Changes in Quality Traits and Phytochemical Components of Blueberry (Vaccinium Corymbosum Cv. Bluecrop) Fruit in Response to Postharvest Aloe Vera Treatment

Umut Ates¹, Ali Islam¹, Burhan Ozturk¹, Erdal Aglar², Orhan Karakaya¹, and Sefa Gun¹

¹Faculty of Agriculture, Department of Horticulture, Ordu University, Ordu-Türkiye; ²Faculty of Agriculture, Department of Horticulture, Van Yüzüncü Yıl University, Van-Türkiye

ABSTRACT

The effect of Aloe vera application (33% and 66% as dipping, AV) on ‘Bluecrop’ blueberry’s (Vaccinium corymbosum) quality properties such as weight loss, respiration rate, fruit color, soluble solids content (SSC), acidity, phytochemical components (vitamin C, total phenolics, and total flavonoids) and antioxidant activity was investigated during the cold storage (at 0 ± 0.5°C and 90 ± 5% RH) for 28 days. During cold storage, significantly lower weight loss was recorded in fruit treated with AV compared to control. At the end of the cold storage, the weight loss was 20% lower in AV treated fruits and AV concentration was not effective in weight loss. On the contrary, the respiration rate (except for the 7th day) and fruit firmness were higher in these fruit. It was observed that color changes were less in AV-treated fruit during storage. In general, AV-treated fruit had significantly lower SSC, while acidity and vitamin C were higher. Moreover, 66% AV application was more effective in delaying the loss of vitamin C at the end of storage. During cold storage, 33% AV-treated fruit had significantly higher total phenolics (except day 28) and total flavonoids content compared to control. In the last two measurements of the cold storage, it was determined that fruit dipped in AV had higher antioxidant activity (both DPPH and FRAP assays) compared to control fruit. As a result, it was revealed that postharvest AV gel applications can be used as an effective postharvest tool to delay the loss of quality, the loss of phytochemical components and antioxidant activity of the blueberry fruit.

KEYWORDS

Antioxidant; color; flavonoids; phenolics; respiration rate; weight loss

Introduction

Blueberry (Vaccinium spp), which is rich in terms of bioactive compounds and minerals, is fruit species increasing production day by day (Wang et al., 2017). It has a significant effects such as anticancer, antiadiabetic, cardioprotective, antioxidant, blood vessel-softening, antimicrobial, antiproliferative, immunity-enhancing, anti-inflammatory, apoptotic and lifespan-prolonging (Ge et al., 2019). However, blueberry fruit is extremely sensitive, it can be spoiled quickly due to loss of water, mechanical damage, microbial infection and loss of nutritional value (Paniagua et al., 2014). It can be stored between 1 and 8 weeks depending on the storage conditions, the method of the harvest, disease presence, and ripening stage (Duan et al., 2011). This negatively affects the shelf life, storage, transportation and marketing processes (Deng et al., 2014). To contribute to the solution of this problem and to maintain fruit quality after harvest, the various post-harvest technologies have been
developed such as use of edible coating (Totad et al., 2019, 2020; Vieira et al., 2016), modified atmosphere packing (Chiabrando and Giacalone, 2009), irradiation treatment (Wang and Meng, 2016), acibenzolar-S-methyl treatment (Ge et al., 2019), chemical preservation (Chea et al., 2019) and acidic electrolyzed oxidizing water dipping (Chen et al., 2019). With the increasing interest in safe and quality fruit consumption, the edible coating applications such as Aloe vera (AV) and chitosan in such postharvest technologies (Khaliq et al., 2019) rise to prominence due to its biodegradable and nontoxic properties (Duan et al., 2011).

Edible coating products are rich in terms of ingredients such as nutrients, antioxidant, colorants, antibrowning agents, and antimicrobial, which can increase the safety and nutritional value of the fruit during shelf life (Rojas-Graü et al., 2008). Tezotto-Uliana et al. (2014) reported that edible coating applications reduced postharvest respiration rate, the loss of moisture, transpiration rate and dissolved matter transport, preserved fruit firmness, and delayed senescence. Although there is no information about the negative effect of AV on fruit quality in cold storage when it is applied as a coating treatment, but in application, the thickness of the edible coating material such as AV and chitosan is significant. Thick coating on fruit surface lead to undesirable barrier that restrict the exchange of respiratory gas (CO₂ and O₂). Subsequently, the condition will accumulate more carbon dioxide, acetaldehyde and ethanol in the fruit. Accumulation of ethanol and acetaldehyde resulted to fermentation and give off-flavor that deteriorating the fruit quality (Porat and Fallik, 2003).

It has been reported that AV gel, which is used as a natural and environmentally friendly coating material obtained from the leaves of the Aloe vera plant, delay maturation and maintain postharvest quality in fruit species such as pomegranate (Martínez-Romero et al., 2013), kiwifruit (Benitez et al., 2013), grapes (Chauhan et al., 2014), raspberry (Hassanpour, 2015), plum, peach (Guillén et al., 2013), blueberry (Vieira et al., 2016), papaya (Mendy et al., 2019), cherry laurel (Ozturk et al., 2019a), sapodilla (Khaliq et al., 2019) and orange (RasouRasouli et al., 2019). Limited research has been conducted on the effect of AV application on postharvest quality losses in blueberry fruit.

The aim of our study based on this idea is to determine the effects of postharvest AV application on the quality properties and phytochemical components of blueberries during the cold storage period.

