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Effect of Aloe Vera and Salicylic Acid Treatments on the Post-harvest Shelf Life Quality of Strawberries

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ABSTRACT

The effects of salicylic acid (SA) and *Aloe vera* (AV) applications on post-harvest quality changes in the fruits of cvs. 'Portola' and 'Monterey' strawberries that were stored were examined in the present study in 2021. Fruits were kept in cold storage for 21 days at 1±1 °C and 90±5% of relative humidity. In addition to the harvest period, the fruits taken from the cold storage on days 7, 14 and 21 were kept under room conditions (21±1 °C and 60±5% of relative humidity) for three days. Pomological and biochemical measurements of fruits made in the 0+3, 7+3, 14+3 and 21+3 shelf-life periods. While no effect of the treatments was observed in the flesh hardness of cv. 'Monterey', the SA+AV33 treatment preserved the hardness better in the cv. 'Portola'. In terms of total acid content, AV33 treatment obtained the highest values in cv. 'Monterey' while SA+AV33 and control treatments resulted the highest values in the cv. 'Portola'. The soluble solid contents level remained at the lowest value in SA and SA+AV66 treatments in the cv. 'Portola' but they increased in the control treatment. In the cv. 'Monterey', on the other hand, the AV66 treatment led to an increase in the soluble solids content. The total phenolic content of the fruits was not affected by the treatments. In terms of total monomeric anthocyanin contents, the highest values were measured in the control treatment in the cv. 'Portola', while in the cv. 'Monterey' the highest level was measured in the SA+AV33 treatment. The total antioxidant activities of the fruits in the cv. 'Portola' were affected by the treatments in the 0+3 period. As a result, it has been revealed that SA applications can be used to delay quality losses during the shelf life of strawberry fruits.

1. Introduction

Strawberry (Fragaria x pineapple D.) is a type of fruit of commercial importance in the group of grape-like fruits, and is grown under different ecological conditions. In addition to its adaptation ability, the richness of varieties has also been effective in spreading of strawberries to wide ecologies (Turk and Sen, 2020). Thanks to the compounds it contains (vitamins, minerals, flavonoids, anthocyanin, phenolic compounds and polyphenols), its positive effects on human health through preventing various diseases have been demonstrated (Koyama et al., 2022). Since strawberries do not have climacteric properties and show high metabolic activity after harvest, their shelf life is very short. The lack of a protective skin on the fruit, its soft texture, its susceptibility to fungal diseases and mechanical injuries that occur after harvest and excessive water loss further shorten its shelf life (Shafiee et al., 2009; Amal et al., 2010). Researchers have been experimenting with various techniques to extend the post-harvest lifespan of strawberries. One of them is the edible coating technique in addition to cold storage (Amal et al., 2010). Edible coatings can be applied to the surfaces of the products in the form of brushing, spraying or completely immersion. The coating technique can extend the shelf life of fresh products by controlling physical, chemical and

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biological changes through minimizing the effect of mechanical damage. Studies reported that edible coatings act as a natural barrier reducing moisture loss in the product, slowing the respiratory rate and preventing the loss of aromatic compounds (Alharaty and Ramaswamy, 2020; Galus et al., 2020; Mahfoudhi and Hamdi, 2015).

One of the best known among the coating materials is *Aloe vera* (AV). *Aloe vera* is an evergreen, herbaceous plant native to tropical and South Africa. The fact that *Aloe vera* gel is colorless, odorless, tasteless, anti-microbial and not harmful to human health has made it one of the most preferred coating materials in the field of storage (Noorbakhesh and Danee, 2021). In some conservation studies, it was reported that fruit decay rate and weight losses in AV-coated fruits were reduced compared to control groups in fruit species such as strawberries (Emamifar, 2015; Amiri et al., 2021a; Mohammadi et al., 2021a; Mohammadi et al., 2021b; Noorbakhesh and Danee, 2021), raspberry (Hassanpour, 2015) and litchi (Ali et al., 2019; Mani et al., 2021). In addition, the antioxidant capacity of the fruits, the total anthocyanin amounts, the total phenolic contents and the fruit weight were largely preserved.

In addition to *Aloe vera*, one of the preferred post-harvest materials is salicylic acid (SA). Salicylic acid is a metabolic molecule produced in plants. This molecule, which is closely related to the growth and development of the plant, regulates the defense mechanism and stress management in the plant. It is also a natural plant hormone that reduces ethylene biosynthesis and fruit aging (Haider et al., 2020). In the previous studies, it was reported that salicylic acid treatments significantly maintained post-harvest fruit quality characteristics, reduced the rate of weight loss and decay, and preserved fruit color and bioactive compounds in species such as strawberries (El-Mogy et al., 2019), cherries (Bal and Torcuk, 2020), oranges (Amiri et al., 202 b), mandarin (Haider et al., 2020) and papaya (Hanif et al., 2020).

