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Potential Effects of *Aloe vera* Gel on Maintaining the Quantitative and Qualitative Characteristics of Lime Fruits (*Citrus aurantifolia* L.) in Cold Storage

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ABSTRACT

The present study was conducted to investigate the effects of two concentrations of *Aloe vera* gel (7.5 and 15%) on quantitative and qualitative characteristics of lime during storage time (20, 40, and 60 days). The study was performed as a factorial experiment in a completely randomized design with four replications. After dipping (5 minutes) and drying, the fruits were packaged in low-density polyethylene containers and transferred to cold storage at 4±1°C and 85±2% relative humidity. The results showed a decrease in fruit sourness and aroma and an increase in fruit bitterness during storage. The highest rate of chilling injury and decay belonged to the control. *Aloe vera* gel 15% had the lowest fruit bitterness (30%), decay, and malondialdehyde compared to the control on day 60 of storage. The *Aloe vera* gel enhanced peroxidase activity as an antioxidant enzyme and decreased defense-related enzymes such as phenylalanine ammonia-lyase activity. The maximum vitamin C was related to *Aloe vera* gel 15%. According to the results, Aloe vera gel, could not effectively control weight loss and firmness. During 60 days of storage, compared to the control, Aloe vera gel 15% increased Chroma index (2.07%) and vitamin C (26.37%), and prevented decay (100%), chilling injury (25.75%), bitterness (42.85%), and malondialdehyde (35.80%) of lime fruit.

Keywords: Chilling injury, Decay, Enzyme activity, Phenolic compounds.

INTRODUCTION

Lime fruit is rich in citric acid, flavonoids, phenols, pectin, limoloid, vitamin C (Altemimi *et al*., 2021). Lime juice is used to treat some diseases such as sore throat, fever, scurvy, rheumatism, chest pain, and high blood pressure. Lemon fruit is used for fresh consumption, but it is also used in fruit juices, jams, jellies, and molasses (Altemimi *et al*., 2021). In most cases, due to the lack of proper storage conditions at home, the juice has a very undesirable brown color, which seems to be associated with a decrease in nutritional value, and a significant decrease in vitamin C (Burdurlu, 2005). The quality of lime juice during storage showed a reduction in quality characteristics such as pH, ascorbic acid, Brix, an increase in browning, and color index (Burdurlu, 2005). Ascorbic acid, due to its particular structure, oxidizes rapidly and decreases during storage. Fresh fruit limes can be kept for several days, maintaining their juice levels, vitamins, minerals, fiber, and carbohydrates, but it has a low shelf life due to its high water content (87%) (Altemimi *et al*., 2021). During the storage of lime juice, quality factors such as color, vitamin C, and bitterness are strongly influenced by environmental conditions that have a significant effect on customer product satisfaction (Burdurlu, 2005). It seems that the use of coating food packaging technique can maintain the quantitative and qualitative characteristics of the fruit.

Aloe Vera (AV) gel is one of the natural edible coatings that have been shown to

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contain an active ingredient (mucilaginous polysaccharides (Eshun and He, 2004)) with proven medicinal and therapeutic properties (Adetunji *et al*., 2019). This gel is extracted from the inner part of the leaf (leaf parenchyma cells) of the AV plant and shows good potential in storing the harvested mango fruits (Shah and Hashmi, 2020). This gel is entirely compatible with the environment and health, and its pH is about 4.5. There are some reports on the antifungal activity of AV gel against several pathogenic fungi including Botrytis cinerea (Valverde *et al*., 2005). The positive effect of AV gel is in controlling yeasts and molds, and reducing the proliferation of microorganisms in grapes (Valverde *et al*., 2005) and cherries (Martinze-Romero *et al*., 2006) is reported. Fruit coating with AV gel is effective in maintaining post-harvest quality of guava (Nasrin *et al*., 2020), Kiwifruits (Passafiume *et al*., 2020), fresh-cut papaya (Farina *et al*., 2020), Agee Sweet (Adetunji *et al*., 2019), and mango fruits (Shah and Hashmi, 2020). The AV gel is a safe and environmentally friendly alternative for enhancing the storage of table grape (Valverde *et al*., 2005). Studies have shown that AV gel can be effective in improving shelf life, maintaining the quality of orange fruit, and reducing postharvest losses during storage (Arowora, 2013). AV gel can extend the shelf life of fresh strawberries up to 16 days without adversely affecting sensory properties at 4°C (Sogvar *et al*., 2016). The main reasons for losses after harvesting lime fruit are water loss, excessive softening, decay, and reduced quality of appearance. Because little research has been done on the change of beneficial nutrients in the post-harvest period of lime fruits, in this study, the effect of AV gel on the quantitative and qualitative characteristics of lime fruit (Jahromi) during cold storage has been investigated.

MATERIALS AND METHODS

Plant Material, Coating, and Storage

Jahromi lime fruit produced in the Chedruyeh garden in Jahrom City, Iran, were picked at the mature green stage in the month of September [based on the percentage color change from green to yellow (10%), TSS: 9.8 and Acid: 7]. Harvested fruits were transferred to the laboratory after harvesting. Uniform-sized fruits free from blemishes, injuries, bruises, and pest infestation were selected and treated with AV gel (ALFA PRODUCTS 99% made in Greece) with concentrations of 7.5 and 15% (in terms of weight), while the uncoated fruit served as the control. Fruits were immersed in AV gel solutions for five minutes. After the surface of the fruits was dried, they were packed in low-density polyethylene containers in groups of 10 fruits. Then, the packed samples were placed in cold storage (4±1°C, 85–90% RH). When the storage time was finished (0, 20, 40, and 60 days), the fruits were transferred to room temperature (25°C) for 4 hour. Some quantitative and qualitative characteristics were examined by the following methods. The effect of AV gel on the enzymatic activities was determined on days 0 and 60.