**Materials and Methods**

**Plant Material**

Blueberry fruit (Vaccinium corymbosum cv. ‘Blucrop’) were hand-harvested (9 August 2016) by farm pickers in 80% dark purple color stage (harvest index) from an orchard belonging to UMKAN Company, Ordu, Turkey. Soil texture in the orchard is clay loam with 26.10% sand, 10.87% clay and 63.03% loam and 2.76% organic matter. The soil pH and lime is 4.94% and 0.16%, respectively. Standard cultural practices (pruning, fertilization and irrigation) were carried out during the experiments. The fruit were immediately transferred at 12 ± 1°C and 75 ± 5.0% RH for 1.0 h by frigorific truck to Postharvest Laboratory of Horticulture Department of Ordu University, Ordu, Turkey.

**Experimental Design and Treatments**

Initially, blueberry fruit with uniform shape, size and color and free from visual symptoms of any disease or blemishes were selected. Then, fruit were randomly divided into three groups. The 1st group (control) fruit were dipped only into distilled water. The 2nd and 3rd group fruit were dipped into 33% and 66% Aloe vera (AV)-including solution (Forever living products, Turkey) for 5 second (Ozturk and Aglar, 2019), respectively and dried at 20 ± 1°C and 80 ± 5% RH for 30 min.

Then, each group of fruit were randomly placed into 12 commercial polyethylene terephthalate (PET) vented clamshell containers (each of about 300 g fruit) with four perforations of 3 mm² [500 g-capacity, (Vempi, Manisa, Turkey)], which were snap-fitted. Fruit were subjected to pre-cooling at 4 ± 0.5°C and 90 ± 5% RH for 24 h, after that fruit were kept at 0 ± 0.5°C and 90 ± 5%
RH for 28 d. Measurements and analyses were performed on 7, 14, 21 and 28th days (d) of cold storage. In each measurement period, 3 PET-clamshells were taken for each treatment. Each PET-clamshells represented a replicate. The quality characteristics mentioned below were determined in the fruit.

**Weight Loss**

At the beginning of cold storage, initial weights (Wi) of the fruit were determined by a digital scale with a precision of 0.01 g (Radwag, Poland). Then, on d 7, 14, 21 and 28 of the storage, final weights (Wf) were determined. The weight loss (WL) that occurs in fruit was based on the weight at the beginning of each measurement period and determined as a percentage through the equation given below (Eq.1).

\[
WL = \frac{W_i - W_f}{W_i} \times 100
\]  

**(1)**

**Respiration Rate**

The 2 L airtight chambers were used to measure respiration rate. The chambers were fitted with a rubber septum and 50 g fruit were sealed in each chamber at 20 ± 1°C temperature and 90% RH for an h. The chambers were then connected to a gas analyzer (Vernier, Oregon, USA) and the amount of CO2 produced by the fruit was considered as the respiration rate. Results were expressed as nmol CO2 kg\(^{-1}\) s\(^{-1}\).

**Fruit Firmness**

Twenty fruit from each replication were used for firmness measurements. The measurements were made on two opposite sides of the equatorial part of the fruit through a portable digital durometer (nondestructive device, Agrosta* 100 Field, France) with a flat cylindrical tip and with a diameter of 4.1 mm. The tip of the durometer was slightly and longitudinally pressed into the outer skin of the fruit, and the results were expressed as Durofel Units (%). In Durofel Units, 0 indicates that the fruit is very soft and 100 is very firm (Ozturk et al., 2019b).

**Color Characteristics**

Color measurements were performed with a color meter (Konica Minolta, CR–400, Japan). Color data of blueberry fruit were presented according to CIE system (Commission Internationale de l’Eclairage). Color characteristics were measured at two different points in the equatorial part of 20 fruit randomly selected from each replicate. 3-D color space was defined with the aid of L*, a* and b* values. Equations in parenthesis were used to calculate chroma \[C* = (a^2 + b^2)^{1/2}\] and hue angle \[h^\circ = \tan^{-1}b^*/a^*\].

**Soluble Solids Content, Titratable Acidity and Vitamin C**

Fifty fruits in each replication were washed with distilled water. The fruit were homogenized by a blender (Model No. Promix HR2653 Philips, Turkey). Then, the homogenate was filtered through a cheesecloth, and the juice was obtained. Soluble solids content (SSC) was measured with a portable digital refractometer (Atago PAL-1, USA) and expressed as a percentage (%). For titratable acidity measurement, 10 mL juice was taken and 10 mL distilled water was added on. Then, 0.1 N NaOH (sodium hydroxide) was added until the pH of the solution reached to 8.2. Based on the amount of NaOH consumed in titration, titratable acidity was determined and expressed as g malic acid kg\(^{-1}\). For
vitamin C measurement, 0.5 mL juice was taken, and 5 mL of 0.5% oxalic acid was added on it. The ascorbic acid test strip (Catalog no: 116981, Merck, Germany) was then taken from a collapsible sealed gas-tight tube. Reflectometer (Merck RQflex plus 10) was started. The test strip was plunged into the solution for 2 seconds, then removed from the solution. It was then held for 8 seconds, and reading was done at the end of the 15th second. Results were presented as g kg⁻¹ (Ozturk et al., 2019b).

**Total Phenolics, Total Flavonoids, Antioxidant Activity**

During each measurement period, Fifty fruit taken from each replication were first washed with distilled water. The fruit were homogenized by a blender (Model No. Promix HR2653 Philips, Turkey). About 30 mL of homogenate was taken and placed into a 50 ml falcon tube. The prepared tubes were kept at −20 C until the time of analyses.