It has been reported in the literature that SA or AV has a significant effect on the postharvest physiology of fruits. In line with the information given in the literature, the effect of SA and AV treatments on the shelf-life quality of 'Portola' and 'Monterey' strawberries was investigated in the present study.

2. Material and Method

2.1 *Plant Material and Experimental Design*

In the present study, 'Portola' and 'Monterey' strawberry cultivars were used as plant materials. Strawberries were harvested from a commercially produced greenhouse in Tokat in the early morning hours of May 2021. The harvested fruits were brought to the Tokat Gaziosmanpasa University, faculty of agriculture, department of horticulture, fruit growing laboratory and subjected to pre-cooling process at 1±1°C and 90±5% of relative humidity for one day. Afterwards, the fruits were immersed individually in AV solutions (33 and 66%) and 2 mM of SA (Merck, Germany) solution for five minutes and then allowed to dry for two hours at ambient temperature (23 °C). In combined treatments, the fruits were first immersed in the SA solution for five minutes and dried, followed by immersing in AV solutions for five minutes and kept drying again (Table 1). Then the fruits were placed in the plastic boxes with three replications as 400 g of fruit in each replication. Fruits were kept in cold storage for 21 days at 1±1 °C and 90±5% of relative humidity. In addition to the harvest period, the fruits were taken from the cold storage on the 7th, 12th and 21st days and stored in the room conditions (at 21±1 °C and 60±5% of relative humidity) for three days. Physical and chemical measurements were made in the 0+3, 7+3, 14+3 and 21+3 shelf life periods.

Table 1. Treatments used in the study.

#	Treatment	Abbreviation
1	Control	Control
2	%33 *Aloe vera* gel	AV33
3	%66 *Aloe vera* gel	AV66
4	2 mM Salicylic acid	SA
5	2 mM Salicylic acid + 33% *Aloe vera* gel	SA+AV33
6	2 mM Salicylic acid + 66% *Aloe vera* gel	SA+AV66

2.2. Fruits Measurements

2.2.1 Fruit decay rate

Fruit decay rate was determined according to the method described by Amiri et. al. (2021b). Areas of decay (tissue or discoloration due to darkening of the skin or the formation of fungi) were visually assessed during the storage period, and the decay rate (%) was recorded as follows: Decay rate = (Number of fruits with signs of decay / Total number of fruits in each plastic box) × 100.

2.2.2 Fruit flesh hardness (FFH)

To determine the FFH, measurements were carried out with a digital hardness tester (Agrosta® 100, France) on both sides of 10 randomly selected fruits from each replication. The hardness measuring range of the instrument varies between 0 and 100.

2.2.3 Titratable acidity (TA %)

For the determination of titratable acidity, 5 ml of extracted juice was diluted to 100 ml of distilled water and titrated to pH = 8.1 with 0.1 N sodium hydroxide. Titratable acidity was calculated as a percentage of citric acid using the formula:

$$A = \frac{\mathrm{S \times N \times F \times E}}{\mathrm{C}} \times 100$$

A: Percentage of acidity (%),
S: Amount of sodium hydroxide used (ml),
N: Normality of sodium hydroxide used,
F: Factor of sodium hydroxide used,
C: Amount of sample taken (ml),
E: equivalent value of the corresponding acid (0.064 for citric acid).

2.2.4. Soluble solid contents (SSC %)

After the fruits mashed in a homogenizer, the juice was extracted by centrifugation. Then, readings were made with a digital refractometer (Atago PAL-1, Japan (Brix = 0-53%) calibrated with distilled water and the values were expressed as %.

2.2.5. Total phenolic contents (TPC)

Total phenolic contents were determined using Folin-Ciocalteu's chemical as described by Singleton and Rossi

(1965). Extraction process was applied for 24 hours by weighing 2 g of pureed fruit samples in the homogenizer and adding acetone, water and acetic acid (70:29.5:0.5) solution. The next day, 0.5 mL was taken from the samples removed from the refrigerator, and 0.5 mL Folin-Ciocalteu's chemical and 9 mL of pure water were added. Eight minutes later, 2.5 mL of 7% sodium carbonate was added. After two hours of incubation, the absorbance of the solution that acquired a bluish color was read at a wavelength of 750 nm with a spectrophotometer. The measured values were used to calculate µg gallic acid equivalent/g fresh weight (fw) in gallic acid.