Weight Loss, Titratable Acidity (TA), pH, and Vitamin C

The weight loss of packaged lime samples in the specific storage time compared with the first day of the experiment, was calculated by the formula given below:

Weight loss%= (Initial weight−Weight in the specific time of storage)/Initial weight)×100

The TSS content of fruit juice was recorded using a digital refractometer (DBR 95) at 25°C and was expressed as % (°Brix). By titrating 5 mL of juice with NaOH (0.1N) and phenolphthalein, the titratable acidity, which is described as citric acid (%), was measured when the color of the solution changed (light pink - pH 8.1). The pH of fruit juice was measured with a pH meter (Germany inolab720, WTW82362). The amount of vitamin C in the fruit was determined by titration with iodine solution and using the redox reaction, and expressed

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as mg of vitamin C in 100 mL of fruit juice (Martinez-Romero *et al*., 2013).

Skin and Albedo Firmness

Tissue firmness was measured using a digital force tester (Lutron fg5020, Taiwan), equipped with an 11 mm sharp probe. Measurements were performed on opposite sides of the central area of skin (three rounds of constant pressure) and albedo (two rounds of constant pressure). Values were expressed as kilograms-Force (kg F).

Color Measurement

Color values of skin were measured with a color meter (Minolta Chroma Meter Model CR-400, Minolta, Japan). The color was measured as red-green (a*) and blue-yellow (b*). The Chroma value was calculated by the formula given below:

$$\text{Chroma} = \sqrt{(a*)^2 + (b*)^2}$$

Ion Leakage, Chilling Injury, Decay Index, and Malondialdehyde (MDA)

Peel ion leakage was measured by EC meter (WTW model pH 330i/SET) and expressed as a percentage (Sogvar *et al*., 2016). Brown spots on the skin were considered as signs of cold stress. In any case, disease incidence was expressed as the percentage of fruit showing apparent decay symptoms. The degree of chilling injury and decay was determined based on a scale from 1 to 6, which is set according to the degree of peel indentation. 1: no symptoms of chilling injury, 2: 1 to 20%, 3: 20 to 40%, 4: 40 to 60%, 5: 60 to 80%, and 6: More than 80%. Peel MDA concentration was determined according to Arowora (2013) with absorbance measurement at 450, 532, and 600 nm with the formula given below:

MAD (nmol g^{-1} FW)= 6.45 (OD_{532}–OD_{600})–0.56 OD_{450}

MDA: Malondialdehyde

OD: Optical Density of the sample

FW: Fresh Weight

Antioxidant Activity (AA) and Total Phenolic (TP) Concentrations

Skin AA was determined by the 2,2-Diphenyl-1-Picryl-Hydrazyl (DPPH) radical-scavenging method (Serrano *et al*., 2005). The absorbance was measured at 517 nm, using a spectrophotometer (Lambda Elmer Perkin, American), and was expressed as the inhibition percentage of the DPPH radical. Skin TP concentration was determined according to the Folin–Ciocalteu procedure with absorbance measurement at 760 nm using gallic acid for preparing the standard curve. The results were expressed as mg kg^{-1} of gallic acid on a fresh weight basis.

Enzymatic Activities

All the enzymes were extracted by homogenizing 2 g of frozen pulp (juice sacs) in a phosphate buffer solution (pH7 and 4% poly vinyl polypyrrolidone). After centrifugation at 12,000 rpm for 30 minutes at 4°C, the supernatants were used for studying the enzyme activity. The activity of Phenylalanine Ammonia-Lyase (PAL) was assayed with the method of Meng *et al.* (2008). Peroxidase (POD) activity was determined by the method of Chance *et al.* (1955).

Superoxide Dismutase (SOD) activity was measured by Misra and Fridovich's (1972) methods, Catalase activity (CAT) based on Aebi (1983), and Ascorbate Peroxidase activity (APX) by Nakano and Asada (1989) methods. The activity of these enzymes is expressed as a Unit (U) per g of fresh pulp weight (U g^{-1}).

Sensory Attributes

The sensory analysis, including aroma and sourness, was performed by ten trained students. The panelists evaluated the scent and taste of the fruit. Excellent was shown

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with 5, very good with 4, good with 3, moderate with 2, poor with 1, extremely poor with 0. To measure the bitterness index, number 1 was the lowest value of bitterness and number 5 was the highest value (Bourtoom, 2008).

Statistical Analysis

The study was a factorial experiment based on a completely randomized design with four replications. Sources of variation were storage time (0, 20, 40, and 60 days), cold storage (4±1°C, 85–90% RH), treatments (control, 0, 7.5, and 15%) and their interaction. Mean values were calculated and reported as the mean ± standard error of means. Data were analyzed by SAS 9 statistical software package, and the least significant difference (Duncan) test at P= 0.01 or 0.05 was used to compare the means among treatments. The graphs were plotted in Excel 2016 software package.

RESULTS AND DISCUSSION

Weight Loss, Firmness, and Vitamin C

The results showed that by increasing the storage time, the weight of fruits decreased significantly. The results also showed that AV treatments resulted in higher weight loss of lime during storage. The highest percentage of weight loss on the 60th day of storage was related to AV 7.5% and AV 15% treatments, which were 28 and 20% higher than the control, respectively (Figure 1-A). AV gel acts as a barrier to water transfer and prevents fruit weight loss (Kahramanoglu *et al*., 2019). According to studies, AV gel can effectively prevent the weight loss of button mushrooms (Mohebbi *et al*., 2012) and cherries (Martinez-Romero *et al*., 2013). This gel acts as a protective layer on the product and protects the cells of the protective layer against mechanical damage and prevents the loss of fruit weight. According to the results of this study, the weight of lime fruit treated with AV gel decreased more than the control sample during storage. This could be due to the immersion of lime fruit in AV solutions, which may have opened the pores of the fruit peel, allowing more water to escape. On the other hand, the control treatment was not immersed in any solution, thus preserving the fruit cuticle cover. Similar results were obtained in fresh-cut papaya (Farina *et al*., 2020) and Kiwifruits (Passafiume *et al*., 2020), which demonstrated that a low concentration of AV gel compared to other treatments could not be effective in controlling weight loss. Therefore, the concentration of AV gel was not appropriate in this study since lime fruits lost their marketability, and it is necessary to use more concentration.