Before the analyses, the frozen samples were dissolved under room temperature (21°C). Pulp and juice were separated from each other by a centrifuge at 12.000 × g at 4°C for 35 min. The resultant filtrate was used to determine the content of total phenolics, total flavonoids, antioxidant activity.

Spectrophotometric measurements for total phenolics, total flavonoids and antioxidant activity were performed at the UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan). Total phenolics were determined in accordance with the method described by Singleton and Rossi (1965) and was expressed as g GAE (gallic acid equivalent) kg⁻¹ fresh weight (fw). Total flavonoids were measured according to the method described by Chang et al. (2002) and was expressed as g QE (quercetin equivalent) kg⁻¹ fw. The antioxidant activity of blueberry fruit was determined according to two different procedures of DPPH (Aglar et al., 2017) and Ferric Ions (Fe⁺³) Reducing Antioxidant Power (FRAP) (Benzie and Strain, 1996), and the results were expressed in mmol Trolox equivalent (TE) kg⁻¹ fw.

**Statistical Analysis**

Whether the data was normally distributed was checked by Kolmogorov-Smirnov Test. Homogeneity control of the group/subgroup variances was confirmed by Levene’s test. After the variance analysis of the data, Tukey’s multiple-comparison test was used to check whether there were significant differences between treatments. The statistical analyses were performed by using SAS software (SAS 9.1 version, USA).

**Results**

**Weight Loss**

It was determined that the AV application reduced the weight losses in the cold storage, and in the measurements made at 1-week intervals during the storage, there were statistically significant differences in the weight losses in the fruit of the AV and control applications. However, increasing the AV concentration did not occur changes in the effect (Figure 1).

**Respiration Rate and Fruit Firmness**

The respiration rate increased in the measurements made 1 week after harvest while it was determined that a decrease in the respiration rate occurred with increasing storage period. The changes in respiration rate during cold storage were more in the control application, but AV applications had the same respiration rate. The effect of AV application on respiration rate during cold storage was significant. In all measurement periods, significant differences occurred between AV and control applications. The
respiration rate was higher in the fruit of control application on the 7th day of the cold storage, whereas higher respiration rate in AV-treated fruit at other measurement periods was recorded. However, the changes in respiration rate did not occur depending on AV concentration (Figure 2).

It was determined that AV application was effective in maintaining of the fruit firmness during the cold storage. While the lowest fruit firmness values were recorded in the fruit of control application on the 7th day of cold storage, the difference between AV concentrations was not significant. However, there were statistically significant differences between all applications on 14th days of cold storage. The highest fruit firmness value was recorded with AV, 66% application, but the lowest values were obtained with the control application (Figure 2).

**Fruit Color**

In the study, a decrease in all color values (L, hue angle, chroma) occurred in proportion to the storage time. However, it was determined that this decrease was higher in the fruit of control application, but the color changes were less in AV-treated fruit. The higher L and hue angle values were recorded with AV application during all measurement periods, there were no statistically significant differences between AV concentrations. However, there was an inconsistency in the effect in chroma values. The fact that, it was determined that the effect of AV application was not significant on 7th day of the cold storage, and the significant differences occurred between applications on other measurement days. During cold storage, the highest Chroma values were measured in 66% AV-treated fruit. The effect of AV concentration on chroma values was significant on 14th and 21st days of the cold storage. It was determined that the change in chroma values was less with increasing concentration. AV concentration was not effective at the end of the cold storage (Figure 3).

**Soluble Solids Content, Titratable Acidity, and Vitamin C**

AV application was effective on the increase in SSC during cold storage, but there was no statistically significant difference between 33% and 66% AV applications. The highest SSC values on all measurement days were determined in control application (Figure 4). It was determined that AV application was effective in delaying the decrease in titratable acidity during cold storage, but there were no significant differences between AV concentrations (Figure 4). Vitamin C ratio decreased in proportion to the storage period. The statistically significant differences occurred between
applications in terms of vitamin C content in all measurement periods. In total, 66% AV-treated fruit had the highest vitamin C on all measurement days. In the measurements on 7th and 21st days of the cold storage, the vitamin C ratios of AV 33% and control applications were similar whereas lower vitamin C values were recorded with control application on 14th day of and at the end of cold storage (Figure 4).

**Total Phenolics, Total Flavonoids, and Antioxidant Activities**

The total amount of phenolics increased significantly in proportion to fruit maturity during storage. It was determined that the effect of AV application on total phenolic content at the cold storage is significant and varies depending on AV concentration. At the end of the cold storage, the highest total phenolic values were recorded with AV 66% application. In the measurements on 7th, 14th and 21st days of the cold storage, 33% AV-treated fruit have a higher total phenolic content while the total phenolic content of the fruit of the other two applications (AV 66 and control) was similar.
At the end of the cold storage, it was determined that the total flavonoid content increased significantly compared to the amount measured at harvest, and the effect of AV treatment on this increase was significant and changes occurred in this effect depending on the application concentration. At the end of the cold storage, there were statistically significant differences among

(Figure 5).
Figure 4. Effect of Aloe vera treatments on soluble solids content (SSC), titratable acidity and vitamin C of blueberry fruit (Vaccinium corymbosum cv. Bluecrop) during storage at 0°C and 90% RH. n = 9 for the SSC, acidity and vitamin C (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at P < .05. Vertical bars indicate the standard errors.
all application and the highest value was recorded with AV 66% application, while the fruit of the control application had the lowest total flavonoid content. In the measurements on 7th, 14th and 21st days of the cold storage, there was no difference between the values of AV 66 and control applications in terms of total flavonoid amount, but the highest total flavonoid content was measured in in 33% AV-treated fruit (Figure 5). It was determined that an increase in antioxidant activity, which was detected as DPPH and FRAP during cold storage, occurred and AV-treated fruit had higher antioxidant activity. On the DPPH and FRAP values on 7th, 21st and 28th days of the cold storage, there was no effect of AV concentration, but in the 14th days of the cold storage, antioxidant activity changed depending on the AV concentration. In this measurement period, while the highest DPPH and FRAP values were obtained in 66% AV-treated fruit, there were no statistically significant differences among other treatments (Figure 5).

