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Research Paper

The effect of pre-harvest and post-harvest *aloe vera gel* treatments on fruit quality and storage performance of table grapes

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ABSTRACT

This study investigated the impacts of pre-harvest, post-harvest, and combined pre-harvest+post-harvest *Aloe vera* gel treatments on various quality parameters of the 'Red Globe' grape cultivar during a 150-day storage period. The quality parameters assessed were weight loss, decay ratio, color attributes, firmness, soluble solids content (SSC), titratable acidity (TA), levels of total phenolics and total antioxidant capacity, as these are indicative of bioactive compounds. Post harvest Aloe vera treatment resulted in the lowest weight loss among three treatments, while the combined treatment surprisingly led to the highest weight loss. Pre-harvest treatments resulted in the lowest SSC values, while the combined treatments led to the highest values. Differences in TA value were not statistically significant, neither between treatments nor during the storage period. Storage duration alone significantly affected pH values. The *Aloe Vera* treatments significantly increased total phenols compared to the control group, and this increase remained consistent throughout the storage period. The combined treatments yielded the highest total phenols (3389.45 μg gallic acid equivalent/g fresh fruit). Similarly, *Aloe Vera* treatments significantly increased total antioxidant capacity (TAC) throughout the storage period. While the combined treatment yielded the highest TAC on day 150 (6.66 μMol trolox equivalent/g fresh weight), it negatively affected physical and chemical parameters. However, compared to other treatments, this combined approach significant boosted phytochemical levels. These findings suggest that for fresh table grapes, separate pre-harvest or post-harvest *Aloe Vera* treatments might be preferable. On the other hand, for those prioritizing elevated phytochemical content for health benefits, the combined application offers an option despite its drawbacks.

1. Introduction

The grape (*Vitis vinifera* L.) is a widely cultivated berry, extensively grown on a global scale. Due to its rich nutritional composition and potent antioxidant properties, grapes are frequently used for both nutritional and health protective purposes (Nia et al., 2021).

Cold storage is commonly recommended for extending the shelf life of diverse products (Aboryia et al., 2022; Cai et al., 2021). Grapes, however, are particularly challenging to preserve due to their unique characteristics. Grapes have a thin shin (pericarp), high juice content, limited shelf life and are classified as non-climacteric, meaning they do not ripen further after harvest (Shahkoomahally and Ramezanian, 2014) and storing grapes presents several challenges, including decay, dehydration, softening, weight loss, discoloration and loss of flavor. These combined features pose significant obstacles to their preservation. A significant portion of harvested grapes, unfortunately, end up unfit for consumption as table grapes due to post-harvest losses and rot (Golly et al., 2019; Nia et al., 2021. The limited shelf life is attributed to various factors (X.-.H. Meng et al., 2010; Champa et al., 2014; Mirdehghan and Rahimi 2016). Notably, the presence of microorganisms, particularly *Botrytis cinerea*, significantly deteriorates the quality of table grapes (Guillén et al., 2007; Castillo et al., 2010a). The exponential growth of the global population poses challenges to nutrient security. Therefore, implementing strategies to enhance the shelf life and the consumption period of agricultural products becomes crucial. These strategies should particularly focus on preventing microbial growth, minimizing water loss, and improving the mechanical resistance of the products.

Renewable coatings form a semi-permeable protective layer on the surface of fruits, regulating oxygen and carbon dioxide levels. These coatings significantly reduce weight loss, respiration rates, enzymatic

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browning, microbial growth and ultimately extending the shelf life of fruits. This technology, in fact, has been used since ancient times to preserve perishable food items from deterioration (Atabey, 2023). The common coating materials, such as hydrocolloids, polysaccharides, proteins, lipids, and waxes, are odorless, colorless and tasteless. These substances form an imperceptible film on the fruit's surface, effectively isolating it from the surrounding atmosphere (Krochta et al., 2002). *Aloe Vera* gel has emerged as preferred edible coating in recent years (Nicolau- Lapeña et al., 2021; Sarker and Grift, 2021; Raheemullah et al., 2023). This eco-friendly alternative to synthetic preservatives provides protection against microorganisms thanks to its antibacterial and antifungal properties. The gel's protective barrier stems from a synergy of active compounds including vitamins, enzymes, minerals, lignin, saponins, like salicylic acid and amino acids. Consequently, it inhibits the growth of microorganisms in food, thereby, promoting its preservation (Eshun and He, 2004; Padmaja and Bosco, 2014). Applying *Aloe Vera* coatings has been shown to reduce post-harvest losses and extend the shelf life of various fruits, such as table grapes (Serrano et al., 2006; Valverde et al., 2005), sweet cherries (Martínez-Romero et al., 2006), papaya (Farina et al., 2020) and plums (Guillén et al., 2013).

While pre-harvest or post-harvest *Aloe Vera* coating applications are common, their combined use remains rare. The aim of this study was to investigate the effects of Aloe vera coating application on grapes, both before and after harvest, and the combined application before and after harvest, on storage characteristics and grape quality.

2. Materials and methods

2.1. Plant and coating materials

Field treatments were conducted in a vineyard owned by a producer located in Çarıksız village (40°19′24.1"N - 36°15′42.2"E), Turhal district, Tokat province, Central Black Sea Region of Turkiye, during August-September 2021. An experimental vineyard employing a trellis system was established. Vines were 7-year-old Red Globe variety grafted on Rupestris du Lot rootstock. The study comprised 36 vines, with three replicates for both control and Aloe vera treatments, with each replicate consisting of 3 grapevines.

The experiment used *Aloe Vera* (AV) gel produced by Forever company, containing 99.5 % water and 0.5 % solids. Approximately, half of the solids, consist of carbohydrates (Ağırgan, 2013).

2.2. Treatments

After harvest, the harvested grapes placed in plastic boxes (39 × 29 × 21 cm, Plastas, Türkiye) and stored at 0 °C and 85±5 % a relative humidity in the cold storage facility at Tokat Gaziosmanpaşa University's Faculty of Agriculture (Leng et al., 2022). Subsequently, analyses were carried out in the bioactive molecular laboratory located within the same faculty.

For both pre-harvest and post-harvest periods, *Aloe Vera* coatings were applied at a concentration of 33 %. At the pre-harvest treatment, 10 days before harvesting, entire canopy was sprayed with the solution (Castillo et al., 2010b). At the post-harvest treatments, on the day of harvest, clusters were immersed in the solution (5 min). Identical procedures with distilled water were used for the control group. To achieve uniform coating in all treatments, a surfactant (Tween 20) was used. Treated clusters were then placed in cold storage, and periodically removed (every 30 days) for physical, chemical, and phytochemical analyses (Fig. 1). For each treatment and period, sampling was conducted in triplicate using 1 kg of grapes per replicate. These grapes were chosen homogeneously from three clusters representing the replication.