2.2.6. Total monomeric anthocyanins (TMA)

The determination of TMA in fruits was performed by the pH differential difference method (Giusti et al., 1999). pH = 1.0 and pH = 4.5 buffers were added to the 0.3 mL samples separately in a total volume of 3 mL, and after 15 minutes, readings were made at 520 and 700 nm wavelengths with the spectrophotometer. The total amount of anthocyanin was calculated as absorbance values [pH 1.0 (A520–A700) - pH 4.5 (A520–A700)] µg pelargonidin-3-glucoside/g fresh weight (pelargonidin-3-glucoside; molecular weight 433.2, molar absorptivity (ϵ) = 22.400).

2.2.7. Total antioxidant activity (TAA)

The TAA of the fruits was assayed using TEAC (Trolox equivalent antioxidant capacity) method according to Ozgen et al. (2006). For TEAC, 7 nm ABTS (2,2'-Azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) was mixed with 2.45 mM potassium bisulfate and left for 12-16 hours in the dark at +4 °C. This solution was then diluted with 20 mM sodium acetate (pH = 4.5) buffer to have an absorbance of 0.700±0.01 at a wavelength of 734 nm in a spectrophotometer. Finally, 2.97 mL of TEAC solution was added to the 30 µL sample and after a 10-minute incubation time, readings were performed at 734 nm wavelength on the spectrophotometer. The absorbance values after the measurement were calculated with the standard inclination curve of Trolox (10-100 µmol/L) and given as µmol Trolox equivalent/g fresh weight.

2.2.8. Fruit exterior color (L, a*, b*)*

The color determination of fruit was made with the Minolta colorimeter device (CR-400 model). Before the measurement colorimeter was calibrated on a white standard plate, and then the exterior color of the fruits was determined by measuring the Hunter color measurement parameters of L*, a* and b*. L* stands for brightness and takes values between 0 and 100. Higher scores indicate more brightness. The a* value represents the colors red and green: the positive values represent red and its shades while the negative values represent green and its shades. While, b* represents the colors yellow and blue: the positive values of b* represent yellow and its shades whereas the negative values represent blue and its shades. The measurements were made in 10 randomly selected fruits from each replication, and the exterior color of each fruit was determined in two measurements made on two vertical sides.

2.3. Statistical Analyses

The experimental design was completely in three replications according to the randomized plots. Since the main purpose of the study was to see the effect of the applications, statistical analysis was made between the application averages in each storage period. All statistical data were subjected to analysis of variance using SAS software (ver. 9.3, SAS Institute Inc., Cary, NC, USA). The significance of the differences among the means were determined according to the Tukey's multiple comparison test ($p < 0.05$).

3. Results and Discussion

***3**.1. Fruit Decay Rate (%)*

During the shelf life, the treatments had no statistical effect on the fruit decay rate of both cvs. 'Portola' and 'Monterey' fruits (Table 2). In cv. 'Portola', decay began to be observed in the first shelf-life period (0+3) in treatments other than AV66. In the AV66 treatment, no decay occurred until the 14+3 period. The fruit decay rate in the measurements made on the last measurement date (21+3) was 28.10% in SA+AV66 treatment and 72.50% in AV33 treatment. The difference between these two values was not significant. In the cv. 'Monterey', there was no decay in the fruits until the 14+3 period. In the observations made at 14+3, while the AV33 and AV66 treatments still did not show any decay, decay began in other treatments. In the last observation date, decay was observed in all treatments, and there was no significant difference among them. In a shelf life study of Mohammadi et al. (2021b), it was reported that strawberries treated with *Aloe vera* supplemented with basil (*Ocimum basilicum*) oil had lower fruit decay rate in the observations made on days 1, 3, 5 and 7. In other studies on strawberries, similar results were reported by Amiri et al. (2021a) and Emamifar (2015). In addition, AV coatings were shown to reduce fruit decay rate in raspberry (Hassanpour, 2015) and litchi (Mani et al., 2021) fruits. The role of *Aloe vera* gel in reducing post-harvest decay in fruits and vegetables is due to its antimicrobial effect (Ozturk, 2020). Our findings showed that no decay was observed in the fruits treated with AV66 during the 7+3 shelf-life period of cv. 'Portola' and 14+3 in cv. 'Monterey'. However, the differences among the treatments were not significant. In our study, the effect of salicylic acid on fruit decay rate was similar to that of control. Contrary to our findings, El-Mogy et al. (2019) reported that salicylic acid reduced fruit decay rate in strawberries.