Discussion

Weight loss causes significant economic problems by leading structural and visual quality deterioration in the fruit (Miller et al., 1993). As reported in previous studies (Chen et al., 2017; Duan et al., 2011; Liu et al., 2019), in this study, weight loss increased with increasing storage time. AV applications delayed the increasing in weight loss. Many other researchers have also determined that edible coating materials are effective in reducing weight loss in fruit at the cold storage (Ali et al., 2019; Carvalho et al., 2016; Chiabrando and Giacalone, 2015; Ozturk et al., 2019a). The effect of AV
application on weight loss can be explained by the fact that the AV gel (Khaliq et al., 2019), which forms a semi-permeable barrier on the fruit surface, reduces moisture loss and dehydration in the fruit (Sogvar et al., 2016).

It is generally known that edible coating applications such as AV and chitosan reduce the respiration rate by limiting oxygen and carbon dioxide gas transfer (Mahajan et al., 2018; Tezotto-Uliana et al., 2014). In this study, the reducing effect of AV on respiration was seen only on day of storage. In the subsequent date, respiration rate of fruits coated with AV was higher than those of control fruit. This situation can be explained by findings of Falagan et al. (2020) who stated that the low O₂ concentration may induce an abiotic stress and consequently an increase in CO₂ production in blueberry fruits.

Fruit firmness, which is the most significant quality trait that determines the storability of the product in processes such as postharvest processing, storage and marketing (Chiabrando and Giacalone, 2017), affects consumer preferences (Chen et al., 2017). Similar to the results obtained from previous studies on blueberry (Mannozzi et al., 2018) and other fruit species (Khaliq et al., 2019; Ozturk et al., 2019b; Vieira et al., 2016), AV treatments in this study also reduced firmness the loss during storage. Fruit softening occurs due to the degradation of the cell wall components such as pectin substances, hemicellulose and cellulose (Wang et al., 2015) and the decrease in turgor pressure in the cell (Mannozzi et al., 2018). It was reported that AV application delayed the fruit softening by reducing the cell wall enzyme activity (Khaliq et al., 2019) and maintain the cell turgor pressure by limiting transpiration (Mannozzi et al., 2018).

During the storage period, L*, chroma and hue values decreased regularly in both control and AV treatments. This decrease was significantly slowed down by AV treatments. Hoagland and Parris (1996) reported that the edible coating materials affected the coloring of the fruit because of causing changes in fruit surface properties and limiting the ripening process. In previous studies, it was reported that the edible coating applications such as alginate (Chiabrando and Giacalone, 2015), parka (Ag lar et al., 2017) in sweet cherry and AV in mango (Carrillo-Lopez et al., 2000) delayed coloration during cold storage. Mannozzi et al. (2018) reported that edible coating application based on polysaccharide such as alginate and pectin decreased color changes in fruit in blueberry after harvest. Phenolic compounds, especially anthocyanins, play a significant role in fruit color formation (Cheynier, 2012). As the anthocyanin content, which increases with ripening, decomposes rapidly after harvest, it decreases in proportion to the storage period (Ali et al., 2019). The breakdown of the vacuoles in cell causes the degradation of the anthocyanins and loss of the cellular compartmentation (Jiang et al., 2018). Ali et al. (2019) reported that the AV-applied fruit had higher anthocyanin pigments as cellular compartmentation on these fruit was conserved, and as a result, the fruit color is maintained.

SSC is a significant quality trait that is taken as a criterion in determining the ripening stage of fruit. As fruit ripeness progresses, SSC increases as a result of hydrolysis of undissolved polysaccharides in simple sugars. Hassanpour (2015) reported that there was an increase in the rate of SSC with the increase of the metabolic activities in raspberry fruit during the maturity stage, then the SSC decreased after 8 weeks of storage, and AV-treated fruit had higher SSC. Contrary to these results, in our study, it was observed that an increase in SSC occurred in proportion to the storage time and AV application limited the increase in SSC at the cold storage. In previous studies, it has been determined that AV application is effective in maintaining the rate of SSC in storage in grapes (Chauhan et al., 2014), strawberry (Zafari et al., 2015) and plum (Martinez-Romero et al., 2017). Edible coating applications slow the respiration and maturation by controlling the exchange of important gases such as oxygen, carbon dioxide and ethylene (Embuscado and Huber, 2009). The lower SSC in fruit treated with AV was explained by its effect on the decrease of respiration rate (Khaliq et al., 2019).

At harvest, fruit have the highest titratable acidity, but after harvest titratable acidity decreases gradually (Reque et al., 2014). In our study, the titratable acidity of the fruit decreased depending on the storage period. However, titratable acidity of AV-treated fruit was higher at the end of the cold storage. It can be said that AV application is effective in maintaining the titratable acidity in storage.
Bahmani et al. (2015), support our study results, reported that the titratable acidity in the fruit decreased due to high respiration after harvest, and Valverde et al. (2005) found that AV application decreases the respiration rate by regulating the inner atmosphere in the fruit and consequently slows down the decrease of titratable acidity in storage. However, Serrano et al. (2006) and Reque et al. (2014) reported that AV application had no effect on the change in titratable acidity in storage. But, Harb et al. (2010) found that oxygen uptake in fruit with AV application is limited, thus, the respiration slows down and the titratable acidity of these fruits is higher.

