetable storage is still limited, and sporadical information is available on the use of *Aloe vera* gel edible coating on honeydew melons. Therefore, the objective of this work was to evaluate the efficacy of *Aloe vera* gel edible coating in modulating the quality of honeydew melons under ambient storage conditions.

Materials and Methods

Materials

Fresh Ngan Huy honeydew melons cultivated in Dong Xuan, Soc Son, Hanoi, Vietnam were harvested at the stage, exhibiting a slightly waxy peel, bright canary-yellow skin, firm and unyielding blossom-end, and a slight aroma. Fruits were then transported to the postharvest laboratory within two hours after harvesting. Fruits were selected on the basis of size, color, and absence of defect or injury.

Fresh *Aloe vera* leaves were purchased from Big C supermarket located in Long Bien district, Hanoi, Vietnam, and were kept at a temperature of 10^oC before using.

Methods

Preparation of edible coating solution

Aloe vera gel matrix was separated from the outer cortex of leaves, and these colorless hydroparenchyma were ground in a common fruit blender at room temperature to yield a mucilaginous gel. The liquid obtained from filtered mixture was the fresh *Aloe* gel (AG 100%). The gel was pasteurized at 70^oC for 45 min, cooled immediately at room temperature (25 - 28^oC), and then ascorbic acid 2 g L^{-1} (for stabilizing) and citric acid 4.6 g L^{-1} (pH = 4.0) were added. The gel was diluted with distilled water for the *Aloe vera* 30%, 40%, 50%, 60%, and 70% (v/v) treatments. The coating efficiency was improved by mixing the different concentrations of *Aloe vera* gel with 0.05% Tween 80, 1% CMC, and 2% glycerol.

Application of edible coating solution

Before coating, the honeydew melons were washed in clean water and then air dried. There were 36 fruits in each treatment. Fresh fruits were completely immersed in coating solutions with concentrations of *Aloe vera* gel of either 30%, 40%, 50%, 60%, or 70% (labeled as AG1, AG2, AG3, AG4, and AG5, respectively) for 5 min at room temperature. After the treatment, all fruits were air dried at room temperature to allow a thin film layer to form on the fruits. Uncoated fruits were the negative control. The fruits were then weighed and stored in carton boxes with 0.5% of the perforated area under atmospheric conditions (temperature 28 ± 3^{o}C and 80 - 90% relative humidity). Research parameters were measured initially and after 4, 7, and 9 days. The parameters analyzed included weight loss, firmness, respiration and ethylene production rate, total soluble solids (TSS) and vitamin C content, and rate of fruit spoilage.

Weight loss

Weight loss was calculated by the equation *(A-B)*100/A*, where, *A* is the initial weight of the fruit (day 0) and *B* is the weight of fruit after the storage period.

Firmness

Firmness of a fruit was measured by the puncture method using an Agrosta 14 digital firmness tester with an 8-mm diameter flat-head stainless-steel probe. The tissue's opposing force against the penetration was recorded on 3 points in the equatorial area of the fruit. The firmness of the fruits was expressed as kg/cm^2.

Respiration and ethylene production rate

The CO_2 and ethylene production were measured by placing the fruits in hermetically sealed plastic boxes. After 1 h, the concentration of carbon dioxide and ethylene in the boxes were measured by an ICA250 dual gas analyzer (International Control Analyzer Ltd.) and ICA56 ethylene analyzer (International Control Analyzer Ltd.). The results were recorded as CO_2 kg^{-1} h^{-1} mL and C_2H_4 kg^{-1} h^{-1} µL.

Total soluble solids and vitamin C content

An Atago PAL 1 digital refractometer (Atago Co Ltd.) was used to determine the TSS of flesh juice mixed from 9 fruits for each treatment. Two pieces on the opposite sides of each fruit were used. TSS content was expressed as ^{o}Brix. These flesh juice samples were also used to measure vitamin C content of the fruits by iodine titration. The results were expressed as mg% of vitamin C.

Rate of fruit spoilage

The fruits were visually observed for fungal spoilage and fruit rots. The number of fruits spoiled was recorded and the disease percentage was calculated as follows:

$$\% \text{ Disease} = \frac{A}{B} \text{ x } 100$$

where, A is amount of spoilage fruits and B is the total amount of fruits in the sample.

Statistical analysis

The data obtained from the experiments were expressed as mean ± standard errors (SE) of nine measurements (n = 9). The significant differences (P<0.05) among means were subjected to one-way analysis of variance (ANOVA) with Tukey's test.