Table 2. The effect of AV and SA treatments on the decay rate of strawberry fruits during shelf life

	Fruit Decay Rate (%)							
	Portola				Monterey			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	30.00^{ns}	26.67	60.00	43.35	0.00	0.00	11.13	28.60
AV33	10.00	37.50	65.30	72.50	0.00	0.00	0.00	5.57
AV66	0.00	0.00	56.30	40.27	0.00	0.00	0.00	31.10
SA	20.00	28.57	23.23	47.60	0.00	0.00	5.57	4.77
SA+AV33	20.00	20.63	20.83	28.10	0.00	0.00	14.30	11.10
SA+AV66	5.00	4.17	29.17	52.37	0.00	0.00	9.53	4.77

ns: Means in columns without any letter *are not significant according to Tukey's test at p < 0.05.*

3.2. Fruit Flesh Hardness (FFH %)

In terms of FFH, the treatments had significant effects in cv. 'Portola' in the 7+3 and 14+3 shelf-life periods (Table 3). Hardness values of the fruits kept in room conditions for three days after seven days of cold storage were lower in the control treatment while an increase in hardness values was observed in AV and SA treatments. At the 14+3 shelf life period, FFH values started to decline in all treatments. The FFH was best maintained in SA+AV33 treatment. The effect of other treatments remained at a level similar to control. In the last shelf life period, the hardness values decreased in all treatments and the differences among the treatments were not significant. In the cv. 'Monterey', the effect of the treatments on FFH during the shelf life was not significant. In their study with the cv. 'Parous', Hosseinifarahi et al. (2020) reported that FFH after 15 days of storage was better preserved in 1 mM SA+AV treatment and that *Aloe vera* extract could reduce respiration rate, loss of weight and therefore tissue softening by inhibiting ethylene biosynthesis. In the present study, SA+AV33 treatment maintained FFH of cv. 'Portola' better during the 14+3 shelf-life period. It was also reported in the literature that FFH is better preserved as a result of the treatment with 2 mM salicylic acid in 'Albion', 'Kabarla' (Ozgan ve Sabir, 2018) and 'Camarosa' (Shafiee et al., 2010) strawberry cultivars. In previous studies, Srivastava and Dwive (2000) stated that in the presence of salicylic acid, the activities of enzymes that break down the main cell wall (cellulase, polygalacturonase and xylanase) decrease.

Table 3. The effect of AV and SA treatments on the hardness of strawberry fruits during shelf life

	Fruit Flesh Hardness (%)							
	Portola				Monterey			
Treatments/Days	**0+3**	**7+3**	**14+3**	**21+3**	**0+3**	**7+3**	**14+3**	**21+3**
Control	58.00^{ns}	48.70 b*	42.85 b	38.75	52.30	61.77	56.77	49.50
AV33	52.70	60.37 a	50.87 ab	38.73	55.17	58.17	51.20	50.70
AV66	54.15	60.47 a	47.73 ab	39.47	56.10	59.70	51.00	49.23
SA	53.55	59.30 a	49.77 ab	46.50	56.30	61.07	57.10	47.63
SA+AV33	50.15	57.43 ab	54.83 a	48.37	57.50	57.43	57.27	49.13
SA+AV66	52.15	59.17 a	43.37 b	43.23	51.60	58.53	54.67	47.63

*Means in columns with different letters are significantly different according to Tukey's test at p < 0.05. ns: Means in columns without any letter are not significant according to Tukey's test at p < 0.05.

3.3. Titratable Acidity (TA %)

The TA levels of both cv. 'Portola' and 'Monterey' fruits were affected by the treatments during their shelf life (Table 4). In the cv. 'Portola', the TA values of the fruits tended to decrease over the shelf-life period in all treatments. At the end of the first three-day shelf life period, the TA value of fruits treated with SA+AV33 was lower than that of the control group fruits, while the effect of other treatments remained at the same level as the control. This effect continued for three days in fruits that were kept in room condition after seven days of cold storage. In the measurements made during the last shelf life period, AV33, SA and SA+AV66 treatments led to reductions in TA values compared to the control. The effects of SA+AV33 and AV66 treatments were similar to the control. At the end of the first three-days of shelf life period, the TA level in the cv. 'Monterey' fruits was higher in SA+AV33 and AV66 treatments compared to the control. By the last shelf life period, the highest TA value was reached in the AV33 treatment, while other treatments remained at the same level as the control. In the studies conducted by Akin (2014) and Rahimi et al., (2018) on strawberries, it was reported that there were decreases in the total acid contents of the fruits at the end of the preservation period. Similarly, the total acid contents of cv. 'Portola' fruits decreased at the end of the shelf-life period in the present study. In this regard, Sayyari et al. (2022) stated that there may be a decrease in TA and an increase in TSS of most stored fruits as a result of the hydrolysis of insoluble polysaccharides to simple sugars due to the breakdown of glycosides into subunits and the degradation of organic acids in the respiration process. In the study conducted by Hosseinifarahi et al. (2020) on strawberries, it was stated that the effect of AV gel on pH, TA and SSC was

