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Postharvest Salicylic Acid Application Affects the Biochemical Quality and Stability of Strawberry (*Fragaria* x *ananassa* Duch.) cv. Chandler Fruits under Ambient Storage Conditions

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The present study aimed to determine the effect of postharvest salicylic acid (SA) application on storability and biochemical quality of strawberry fruits cv. Chandler under ambient storage conditions. Freshly harvested fruits were subjected to salicylic acid treatment at 0 (control), 0.5, 1 or 2 mM and fruits were stored at room temperature for 6 days storage studies. Data on physiological loss in weight (PLW), fruit spoilage and biochemical quality of fruits (total soluble soils, titratable acidity, ascorbic acid, reducing and total sugars) were recorded. Results showed that postharvest salicylic acid treatment significantly minimized the PLW and fruit spoilage. At 6 days of storage, the lowest PLW (14.43 %) and fruit spoilage (21.70 %) was observed with SA at 2 mM. All the salicylic acid treatments were effective in retaining the biochemical quality of fruit (total soluble soils, titratable acidity, ascorbic acid, reducing and total sugars). In conclusion, Salicylic acid at 2 mM treatment of strawberry fruits after harvest can be useful in minimizing PLW and fruit spoilage and also maintaining the biochemical quality of fruits during ambient storage conditions.

Keywords: Ambient storage; fruit quality; salicylic acid; strawberry; storability.

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1. INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.; Family *Rosaceae*) is most important berry fruit [1]; and widely cultivated in temperate, the mediterranean and subtropical regions of the world [2]. Strawberry is a popular fruit due to its appealing fruits shape, pleasant aroma, juicy texture besides nutritional and health benefits. Globally China is leading in production, followed by USA, Mexico, Egypt, Turkey and Spain among others countries are major producers of strawberries [3]. It has been witnessed that worldwide strawberry production has expanded substantially in recent decades [4]. India's temperate regions of Jammu Kashmir, Himachal Pradesh and Uttarakhand are widely known for commercial strawberry growing long back, but its commercial cultivation has increased substantially in subtropical and tropical plains of India in recent decades. Growers of Haryana, Punjab, Maharashtra, Karnataka, Uttar Pradesh and in the vicinity of Delhi are successfully cultivating strawberries in the winter using planting materials from the Himachal Pradesh and Uttarakhand [5].

Strawberry is a non-climacteric and highly perishable fruit. Strawberry fruits have very short storage and shelf-life which is one of the primary bottlenecks in the strawberries fresh market supply chain. The postharvest management practices greatly influence the shelf life and quality of strawberry fruits. The respiration rate and ethylene production does not increase sharply during ripening of fruit [6]. After harvest, mechanical damage, physiological deterioration, water loss, and microbial spoilage rapidly decrease the quality of the fruit, resulting in post-harvest losses [7]. The most efficient approach for maintaining strawberry fruit quality is postharvest fast cooling and storage at low temperatures (0-4 °C) [8]; although, ensuring optimal storage and temperature control after harvest is not always achievable because of the short storage life of fruit, insufficient cold storage and cold chain facilities.

Fruit postharvest treatment solutions primarily focus on the limiting water losses, preserving biochemical quality and extending fruit shelf-life while preventing the emergence of postharvest infections. Several synthetic compounds have been used to extend the postharvest life of various fruits; nonetheless, public concern over fungicide residues is growing day by day. Because of the negative impacts of pesticides on human health and the environment, it is critical to focus on better fungicide alternatives [9]. Use of natural compounds in postharvest storage and quality control of fruits has attracted attention among the scientific community and end users during the last few decades. Salicylic acid (SA), a natural plant molecule that has the key role in photosynthesis, plant water relations, various enzyme activities and its effect on the plants exposed to various biotic and abiotic stresses [10]. Salicylic acid has been shown to play an important function in the expression of pathogenic genes and to impart resistance to infections [11,12]. It has been demonstrated that use of salicylic acid to be effective in preserving the quality of numerous fruits during storage [13-16]. In furtherance, the current study sought to determine the effect of postharvest salicylic acid treatment on strawberry cv. Chandler fruit's storability and biochemical quality under ambient storage environments.

2. MATERIALS AND METHODS

The experiment was conducted at the Division of Horticulture, Faculty of Agriculture (SKUAST-K), Wadura Campus, Sopore, J&K (India) during the year 2017 & 2018. Freshly harvested strawberry cv. Chandler fruits were used for postharvest salicylic acid treatment. The experiment was laid out in Complete Randomized Design where each treatment was replicated five times. The fruits with uniform color and size were individually picked from Strawberry Farm at the Faculty and immediately transferred to the laboratory. The salicylic acid at 0 (control), 0.5, 1 and 2 mM concentration was used for postharvest treatment of fruits. In each treatment, 50 fruits were treated with respective SA concertation and the treated fruits were kept in polypropylene terephthalate (PET) packaging under ambient conditions for 2, 4 and 6 days storage studies. One another lot of 10 fruits was also used for initial data recording on physio-chemical parameters of un-treated fruits. Observations on physiological loss in weight (PLW), decay percentage and biochemical quality attributes of fruits were assessed at 2, 4 and 6 days of storage.