Results and Discussion

The effects of *Aloe vera* gel in the coating solution on the physical characteristics of the honeydew melons during storage

The changes in weight and firmness due to the respiration and transpiration of fruits were the main factors leading to decreased fruit quality and reductions in postharvest shelf life during storage. The effects of *Aloe vera* gel in the coating solution on weight loss and firmness of the honeydew melons during storage are presented in Figures 1 and 2.

The results showed that weight loss of the fruits increased during storage, but the greatest loss was observed in the first 4 days of storage (Figure 1). The weight loss of the uncoated fruits was significantly higher than in the coated fruits (*P*<0.05). After 4 days of storage, the highest weight loss was 3.29% for uncoated fruits, and the losses in AG1, AG2, AG3, AG4, and AG5 fruits were 3.02%, 2.66%, 2.28%, 1.90%, and 2.20%, respectively. There was a significant difference in the weight loss of the coated fruits (*P*<0.05). After 9 days of storage, there was no difference in weight loss between the AG4 and AG5 treatments, but they were significantly lower (*P*<0.05) than the other coated fruits. The final weight loss values of the AG2 and AG3 treatments were similar, but lower than the AG1 treatment and uncoated fruits. The reduction in weight loss for the coated fruits was potentially due to the effects of their coatings as barriers against gas and moisture movement, resulting in the reduction of respiration and water loss (Park, 1999). The results obtained in this study are in agreement with the findings of Arowora *et al.* (2013) who reported that the weight loss of oranges coated with an *Aloe vera* gel coating was 24.1% lower than in uncoated fruits. Similar results were observed by Marpudi *et al.* (2011) when using a 50% *Aloe vera* gel based coating for papaya. Martínez-Romero *et al.* (2006) applied an *Aloe vera* based coating solution on sweet cherries and also found a significant reduction of weight loss for fruits stored at 1ºC for 16 days.

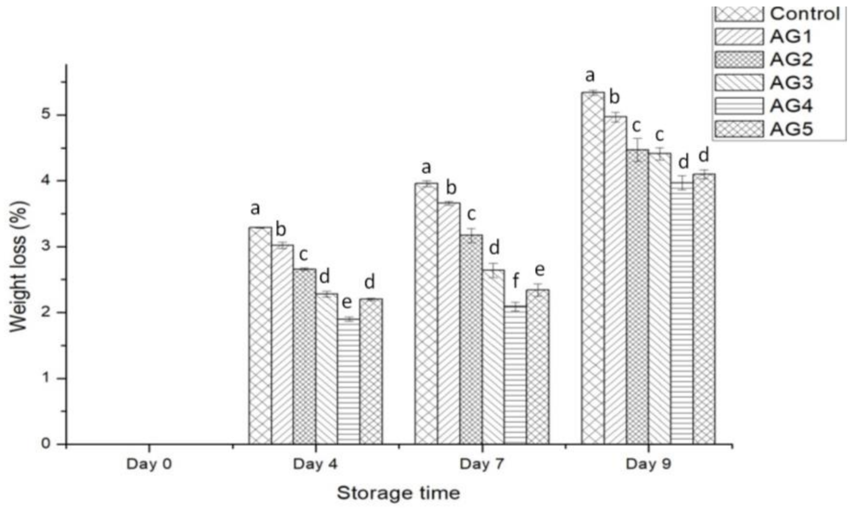

Figure 1. Effects of the *Aloe vera* gel coating solution on loss in weight of honeydew melons
Note: Bars not sharing a common superscript differ significantly at *P*<0.05.