more pronounced than that of salicylic acid. This finding was in agreement with the results obtained from the cv. 'Monterey' in the present study. At the end of the shelf life period, the AV33 treatment preserved the TA content of the fruits better. Ozgan and Sabir (2018) stated that salicylic acid and oxalic acid preserved the TA value better in cv. 'Albion', while oxalic acid only treatment provided better protection in the cv. 'Kabarla'. Some discrepancies between our results and the results were reported in the literatures may have been due to the different cultivars used. Considering the fact that the two cultivars used in our study showed different reactions to the treatments applied.

Table 4. The effect of AV and SA treatments on the titratable acidity of strawberries during shelf life

	Titratable Acidity (%)							
	Portola				Monterey			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	1.71 ab*	1.67 ab	1.47 a	1.39 a	1.87 cd	2.03 bc	2.13 a	1.94 b
AV33	1.75 ab	1.67 ab	1.42 ab	1.17 c	1.89 cd	2.09 abc	2.03 ab	2.07 a
AV66	1.79 a	1.76 a	1.28 c	1.29 ab	2.05 ab	2.19 a	1.96 b	2.04 ab
SA	1.72 ab	1.59 bc	1.46 a	1.21 bc	1.86 d	2.01 c	2.00 b	1.93 b
SA+AV33	1.58 c	1.49 c	1.43 ab	1.39 a	2.13 a	2.12 ab	2.06 ab	1.98 ab
SA+AV66	1.67 bc	1.63 b	1.33 bc	1.23 bc	1.98 bc	2.00 c	2.12 a	1.96 b

*Means in columns with different letters are significantly different according to Tukey's test at $p < 0.05$.

3.4. Soluble Solid Contents (SSC %)

The SSC values of the fruits are given in Table 5. In the cv. 'Portola', treatments had significant effects during the shelf-life period. At the end of the first three-days of shelf life period, the highest SSC value was obtained from AV66 treatment. In the measurements made during the 7+3 period, the treatments with the highest SSC value were AV33 and AV66. By the last shelf life period (21+3), the highest SSC value was measured in the control treatment, followed by SA+AV33 and AV33. The low SSC value was observed in SA treatment. In the cv. 'Monterey', the treatments had significant effects on the SSC values of the fruits during the shelf life period. At the end of the first shelf life period (0+3), the highest SSC value was measured in the SA+AV33 treatment, and the lowest was in the control. SSC values of the fruits in the control group increased at the end of 7+3 period and reached to the highest level. In this period, the lowest SSC value was in SA treatment. In the last period of shelf life, the highest SSC value was obtained from the AV66 treatment, while the effect of other treatments remained at the same level as the control. In previous conservation studies on strawberries, it was noted that the salicylic acid treatment had no effect on the amount of *SSC* (Ozgan and Sabir, 2018; Shafiee et al., 2010). In the present study, salicylic acid reduced the SSC level compared to control and *Aloe vera* treatments in cv. 'Portola' at the end of the shelf-life period. In other conservation studies on strawberries, Oz and Kafkas (2015) and Korkut (2019) reported that the SSC levels decreased. In this regard, Oz and Kafkas (2015) stated that the decrease in SSC values may be due to the increased respiratory rate in strawberry fruits.

Table 5. Effect of AV and SA treatments on soluble solid contents of strawberries during shelf life

	Soluble Solid Contents (%)							
	Portola				Monterey			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	6.40 b*	5.80 b	6.40 ab	7.53 a	8.07 c	9.00 a	6.60 d	8.67 b
AV33	6.40 b	6.73 a	5.40 d	6.00 b	8.80 b	7.40 b	9.07 bc	8.80 b
AV66	7.40 a	6.60 a	5.60 cd	5.93 bc	9.03 ab	7.40 b	9.67 a	9.40 a
SA	6.73 b	5.87 b	5.93 bc	5.33 d	8.27 c	6.53 c	8.60 c	9.00 ab
SA+AV33	6.47 b	5.80 b	6.13 ab	6.13 b	9.47 a	7.00 bc	9.13 b	8.53 b
SA+AV66	6.73 b	5.87 b	6.60 a	5.47 cd	8.53 bc	7.07 b	8.80 bc	8.93 ab

*Means in columns with different letters are significantly different according to Tukey's test at $p < 0.05$.