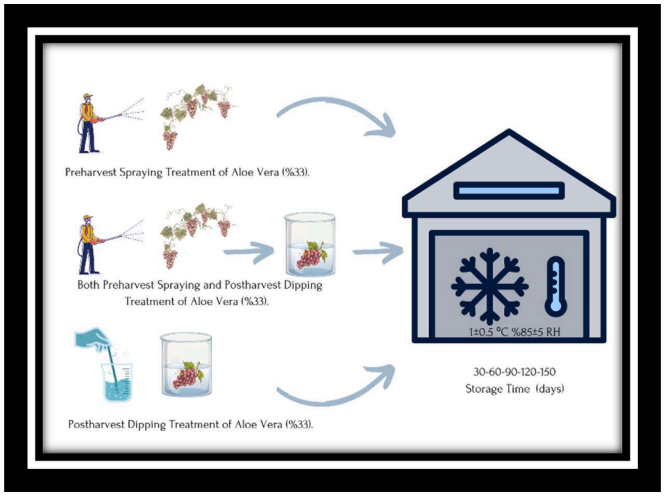

Fig. 1. A diagram illustrating the various treatment modalities.

2.3. Fruit quality parameters

2.3.1. Weight loss ratio (%)

Fruit weight was measured at beginning of cold storage and at the end of each analysis period using of a precise scale (±0.01 g). A 1 kg of fruit sample was used for each replicate. Weight loss ratio (%) was calculated as:

$$\text{Weight loss}(\%) = (\text{Initial weight} - \text{measured weight})/(\text{Initial weight}) \times 100$$

2.3.2. Decay ratio (%)

Decay ratio was determined in replicate using 1 kg grape sample. Berries were initially counted, and then those exhibiting visible mycelial growth were considered decayed. The decay ratio was calculated using the following equation (Amiri et al., 2021):

$$\text{Decay ratio}(\%) = (\text{Total number of berries} - \text{Number of healthy berries}) /(\text{Total number of berries}) \times 100$$

2.3.3. Fruit color parameters

Three replicates were conducted for per treatment, each using 10 fruits to represent the respective replicate. We measured color parameters using a Minolta colorimeter (CR-400 model) calibrated with a standard white plate (Y = 92,40 x = 0,3137 y = 0,3195). The L* (lightness), a* (red/green), and b* (yellow/blue) values were measured for both fruit flesh and peel (Sacks and Shaw, 1994). Chroma (C^*) and hue angle (h°) were calculated as follows (McGuire, 1992):

$$(C^*) = \left(a^{*2} + b^{*2}\right)^{1/2},$$

$$\mathrm{h}^{\circ} = \tan^{-1} b* / a* .$$

2.3.4. Fruit firmness (%)

Each treatment had three replicates with 10 fruits per replicate. Ten berries were randomly chosen from each replicate to measure flesh firmness using an Agrosta® 100 digital portable durometer (0–100 range) on both sides of each berry. Data is expressed in Durofel units (%), softening is indicated by values closer to 0 and firming by values closer to 100.

2.3.5. Total acidity

To prepare juice samples, 40 fruits were used from each replicate. Fruits extraction was performed using a Philips HR1855/70 juice extractor (Turkiye). The extracted fruit juice was then centrifuged for 10 min at 10,000 rpm. Acidity was measured by titration method and

expressed as the percentage of tartaric acid (equivalent value of 0.075 for tartaric acid)

2.3.6. pH

Selected berries were homogenized in fruit juice extractor. The pH of homogenized berries was measured by a digital pH meter with a glass electrode (Hanna 221, Romania).

2.3.7. Soluble solids content (SSC)

Homogenized berries were filtered using a coarse filter paper, and the initial drops collected were used to measure SSC. The measurement was performed with calibrated PAL-1 digital refractometer (McCormick Fruit Tech. Yakima, USA) and results were expressed as percentage.

2.3.8. Total phenols

Total phenolic content was determined using Folin-Ciocalteu's reagent following the method of Singleton and Rossi (1965). Homogenized whole berry samples were extracted for one hour in tubes containing a 70:29.5:0.5 acetone, water and acetic acid solution. A Folin-Ciocalteu's reagent and distilled water were added to sample extract and incubated for 8 min. Subsequently, 7 % sodium carbonate solution was added and incubated for two hours, resulting in blue color. Absorbance was then measured at 750 nm using a spectrophotometer. Results were expressed as μg gallic acid equivalent per gram fresh fruit.

2.3.9. Total antioxidant capacity (TAC)

The Total Antioxidant Capacity (TAC) of homogenized whole berry extract was determined using the Trolox equivalent antioxidant capacity (TEAC) method (Ozgen et al., 2006), commonly used for plant materials. In this method, a solution of 7 mM ABTS (2,2′-Azino-bis 3-ethylbenzothiazoline-6-sulfonic acid) and 2.45 mM potassium bisulfate was incubated for 12–16 h in darkness. This solution was then diluted with a 20 mM sodium acetate buffer (pH of 4.5) to achieve an absorbance of 0.700±0.01 at 734 nm. Subsequently, 30 μL of extract was mixed with 2.97 mL buffer solution and incubated for 10 min. Absorbance was measured at 734 nm using a spectrophotometer (Saracoglu, 2018), and results were expressed as μmol Trolox equivalents per gram of fresh weight using standard curve of Trolox (10–100 μmol/L).

2.4. Statistical analysis

The experimental layout was a randomized plots in factorial design with 3 replicates using one kg of berry fruits per replicate. The collected data were subjected to a variance analysis using SAS statistical analysis software at 0.05 level of significance. Duncan's multiple comparison test was employed to compare the significance of the means.

3. Result and discussion

3.1. Weight loss, decay and firmness

Weight loss from berry surfaces can lead to undesirable changes, potentially triggering adverse physiological and morphological consequences. It also reduces nutrient composition and market appeal of grapes (Destiana et al., 2021). Edible coatings provide a promising approach to prevent deterioration during storage, as they can act as a semipermeable barrier to O2, CO2 and water-vapor, thus preventing water loss, changes in firmness or oxidation, amongst others (Raghav et al., 2016; Nicolau-Lapeña et al., 2021). During the 150-day storage period, post-harvest Aloe Vera treatments exhibited the lowest weight loss (10.86 %), while the pre-harvest + post-harvest combination had the highest (12.89 %) (Fig. 2). Nia et al. (2021) reported lower weight loss with 2 % and 3 % pre-harvest chitosan and 33 % post-harvest *Aloe Vera* treatments. Destiana et al. (2021) found the emost significant weight loss decrease using 5 % glycerol-supplemented *Aloe Vera* coatings by 13th day. Shahkoomahally and Ramezanian (2014) observed