The results showed that only the simple effect of storage (P= 0.01) on skin firmness was significant. According to the results, on the 20th day, skin firmness increased, and on the 40th and 60th day of storage decreased and remained statistically constant (Figure 1-B). According to the results, the albedo firmness was significantly reduced in all treatments during storage time. The highest degree of fruit albedo firmness belonged to the time of harvest, and the lowest degree of firmness belonged to the 60th day of storage, in which no significant difference was observed between treatments (Figure 1-C). Citrus skin usually loses water faster than albedo, due to the hydrolysis of pectate between the cell walls during storage, the skin of the fruit becomes dry and leathery (Adetunji *et al*., 2019), which can increase the firmness of the skin fruit on day 20 of storage. The enzymes beta-galactosidase, polygalactronase, and pectin methyl esterase have caused cell wall destruction and softened the fruit, which AV gel reduces the activity of these enzymes (Bourtoom, 2008). Passafiume *et al*. (2020), on kiwi, showed that AV gel treatment alone could not maintain fruit firmness compared to combination treatment. Fruits coated with AV gel have been reported to maintain turgor pressure on cell walls and maintain

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fruit firmness by increasing tissue strength (Kahramanoglu *et al*., 2019). These results contradicted the results of the present study, which may be due to the physiological characteristics of the fruit.

The results showed that AV treatments caused a significant increase in vitamin C during storage. In the final period of storage, the maximum vitamin C was related to AV 15% (Figure 1-D). Vitamin C in citrus is an unstable compound that decreases during storage depending on storage conditions such as light, oxygen, temperature as well as the activity of enzymes such as ascorbate oxidase and peroxidase. Ascorbic acid content is significantly affected by temperature and storage time (Altemimi *et al*., 2021). Vitamin C repairs cells and reduces the effects of stress, resulting in vitamin C accumulating in plant cells. Decreased oxygen permeability is the most important factor in the retention of vitamin C in freshly coated fruits. It delays the destructive oxidation reaction of vitamin C in mango (Shah and Hashmi, 2020), and 'Agege Sweet' orange (Adetunji *et al*., 2019). The decrease in ascorbic acid consumption in guava coated may be due to the positive effect of AV gel in reducing fruit ripening rate, which reduces respiration rate senescence (Rehman *et al*. 2020). In this study, the increase in vitamin C may be due to its synthesis or due to water loss. Fruit coating has been shown to cause mild stress on the fruit and increase stress intensity and produce vitamin C (Shah and Hashemi, 2020).

Acidity, pH, and Color Index

According to the results, during storage, the amount of acids decreased. The highest level of acidity belonged to the 20th day of storage and the lowest level belonged to the 60th day. According to the results, there was no significant difference between the treatments and the control sample (Figure 2-A). Some researchers have expressed that the decrease in acidity is due to its consumption in respiration during the ripening and senescence process and the conversion of citric acid to other substances during storage (Farina *et al*., 2020). Preservation of organic acids in coated fruits can be due to lower fruit respiration rate and low oxygen permeability, thus preventing the oxidation of organic acids (Adetunji *et*

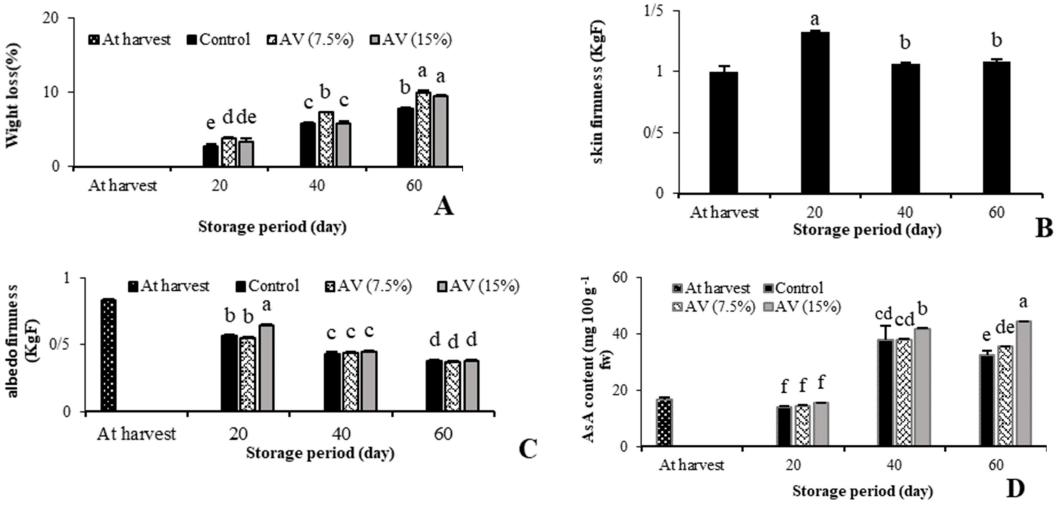

Figure 1. Effect of *AV* gel treatments and storage time on weight loss (A), peel (B), and pulp (C) firmness and vitamin C (D) of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

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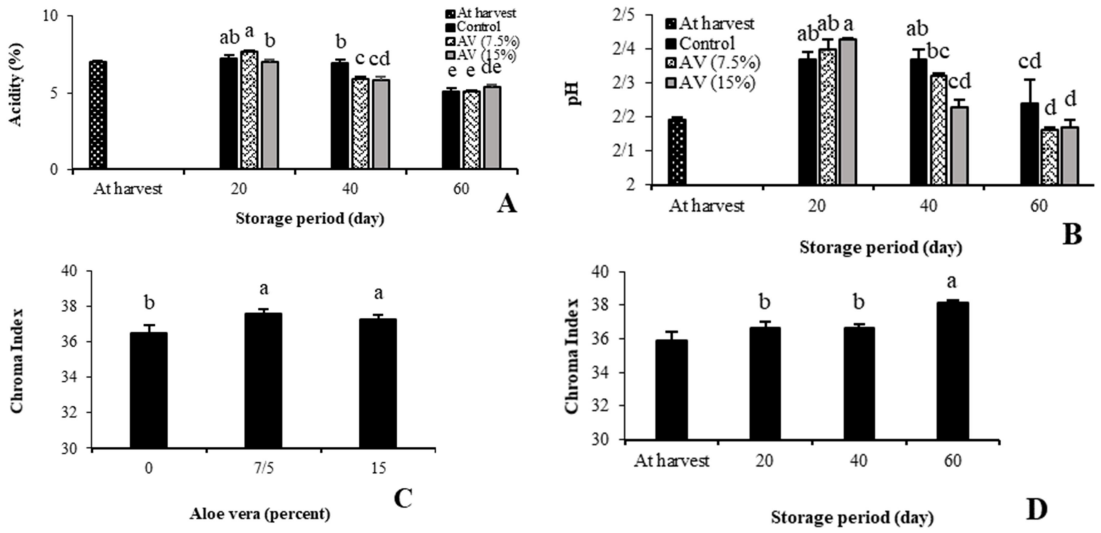

Figure 2. Effect of AV gel treatments and storage time on acidity (A), pH (B), and Chroma index (C, D) of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

al., 2019; Shah and Hashmi, 2020). The lack of significant difference may be due to the low concentration of treatment used, given that lower concentrations of edible coating on fruit did not affect acidity (Bourtoom, 2008; Passafiume *et al*., 2020).