3.5. Total Phenolic Contents (TPC-µg GAE/g fw)

It is important to maintain higher levels of phytochemical content of fruits and vegetables throughout their storage and shelf life. This is because phenolic and anthocyanin contents have antioxidant activity as one of their most important biological properties and are able to protect cell components against oxidative damage (Sayyari et al., 2022). In the present study, the TPC of the cv. 'Portola' fruits showed a tendency to increase during shelf-life periods except for 14+3. In case of the cv. 'Monterey', this increase continued in the periods before the last shelf life period. Nevertheless, the effect of treatments on TPC in 'Portola' and 'Monterey' cultivars was not significant (Table 6). In previous studies, Ozgan and Sabir (2018) showed that in the 'Albion' and 'Kabbarla' cultivars there was an increase in the TPC during the preservation period of the strawberries compared to the beginning, and that increase was highest in the control group. Celer et al. (2019), on the other hand, reported that the TPC of strawberries decreased during the storage period. Changes in the TPC of fruits after harvest could vary due to the cultivar used, the maturity stage during harvest, growing season and length of storage (Ozgan and Sabir, 2018).

Table 6. The effect of AV and SA treatments on the total phenolic contents of strawberries during shelf life

	Total Phenolic Contents (µg GAE/g fw)							
	Portola				**Monterey**			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	2262.23^{ns}	2673.89	1863.89	2697.23	4108.89	4307.23	4523.89	3957.23
AV33	2202.23	2403.89	2087.23	2895.56	4120.56	3770.56	4222.23	3495.56
AV66	2242.23	2398.89	1400.56	2403.89	4365.56	4195.56	4315.56	3288.89
SA	2178.89	2417.23	1643.89	2150.56	3878.89	4063.89	3980.56	3732.23
SA+AV33	1825.56	2172.23	2028.89	2477.23	3770.56	3955.56	4373.89	3452.23
SA+AV66	1818.89	2227.23	2163.89	2422.23	3562.23	4072.23	4405.56	3900.56

ns: Means in columns without any letter *are not significant according to Tukey's test at p < 0.05.*

3.6. Total Monomeric Anthocyanins (TMA µg plg-3-glu/g fw*)*

The total monomeric anthocyanin values are given in Table 7. There were significant differences among the treatments for total monomeric anthocyanin levels measured at 7+3 and 21+3 periods of the cv. 'Portola'. During the period from the first shelf life to the 7+3 period, decreases were observed in anthocyanin contents in all treatments. In the measurements made in the 7+3 period, the highest TMA content was obtained from the fruits treated with AV33. The lowest TMA content was measured in fruits treated with SA+AV66. By the 21+3 period, SA and SA+AV66 treatments led to reductions in TMA content compared to the control. AV33, AV66 and SA+AV33 treatments had effects similar to control. The effect of the treatments in the cv. 'Monterey' was evident throughout the shelf life. In observations made at the end of the initial shelf life, the SA+AV66 treatment increased the TMA content compared to the control, while the effect of other treatments was similar to the control. By the end of its shelf life (21+3), the highest TMA content was measured in the SA+AV33 treatment. In SA+AV66 and AV66 treatments, the TMA content was found to be lower than that in control group. Anthocyanin compounds are a group of phenolic compounds that are responsible for the red-blue color of many fruits and vegetables, and exhibit antioxidant properties (García-Alonso et al., 2004). As with phenolic compounds, anthocyanin contents may vary according to storage and shelf life periods. In one study, it was reported that there were decreases in the total monomeric anthocyanin content at the end of the storage (15 days) and shelf life period of strawberries (15+2 days) (Korkut, 2019). In another study, were found that the anthocyanin level increased in fruits preserved for three days (Rahimi et al., 2018). In a study similar to ours, it was reported that the highest TMA contents of cv. 'Parous' fruits after 15 days of cold storage were measured in control, 2 mM SA and 2 mM SA+AV treatments (Hosseinifarahi et al., 2020). In the present study, the highest TMA content of the fruits in the cv. 'Portola' was observed in the control treatment, while in the cv. 'Monterey' the highest level was measured in the SA+AV33 treatment.