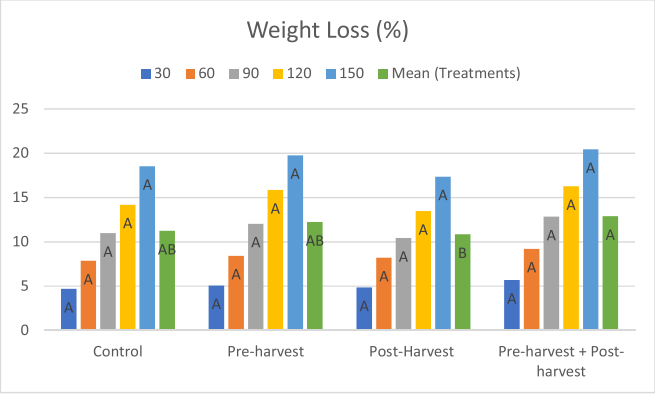

Fig. 2. Effects of Aloe Vera treatments on weight loss of berries (%). There is no statistical difference between columns marked with the same letter for each treatment (Duncan, $p < 0.05$).

positive effects on weight loss from post-harvest $CaCl_2$-enriched *Aloe Vera* coatings on 'Askari' grape cultivar. Similarly, our study demonstrates the beneficial impact of post-harvest *Aloe Vera* treatments on reducing weight loss. According to Farina et al. (2020), *Aloe Vera* coatings reduce fruit surface evaporation and increase weight retention. However, Castillo et al. (2010a) documented positive effects of pre-harvest *Aloe Vera* treatments on weight loss, which was not observed in our study. This variation could be attributed to differences in grape cultivar, ecological factors, or treatment doses.

Although pre-harvest and post-harvest *Aloe Vera* treatments didn't significantly affect decay ratios, significant differences emerged across storage periods (Fig. 3). The highest decay ratio (14.87 %) was observed on day 150. Researchers are actively seeking alternatives to chemical fungicides for controlling post-harvest fruit decay caused by pathogens. The focus lies on sustainable materials like *Aloe Vera* (Romanazzi et al., 2012). Shah and Hasmi (2020) found that both *Aloe Vera* gel and chitosan treatments positively impacted mango fruit decay ratios over 28 days. Similarly, our study showed favorable outcomes for microbial decay with *Aloe Vera* ger treatments. Nia et al. (2022) observed that grapes treated with a combination of pre-harvest salicylic acid (SA) (2 and 3 mM) and post-harvest *Aloe Vera* gel (25 % and 33 %) started decaying before the 16th day of storage. However, their SA3mM + AV 33 % treatment had the lowest decay rate on the 32nd day of storage. The AV demonstrates antifungal activity as an effective natural compound. Also, Vera gel has a strong antimicrobial activity against a wide range of pathogenic microorganism; hence reduce fruit decay percentage and maintain fruit quality (Navarro ve ark., 2011; Valverde et al., 2005). The differing results of our post-harvest Aloe Vera dipping

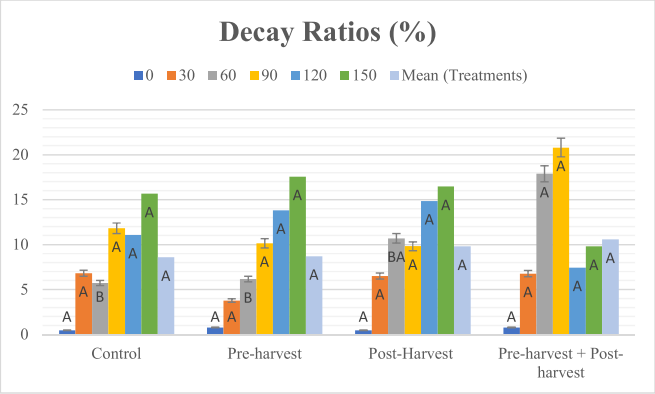

Fig. 3. Effects of Aloe Vera treatments on decay ratios (%) throughout the storage period. There is no statistical difference between columns marked with the same letter for each treatment (Duncan, $p < 0.05$).

treatment compared to other studies may be due to variations in materials and grape cultivars used.

Experimental treatments significantly affected fruit firmness during storage (Fig. 4). The highest firmness values were noted on the 30th day (72.37) and in the control group (65.08). Grape firmness naturally decreases over time, varying in pace depending on storage duration. This decrease can be attributed to the gradual breakdown of pectic polymers in the fruit (Artes-Hernandéz et al., 2004; Pretel et al., 2006). Huiling (2006) compared the anatomy of four grape cultivars ('Red Globe', 'Kyoho', 'Autumn Black' and 'Autumn Red') and found a direct link between storage performance, pericarp characteristics and fruit texture. Nia et al. (2021) demonstrated that pre-harvest chitosan and post-harvest *Aloe Vera*, and a combination of both treatments best preserved firmness in 'Yaghouti' grape cultivar. Similarly, our results showed varying fluctuations in firmness across treatments. Notably, pre-harvest + post-harvest a treatment yielded the smallest change in firmness compared to initial values.

3.2. Color characteristics (L*, a, b, chroma, and hue angle)

L* represents the lightness of a surface with 00 being white and0 being black). Similarly, a* represents the color hue, ranging from green (negative) to red (positive), and b* ranges from yellow (negative) to blue (positive). These values are used to calculate chroma (C), and hue angle (h*) (Carreño et al., 1995). While experimental treatments didn't significantly affect L* values, significant differences emerged over the storage period. The highest L* value, indicating greater brightness, was observed on day 90 (41.15) (Table 1).

Pre-harvest Aloe Vera treatment in Sultani Cekirdeksiz (syn. Thompson Seedless) grapes caused a slight decrease in L* and an increase in C* values. During storage, all groups showed gradual decrease in L*, C*, and hue angle values. At the end of the storage period, the most significant changes in L and C* values were observed in the control grapes, while Aloe Vera treatments significantly delayed these color changes (Unal et al., 2022). Artes-Hernandez et al. (2004) reported a gradual decreasing in the L* values during storage, similar to our findings where L* decreased after day 120.

Significant differences in a* values were found across both treatments and storage periods. The highest a* value (17.28) was obtained in the control group on day 120 (Table 1). Previous research by Bayramoğlu and Sen (2020) showed that increased package openings led to a higher a* Red Globe grapes.We observed fluctuations in a* throughout storage period, which aligns with the documented varietal characteristic of 'Red Globe' grapes for occasional uneven coloration (Dokoozlian et al., 1994).

While experimental treatments didn't affect b* values, significant changes occurred across storage durations. The highest b* value (4.03) was obtained on day 30 (Table 1). Similar to our findings, Babalık et al. (2020) reported changes in b* values during grape storage.