Vitamin C is a significant antioxidant that prevents the harmful effects of reactive oxygen species during ripening. Vitamin C content in the fruit varies depending on the maturity stage and storage period. Vitamin C content decreases in storage and AV application delays this decrease (Khaliq et al., 2019). In accordance with this explanation in our study, a decrease in vitamin C content occurred in storage and vitamin C content in AV-treated fruit was higher. In studies conducted, it has been reported that AV application is effective in maintaining vitamin C content at cold storage in strawberry (Zafari et al., 2015), orange (Radi et al., 2017), raspberry (Hassanpour, 2015) and sweet cherry (Valverde et al., 2005). Vitamin C loss in storage can be explained by increasing the activity of ascorbic acid oxidase and phenoloxidase enzymes, those activities are affected by oxygen content (Zhou et al., 2008). Since AV-treated fruit have lower gas permeability, the respiration rate is limited and all metabolism slower (Hassanpour, 2015).

Depending on the fruit species, different results have been reported regarding the change pattern of total phenol content during the storage time. Khaliq et al. (2019) determined that the total phenolic content of sapodilla fruits decreased in the cold storage was maintained by AV treatment. On the other hand, Aglar et al. (2017) reported that an increase in the bioactive compound content such as flavonoid and phenolics occurred as propotional the cold storage time in sweet cherry. In this study, the total phenolics and flavonoids and the antioxidant capacity associated with them showed a fluctuating pattern according to the measurement dates. Such an irregular change in the total phenol content and antioxidant capacity of blueberry during the storage period was also reported by Li et al. (2019). Different findings in literature on the change in total phenol content during the storage process and fluctuations in the measurement date reveal that more detailed studies should be conducted on the postharvest metabolism of such substances.

Although different results were obtained according to the measurement date, at the end of 28 days of storage, the antioxidant capacities of the fruits treated with AV were higher than those of the control fruits. In previous studies, it has been reported the fruit treated with coating material in fruit species such as guava (Nair et al., 2018), apple (Synowiec et al., 2014), raspberry (Hassanpour, 2015), grapes (Serrano et al., 2006) and sapodilla (Khaliq et al., 2019) have higher antioxidant activity at the end of cold storage. Ali et al. (2019), have reported that AV-coated litchi fruits have higher bioactive compounds content during cold storage, and AV coating possibly conserved cellular compartmentation of litchi peel and maintained higher bioactive compounds pigments. AV gel contains many bioactive compounds (Ni et al., 2004), but aloe-emodin is one of the main building blocks that contribute to antioxidant activity (Ni et al., 2004). The increase in antioxidant activity with AV application can be explained by the effect of the aloe-emodin compound contained in the AV gel. Also, the present of organic acids, proteins, phenolic compounds, vitamins, minerals and amino acids in Aloe vera gel (Boudreau and Beland, 2006) can explain the increasing on antioxidant activity at cold storage.

As a result, AV application was effective in maintaining fruit quality traits during cold storage in blueberry. During storage, it was observed that the weight and vitamin C loss was lower in AV applied fruits, the fruit firmness was preserved and the content of bioactive compounds in these fruits was higher. In the study, at the cold storage, with AV application, it was revealed that AV application can be used to prolong the postharvest life in blueberry.
Compliance with Ethical Standards

The authors declare that they have no conflict of interest.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

ORCID

Umut Ates http://orcid.org/0000-0002-8050-0616
Ali Islam http://orcid.org/0000-0002-2165-0711
Burhan Ozturk http://orcid.org/0000-0002-0867-3942
Erdal Aglar http://orcid.org/0000-0002-4199-5716
Orhan Karakaya http://orcid.org/0000-0003-0783-3120
Sefa Gun http://orcid.org/0000-0002-9516-386X

