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Effect of postharvest application of salicylic acid on quality and storage life of strawberry fruit cv. Sabrina (1180)

Mohammad Salehi Serbijan[1], Hossein Meighani[2*], Mohammad Sadat Hosseini[1], Sediqeh Afsharipour[3]

1- Department of Horticultural Science, Faculty of Agriculture, University of Jirot, Jiroft, Iran.
2- Department of Horticultural Science, Faculty of Agriculture, University of Birjand, Birjand, Iran.
3- Department of f Agricultural Engineering, University of Hormozgan, Bandar Abbas, Iran.
*Corresponding author Email: hosseinmeighani@birjand.ac.ir

Abstract

Strawberry is highly perishable fruit, mostly due to their susceptibility to mechanical injury, water loss, physiological deterioration, and microbial decay after harvest. This study aimed to investigate the effects of salicylic acid (0, 1, and 2 mM) on maintaining the quality and shelf life of strawberry fruits cv. 'Sabrina' during 10 days of storage at 4 ±0.5 ˚C with 90-95% RH. Physico-chemical characteristics were monitored during storage at 5-day intervals. The results showed that SA treatments and storage time had no significant effect on the total soluble solids. SA treatment substantially decreased the physiological loss in weight and fruit softness as compared to the control samples. In addition, total anthocyanin content and ascorbic acid content were higher in SA-treated fruits at the end of storage. Total phenolic content and total antioxidant activity were not affected by SA treatment. Overall, these findings suggest that SA treatment exhibits a high potential in preserving the postharvest quality of strawberry fruit.

Keywords: Anthocyanin, Antioxidant compound, Ascorbic acid, Firmness.

Introduction

Strawberry, belonging to the Rosaceae family, is one of the most popular fruits in the world. Strawberry fruits are appreciated for their juicy texture, red colour, and sweet taste. It is very rich in minerals, vitamins, phenolics, anthocyanins, and amino acids (Gacnik et al., 2021). Strawberries are non-climacteric fruit, meaning their respiration rate and ethylene production do not increase during ripening (Ali et al., 2021; Babalar et al., 2007). However, postharvest strawberries are highly perishable resulting in a short shelf-life due to mechanical injury, physiological deterioration, water loss, fungal decay, and high respiration rate (Yang et al., 2022; Sogvar et al., 2016). Its fruit quality deteriorates rapidly postharvest due to quick metabolic activity. Therefore, proper fruit storage is an effective way to consistently quality fruit after harvest (Kumar and Kuar, 2019). Salicylic acid (SA), a ubiquitous simple plant phenol, is known as a plant growth regulator and has been reported to regulate a number of processes in plants (Babalar et al., 2007). It is reported that the applications of SA and its derivatives can improve the storage quality by reducing ethylene production and respiration rate, suppressing fruit softening and color change, preserving sugars, ascorbic acid, organic acids, and aroma, preventing chilling injury, promoting pathogen resistance and activating antioxidant system (Gacnik et al., 2021; Ali et al., 2021; Darwish et al., 2021).

Previous studies showed that crop quality traits were improved following exogenous SA treatment. For example, treatment of "Kinnow" mandarin fruit with SA showed higher levels of ascorbic acid, phenolic compounds, total antioxidants, and antioxidants enzyme activity of the fruit during storage (Haider et al., 2020). Furthermore, SA treatment significantly suppressed weight loss, decay, fungal growth, respiration rate, and also maintained fruit firmness, ascorbic acid, and bioactive compounds level of strawberry cv. 'Festival' fruits during storage (El-Mogy et al., 2019). However, there have been few reports on the effects of the application of SA on the postharvest storage of strawberry cv. 'Sabrina' fruit.

To ensure food supply and the safety of horticultural products, SA has the potential as an alternative of synthetic chemicals used in postharvest handling of strawberry. Therefore, the present study was conducted to optimize the best dose of postharvest application of SA to extend the storage life with best quality of 'Sabrina' strawberry fruit. The main goal of our study was to evaluate the influence of different postharvest SA treatments on the physiochemical parameters, including fruit firmness, physiological loss in weight, ascorbic acid, total phenolic and anthocyanin content in strawberry fruit during cold storage.

Materials and Methods

Plant material and treatment

Strawberry (*Fragaria* × *anannasa* cv. Sabrina) fruits were hand-harvested at a commercially mature stage (80% red color) from a commercial greenhouse in the Jiroft region, Kerman province, Iran, and immediately transferred to the research laboratory.

Treatments included different concentrations of SA (1 and 2 mM, Sigma–Aldrich, Germany). Distilled water was used as a control. For SA treatment, the fruits with uniform color and size, without any visual defect were randomly selected and dipped for 5 min in the SA solution.

After applying the treatment, the fruits were allowed to air dry at ambient temperature, packed in polystyrene boxes, weighed, and placed at 4 ±0.5 ˚C with 90-95% relative humidity for 10 days. After 0 (at harvest), 5, and 10 days of cold storage, three boxes from each treatment were randomly sampled to evaluate fruit characteristics.