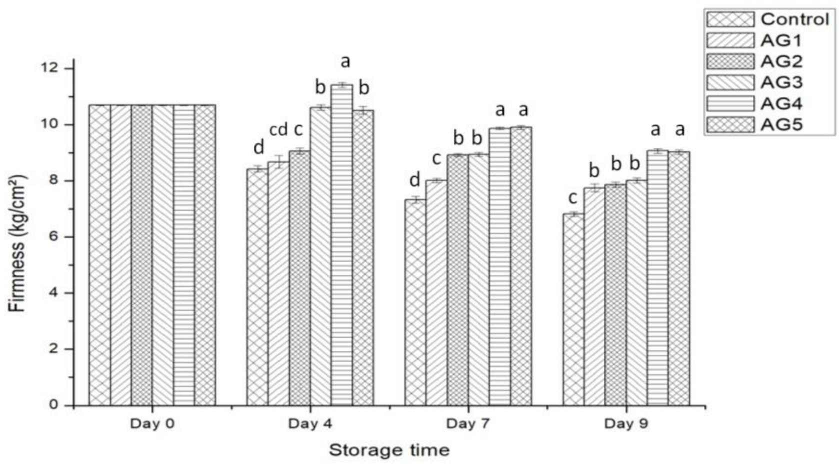

Figure 2. Effects of the *Aloe vera* gel coating solution on firmness of honeydew melons
Note: Bars not sharing a common superscript differ significantly at *P*<0.05.

With respect to firmness, honeydew melon fruits softened during storage for both the treated and control fruits (Figure 2). However, increasing the *Aloe vera* gel concentration in the coating solutions increased the firmness of honeydew melons. The control fruits exhibited a significantly higher loss in firmness ($P<0.05$) than the treated fruits on the 7th day of storage. After 9 days of storage, the highest mean values for firmness were seen in the AG4 and AG5 treatments (9.07 and 9.02 kg cm^{-2}), while that of uncoated fruits was 6.82 kg cm^{-2} at the same time. There was no significant difference in the firmness among the AG1, AG2, and AG3 fruits, but the firmness of these fruits was significantly higher than that of the control fruit, and lower than that of the AG4 and AG5 treatment fruits ($P<0.05$). The reason for the honeydew melon firmness maintenance may be related to modifications in internal gas levels created by the *Aloe vera* gel coating. The results of this study are consistent with the findings by Arowora *et al.* (2013) who reported that control oranges exhibited higher losses in firmness than oranges coated with *Aloe vera* gel samples. Also, the results of this work are in line with those of Yulianingsih *et al.* (2013) who concluded that the application of *Aloe vera* coating was effective in retaining the firmness of the minimally processed cantaloupe.

Effects of *Aloe vera* gel in the coating solution on the physiological characteristics of honeydew melons during storage

From the postharvest point of view, respiration is important for fruits because its function is to release energy stored chemically as sugar, lipids, and other substrates. However, respiration also causes the loss of substrate from stored plant products and results in a decrease in energy reserves within the tissue (Kays, 1997). The respiratory rate of both the control and coated honeydew melons increased dramatically to peak values after 4 days of storage (Figure 3). The respiratory rates of the uncoated and AG1 coated fruits exhibited the highest values (31.49 and 31.42 mL CO_2 kg^{-1}h^{-1}) and were significantly different ($P<0.05$) from the other coated fruits after 4 days of storage. At that time, the lowest rate of respiration was recorded in the AG4 coated fruits (19.45 mL CO_2 kg^{-1}h^{-1}). After 9 days of storage, the respiratory rates of the AG4 and AG5 coated fruits were significantly lower than in the control and other coated fruits. Being a hydrophilic material, *Aloe vera* gel coating films provide a good barrier to CO_2 and O_2, thereby retarding both the respiration rate and ripening of fruits (De Azeredo, 2012). Martínez-Romero *et al.* (2006) reported similar findings with their study in that sweet cherries treated with *Aloe vera* gel coating

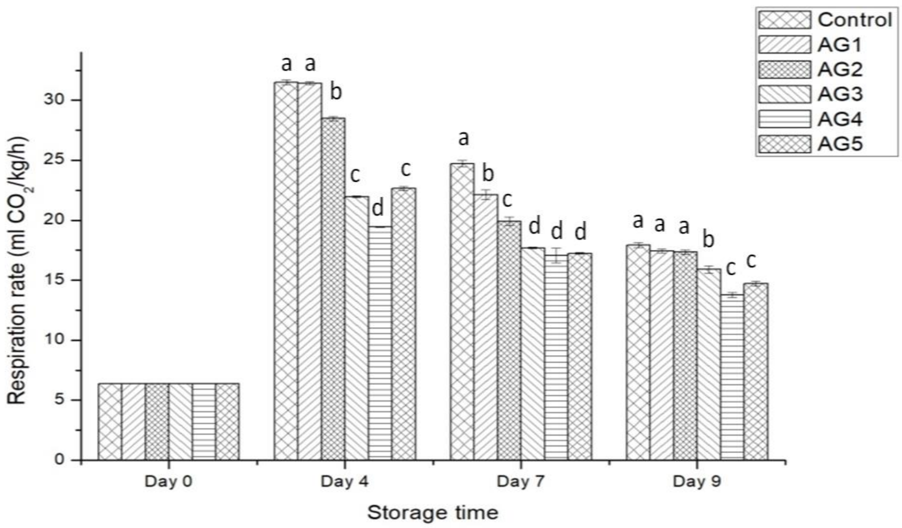

Figure 3. Effects of *Aloe vera* gel coating solution on respiratory rates of honeydew melons
Note: Bars not sharing a common superscript differ significantly at $P<0.05$.