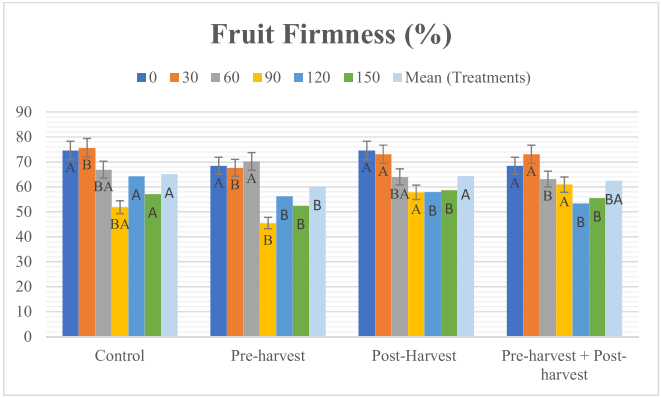

Fig. 4. Effects of Aloe Vera treatments on fruit firmness throughout the storage period. There is no statistical difference between columns marked with the same letter for each treatment (Duncan, $p < 0.05$).

Chroma is a numerical measure of color saturation. Both treatments and storage durations significantly impacted chroma values. The highest chroma value (17.38) was recorded on day 120 in the control group (Table 2). Similarly, hue angle differed significantly across storage durations, with the highest value (16.57) on day 30 (Table 2). Qaderi (2018) found that chitosan and cyclic acid treatments significantly affected chroma in Red Globe grapes. The findings of the study revealed that the experimental treatments had a significant influence on chroma values. Eing et al. (2023) reported a decrease in chroma compared to the control when pre-harvesting Rupi grapes with 100 mL L^{-1} Aloe Vera or chitosan, aligning with our results. Additionally, Castillo et al. (2010) observed a decrease in color index values in Autumn Royal grapes treated with Aloe Vera. These findings suggest that Aloe Vera may reduce color saturation of grapes, making grapes opaquer. This decrease in brightness could be a natural protective mechanism involving increased epicuticular wax production (Chitarra ve Chitarra, 2005; Côrrea ve Boliani, 2001).

3.3. Soluble solids content (SSC), pH and total acidity (TA)

Pre-harvest treatments yielded the lowest SSC values, while the combination of pre-harvest and post-harvest treatments led to the highest values. Neither experimental treatments nor storage durations significantly affected TA values. However, pH values did change significantly across storage periods (Table 3). Studies by Hasan et al. (2021) and Nia et al. (2022) demonstrated the effectiveness of Aloe Vera gel in maintaining SSC in fruits and vegetables. Our findings align with this, as the pre-harvest + post-harvest combination yielded the highest SSC. During storage, fruit juice reduction and complex sugar breakdown into simple forms lead to increased SSC. However, a high hydrolysis rate can negatively impact the fruit quality. Khan et al. (2016) explained that faster hydrolysis softens the fruit, making it more vulnerable to storage pathogens, and the storage period is shortened. The lower SSC observed with pre-harvest Aloe Vera applications suggests that these treatments inhibit the hydrolysis of sugars in the fruit.

Titratable acidity (TA) is an important biochemical parameter affecting the success of storage for many horticultural crops. The absence of significant differences in TA during storage with Aloe Vera gel applications can be interpreted as a positive effect on the stability of grape ripening. The pH value also fluctuated during the storage period. These changes likely stem from metabolic processes and reactions during post-harvest storage, as well as microbial activity (Cong et al., 2007; Meng et al., 2010; Unal et al., 2022). Unal et al. (2023) identified the highest and lowest TA values in Aloe Vera gel applications for the 'Thompson Seedless' grape variety after 120 days of storage in post-harvest AV application and the control group, respectively. Similarly, Shahkoomahally and Ramezanian (2014), found no significant changes in TA with post-harvest $CaCl_2$-supplemented *Aloe Vera* coating, aligning with our observations.

3.4. Total phenolics and total antioxidant capacity

Applying *Aloe Vera* treatments significantly increased total phenols of Red Globe grape cultivar compared to the control group, and this effect persisted throughout the storage period. The pre-harvest + post-harvest *Aloe Vera* treatments yielded the highest value (3389.45 μg gallic acid equivalent/g fresh fruit) (Table 4). Phenolic compounds also known as vitamin P, significantly influence food quality. They possess antioxidant and antimicrobial properties, inhibit enzyme activity, and offer health benefits (Nizamoğlu and Nas 2010; Özcan 2018). The application of pre-harvest *Aloe Vera* treatments resulted in a decrease in total phenols of 'Crimson Seedless' grape cultivar during the storage period and the lowest value was recorded on day 35 of storage period. In the present study, total phenols significantly increased throughout the

Table 1
Changes in L*, a* and b* values throughout the storage period.

	Day / Treatment	Control	Pre-harvest	Post-harvest	Pre-harvest + Post-harvest	Mean (stotage time)
L* values	0	35.02 C a	36.15 DC a	35.02 C a	36.15 C a	**35.59 C**
	30	33.70 C a	33.02 E a	31.96 D a	32.79 D a	**32.87 D**
	60	34.84 C b	36.89 BCE ba	36.39 C ba	39.34 B a	**36.86 B**
	90	38.22 B c	40.56 A b	43.10 A a	42.71 A a	**41.15 A**
	120	43.12 A a	39.35 BA b	40.28 B b	40.58 BA b	**40.83 A**
	150	35.54 CB a	34.13 DE a	34.57 DC a	34.51 DC a	**34.69 C**
	Mean (treatments)	**36.74 a**	**36.68 a**	**36.89 a**	**37.68 a**	
a* values	0	13.59 A a	8.77 BA a	13.59 A a	8.77 B a	**11.18 A**
	30	11.06 A b	8.54 BA c	13.96 A a	11.94 A ba	**11.37 A**
	60	10.84 A a	10.09 A ba	8.93 B bc	7.72 B c	**9.39 BA**
	90	8.78 A a	6.22 BCE b	6.50 CB b	6.59 CB b	**7.02 BCE**
	120	17.28 A a	8.47 BA a	7.79 B a	5.96 CB a	**9.87 BA**
	150	5.47 A a	4.57 C a	4.95 C a	4.30 C a	**4.82 C**
	Mean (treatments)	**11.17 a**	**7.77 b**	**9.28 ab**	**7.55 b**	
b* values	0	2.41 B a	3.18 A a	2.41 A a	3.18 BA a	**2.79 B**
	30	4.39 A a	2.74 A a	3.17 A a	5.83 A a	**4.03 A**
	60	0.97 C a	0.45 B a	0.97 C a	0.84 B a	**0.81 C**
	90	−0.54 D c	0.04 B c	1.59 BCE a	0.95 B b	**0.51 C**
	120	0.04 DC a	−0.09 B a	−0.39 D a	−0.99 B a	**−0.35 C**
	150	−0.42 D c	0.44 B a	0.28 DC ba	0.05 B b	**0.08 C**
	Mean (treatments)	**1.14 A**	**1.12 A**	**1.33 A**	**1.64 A**	

Means indicated storage time with the same upper-case letters in the same row are not significantly different (Duncan, $p < 0.05$). Means indicated Aloe Vera treatments with the same lower-case letters in the same column are not significantly different (Duncan, $p < 0.05$).