With increasing storage time, pH first increased and then decreased. The highest increase was related to the 20th storage day, and the lowest was related to the two AV gel treatments on the 60th storage day, which was not statistically significant with the control sample (Figure 2-B). pH indicates the acidity of the juice. Decreased fruit acidity indicates ripening and decay (Shah and Hashmi, 2020). According to the results, it can be stated that, with the prolongation of the storage period, the juice distribution increased to 20th storage days and then decreased. On day 60 of storage, no statistically significant difference was observed between AV treatments and the control sample. Since organic acids are used as a substrate for respiratory enzymatic reactions, it is expected that, during the storage period, the acidity of the product decreases, and its pH values increase (Kahramanoglu *et al*., 2019).

The AV gel treatment, storage time, and their interaction had no significant effect on L* index and Hue angle. According to the results, the Chroma index increased significantly with increasing storage. The Chroma was observed in fruits stored for 60 days (Figure 2-D). AV gel treatment also increased the Chroma index (Figure 2-C). Citrus fruits have a low respiration rate and ethylene production level during ripening (Adetunji *et al*., 2019). Studies have shown that the fruit's skin does not follow this rule and changes in ripening after harvest still occurs in the fruit's skin. As the post-harvest period increases, the skin's chlorophyll breaks down into carotenoids, making the skin darker during storage (Kahramanoglu *et al*., 2019). The results of the present study showed that the Chroma index increased during storage and AV treatments were able to keep the Chroma index at a higher level. Coating affects color changes in the extended storage. AV gel maintains fruit color (Bourtoom, 2008) and delays color changes (Martinze-Romero *et al*., 2006), and maintains fruit quality. Also, in an experiment with AV gel coating, the quality of freshly cut papaya was maintained

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compared to the control, which significantly increased the shelf life of the fruit (Farina *et al*., 2020), which confirmed that AV gel is an oxygen barrier that it slows down respiration and leads to delays in activities that reduce Chroma values.

Enzyme Activity

The interaction of AV gel and storage time had significant (P= 0.01) effects on POD, PAL, SOD, and CAT activity. The change in enzyme activity is shown in Figure 3. All enzyme activities increased in all treatments and peaked on day 60. Fruits coated with AV gel showed the highest POD, SOD, and CAT activity compared to the control. As shown in Figure 3-B, control fruits had high PAL activity compared to AV gel treatments. The PAL activity in AV 7.5% was lower. The AV gel treatment had no significant effect on APX activity, but during storage time, APX activity was increased (Figure 3-E)

In this study, we found that in fruits coated with AV gel, antioxidant enzymes such as POD, SOD, and CAT showed higher activity than the control treatment. Our results showed that defense-related enzymes such as PAL during storage increased. This indicates that AV coating can improve the activity of some antioxidant enzymes and inhibit defense-related enzymes, thereby delaying aging. The researchers showed that the activity of antioxidant enzymes in fruits was significantly inhibited by edible coating treatment, and internal browning was delayed **(**Kahramanoglu *et al*., 2019). In grapefruit, Alberio *et al*. (2015) showed that

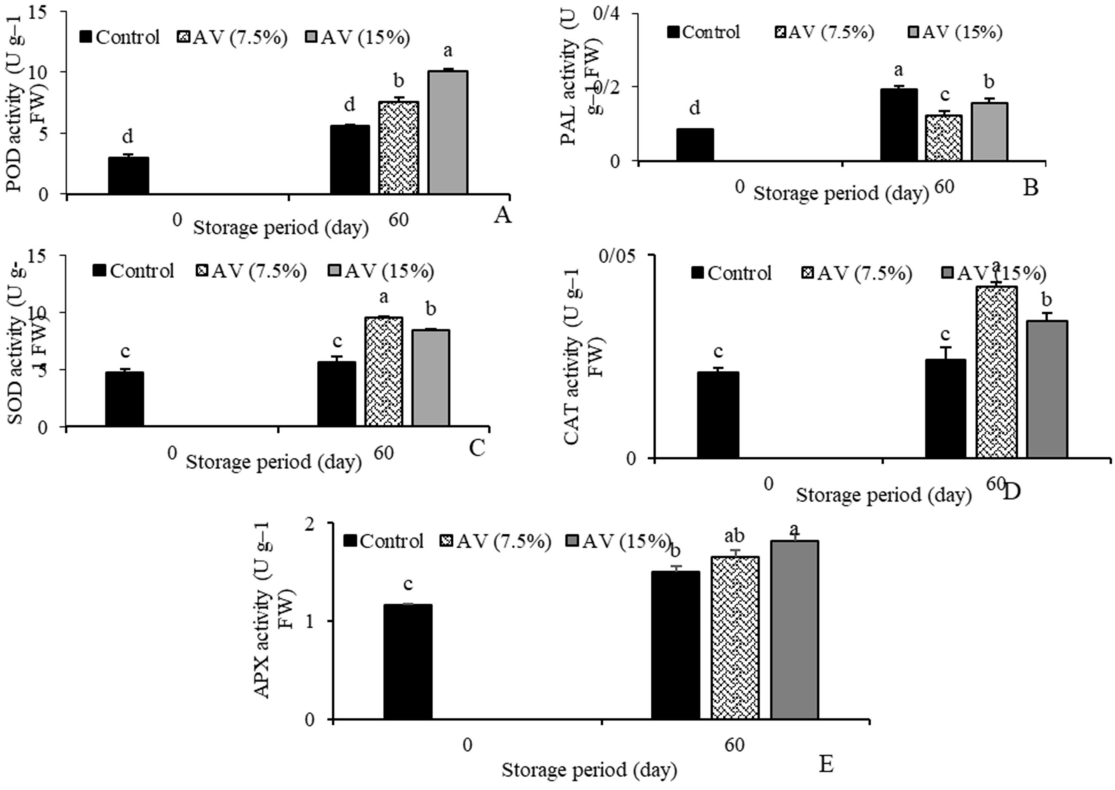

Figure 3. POD, PAL, SOD, CAT and APX activities of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