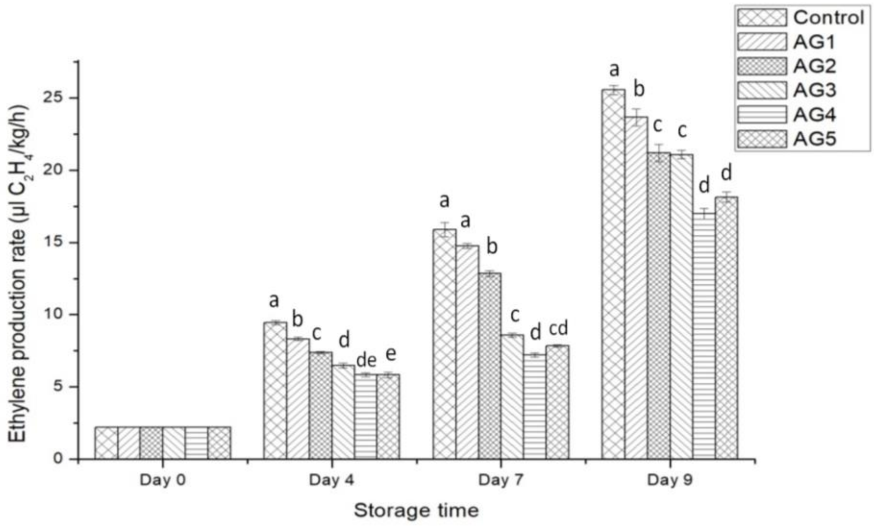

Figure 4. Effects of *Aloe vera* gel coating solution on ethylene production of honeydew melons
Note: Bars not sharing a common superscript differ significantly at $P<0.05$.

had significantly diminished the rates of respiration.

Figure 4 shows that during the first 4 days of storage, the rate of ethylene production increased slightly. From the 7th day of storage, ethylene was produced at a rapid rate. After 9 days of storage, ethylene production in AG4 and AG5 coated fruits (16.99 and 18.14 μL C_2H_4 kg^{-1} h^{-1}) were the lowest, and different from the control and the AG1, AG2, and AG3 treatment fruits (with rates of ethylene production of 25.57, 23.66, 21.2, and 21.08 μL C_2H_4 $kg^{-1}h^{-1}$, respectively). These results are in accordance with findings of Chrysargyris *et al.* (2016) who used *Aloe vera* gel coating on tomato fruits at rates of 0%, 5%, 10%, 15%, and 20% *Aloe vera* gel and maintained the fruits for 14 days at 11^{o}C and 90% relative humidity. They found that both the 10% and 15% *Aloe vera* gel coating treatments reduced fruit ethylene production. Muhammad *et al.* (2009) also reported that *Aloe vera* gel coated 'Arctic snow' nectarines kept at ambient temperatures or in cold storage at 0^{o}C had reduced respiration rates, lessened ethylene production, and retarded fruit softening during ripening compared to the untreated control. Chauhan *et al.* (2015) used shellac and *Aloe vera* gel to develop edible surface coatings for tomato fruits, and reported that the composite coated fruits showed restricted ethylene synthesis compared to those coated with shellac alone or the uncoated samples.

Effects of *Aloe vera* gel coating solution on the biochemical characteristics of honeydew melons during storage

As indicated by the results shown in Figure 5, the TSS content in the uncoated and the AG1 and AG2 coated honeydew melon fruits decreased during the first 7 days of storage, and the most rapid reduction was seen in the uncoated fruits. Soluble solids such as sugar and organic acids can be consumed as respiratory substrates in the Krebs cycle (Dinh and Quyen, 2015). The TSS content in the AG3 and AG5 coated fruits had no considerable changes during the first 4 days of storage, but a reduction was monitored clearly at the 7th day. From the 7th day of storage, the TSS content in the uncoated and coated fruits (except for the AG3 treatment) showed increasing trends. The TSS content in the AG4 coated fruits showed a small increase during the first 7 days of storage but a reduction after 9 days of storage. After 9 days of storage, the coated fruits had a higher content of TSS than the uncoated fruits. The AG4 and AG5 coated fruits gained the highest values of TSS content.