References

Aglar, E., B. Ozturk, S. Koc Guler, O. Karakaya, S. Uzun, and O. Saracoglu. 2017. Effect of modified atmosphere packaging and Parka treatments on fruit quality characteristics of sweet cherry fruits (Prunus avium L. 0900 Ziraat) during cold storage and shelf life. Sci. Hortic. 222:162–168. doi: 10.1016/j.scienta.2017.05.024.
Ali, S., A.S. Khan, A. Nawaz, M.A. Anjum, S. Naz, S. Ejaz, and S. Hussain. 2019. Aloe vera gel coating delays postharvest browning and maintains quality of harvested litchi fruit. Postharvest Biol. Technol. 157:110960. doi: 10.1016/j.postharvbio.2019.110960.
Bahmani, M.S., M. Yusefzadi, H. Hasanzadeh, and M. Yektankhodaei. 2015. The effect of thyme essential oil, calcium chloride and storage time on quantity and quality of sapodilla fruit (Manilkara zapota L.) var. Oval. Int. J. Agric. Crop Sci 8:221–226.
Benitez, M.S., M.H. Hersh, R. Vilgalys, and J.S. Clark. 2013. Pathogen regulation of plant diversity via effective specialization. Trend Ecol. Evol 28(12):705–711. doi: 10.1016/j.tree.2013.09.005.
Benzie, I.F., and J.J. Strain. 1996. The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: The FRAP assay. Anal. Biochem. 239:70–76. doi: 10.1006/abio.1996.0292.
Boudreau, M.D., and F.A. Beland. 2006. An evaluation of the biological and toxicological properties of Aloe barbadensis (Miller), Aloe vera. J. Environ. Sci. Health C. 24:103–154. doi: 10.1080/10590500600614303.
Carrilo-Lopez, A., F. Ramirez-Bustamante, J.B. Valdez-Torrez, R. Rojas-Villegas, and E.M. Yahia. 2000. Ripening and quality changes in Mango fruit as affected by coating with an edible film. J. Food Qual. 23:479–486. doi: 10.1111/j.1745-4557.2000.tb00573.x.
Carvalho, R.L., M.F. Cabral, T.A. Germano, W.M. de Carvalho, I.M. Brasil, M.I. Gallão, C.F.H. Moura, M.M.A. Lopes, and M.R.A. de Miranda. 2016. Chitosan coating with trans-cinnamaldehyde improves structural integrity and antioxidant metabolism of fresh-cut melon. Postharvest Biol. Technol. 113:29–39. doi: 10.1016/j.postharvbio.2015.11.004.
Chang, C.C., M.H. Yang, H.M. Wen, and J.C. Chern. 2002. Estimation of total flavonoid content in propolis by two complementary colorimetric methods. J. Food Drug Anal 10:178–182.
Chauhan, S., K.C. Gupta, and M. Agrawal. 2014. Application of biodegradable Aloe vera gel to control post harvest decay and longer the shelf life of grapes. Int. J. Curr. Microbiol. Appl. Sci. 3(3):632–642.
Chauhan, O.P., C. Nanjappa, N. Ashok, N. Ravi, N. Roopa, and P.S. Raju. 2015. Shellac and Aloe vera gel based surface coating for shelf life extension of tomatoes. J. Food Sci. Technol. 52(2):200–1205. doi: 10.1007/s13197-013-1035-6.
Chea, S., D.J. Yu, J. Park, H.D. Oh, S.W. Chung, and H.J. Lee. 2019. Preharvest β-aminobutyric acid treatment alleviates postharvest deterioration of ‘Bluecrop’ highbush blueberry fruit during refrigerated storage. Sci. Hortic. 246:95–103. doi: 10.1016/j.scienta.2018.10.036.
Chen, Y.H., Y. Hung, M. Chen, M.S. Lin, and H.T. Lin. 2019. Enhanced storability of blueberries by acidic electrolyzed oxidizing water application may be mediated by regulating ROS metabolism. Food Chem 270:229–235.
Chen, Y.H., J.Z. Sun, H.T. Lin, Y.C. Hung, S. Zhang, and Y.F. Lin. 2017. Paper based 1-MCP treatment suppresses cell wall metabolism and delays softening of Huanghua pears during storage. J. Sci. Food Agric. 97:2547–2552. doi: 10.1002/jsfa.8072.
Cheynier, V. 2012. Phenolic compounds: From plants to foods. Phytochem. Rev 11(2):153–177.
Chiarando, V., and G. Giacalone. 2009. Quality changes of blueberry fruit under modified atmosphere packaging. Ind. Aliment 48(497):15–20.
Chiarando, V., and G. Giacalone. 2015. Anthocyanins: Phenolics and antioxidant capacity after fresh storage of blueberry treated with edible coatings. Int. J. Food Sci. Nutr 66(3):248–253. doi: 10.3109/09637486.2014.986075.

Chiarando, V., and G. Giacalone. 2017. Shelf-life extention of highbush blueberry using 1-methylcyclopropene stored under air and controlled atmosphere. Food Chem. 126:1812–1816. doi: 10.1016/j.foodchem.2010.12.032.

Deng, J., Z.J. Shi, X.Z. Li, and H.M. Liu. 2014. Effects of cold storage and 1- methylcyclopropene treatments on ripening and cell wall degradation in rabbiteye blueberry (Vaccinium ashei) fruit. Food Sci. Technol. Int 75:1–12.

Duan, J., R. Wu, B.C. Strik, and Y. Zhao. 2011. Effect of edible coatings on the quality of fresh blueberries (Duke and Elliott) under commercial storage conditions. Postharvest Biol. Technol. 59:71–79. doi: 10.1016/j.postharvbio.2010.08.006.

Embuscado, M.E., and K.C. Huber. 2009. Edible films and coatings for food applications 7. p. 211–244. New York: Springer.

Falagan, N., T. Miclo, and L.A. Terry. 2020. Graduated controlled atmosphere: A novel approach to increase “Duke” blueberry storage life. Front. Plant Sci. 11:221. doi: 10.3389/fpls.2020.00221.

Ge, Y.H., X. Li, C.Y. Li, Q. Tang, B. Duan, Y. Cheng, J.R. Li, and J. Li. 2019. Effect of sodium nitroprusside on antioxidative enzymes and the phenylpropanoid pathway in blueberry fruit. Food Chem. 295:607–612. doi: 10.1016/j.foodchem.2019.05.160.

Guillén, F., H.M. Díaz-Mula, P.J. Zapata, D. Valero, M. Serrano, S. Castillo, and D. Martínez-Romero. 2013. Aloe arborescens and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest Biol. Technol. 83:54–57. doi: 10.1016/j.postharvbio.2013.03.011.

Harb, J., B. Khraiwesh, J. Streif, R. Reski, and W. Frank. 2010. Characterization of blueberry monodehydroascorbate reductase gene and changes in levels of ascorbic acid and the antioxidative capacity of water soluble antioxidants upon storage of fruits under various conditions. Sci. Hortic. 125:390–395. doi: 10.1016/j.scienta.2010.04.031.