[DOI: 10.22034/JAST.26.1.151]

enzymatic activity increased during prolonged cold storage and AV gel treatment reduced that increase. These results indicate that the beneficial effect of AV is involved in reducing frost stress and increasing the activity of antioxidant enzymes (Hassanpour, 2015).

Antioxidant Activity (AA) and Total Phenolic (TPC) Concentrations

The interaction of AV gel and storage time had significant (P= 0.01) effects on AA and TPC. According to the results, in the final storage stage, the TPC decreased compared to the harvest time. On 40th day of storage, the TPC increased and then decreased. The highest TPC during storage belonged to the control sample and 15% AV gel on the 40th day (Figure 4-A). As shown in Figure 4-B, the trend of changes in AA did not follow a regular, path slight decline in the AA of the samples was observed at the end of the storage period. AV 7.5% gel was able to maintain AA up to 40 days of storage; since, then, it has not been possible to keep this factor, so, the control treatment recorded a greater AA on the 60th day of storage. The decrease in fruit phenolic content at the end of storage is due to the decrease in fruit TPC during aging. Shah and Hashemi (2020) observed an effective increase in the phenolic content of chitosan-treated mango fruit and AV gel coating.

Persistent stress conditions lead to a decrease in antioxidant compounds, which leads to cell destruction and post-harvest disorders (Hassanpour, 2015). The antioxidant system prevents the adverse effects of free radicals (Shah and Hashmi, 2020). Studies have shown that AV gel has antimicrobial, antioxidant, antiviral, and anti-inflammatory properties (Hassanpour, 2015, Kahramanoglu *et al*., 2019). According to the results of this study, AV gel was able to maintain AA until 40 days of storage. According to the results of this study, treatment of grapes with AV gel prevents reduction of AA during storage (Reynolds and Dweck, 1999), but peach fruits treated with AV had 24% fewer antioxidants than the control at full maturity (Muhammad, 2009). Due to its antioxidant properties, this coating material prevents weight loss and the entry of oxygen and carbon dioxide and can be effective in maintaining fruit quality (Kahramanoglu *et al*., 2019).

Chilling Injury, Ion Leakage, Decay Index, and Malondialdehyde (MDA)

The interaction of AV gel and storage time had significant (P= 0.01) effects on the chilling injury, ion leakage, decay, and MDA (Figure 5). The results showed that with increasing the storage period on day 60 of storage, stress indices increased significantly. The highest and lowest rates of cold stress damage and decay were related to

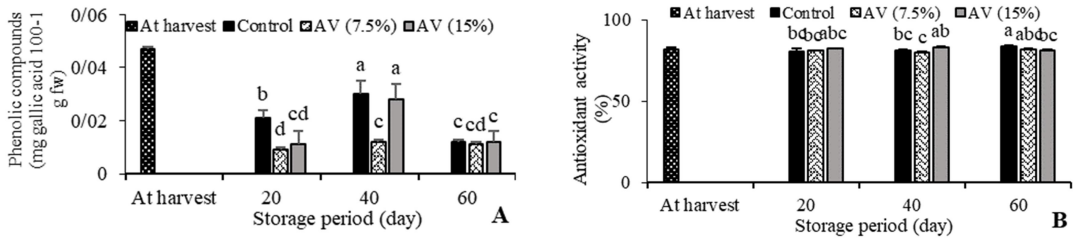

Figure 4. Effect of AV gel treatments and storage time on phenolic compounds and antioxidant activities of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

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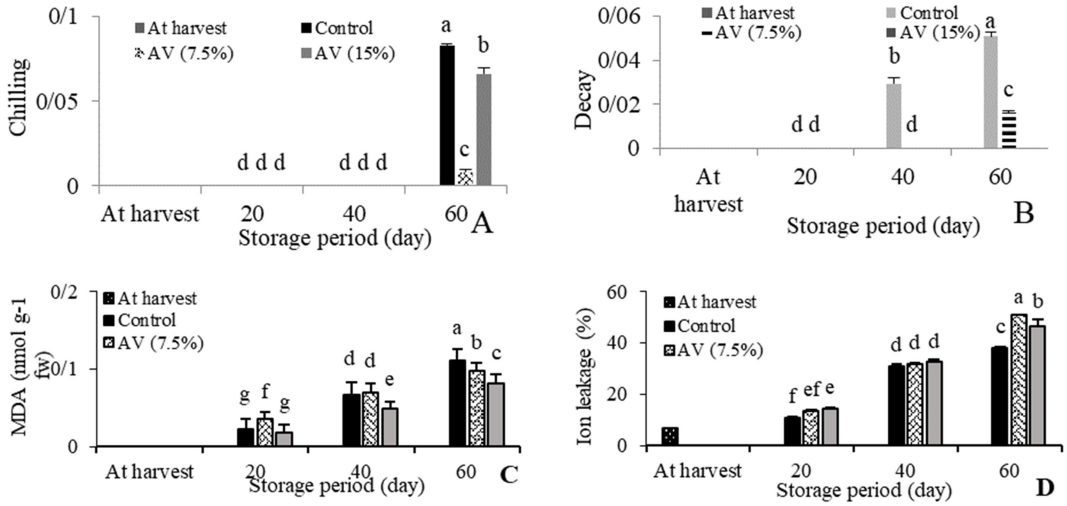

Figure 5. Effect of AV gel treatments and storage time on chilling injury, decay, MDA and ion leakage of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

the control and AV 7.5%, respectively (Figures 5-A and -B). Fruits treated with AV gel 15% had not shown any chilling and decay symptoms. According to the results, the MDA increased with increasing storage period. On 60th day of storage, the control sample and AV gel 15% showed the highest and the lowest MDA respectively (Figure 5-C). The results showed that with increasing the storage time, the ion leakage increased significantly. On the 60th day of storage, the highest percentage of ion leakage was related to AV 7.5%, and the lowest amount belonged to the control sample (Figure 5-D).