Both uncoated and coated fruits showed a reduction of vitamin C content during storage. Vitamin C is very sensitive to be destroyed during postharvest storage. Ascorbic acid, which is the major form of vitamin C, is easily oxidized by ascorbate oxidase enzyme, especially in the presence of oxygen (Lee and Kader, 2000). *Aloe vera* gel coatings were effective in reducing the ascorbic acid loss (Figure 6). After 9 days of storage, the vitamin C contents of the *Aloe vera* gel coated honeydew melons were significantly higher than those of the uncoated fruits. The vitamin C value for the uncoated fruits was 21.74 mg%, while the vitamin C values of the AG3, AG4, and AG5 coated fruits were 38.55, 37.37, and 41.42 mg%, respectively, with no significant differences among these coated fruits. These results are in agreement with those of Adetunji *et al.* (2012) who studied pineapples and similar to the findings of Athmaselvi *et al.* (2013) who worked on tomatoes. The reduction of vitamin C loss in the coated fruits was due to the low oxygen permeability of the *Aloe vera* gel coating, which reduced the activity of the enzymes and prevented oxidation of ascorbic acid (Adetunji *et al.*, 2012).

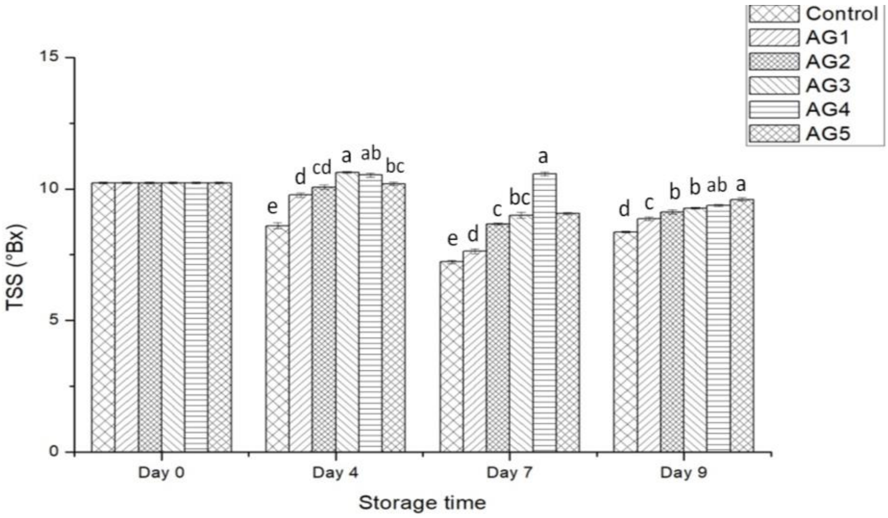

Figure 5. Effects of *Aloe vera* gel coating solution on the TSS of honeydew melons
Note: Bars not sharing a common superscript differ significantly at *P*<0.05.

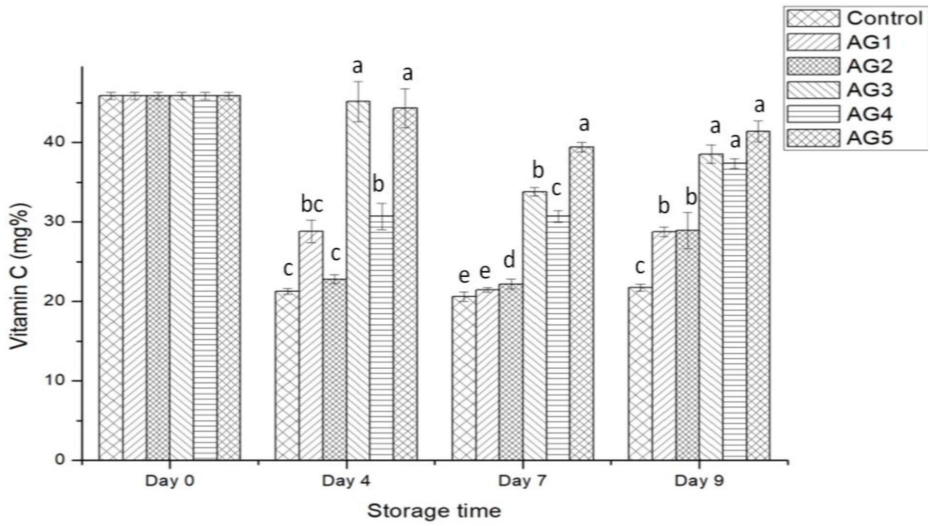

Figure 6. Effects of *Aloe vera* gel coating solution on the vitamin C content of honeydew melons
Note: Bars not sharing a common superscript differ significantly at *P*<0.05.