Hassanpour, H. 2015. Effect of Aloe vera gel coating on antioxidant capacity, antioxidant enzyme activities and decay in raspberry fruit. LWT-Food Sci. Technol. 60:495–501. doi: 10.1016/j.lwt.2014.07.049.

Hoagland, P.D., and N. Parris. 1996. Chitosan/pectin laminated films. J. Agric. Food Chem 44(7):1915–1919. doi: 10.1021/jf950162s.

Jiang, X., H. Lin, J. Shi, S. Neethirajan, Y. Lin, Y. Chen, Y. Lin, and Y. Lin. 2018. Effects of a novel chitosan formulation treatment on quality attributes and storage behavior of harvested litchi fruit. Food Chem. 252:134–141. doi: 10.1016/j.foodchem.2018.01.095.

Khaliq, G., M. Ramzan, and A.H. Baloch. 2019. Effect of Aloe vera gel coating enriched with Fagonia indica plant extract on physicochemical and antioxidant activity of sapodilla fruit during postharvest storage. Food Chem. 286:346–353. doi: 10.1016/j.foodchem.2019.01.135.

Li, H., A. James, X. He, M. Zhang, Q. Cai, and Y. Wang. 2019. Effect of hypobaric treatment on the quality and reactive oxygen species metabolism of blueberry fruit at storage. CyTA-J. Food 17(1):937–948. doi: 10.1080/19476337.2019.1674925.

Liu, B., K. Wang, X. Shu, J. Liang, X. Fan, and L. Sun. 2019. Changes in fruit firmness, quality traits and cell wall constituents of two highbush blueberries (Vaccinium corymbosum L.) during postharvest cold storage. Sci. Hortic. 246:557–562. doi: 10.1016/j.scienta.2018.11.042.

Mahajeran, B.C., R. Tandon, S. Kapoor, and M.K. Sidhu. 2018. Natural coatings for shelf-life enhancement and quality maintenance of fresh fruits and vegetables-A Review. J. Postharvest Technol 6:12–26.

Mannozzi, C., U. Tylewicz, F. Chinnici, L. Siroli, F. Rocculia, M. Dalla Rosa, and S. Romanì. 2018. Effects of chitosan based coatings enriched with procyanidin by-product on quality of fresh blueberries during storage. Food Chem. 251:18–24. doi: 10.1016/j.foodchem.2018.01.015.

Martínez-Romero, D., S. Castillo, F. Guillén, H.M. Díaz-Mula, P.J. Zapata, D. Valero, and M. Serrano. 2013. Aloe vera gel coating maintains quality and safety of ready-to-eat pomegranate arils. Postharvest Biol. Technol. 86:107–112. doi: 10.1016/j.postharvbio.2013.06.022.

Martínez-Romero, D., P.J. Zapata, F. Guillén, D. Paladines, S. Castillo, D. Valero, and M. Serrano. 2017. The addition of rosehip oil to Aloe gels improves their properties as postharvest coatings for maintaining quality in plum. Food Chem. 217:585–592. doi: 10.1016/j.foodchem.2016.09.035.

Mendy, T.K., A. Misran, T.M.M. Mahmud, and S.I. Ismail. 2019. Application of Aloe vera coating delays ripening and extend the shelf life of papaya fruit. Sci. Hortic. 246:769–776. doi: 10.1016/j.scienta.2018.11.054.

Miller, W.R., R.E. McDonald, and T.E. Cracker. 1993. Quality of two Florida blueberry cultivars after packaging and storage. HortScience 28:144–147.

Nair, M.S., A. Saxena, and C. Kaur. 2018. Effect of chitosan and alginate based coatings enriched with pomegranate peel extract to extend the postharvest quality of guava (Psidium guajava L.). Food Chem. 240:245–252. doi: 10.1016/j.foodchem.2017.07.122.

Ni, Y., D. Turner, K.M. Yates, and I. Tizard. 2004. Isolation and characterization of structural components of Aloe vera L. leaf pulp. Int. Immunopharmacol 4(14):1745–1755. doi: 10.1016/j.intimp.2004.07.006.

Ozturk, B., and E. Aglar. 2019. Effects of modified atmosphere packaging (MAP) and Aloe vera treatments on quality characteristics of cornelian cherry fruits during cold storage. Academic J. Agric 8(1):1–8.
Ozturk, B., O. Karakaya, K. Yldz, and O. Saracoglu. 2019a. Effects of Aloe vera gel and MAP on bioactive compounds and quality attributes of cherry laurel fruit during cold storage. Sci. Hortic. 249:31–37. doi: 10.1016/j.scienta.2019.01.030.

Ozturk, A., K. Yldz, B. Ozturk, O. Karakaya, S. Gun, S. Uzun, and M. Gundogdu. 2019b. Maintaining postharvest quality of medlar (Mespilus germanica) fruit using modified atmosphere packaging and methyl jasmonate. LWT-Food Sci. Technol. 111:117–124. doi: 10.1016/j.lwt.2019.05.033.

Paniagua, A.C., A.R. East, and J.A. Heyes. 2014. Interaction of temperature control deficiencies and atmosphere conditions during blueberry storage on quality outcomes. Postharvest Biol. Technol. 95:50–59. doi: 10.1016/j.postharvbio.2014.04.006.

Porat, R., and E. Fallik. 2003. Production of off-flavours in fruit and vegetables under fermentative conditions, p. 150–164. In: B. Bruckner and S. Wylie (eds.). Food science technology and nutrition. Woodhead Publishing Limited, Israel.