Fruit firmness and physiological loss in weight

Fruit firmness was determined using a texture analyzer (Santam, STM-5, Iran) equipped with a flat probe (8 mm) with a penetration depth of 10 mm, and the results were expressed in Newton (N) units (Meighani and Roozkhosh, 2024).

For physiological loss in weight (PLW), strawberry fruits were weighed at the beginning of the experiment, after treatment, and at the end of each sampling time. The percentage of PLW was calculated using the following equation: PLW (%) = (Wi – Wf) × 100/ Wi, where Wi is the initial weight and Wf is the weight at each sampling time (Haider et al., 2020).

Total soluble solids (TSS), and Ascorbic acid content

TSS of strawberry juice was measured at 25˚C with a hand-held digital refractometer (PDR-108-1, Taiwan) and the results were expressed as Brix degrees (˚Brix). Ascorbic acid content was determined based on the 2,6- dichloroindophenol titration method. The amount of ascorbic acid in the strawberry fruits was expressed as mg per 100 g FW (AOAC, 2000).

Total phenolic content, total anthocyanin content, and total antioxidant activity

For the determination of total phenolic content (TPC) and total antioxidant activity (TAA), 2 g strawberry fruit tissue without achene was well homogenized with 10 mL of methanol (80%) and centrifuged at 14000 rpm at 4˚C for 10 min. The supernatant was used for TPC and TAA analysis.

TPC was measured using the Folin–Ciocalteau reagent according to the method of Singleton and Rossi (1965). About 250 µL of the extract was mixed with 1250 µL of 10% Folin-Ciocalteau reagent and 1000 µL of 7.5% Na_2CO_3. The samples were incubated at room temperature in darkness for 60 min, and then the absorbance of the reaction mixture was measured at 765 nm using a UV/VIS spectrometer (Lambda 25, PerkinElmer, USA). Gallic acid was used as an external standard and the results were expressed as mg gallic acid equivalents (GAE) per 100 g fresh weight.

Total antioxidant activity (TAA) was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method as outlined in Brand-Williams et al. (1995). DPPH methanolic solution (950 µl) was mixed with 50 µl of extract and kept in the dark at ambient temperature for 30 min. The solution absorbance was measured at 517 nm, and the TAA was calculated as the following equation: TAA (%)= [(Ac - As)/Ac] × 100, where Ac is the absorbance of the DPPH and As is the absorbance of the sample.

Total anthocyanin content (TAC) was determined using the pH differential method described by Giusti and Wrolstad (2001) with some modifications. Fruit puree without achenes (2 g) was homogenized in 10 ml of methanol/HCl (85/15%, v/v) and centrifuged at 14000 rpm at 4˚C for 10 min. The extract was diluted in pH_1 and pH_7 solution buffers and after 30 min incubation in ambient temperature, the absorbance was measured at 510 and 700 nm. TAC was calculated as mg cyanidin 3-glucoside equivalent per kg of fresh fruit.

Statistical Analysis

This study was conducted as a two-factorial experiment based on a completely randomized design with three replications. The data were analyzed by the PROC ANOVA procedure by SAS version 9.1 (SAS Institute Inc., Cary, NC, USA) software. The means comparison was done with the LSD test.

Results and Discussion

Fruit firmness and physiological loss in weight (PLW)

PLW is one of the key factors affecting the quality of fresh produce, which can initiate fruit shriveling and deterioration (Zhang et al., 2022). Strawberry fruit is highly susceptible to a rapid loss of water due to the extremely thin skin structure. As illustrated in table 1, all fruits showed a gradual PLW throughout the storage period. Compared to the control fruit, SA-treated fruit had lower PLW (%). At the end of storage, the maximum PLW (3.56%) was observed in the control fruits while it was the minimum (1.71%) in the fruits treated with 2 mM SA (Table 1). The change in firmness was opposite to the change in weight loss. The fruit becomes softer after storage. Fruit firmness was 9.0 N at harvest time and decreased during storage in control and SA-treated fruits. SA treatment delayed the decrease of fruit firmness. Nevertheless, no significant difference was observed between different concentrations of SA during storage (Table 1). After 10 days of storage, fruit firmness was significantly higher in the fruits treated with 2 mM SA when compared with the control (table 1).

Table 1 The interaction effect of salicylic acid (SA) and storage time on physiological loss in weight (PLW), firmness, and total anthocyanin content (TAC) of strawberry fruit cv. 'Sabrina'.

Storage time (day)	Salicylic acid (mM)	PLW (%)	Firmness (N)	TAC (mg g^{-1} FW)
0 (at harvest)	-	0.00 f	9.00 a	0.29 b
5	0	0.48 d	6.63 cd	0.37 b
	1	0.31 de	7.17 bc	0.38 b
	2	0.29 de	7.50 b	0.37 b
10	0	3.56 a	5.27 f	0.42 b
	1	2.29 b	5.58 ef	0.43 ab
	2	1.71 c	6.01 de	0.49 a

* Means (n=3) within each column with different letters denote significant differences (*P<0.01*).