Table 2
Effects of *Aloe Vera* treatments on chroma values and hue angles (h°) throughout the storage period.

	Day / Treatment	Control	Pre-harvest	Post-harvest	Pre-harvest + Post-harvest	Mean (stotage time)
Chroma values	0	14.18 A a	10.11 A a	14.18 A a	10.11 B a	**12.14 A**
	30	12.69A ba	9.92 A b	15.06 A a	15.37 A a	**13.26 A**
	60	11.11 A a	10.38 A ba	9.36 B bc	8.22 CB c	**9.77 BA**
	90	8.92 A a	6.46 BCE b	6.87 CB b	6.74 CB b	**7.72 BCE**
	120	17.38 A a	8.66 BA a	7.90 B a	6.12 CB a	**10.01 BA**
	150	5.59 A a	4.67 C a	5.02 C a	4.33 C a	**4.90 C**
	Mean (treatments)	**11.64 a**	**8.37 b**	**9.73 ba**	**8.48 b**	
Hue angles (h°)	0	12.36 BA a	16.44 A	12.36 BA	16.44 BA	**14.40 A**
	30	18.96 A a	12.77 A a	16.18 A a	18.36 A a	**16.57 A**
	60	5.87 BCE a	3.5 A a	5.05 BCE a	6.25 C a	**5.17 B**
	90	−3.35 D c	−0.02 A c	15.26 A a	8.55 BCE b	**5.10 B**
	120	0.62 DC a	−0,18 A a	−2.73 D a	−9.89 D b	**−3.04 C**
	150	−3.36 D c	6.57 A a	3.86 DC ba	0.60 C bc	**1.91 B**
	Mean (treatments)	**5.18 a**	**6.51 a**	**8.33 a**	**6.72 a**	

Means indicated storage time with the same upper-case letters in the same row are not significantly different (Duncan, $p < 0.05$). Means indicated Aloe Vera treatments with the same lower-case letters in the same column are not significantly different (Duncan, $p < 0.05$).

storage period. This variation may be ascribed to the differences in grape cultivars, sections of grape used for analysis (skin, pulp), timing of treatments and storage durations. Liguori et al. (2015) observed that internal packaging concentrations influenced total phenols of 'Superior Seedless' and 'Red Globe' grape cultivars after 21 days, similar to our findings a significant increase in total phenols for Aloe Vera-treated Red Globe grapes compared to the control.

Aloe Vera treatments increased in Total Antioxidant Capacity (TAC) in 'Red Globe' grape cultivar during the storage period. The highest value (6.66 μMol trolox equivalent/g fresh weight) was obtained on day 150 in the pre-harvest + post-harvest treatments (Table 4). While Öztürk et al. (2019) observed a decrease in cherry TAC with Aloe Vera gel and MAP treatments during storage, they still exhibited higher TAC compared to control groups. Piazzolla et al. (2021) found no significant impact of different packaging and storage conditions on TAC during cold storage, further highlighting the potential differences in fruit type and treatment response. In our study, both *Aloe Vera* treatments and storage durations positively affected TAC. Total phenolics and anthocyanins are yer determinants of fruit and vegetable antioxidant capacity (Gimenez et al., 2016; Mirdehghan and Rahimi, 2016; Saracoglu et al., 2017). Notably, our findings showed significant increases in both these comounds with Aloe Vera treatments, likely contributing to the observed TAC boost.

4. Conclusion

The results of the study investigated the effects of *Aloe Vera* treatments on the quality of Red Globe grape cultivar during storage. Pre-harvest treatments minimized weight loss, while post-harvest treatments boosted soluble solids content (SSC) – both crucial parameters for grape shelf life. Interestingly, the combined pre-harvest + post-harvest application, despite negatively impacting some physical and chemical properties, significantly enhanced the grapes' phytochemical content compared to other treatments. These findings suggest tailoring Aloe Vera treatments based on the desired outcome:

For table grapes: Separate pre-harvest or post-harvest treatments are recommended to optimize either weight loss or SSC.
For health-focused consumption: The combined pre-harvest + post-harvest approach might be preferred due to its significantly higher phytochemical content, despite potential drawbacks in other quality aspects.

Table 3
Changes of SSC values (% Brix), titratable acidity (TA) values (%) and in pH values throughout the storage period.

	Day / Treatment	Control	Pre-harvest	Post-harvest	Pre-harvest + Post-harvest	Mean (stotage time)
SSC values	0	15.03 C a	14.3 D b	15.03 C a	14.30 D b	**14.66 E**
	30	14.46 D b	13.23 E c	14.56 D b	15.30 B a	**14.39 F**
	60	14.53 D c	16.00 A a	14.70 D b	14.10 D d	**14.83 D**
	90	15.30 B b	15.06 C c	15.30 A b	16.10 A a	**15.44 B**
	120	15.50 A a	15.03 C b	15.13 BCE b	14.66 C c	**15.08 C**
	150	15.40 BA b	15.46 B b	15.20 BA c	16.26 A a	**15.58 A**
	Mean (treatments)	**15.03 ab**	**14.85 c**	**14.98 b**	**15.12 a**	
TA values	0	1.83 A a	1.90 A a	1.83 A a	1.90 A a	**1.86 A**
	30	1.86 A a	2.02 A a	1.68 A a	2.17 A a	**1.93 A**
	60	1.91 A a	2.22 A a	1.88 A a	2.32 A a	**2.08 A**
	90	1.97 A a	1.98 A a	1.98 A a	2.08 A a	**2.00 A**
	120	2.03 A a	1.98 A a	2.10 A a	2.06 A a	**2.04 A**
	150	1.90 A a	2.03 A a	2.04 A a	2.13 A a	**2.03 A**
	Mean (treatments)	**1.91 a**	**2.02 a**	**1.92 a**	**2.11 a**	
pH values	0	3.55 CB a	3.54 B a	3.55 B a	3.54C a	**3.55 DC**
	30	3.54 CB b	3.50 C c	3.58 BA a	3.51 C c	**3.53 D**
	60	3.57 B a	3.52 CB b	3.55 B ba	3.55 C ba	**3.55 DC**
	90	3.57 B b	3.55 B b	3.55 B b	3.67 A a	**3.58 B**
	120	3.51 C b	3.61 A a	3.59 BA a	3.53 C b	**3.56 C**
	150	3.71 A a	3.59 A b	3.62 A b	3.61 B b	**3.63 A**
	Mean (treatments)	**3.57 a**	**3.55 a**	**3.57 a**	**3.57 a**	

Means indicated storage time with the same upper-case letters in the same row are not significantly different (Duncan, $p < 0.05$). Means indicated Aloe Vera treatments with the same lower-case letters in the same column are not significantly different (Duncan, $p < 0.05$).