Table 7. The effect of AV and SA treatments on the total monomeric anthocyanin contents of strawberries during shelf life

	Total Monomeric Anthocyanin (µg plg-3-glu/g fw)							
	Portola				**Monterey**			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	164.77^{ns}	121.58 ab*	130.09	156.78 a	198.68 b	251.80 a	288.28 a	279.78 ab
AV33	180.89	151.75 a	110.36	139.24 ab	225.63 ab	217.89 ab	211.96 b	244.45 bcd
AV66	173.28	115.39 ab	113.59	145.56 ab	212.22 b	234.65 ab	304.79 a	227.04 cd
SA	177.28	136.15 ab	137.82	108.30 b	194.94 b	206.03 b	286.48 a	249.73 bc
SA+AV33	169.93	132.02 ab	119.65	140.92 ab	231.68 ab	230.91 ab	234.65 b	294.99 a
SA+AV66	181.53	109.85 b	140.15	113.97 b	256.57 a	247.80 a	232.33 b	206.93 d

*Means in columns with different letters are significantly different according to Tukey's test at p < 0.05. ns: Means in columns without any letter are not significant according to Tukey's test at p < 0.05.

3.7. Total Antioxidant Activity (TAA-µmol TE/g fw*)*

The treatments had significant effects on TAA of the 'Portola' cultivar at the 0+3 shelf-life period (Table 8). After this period, the effects of the treatments were not significant. In the observations of the fruits after keeping them in room condition for the first three days, the highest TAA level was measured in AV33 treatment. The effects of other treatments were similar that of the control. The treatments resulted in significant differences in the TAA levels of cv. 'Monterey' fruits in other shelf life periods except for the 14+3. In the measurements made in the 0+3 period, the control and AV33 treated fruits had the lowest TAA level while the AV66 and SA+AV66 group fruits had the highest TAA levels. At the end of the 7+3 shelf life period, the lowest TAA was measured in the control and AV33 treated fruits, while the highest TAA level was in SA and SA+AV66 group fruits. In the last shelf life period, the TAA level of AV66 group fruits was low compared to the control. The effects of other treatments at this period were similar to that of the control. In the conservation studies where *Aloe vera* and salicylic acid were applied, Asghari et al. (2015) reported that 33% AV and 2 mM SA treatments could significantly maintain

antioxidant activity in grapes by increasing the fruit catalase activity. Hosseinifarahi et al. (2020) observed a similar effect in the strawberries treated with 2 mM+AV. Haider et al., (2020) stated that the antioxidant activity of fruits was directly related to polyphenols, including flavonoids, and thus the antioxidant activity of the fruit may also increase with increased phenolic contents. The positive relationship between total phenolic contents and total antioxidant activities was also observed in oranges (Amiri et al. 2021b), mandarin (Haider et al. 2020) and strawberries (Sogvar et al., 2016). In the present study, this relationship was observed especially in the cv. 'Portola'.

Table 8. Effect of AV and SA treatments on the total antioxidant activities (TAA) of strawberries during shelf life

	Total Antioxidant Activities (µmol TE/g fw)							
	Portola				Monterey			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	11.25 bc*	12.78^{ns}	12.42	14.49	16.20 c	19.29 cd	21.08	23.69 a
AV33	14.12 a	14.21	12.71	13.02	16.62 c	17.69 d	23.12	21.61 ab
AV66	12.46 ab	13.51	10.57	13.93	21.84 a	20.71 bc	21.45	20.74 b
SA	8.98 c	13.96	11.57	12.10	18.88 bc	24.08 a	21.37	21.58 ab
SA+AV33	11.04 bc	13.85	12.08	13.75	18.69 bc	20.14 bcd	21.50	21.23 ab
SA+AV66	13.40 ab	12.96	10.34	13.59	20.67 ab	22.79 ab	22.70	22.73 ab

*Means in columns with different letters are significantly different according to Tukey's test at $p < 0.05$. ns: Means in columns without any letter are not significant according to Tukey's test at $p < 0.05$.

3.8. Fruit Exterior Color (L, a*, b*)*

The color parameters L*, a* and b* are given in Table 9. The effect of treatments on L* values in the cv. 'Portola' was evident only in the last period of the shelf life. The measurements made during this period revealed that effects of AV and SA treatments were similar to that of the control. However, effects of AV33 and SA treatments were different, and SA treatment had a higher L* value. No significant effect of the treatments was observed in the cv. 'Monterey'. In addition, the effects of treatments on a* and b* parameters in both cultivars were not statistically significant. In previous similar studies, Akin (2014) reported that there were decreases in the color values of strawberry fruits that were kept on the shelf for two days after storing them in a modified atmosphere conditions for 12 days compared to the beginning of preservation. Oz and Kafkas (2015), on the other hand, stated that L*, a* and b* color parameters of strawberry fruits were comparable to the initial values during the 12-day of storage period. Nasrin et al. (2017) reported that strawberries treated with AV gel were brighter compared to control samples. In the present study, AV gel did not exert such an effect. In the cv. 'Portola', SA-treated fruits were found to be brighter compared with AV33.