Lime is usually stored at 13 and 14°C, which leads to severe rot of the product. On the other hand, storage at temperatures below 10°C causes chilling injury in them, which causes changes in membrane lipids, thereby increasing membrane permeability (Nasrin *et al*., 2020). This study showed that AV gel treatment reduced the chilling injury, decay, and MDA. AV gel coating by maintaining firmness and improving fruit texture can improve the shelf life, maintain fruit quality, and reduce post-harvest losses during storage and be effective in reducing wounds and other physical injuries (Arowora, 2013). AV gel reduces the activity of beta-galactosidase, polygalacturonase, and pectin methylesterase. These enzymes destroy the fruit cell wall (Bourtoom, 2008). Studies on cherry fruit treated with AV gel showed that the fruits did not show signs of decay and browning on the fruit tissue (Martinez-Romero *et al*., 2013).

AV gel has various compounds, the most important of which are enzymes, vitamins, anthraquinones, amino acids, saponins, and salicylic acid. Salicylic acid and saponins have antifungal properties and prevent the growth, proliferation, and death of fungi (Kahramanoglu *et al*., 2019). The inhibitory effects of AV gel on the fungal and bacteria disease on raspberry (Hassanpour *et al*. 2015), pomegranate arils (Martínez-Romero *et al*. 2013), mango (Shah and Hashmi, 2020), and 'Agege Sweet' orange (Adetunji *et al*., 2019) were reported. To express the degree of cell membrane degradation, the concentration of MDA in plant tissue can be examined, because this compound is produced due to the peroxidation of

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membrane lipids and mechanical damage to the membrane. In the present study, AV gel maintained antioxidants for 15% up to 40 days of storage and since then reduced AV gel antioxidant treatments. AA decreases during storage in fruits due to the protection of the cell against damage caused by free radicals, which prevent the production of MDA (Hassanpour *et al*. 2015). AV gel coating reduces wounds and other physical injuries by maintaining firmness and improving fruit texture (Sogvar *et al*., 2016). Cherry fruits treated with AV gel showed no signs of chilling injury of fruit tissue (Martinez-Romero *et al*., 2013), which contradicted the results of this study.

Sensory Attributes

Figure 6 shows the sensory attribute scores including sourness, bitterness, and aroma of lime. Only the simple effect of storage was significant (P= 0.01) on fruit sourness. The results showed that with increasing storage time, the sourness of lime fruit decreased. The highest fruit acidity was related to harvest time and the lowest was related to the final stage of storage period (Figure 6 A). According to the results, lime fruits had the lowest bitterness at harvest time and on the 20th day of storage. The treatments were not statistically significant, and the bitterness index increased with the storage period. On 60th day of storage, there was no significant difference between AV gel 7.5% treatment and the control sample, but AV gel 15% treatment reduced fruit bitterness by 30% compared to the control (Figure 6-C). The two factors (AV and storage) and their interaction had significant (P = 0.05) effects on fruit aroma. The results showed

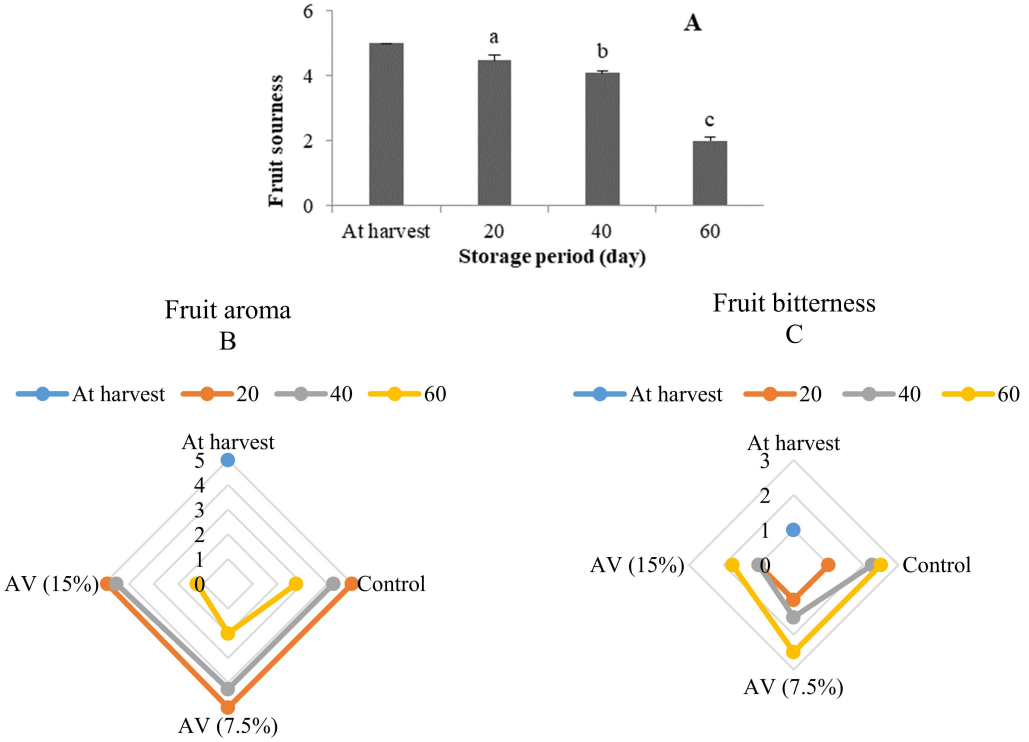

Figure 6. Effect of AV gel treatments and storage time on sourness (A), aroma (B), and bitterness (C) of lime fruit stored at 4±1˚C, 85±2% RH. Vertical bars indicate the standard errors of 4 replicates. Values with similar letters are not significantly different (P≤ 0.05).