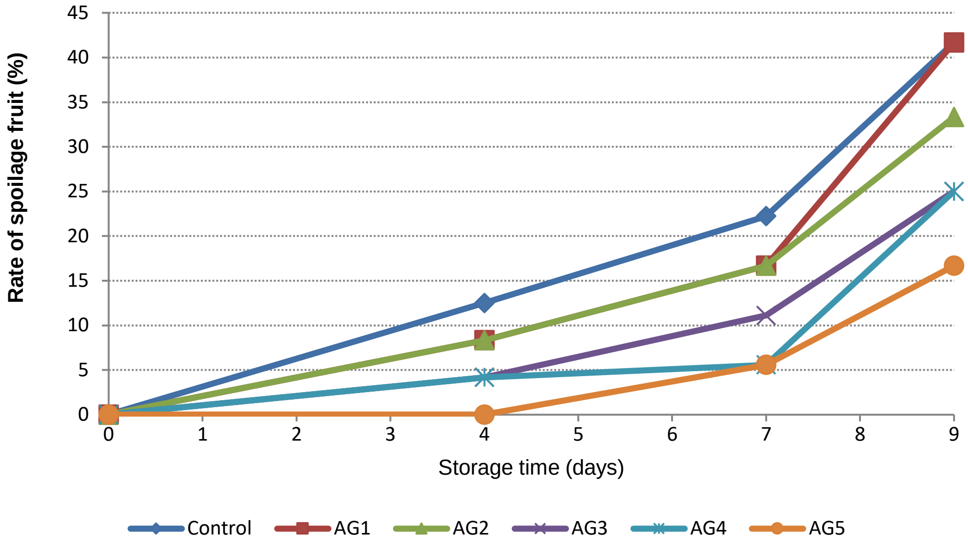

Figure 7. Effects of *Aloe vera* gel coating solution on the rate of fruit decay of honeydew melons

Effects of *Aloe vera* gel coating solution on the rate of spoilage of honeydew melons during storage

The rate of fruit spoilage was used as a measure to indicate the effects of the *Aloe vera* gel coating on the microbial quality of the fruits. The rate of spoilage was higher in non-coated fruits than in coated fruits during the first 7 days of storage (Figure 7). After the first 4 days of storage, the fruit deterioration did not appear in the AG5 coated fruits. After 9 days of storage, the rate of spoilage of fruits was found to be the highest in the uncoated and AG1 coated fruits, both at 41.67%. At that time, the recorded rates of fruit spoilage for the AG3 and AG4 coated fruits were 25%, and the rate for the AG5 coated fruits was 16.67%.

It was observed that the uncoated fruits had a more rapid ripening than the coated fruits due to the higher levels of respiration and ethylene production rates (Figures 3 and 4). The ripening hastened the softening of the fruits, which provided good conditions for microbial spoilage. The *Aloe vera* gel coating delayed the ripening of fruits, resulting in reductions of spoilage in the coated fruits. In addition, it can be explained that the antifungal and antimicrobial activity of *Aloe vera* gel protected the coated fruits against the attacks caused by microbes during storage.

Conclusions

The applications of *Aloe vera* gel coatings on honeydew melons were shown to be effective in maintaining the quality of the melons and protecting the fruits against deterioration. This coating helped reduce weight loss, minimize respiratory and ethylene production rates, and retain the firmness and biochemical components of fruits. The coating solutions with 60% and 70% *Aloe vera* gel gave the best results with fruit firmness measured at 1.3 times higher than in uncoated fruits and ethylene production levels measured at 1.5 times lower than in uncoated fruits. Coating solutions with 60% and 70% *Aloe vera* gel also maintained vitamin C content at 37.37% and 41.42%, respectively, and had significantly lower rates of decay compared to uncoated fruits. *Aloe vera* gel coating is a potential and safe technique for the storage of honeydew melons.

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