PLW and softening of 'Sabrina' strawberry occurred during cold storage, and these changes were also present in the postharvest period of other strawberry cultivars (Zhang et al., 2022; El. Mogy et al., 2019). The positive effects of SA for reducing PLW and softening are related to its overall effects in reducing the respiratory metabolism and delaying fruit senescence, which was confirmed in blueberry fruit (Jiang et al., 2022).

Total soluble solids (TSS) and ascorbic acid

TSS is an important internal quality attribute, that can be used to assess fruit maturity. The results showed that SA treatment had no significant effect on the TSS of strawberry fruits during cold storage (Table 2). These results are in line with the findings of Zhang et al. (2022) and Salari et al. (2013) in other strawberry cultivars.

The effect of different concentrations of SA on ascorbic acid, total phenolic content (TPC), and total antioxidant activity (TAA) of strawberry cv, 'Sabrina' during cold storage is shown in table 2. The interaction between SA treatment and storage time had no significant effect on these traits.

Table 2. Effect of salicylic acid and storage time on the biochemical characteristics of strawberry fruit cv. 'Sabrina'.

Storage time (day)	Ascorbic acid (mg $100g^{-1}$FW)	Total soluble solids (˚Brix)	TPC (mg GAE g^{-1} FW)	TAA (%DPPHsc)
0 (at harvest)	108.14 a	7.80 a	3.86 a	79.73 b
5	107.29 a	7.47 a	3.64 b	86.39 a
10	58.47 b	6.90 a	2.96 c	81.09 b
Salicylic acid (mM)				
0	87.58 b	7.33 a	3.33 a	81.38 a
1	90.32 b	7.07 a	3.51 ab	82.28 a
2	95.99 a	7.77 a	3.63 a	83.55 a

Means (n=3) in each column and for each factor with different letters indicate significant differences. TPC, total phenolic content; TAA, total antioxidant activity.

Ascorbic acid content in strawberry fruit gradually decreased with increasing storage time. After 10 days of storage, the ascorbic acid content of strawberry fruit was almost 2 times lower than at harvest. On the other hand, strawberry fruits treated with SA exhibited higher ascorbic acid content. Although, there was no significant difference between 1 mM SA and control fruits (Table 2). Ascorbic acid is a natural antioxidant that is water-soluble vitamin and is rapidly oxidized by the effect of temperature, light, and ascorbic acid oxidase enzymes (Haider et al., 2020). Reduction of ascorbic acid contents during storage may be due to the exposure of fruit at low temperatures. We observed a positive influence of SA on increasing the ascorbic acid content, which may be related to the effects of SA, a lower activity of ascorbic acid oxidase, which catalyses the oxygenation of ascorbic acid to dehydroascorbic acid, an increase in the activity of ascorbate peroxidase and glutathione reductase or a higher content of reducing sugars (Gacnik et al., 2021). The positive effect of SA in reducing the loss of ascorbic acid is in line with a previous study reported by El-Mogy et al. (2019) on strawberry fruit cv. 'Festival'.

Total phenolic content, total anthocyanin content, and total antioxidant activity

The total phenolic content (TPC) in strawberry fruit was 3.86 mg. g^{-1} fresh weight at harvest time and significantly decreased with increasing storage time so that after 10 days of storage, the TPC of strawberry fruit was 1.3 times lower than at harvest (day 0). SA treatment had no significant effect on the TPC of strawberry fruit (Table 2). The decrease in TPC during postharvest storage could be due to the polymerization or degradation of phenolic compounds by PPO enzyme activity (Meighani and Roozkhosh, 2024). Higher TPC in the SA-treated fruits may be because of exposure in part water loss during storage (Haider et al., 2020).

The total anthocyanin content (TAC) of strawberry fruits was significantly affected by storage time and treatment. TAC increased progressively in SA-treated and the control strawberry fruit during cold storage. After 10 days of cold storage, the highest TAC of strawberry fruit was observed in 2 mM SA treatment (0.49 mg g^{-1} FW) and the lowest TAC was recorded in the control (0.42 mg g^{-1} FW) fruits (Table 2).

Anthocyanin is one of the major compounds present in strawberries. Postharvest anthocyanin synthesis has been reported in strawberries (Gacnik et al. 2022), and pomegranates (Nazoori et al., 2023) in previous research, which is consistent with our results. In our study, we observed an increase in the TAC of strawberry fruits treated with SA, in line with the investigation by Zhang et al. (2022).

The total antioxidant activity (TAA) in strawberry fruit reached a higher level from 79.73% at 0 days (at harvest) to 86.39% at 5 days during the initial storage and then significantly reduced by the end of storage. Despite the increase in TAA with the postharvest application of salicylic acid, no significant difference in TAA level was detected by statistical analysis among SA-treated and control fruits (Table 2).

Conclusions

This study showed that the SA treatment is effective in enhancing the quality and extending the shelf life of strawberry fruits during cold storage. However, fruit treated with 2 mM SA exhibited highest levels of antioxidant compound and quality during storage. Overall this study suggests that 2 mM SA performed best to maintain the fruit quality during storage and can be used effectively long term cold storage of 'Sabrina' Strawberry.

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