[DOI: 10.22034/JAST.26.1.151]

that the fruits could retain their aroma during storage on days 20th and 40th of storage, which decreased with the duration of storage on days 60th during storage. The lowest aroma was related to the fruit treated with 15% AV gel on the 60th of storage (Figure 6-B).

The main cause of citrus bitterness is some of these flavonoids such as limonine, neohsperidine, and orange in the peel of their fruit (Burdurlu, 2005). Lime has a thin peel compared to other citrus fruits, which causes the juice to leak during storage. Contamination leads to dry peel, biochemical deterioration, browning, change in taste, and reduced appearance (Sogvar *et al*., 2016). The edible coating reduces the oxygen penetration by creating a barrier on the surface of the fruit and thus increases the shelf life and maintaining the quality of the product. The use of oral coatings increases the quality of the product, increases the sensory properties, prevents microbial growth, and improves immunity and thus increases the shelf life of the product (Kahramanoglu *et al*., 2019). The use of coating reduces the rate of respiration and increases the shelf life of fruits and vegetables. Reducing the rate of respiration leads to maintaining the desired taste and pH, reducing the degradation of organic acids, and preventing sugar loss. AV gel maintains the quality of harvested fruits and increases their shelf life (Bourtoom, 2008). AV gel can extend the shelf life of fresh strawberries up to 16th days without adversely affecting the sensory properties at 4 °C (Sogvar *et al*., 2016), which was consistent with the results of this study and was able to maintain the quality of its fruit until 40 days of storage. According to this study (60 days of storage), fruit coating treatment may in cases that cause the taste and flavor of alcohol and thus reduce the quality of food. This can be caused by anaerobic fermentation or respiration, which leads to the production of acetaldehyde and the development of unpleasant taste (Kahramanoglu *et al*., 2019).

CONCLUSIONS

In accordance with, and against, some studies concerning the application of AV gel, our results state that it is possible to prolong some of the quality and quantity characteristics of lime fruit by applying AV gel coating. This study proved the ability of AV gel coatings to maintain the quality characteristics of lime fruits. The AV gel treatment could not effectively control weight loss and firmness, so, the concentration of AV gel may not be appropriate in this study, and it is necessary to use more concentration. Finally, AV gel 15% treatment showed a greater ability to preserve some of the quality and quantity characteristics of lime fruit during 60 days of storage at 4±1°C and preserves acidity and prevents decay, chilling injury, browning, and MDA formation.

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REFERENCES

1. Adetunji, C. O., Afolabi, I. S. and Adetunji, J. B. 2019. Effect of Rhamnolipid-*Aloe vera* Gel Edible Coating on Post-Harvest Control of Rot and Quality Parameters of 'Agege Sweet' Orange. *Agric. Nat. Resour.* **53:** 364–372.
2. Aebi, H. 1983. Catalase. In: "*Methods in Enzymatic Analysis"*, (Ed.): H. U. Bergmeyer. Vol. 3, Academic Press, New York, PP. 276–286. https://ci.nii.ac.jp/naid/10024721256/
3. Alberio, G.R.A., Muratore, G., Licciardello, F., Giardina, G. and Spagna, G. 2015. AV Extract as a Promising Treatment for the Quality Maintenance of Minimally-Processed Table Grapes. *J. Food Sci. Technol.,* **35(2):** 299-306.
4. Altemimi, A. B., Al-Hilphy, A. R., Abedelmaksoud, T. G., Aboud, S. A.,

[DOI: 10.22034/JAST.26.1.151]