Table 9. The effect of AV and SA treatments on L*, a* and b* values of strawberry fruits during shelf life

	L*							
	'Portola'				'Monterey'			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	34.60^{ns}	37.60	36.80	33.65 ab*	31.97	36.93	33.60	32.00
AV33	33.75	38.30	37.60	33.53 b	33.57	37.97	33.17	34.53
AV66	34.30	40.37	38.97	36.00 ab	36.30	38.53	32.57	33.93
SA	33.10	40.27	35.50	40.70 a	33.60	35.67	32.30	34.70
SA+AV33	32.70	37.83	36.83	34.47 ab	33.47	38.63	34.33	32.13
SA+AV66	33.05	36.10	37.20	35.37 ab	33.77	37.67	36.43	36.53
	a*							
	'Portola'				'Monterey'			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	28.00	27.87	25.80	30.80	22.83	21.70	21.83	23.57
AV33	25.60	26.83	26.13	29.63	25.00	21.20	22.23	24.23
AV66	26.45	26.03	28.83	27.07	23.57	21.53	21.33	21.90
HIS	28.00	24.17	29.30	26.87	24.40	23.57	25.13	23.27
SA+AV33	25.60	27.63	29.80	27.67	21.93	20.80	21.40	23.93
SA+AV66	26.05	27.43	28.67	26.10	23.53	20.33	19.70	22.53
	b*							
	'Portola'				'Monterey'			
Treatments/Days	0+3	7+3	14+3	21+3	0+3	7+3	14+3	21+3
Control	10.70	14.53	14.75	15.00	7.63	6.47	5.80	7.43
AV33	8.00	9.17	11.37	14.67	9.17	6.23	6.00	8.53
AV66	9.65	10.13	11.37	9.90	8.33	7.50	7.33	6.63
HIS	10.90	9.30	13.20	10.20	8.50	7.97	9.50	9.00
SA+AV33	8.85	10.70	12.47	11.57	7.57	6.47	6.80	6.53
SA+AV66	8.70	11.27	12.50	14.23	7.93	5.53	5.37	7.53

*Means in columns with different letters are significantly different according to Tukey's test at $p < 0.05$. ns: Means in columns without any letter are not significant according to Tukey's test at $p < 0.05$.

4. Conclusion

It was found in the present study that fruits of 'Portola' and 'Monterey' strawberry cultivars showed different reactions to *Aloe vera* and salicylic acid treatments during their shelf life. In terms of decay rate, AV66 treatment was more effective in both cultivars. While the cv. 'Monterey' was not affected from treatments in terms of fruit hardness, the SA+AV33 treatment in the cv. 'Portola' preserved the hardness better. In terms of total acid content, AV33 treatment produced the highest value in the cv. 'Monterey', while it remained at the lowest value in the cv. 'Portola' (the highest TA values in the cv. 'Portola' were measured in SA+AV33 and control treatments). While the amount of soluble solid contents was lowest in SA and SA+AV66 treatments in the cv. 'Portola', they increased in the control treatment. In the cv. 'Monterey', AV66 treatment led to an increase in the SSC values. The total phenolic contents of the fruits were not affected by the treatments. In terms of TMA contents, the highest values were measured in the control treatment in the cv. 'Portola', and in the SA+AV33 treatment in the cv. 'Monterey'. The total antioxidant activities of the fruits of the cv. 'Portola' were affected by the treatments in the 0+3 period. Here, SA treatment reduced TAA value compared to the control while AV 33 treatment increased it. In the cv. 'Monterey', the AV66 treatment resulted in the highest TAA during the first shelf life period, while it caused the lowest TAA in the last period of shelf life. The highest TAA was obtained from the control treatment. For the fruit exterior color, the treatments affected only the L* parameter in cv. 'Portola'. In terms of the measurements made during the last shelf-life period of the cv. 'Portola', the AV33 treatment decreased the L* value while the SA treatment increased it.

In the present study, the effects of different surface covering materials on the shelf life qualities of strawberry fruits were examined. Similar applications on different species and cultivars will be a source for both scientific studies and commercial production uses.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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