Table 4
Effects of *Aloe Vera* treatments on total phenols (µg gallic acid equivalent /g fresh weight) and TAC values (µMol trolox equivalent/g fresh weight) throughout the storage period.

	Day / Treatment	Control	Pre-harvest	Post-harvest	Pre-harvest + Post-harvest	Mean (stotage time)
Total phenols (mg gallic acide quivalent /g fresh weight)	0	2.39 C b	2.97 C a	2.39 C b	2.97 D a	**2.68 C**
	30	3.04 B b	2.73 D c	3.41 B a	3.13 DC b	**3.08 B**
	60	3.60 A ba	3.85 A a	3.23 B c	3.43 BA bc	**3.53 A**
	90	3.17 B b	2.37 E c	3.60 BA a	3.73 A a	**3.22 B**
	120	3.40 BA b	3.74 A a	3.25 B b	3.36 BCE b	**3.43 A**
	150	3.60 A c	3.43 B bc	3.98 A a	3.72 A ba	**3.58 A**
	Mean (treatments)	**3.13 b**	**3.18 b**	**3.31 a**	**3.39 a**	
TAC values (µMol trolox equivalent/g fresh weight)	0	3.44 C a	3.90 B a	3.44 D a	3.90 C a	**3.67 D**
	30	4.37 BAC a	3.88 B a	4.36 CB a	4.55 CB a	**4.29 C**
	60	4.03 BCE a	4.15 B a	3.97 CD a	4.46 CB a	**4.15 C**
	90	4.07 BAC a	4.23 B a	5.13 B a	4.90 CB a	**4.58 CB**
	120	5.00 BA a	4.50 B a	4.20 CD a	5.44 B a	**4.79 B**
	150	5.29 A c	6.05 A b	6.33 A ba	6.66 A a	**6.08 A**
	Mean (treatments)	**4.36 b**	**4.45 b**	**4.57 b**	**4.99 a**	

Means indicated storage time with the same upper-case letters in the same row are not significantly different (Duncan, $p < 0.05$). Means indicated Aloe Vera treatments with the same lower-case letters in the same column are not significantly different (Duncan, $p < 0.05$).

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CRediT authorship contribution statement

Alperen Donat: Resources, Conceptualization, Methodology, Data curation. **Seda Sucu:** Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors have no conflicts of interest to declare.

Data availability

The data that has been used is confidential.

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References

Aboryia, M.S., El-Gioushy, S.F., Sami, R., Aljumayi, H., Alyamani, A., Almasoudi, A., Gawish, M.S., 2022. Synergistic effect of dipping in aloe vera gel and mixing with chitosan or calcium chloride on the activities of antioxidant enzymes and cold storage potential of peach (Prunus persica L.) fruits. Coatings 12 (4), 498. https://doi.org/10.3390/coatings12040498.

Agirgan A.Ö., 2013. Effects of aloe vera gel on the mechanical and thermal properties of nanocomposite produced from biopolymer blends. Doctoral Thesis, Marmara University, Institute of Science, İstanbul, Turkey 113 p.

Amiri, S., Nicknam, Z., Radi, M., Sayadi, M., Bagheri, F., Karimi Khorrami, N., Abedi, E., 2021. Postharvest quality of orange fruit as influenced by salicylic acid, acetic acid,