Radi, M., E. Firouzi, H. Akhavan, and S. Amiri. 2017. Effect of gelatin-based edible coatings incorporated with Aloe vera and black and green tea extracts on the shelf life of fresh-cut oranges. J. Food Qual 10:9764650.

Rasouli, M., M.K. Saba, and A. Ramezanian. 2019. Inhibitory effect of salicylic acid and Aloe vera gel edible coating on microbial load and chilling injury of Orange fruit. Sci. Hortic. 247:27–34. doi: 10.1016/j.scienta.2018.12.004.

Reque, P.M., R.S. Steffens, A. Jablonski, S.H. Flores, A.O. Rios, and E.V. de Jong. 2014. Cold storage of blueberry (Vaccinium spp.) fruits and juice: Anthocyanin stability and antioxidant activity. J. Food Compost. Anal. 33:111–116. doi: 10.1016/j.jfca.2013.11.007.

Rojas-Graü, M.A., M.S. Tapia, and O. Martín-Belloso. 2008. Using polysaccharide-based edible coatings to maintain quality of fresh-cut Fuji apples. LWT-Food Sci. Technol. 41(1):139–147. doi: 10.1016/j.lwt.2007.01.009.

Serrano, M., J. Miguel, F. Guillen, S. Castillo, D. Martinez-Romero, and D. Valero. 2006. Use of Aloe vera gel coating preserves the functional properties of table grapes. J. Agr. Food Chem. 54:3882–3886. doi: 10.1021/jf060168p.

Singleton, V.L., and J.L. Rossi. 1965. Colorimetry of total phenolics with phomophombydic-phosphotungstic acid reagents. Am. J. Enol. Vitic 16:144–158.

Sogvar, O.B., M.K. Saba, and A. Emamifar. 2016. Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. Postharvest Biol. Technol. 114:29–35. doi: 10.1016/j.postharvbio.2015.11.019.

Synowiec, A., M. Gniewosz, K. Krasniewska, J.L. Przybyl, K. Baczek, and Z. Weglarz. 2014. Antimicrobial and antioxidant properties of pullulan film containing sweet basil extract and an evaluation of coating effectiveness in the prolongation of the shelf life of apples stored in refrigeration conditions. Innov. Food Sci. Emerg. Technol. 23:171–181. doi: 10.1016/j.ifset.2014.03.006.

Tezotto-Ulana, J.V., G.P. Fargoni, G.M. Geerdink, and R.A. Kluge. 2014. Chitosan applications pre-or postharvest prolong raspberry shelf-life quality. Postharvest Biol. Technol. 91:72–77. doi: 10.1016/j.postharvbio.2013.12.023.

Totad, M.G., R.R. Sharma, S. Sethi, and M.K. Verma. 2019. Effect of edible coatings on ‘Misty’ blueberry (Vaccinium corymbosum) fruits stored at low temperature. Acta Physiol. Plant. 41:183–190. doi: 10.1007/s11738-019-2973-z.

Totad, M.G., R.R. Sharma, S. Sethi, and M.K. Verma. 2020. Effect of edible coatings on quality of blueberry fruits under supermranet storage conditions. Indian J. Agric. Sci 90(4):780–783.

Valverde, J.M., D. Valero, and D. Martinez-Romero. 2005. Novel edible coating based on Aloe vera gel to maintain pistachio quality. J. Agric. Food Chem 53(3):7807–7813. doi: 10.1021/jf050962v.

Vieira, J.M., M.L. Flores-López, D.J. de Rodríguez, M.C. Sousa, A.A. Vicente, and J.T. Martins. 2016. Effect of chitosan–Aloe vera coating on postharvest quality of blueberry (Vaccinium corymbosum) fruit. Postharvest Biol. Technol. 116:88–97. doi: 10.1016/j.postharvbio.2016.01.011.

Wang, H.L., X.B. Guo, X.D. Hu, T. Li, X. Fu, and R.H. Liu. 2017. Comparison of phytochemical profiles, antioxidant and cellular antioxidant activities in different varieties of blueberry (Vaccinium Spp.). Food Chem. 217:773–781. doi: 10.1016/j.foodchem.2016.09.002.

Wang, L., P. Jin, J. Wang, L.L. Jiang, T.M. Shan, and Y.H. Zheng. 2015. Effect of baminobutyric acid on cell wall modification and senescence in sweet cherry during storage at 20 C. Food Chem. 175:471–477. doi: 10.1016/j.foodchem.2014.12.011.

Wang, C., and X.J. Meng. 2016. Effect of 60Co γ-irradiation on storage quality and cell wall ultra-structure of blueberry fruit during cold storage. Innov. Food Sci. Emerg. Technol. 38:91–97. doi: 10.1016/j.ifset.2016.09.010.

Zafari, E., A. Mohammadkhani, V. Roohi, A. Fadaei, and H. Zafari. 2015. Effect of exogenous putrescine and Aloe vera gel coating on post-harvest life of strawberry (Fragaria ananassa Duch.) fruit, cultivar Kamarosa. Int. J. Agric. Crop Sci 8:578–584.

Zhou, R., Y. Mo, Y. Li, Y. Zhao, G. Zhang, and Y. Hu. 2008. Quality and internal characteristics of Huanghua pears (Pyrus pyrifolia Nakai, cv. Huanghua) treated with different kinds of coatings during storage. Postharvest Biol. Technol. 49:171e179. doi: 10.1016/j.postharvbio.2007.12.004.