Badwaik, L. S., Noore, S. and Pratap-Singh, A. 2021. Infrared Radiation Favorably Influences the Quality Characteristics of Key Lime Juice. *Appl. Sci.* **11(6):** 2842.
5. Arowora, K., Williams, J., Adetunji, C., Fawole, O., Afolayan, S., Olaleye, O., Adetunji, J. and Ogundele, B. 2013. Effects of *Aloe vera* Coatings on Quality Characteristics of Oranges Stored under Cold Storage. *Greener J. Agric. Sci.* **3(1):** 39-47.
6. Bourtoom, T. 2008. Edible Films and Coatings: Characteristics and Properties. *Int. Food Res. J.,* **15:** 237-248.
7. Burdurlu, H.S., Koca, N. and Karadeniz, F. 2005. Degradation of Vitamin C in Citrus Juice Concentrates during Storage. *J. Food Eng.,* **74:** 211-216.
8. Chance, B., Machly, A. C. and Colowick, S. P. 1995: Assay of Catalase and Peroxidases. *Meth. Enzymol.,* **2:** 764–775.
9. Eshun, K. and He, Q. 2004. *Aloe vera*: A Valuable Ingredient for the Food, Pharmaceutical and Cosmetic Industries—A Review. *Crit. Rev. Food Sci. Nutr.,* **44:** 91-96
10. Farina, V., Passafiume, R., Tinebra, I., Scuderi, D., Saletta, F., Gugliuzza, G. and Sortino, G. 2020. Postharvest Application of *Aloe vera* Gel-Based Edible Coating to Improve the Quality and Storage Stability of Fresh-Cut Papaya. *J. Food Qual.,* Volume 2020, Article ID 8303140, 10 PP.
11. Hassanpour, H. 2015: Effect of *Aloe vera* Gel Coating on Antioxidant Capacity, Antioxidant Enzyme Activities and Decay in Raspberry Fruit. *LWT - Food Sci.* Technol., **60(1):** 495-501.
12. Kahramanoglu, I., Chen, C., Chen, J. and Wan, C. 2019: Chemical Constituents, Antimicrobial Activity, and Food Preservative Characteristics of *Aloe vera* Gel. *Agronomy*, **9(12):** 1-18.
13. Martinez-Romero, D., Alburquerque, N., Valverde, J. M., Guillen, F., Castillo, S., Valero, D. and Serrano, M. 2006: Postharvest Sweet Cherry Quality and Safety Maintenance by *Aloe vera* Treatment: A New Edible Coating. *Post. Biol. Technol.,* **39**: 93-100.
14. Martinez-Romero, D., Castillo, S., Guillen, F., Diaz-Mula, H. M., Zapata, P. J., Valeroa, D. and Serranoba, M. 2013: *Aloe vera* Gel Coating Maintains Quality and Safety of Ready-to-Eat Pomegranate Arils. *Post. Biol. Technol.,* **86:** 107–112.
15. Meng, X., Li, B., Liu, J. and Tian, S. 2008: Physiological Responses and Quality Attributes of Table Grape Fruit to Chitosan Preharvest Spray and Postharvest Coating during Storage. *Food Chem.,* **106:** 501–508.
16. Misra, H. P. and Fridovich, I. 1972: The Role of Superoxide Anion in the Autoxidation of Epinephrine and a Simple Assay for Superoxide Dismutase. *J. Biol. Chem.,* **247(10):** 3170–3175.
17. Mohebbi, M., Ansarifar, E., Hasanpour, N. and Amiryousefi, M. 2012. Suitability of *Aloe vera* and Gum Tragacanth as Edible Coatings for Extending the Shelf Life of Button Mushroom. *Food Bioproc. Tech.,* **5:** 3193-3202.
18. Muhammad, J.A., Sigh, Z. and Ahmad, S. K. H. 2009: Postharvest *Aloe vera Gel*-Coating Modulates Fruit Ripening and Quality of 'Arctic Snow' Nectarine Kept in Ambient and Cold Storage. *Int. J. Food Sci. Technol.,* **44**: 1024-1033.
19. Nakano, Y. and Sada, K. 1989. Hydrogen Peroxide Is Scavenged by Ascorbate Specific Peroxidase in Spinach Chloroplasts. *Plant Cell Physiol.,* **22(5):** 867–880.
20. Nasrin, T. A. A., Rahman, M. A., Arfin, M. S., Islam, M. N. and Ullah, M. A. 2020. Effect of Novel Coconut Oil and Beeswax Edible Coating on Postharvest Quality of Lemon at Ambient Storage. *J. Agric. Food Inf.* **2:** 1-10.
21. Passafiume, R., Gaglio, R., Sortino, G. and Farina, V. 2020. Effect of Three Different *Aloe vera* Gel-Based Edible Coatings on the Quality of Fresh-Cut "Hayward" Kiwifruits. *Foods,* **9(7):** 1-17.
22. Rehman, M. A., Asi, M. R., Hameed, A., Bourquin, L. D. 2020. Effect of Postharvest Application of *Aloe vera Gel* on Shelf Life, Activities of Anti-Oxidative Enzymes, and Quality of 'Gola' Guava Fruit. *Foods*, **9(10):** 1361.
23. Reynolds, T. and Dweck, A. C. 1999. *Aloe vera* leaf gel: a review uptake. *J. Ethnopharmacology*, **68**: 3-37.
24. Serrano, M., Guillen, F., Martinez-Romero, D., Castillo, S. and Valero, D. 2005. Chemical Constituents and Antioxidant Activity of Sweet Cherry at Different Ripening Storages. *J. Agri. Food Chem.,* **53:** 2741-2745.

[DOI: 10.22034/JAST.26.1.151]

25. Shah, S. and Hashmi, M. S. 2020. Chitosan– *Aloe vera Gel* Coating Delays Postharvest Decay of Mango Fruit. *Hortic. Environ. Biotechnol.,* **61:** 279–289.
26. Sogvar, O. B., Saba, M. K. and Emamifar, A. 2016. *Aloe vera* and Ascorbic Acid Coatings Maintain Postharvest Quality and Reduce Microbial Load of Strawberry Fruit. *Postharvest Biol. Technol.,* **114**: 29–35.
27. Valverde, J. M., Valero, D., Martinze-Romero, D., Guillen, F., Castilo, S. and Serrano, M. 2005. Novel Edible Coating Based on *Aloe vera Gel* to Maintain Table Grape Quality and Safety. *J. Agri. Food.,* **53:** 7807-7813.

اثرات بالقوه ژل آلوئه‌ورا (*Aloe vera*) بر حفظ ویژگی های کمی و کیفی میوه های لیمو (*Citrus aurantifolia* L.) در انبار سرد

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چکیده

این مطالعه با هدف بررسی اثرات دو غلظت از ژل آلوئه‌ورا (۷/۵% و ۱۵%) بر ویژگی‌های کمی و کیفی لیموترش در طول دوره انبارمانی (۲۰، ٤٠ و ٦٠ روز) انجام شد. این آزمایش به صورت یک آزمایش فاکتوریل در یک طرح کاملاً تصادفی با چهار تکرار انجام شد. پس از غوطه‌وری (۵ دقیقه) و خشک شدن، میوه‌ها در ظروف پلی‌اتیلن با چگالی پایین بسته‌بندی و در ۱±٤ درجه سانتی‌گراد و ۲±۸۵ % رطوبت نسبی به سردخانه منتقل شدند. نتایج کاهش ترشی و عطر میوه و افزایش تلخی میوه در طول دوره انبارمانی را نشان داد. بیشترین میزان آسیب سرمازدگی و پوسیدگی مربوط به کنترل بود. ژل آلوئه‌ورا ۱۵% کمترین تلخی میوه (۳۰%)، پوسیدگی و مالون‌دی‌آلدهید را نسبت به کنترل در روز ٦٠ ذخیره‌سازی داشت. ژل آلوئه‌ورا فعالیت پراکسیداز را به عنوان یک آنزیم آنتی‌اکسیدانی افزایش داد و آنزیم‌های دفاعی مانند فعالیت فنلانین آلانین آمونیالایاز را کاهش داد. حداکثر ویتامین‌ث مربوط به ژل آلوئه‌ورا ۱۵% بود. با توجه به نتایج به دست آمده، ژل آلوئه‌ورا، نمی‌تواند به طور مؤثری کاهش وزن و سفتی را کنترل کند. در طول ٦٠ روز انبارمانی در ۱±٤ درجه سانتی‌گراد، ژل آلوئه‌ورا ٪۱۵ نسبت به تیمارکنترل، شاخص کروم (۲/۰۷%) و ویتامین‌ث (۲٦/۳۷%) را افزایش و از پوسیدگی (۱۰۰%)، آسیب سرمازدگی (۲۵/۷۵%)، تلخی (٤۲/۸۵%) و افزایش مالون‌دی‌آلدهید (۳۵/۸۰%) میوه لیموترش جلوگیری کرد.

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