and carboxymethyl cellulose coating. J. Food Meas. Charact. 15 (5), 3912–3930. https://doi.org/10.1007/s11694-021-00966-y.
Artés-Hernández, F., Aguayo, E., Artés, F., 2004. Alternative atmosphere treatments for keeping quality of 'Autumn seedless' table grapes during long-term cold storage. Postharvest Biol. Technol. 31 (1), 59–67. https://doi.org/10.1016/S0925-5214(03)00116-9.
Atabey, S., 2023. A Journey from antiquity to the present: a comparative analysis from oxymellite to sirkencebin. Int. J. Curr. Res. Sci. Soc. 13 (3), 437–448. https://doi.org/10.26579/jocress.13.3.7.
Babalık, Z., Demirci, T., Aşcı, Ö.A., Baydar, N.G., 2020. Brassinosteroids modify yield, quality, and antioxidant components in grapes (*Vitis vinifera* L. cv. 'Alphonse Lavallée'). J. Plant Growth Regul. 39, 147–156. https://doi.org/10.1007/s00344-019-09970-5.
Bayramoğlu, A., Şen, F., 2020. The effects of different package openings on storage of 'red globe' grape variety. Ege Üniv. Ziraat Fak. Derg. 57 (4), 563–570. https://doi.org/10.20289/zfdergi.698873.
Côrrea, L.S., Boliani, A.C., 2001. Cultura De Uvas De Mesa Do Plantio à Comercialização. ALGRAF, Ilha solteira, Brasil, p. 328.
Cai, N., Wan, C., Chen, J., Chen, C., 2021. Evaluation of postharvest storability of Ponkan mandarins stored at different temperatures. Folia Hortic. 33 (2), 354–364. https://doi.org/10.2478/fhort-2021-0027.
Carreño, J., Martínez, A., Almela, L., Fernández-López, J.A., 1995. Proposal of an index for the objective evaluation of the colour of red table grapes. Food Res. Int. 28, 373–377.
Castillo, S., Navarro, D., Zapata, P.J., Guillén, F., Valero, D., Serrano, M., Martínez-Romero, D., 2010. Antifungal efficacy of aloe vera *in vitro* and its use as a preharvest treatment to maintain postharvest table grape quality. Postharvest Biol. Technol. 57, 183–188. https://doi.org/10.1016/j.postharvbio.2010.04.006.
Castillo, S., Navarro, D., Zapata, P.J., Guillén, F., Valero, D., Martínez-Romero, D., Serrano, M., 2010a. Using Aloe vera as a preharvest treatment to maintain postharvest organic table grape quality. Acta Hortic. 933, 621–625. https://doi.org/10.17660/ActaHortic.2012.933.81.
Castillo, S., Navarro, D., Zapata, P.J., Guillén, F., Valero, D., Serrano, M., Martínez-Romero, D., 2010b. Antifungal efficacy of aloe vera *in vitro* and its use as a preharvest treatment to maintain postharvest table grape quality. Postharvest Biol. Technol. 57 (3), 183–188. https://doi.org/10.1016/j.postharvbio.2010.04.006.
Champa, W.H., Gill, M.I.S., Mahajan, B.V.C., Arora, N.K., 2014. Postharvest treatment of polyamines maintains quality and extends shelf-life of table grapes (*Vitis vinifera* L.) cv. 'Flame Seedless. Postharvest Biol. Technol. 91, 57–63. https://doi.org/10.1016/j.postharvbio.2013.12.014.
Chitarra, M.I.F., Chitarra, A.B., 2005. Perdas pós colheita. Estresses e desordens fisiológicas. Qualidade pós-colheita. Chitarra M.I.F. & Chitarra A.B. Pós-colheita De Frutas e hortaliças: Fisiologia e Manuseio. UFLA, Lavras, Brasil, p. 785.
Cong, F., Zhang, Y., Dong, W., 2007. Use of surface coatings with natamycin to improve the storability of Hami melon at ambient temperature. Postharvest Biol. Technol. 46, 71–75. https://doi.org/10.1016/j.postharvbio.2007.04.005.
Destiana, I.D., Anisa, Z.N., Mukminah, N., 2021. The effect of aloe vera gel edible coating and glycerol on the physicochemical characteristics of red grapes (*Vitis vinifera* L.). J. Food Sci. Technol. 9 (3), 188–195. https://doi.org/10.21776/ub.jpa.2021.009.03.7.
Dokoozlian, N.K., Luvisi, D.A., Schrader, P.L., Kosareff, J.J., 1994. Influence of vine crop load on 'Redglobe' table grapes. In: Proceedings of the International Symposium on Table Grape Production. Anaheim, CA, USA, pp. 211–214. Rantz, J. M.,.
Eing, K.K.C., Faria, C.M.D.R., Maia, A.J., Garcia, C., Carvalho, F., Botelho, R.V., 2023. Quality of Rubi grapes coated with aloe vera L. gel in the preharvest. Comun. Sci. 14, e3748. https://doi.org/10.14295/CS.v14.3748 v.2023.
Eshun, K., He, Q., 2004. Aloe vera: a valuable ingredient for the food, pharmaceutical and cosmetic industries a review. Crit. Rev. Food Sci. Nutr. 44 (2), 91–96. https://doi.org/10.1080/10408690490424694.
Farina, V., Passafiume, R., Tinebra, I., Scuderi, D., Saletta, F., Gugliuzza, G., Gallotta, A., 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. 1–10. https://doi.org/10.1155/2020/8303140.
Giménez, M.J., Valverde, J.M., Valero, D., Zapata, P.J., Castillo, S., Serrano, M., 2016. Postharvest methyl salicylate treatments delay ripening and maintain quality attributes and antioxidant compounds of 'Early Lory' sweet cherry. Postharvest Biol. Technol. 117, 102–109. https://doi.org/10.1016/j.postharvbio.2016.02.006.
Golly, M.K., Ma, H., Sarpong, F., Dotse, B.P., Oteng-Darko, P., Dong, Y., 2019. Shelf-life extension of grape (Pinot noir) by xanthan gum enriched with ascorbic and citric acid during cold temperature storage. J. Food Sci. Technol. 56, 4867–4878. https://doi.org/10.1007/s13197-019-03956-7.
Guillén, F., Díaz-Mula, H.M., Zapata, P.J., Valero, D., Serrano, M., Castillo, S., Martínez-Romero, D., 2013. Aloe arborescens and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest Biol. Technol. 83, 54–57. https://doi.org/10.1016/j.postharvbio.2013.03.011.
Hasan, M.U., Riaz, R., Malik, A.U., Khan, A.S., Anwar, R., Rehman, R.N.U., Ali, S., 2021. Potential of Aloe vera gel coating for storage life extension and quality conservation of fruits and vegetables: an overview. J. Food Biochem. 45 (4), e13640. https://doi.org/10.1111/jfbc.13640.
Huiling, Z., 2006. The relationship between fruit texture and storage character in grapes. Acta Hortic. Sin. 33 (1), 28.
Khan, A.U., Yuan, Q., Wei, Y., Khan, S.U., Tahir, K., Khan, Z.U.H., Nazir, S., 2016. Longan fruit juice mediated synthesis of uniformly dispersed spherical AuNPs: cytotoxicity against human breast cancer cell line MCF-7, antioxidant and fluorescent properties. RSC Adv. 6 (28), 23775–23782. https://doi.org/10.1039/C5RA27100B.
Krochta, J.M., 2002. Proteins as raw materials for films and coatings: definitions, current status, and opportunities. Protein Based Films and Coat. 1, 1–40.
Leng, F., Wang, C., Sun, L., Li, P., Cao, J., Wang, Y., Zhang, C., Sun, C., 2022. Effects of different treatments on physicochemical characteristics of 'Kyoho' grapes during storage at low temperature. Sci. Hortic. 8 (2), 94. https://doi.org/10.3390/horticulturae8020094.
Liguori, G., D'Aquino, S., Sortino, G., De Pasquale, C., Inglese, P., 2015. Effects of passive and active modified atmosphere packaging conditions on quality parameters of minimally processed table grapes during cold storage. J. Berry Res. 5 (3), 131–143. https://doi.org/10.3233/JBR-150101.
Martínez-Romero, D., Alburquerque, N., Valverde, J.M., Guillén, F., Castillo, S., Valero, D., Serrano, M., 2006. Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. Postharvest Biol. Technol. 39 (1), 93–100. https://doi.org/10.1016/j.postharvbio.2005.09.006.
McGuire, R.G., 1992. Reporting of objective color measurements. Hortic. Sci. 27, 1254–1255. https://doi.org/10.21273/HORTSCI.27.12.1254.
Meng, X.H., Qin, G.Z., Tian, S.P., 2010a. Influences of preharvest spraying Cryptococcus laurentii combined with postharvest chitosan coating on postharvest diseases and quality of table grapes in storage. LWT Food Sci. Technol. 43, 596–601. https://doi.org/10.1016/j.lwt.2009.10.007.
Meng, X.H., Qin, G.Z., Tian, S.P., 2010b. Influences of preharvest spraying Cryptococcus laurentii combined with postharvest chitosan coating on postharvest diseases and quality of table grapes in storage. LWT Food. Sci. Technol. 43 (4), 596–601. https://doi.org/10.1016/j.lwt.2009.10.007.
Mirdehghan, S.H., Rahimi, S., 2016. Pre-harvest application of polyamines enhances antioxidants and table grape (*Vitis vinifera* L.) quality during postharvest period. Food Chem. 196, 1040–1047. https://doi.org/10.1016/j.foodchem.2015.10.038.
Nia, A.E., Taghipour, S., Siahmansour, S., 2021. Pre-harvest application of chitosan and postharvest Aloe vera gel coating enhances quality of table grape (*Vitis vinifera* L. cv. 'Yaghouti') during postharvest period. Food Chem. 347, 129012 https://doi.org/10.1016/j.foodchem.2021.129012.
Nia, A.E., Taghipour, S., Siahmansour, S., 2022. Effects of salicylic acid preharvest and Aloe vera gel postharvest treatments on quality maintenance of table grapes during storage. S. Afr. J. Bot. 147, 1136–1145. https://doi.org/10.1016/j.sajb.2022.05.010, 2022.
Nicolau-Lapeña, I., Colas-Meda, P., Alegre, I., Aguiló-Aguayo, I., Muranyi, P., Viñas, I., 2021. Aloe vera gel: an update on its use as a functional edible coating to preserve fruits and vegetables. Prog. Org. Coat. 151, 106007 https://doi.org/10.1016/j.porgcoat.2020.106007.
Nizamoglu, N.M., Nas, S., 2010. The phenolic compounds found in vegetables and fruit; their structure and importance. J. Food Sci. Technol. 5, 20–25.
Özcan, M., 2018. Importance of colors in consumption and health. Black Sea J. Agric. 1 (3), 83–88. Retrieved from. https://dergipark.org.tr/en/pub/bsagriculture/issue/38529/447069.
Ozgen, M., Reese, R.N., Tulio, A.Z., Scheerens, J.C., Miller, A.R., 2006. Modified 2, 2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) method to measure antioxidant capacity of selected small fruits and comparison to ferric reducing antioxidant power (FRAP) and 2, 2 '-diphenyl-1-picrylhydrazyl (DPPH) methods. J. Agric. Food Chem. 54 (4), 1151–1157. https://doi.org/10.1021/jf051960d.
Öztürk, B., Karakaya, O., Yıldız, K., Saracoglu, O., 2019. 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. https://doi.org/10.1016/j.scienta.2019.01.030.
Padmaja, N., Bosco, S.J.D., 2014. Preservation of jujube fruits by edible Aloe vera gel coating to maintain quality and safety. Indian. J. Sci. Technol. 2 (3), 79–88.
Piazzolla, F., Amodio, M.L., Pati, S., Colelli, G., 2021. Evaluation of quality and storability of "Italia" table grapes kept on the vine in comparison to cold storage techniques. Foods 10 (5), 943. https://doi.org/10.3390/foods10050943.
Pretel, M.T., Martinez–Madrid, M.C., Martinez, J.R., Carreno, J.C., Romojaro, F., 2006. Prolonged storage of aledo table grapes in a slightly CO_2 enriched atmosphere in combination with generators of SO_2. Food Sci. Technol. 39 (10), 1109–1116. https://doi.org/10.1016/j.lwt.2005.07.022.
Qaderi R., 2018. Effectiveness of chitosan treatment on maintaining quality parameters in red globe cultivar (*Vitis Vinifera* L.) during the storage period. Master's Thesis, Niğde Ömer Halisdemir University, Graduate School of Natural and Applied Sciences, Department of Plant Production and Technologies, Niğde, Turkey, 76 p.
Raghav, P.K., Agarwal, N., Saini, M., Vidhyapeeth, J., 2016. Edible coating of fruits and vegetables: a review. Int. J. Sci. Mod. Educ. 1 (1), 188–204.
Raheemullah, F.U., Mehmood, K., Sana, M.Z., Ahmad, R., Mehmood, A., Haris, M., Rahman, U.U., Khan, F., Fida, F., Khan, M.S., Haq, N.U., 2023. Effectiveness of aloe vera coating gel on shelf life of grapes. J. Xi'an Shiyou Univ. Natural Science Edition. 19 (2), 1484–1496.
Romanazzi, G., Lichter, A., Gabler, F.M., Smilanick, J.L., 2012. Recent advances on the use of natural and safe alternatives to conventional methods to control postharvest gray mold of table grapes. Postharvest Biol. Technol. 63 (1), 141–147. https://doi.org/10.1016/j.postharvbio.2011.06.013.
Sacks, E.J., Shaw, D.V., 1994. Optimum allocation of objective color measurements for evaluating fresh strawberries. J. Am. Soc. Hortic. Sci. 119 (2), 330–334. https://doi.org/10.21273/JASHS.119.2.330.
Saracoglu, O., Ozturk, B., Yildiz, K., Kucuker, E., 2017. Pre-harvest methyl jasmonate treatments delayed ripening and improved quality of sweet cherry fruits. Sci. Hortic. 226, 19–23. https://doi.org/10.1016/j.scienta.2017.08.024.
Saracoglu, O., 2018. Phytochemical accumulation of anthocyanin rich mulberry (Morus laevigata) during ripening. J. Food Meas. Charact. 12 (3), 2158–2163. https://doi.org/10.1007/s11694-018-98313.
Sarker, A., Grift, T.E., 2021. Bioactive properties and potential applications of aloe vera gel edible coating on fresh and minimally processed fruits and vegetables: a review.

J. Food Meas. Charact. 15, 2119–2134. https://doi.org/10.1007/s11694-020-00802-9.
Serrano, M., Valverde, J.M., Guillén, F., Castillo, S., Martínez-Romero, D., Valero, D., 2006. Use of aloe vera gel coating preserves the functional properties of table grapes. Agric. Food Chem. 54 (11), 3882–3886. https://doi.org/10.1021/jf060168p.
Shah, S., Hashmi, M.S., 2020. Chitosan–aloe vera gel coating delays postharvest decay of mango fruit. Hortic. Environ. Biotechnol. 61 (2), 279–289. https://doi.org/10.1007/s13580-019-00224-7.
Shahkoomahally, S., Ramezanian, A., 2014. Effect of natural aloe vera gel coating combined with calcium chloride and citric acid treatments on grape (*Vitis vinifera* L. cv. 'Askari') quality during storage. Am. J. Food Sci. Technol. 2 (1), 1–5. https://doi.org/10.12691/ajfst-2-1-1.
Singleton, V.L., Rossi, J.A., 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Vitic. 16 (3), 144–158. https://doi.org/10.5344/ajev.1965.16.3.144.
Unal, S., Sabir, F.K., Sabir, A., 2022. Aloe vera treatments extend the postharvest life of table grapes by delaying weight loss, berry softening, rachis browning, and biochemical changes. Erwerbs-Obstbau 64, 767–775. https://doi.org/10.1007/s10341-022-00710-w, 2022.
Valverde, J.M., Valero, D., Martínez-Romero, D., Guillén, F., Castillo, S., Serrano, M., 2005. Novel edible coating based on Aloe vera gel to maintain table grape quality and safety. J. Agric. Food Chem. 53 (20), 7807–7813. https://doi.org/10.1021/jf050962v.