The PLW was worked out by subtracting the final fruit weight from initial weight fruit weight and then divvied by initial fruit weight in each treatment on specified days after storage using following formula:

$$PLW\,(\%) = \frac{(Initial\ weight - Final\ weight) \times 100}{Initial\ weight}$$

The Fruit spoilage percentage was worked out by subtracting the number of decay fruit from the total number of fruits kept for storage in each treatment at specified days after storage and the divided by total number of stored fruits using following formula:

$$Spoilage\ (\%) = \frac{(No.of\ fruits - No.of\ decay\ fruits) \times 100}{Total\ no.of\ stored\ fruits}$$

The total soluble solid (TSS) was determined using a hand refractometer (Erma, Japan). Titratable acidity was determined using phenolphthalein as an indicator, ascorbic acid with 2,6-dichlorophenol indophenol indicator, and sugars (total and reducing sugars) using Fehling's solutions [17].

The pooled data of two years study were analysed using the Complete Randomized Design methodological approach [18]. The significance of the difference in treatment means at 5% level of significance was compared using critical difference (CD).

3. RESULTS AND DISCUSSION

Data revealed that PLW in strawberry cv. Chandler was increased with increase in storage duration and recorded the highest in untreated fruit (Fig. 1). Postharvest Salicylic acid treatment found effective in reducing the PLW of fruits (Fig. 1). Highest PLW at 2, 4 and 6 days storage was recorded in control fruits (4.36, 11.04 and 15.94 %, respectively). At 6 days of ambient storage, 2 mM salicylic acid provided the minimum PLW of 13.76 %. This might possibly be due to the fact that salicylic acid reduces transpiration and consequently weight loss by inhibiting stomatal reactions [19]. Wolucka et al. [20] has demonstrated that salicylic acid as an electron donor produces free radicals that disrupt normal respiration, leading in reduced weight loss in fruits. Salicylic acid prevents softening and weight loss by decreasing ethylene levels during storage. Our results are consistent with those of Mahsa et al. [21], who observed that the salicylic acid decreased weight loss in strawberry.

Fruit spoilage was observed to be increased with increase in storage duration and recorded the highest in un-treated fruit at all tree dates of observations (Fig. 2). The fruit spoilage was greatly minimized with the salicylic acid treatment at 6 days of storage (Fig. 2). The highest spoilage of fruits at 2, 4 and 6 days storage was recorded under control (4.36, 11.04 and 15.94 %, respectively). At 6 days of storage, control fruit showed 32 % spoilage while salicylic acid treated fruit with 0.5, 1 and 2 mM exhibited significantly lower spoilage i.e. 27.60, 24.10 and 21.70 %, respectively. Lower rotting percentage in SA treated fruits in our study may be attributed to the potential of salicylic acid in triggered defense enzymes chitinase, POD, and PAL to minimize fungal and bacterial infections that cause rotting of fruits [10, 22]. According to Xu and Tian [23], salicylic acid resulting in better resistance to fungal diseases in treated sweet cherry fruits.

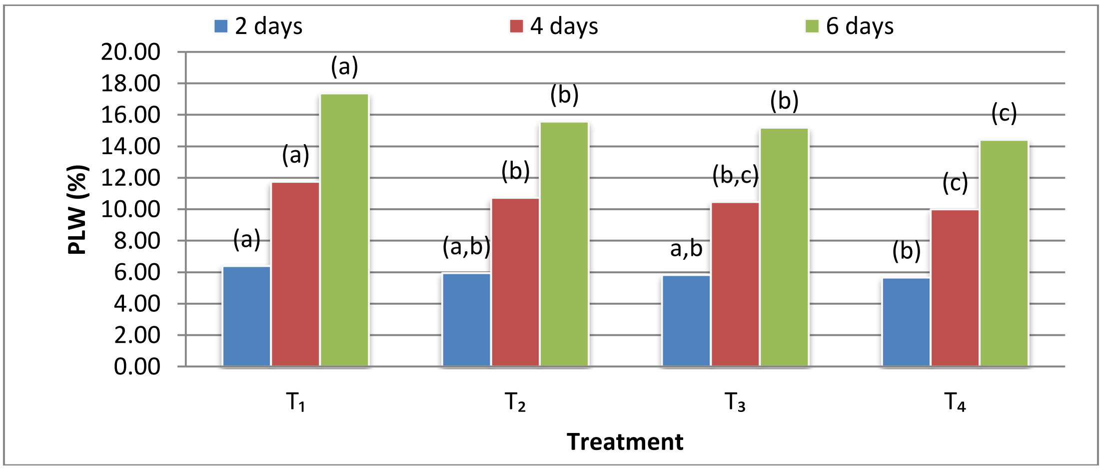

Fig. 1. Physiological loss in weight (PLW) of strawberry cv. Chandler fruits as affected by postharvest salicylic acid. Salicylic acid concentration:- T_1: 0 mM (control), T_2: 0.5, T_3: 1.0 mM T_4: 2.0 mM. Bars with same alphabets within same date of observation have no-significant difference

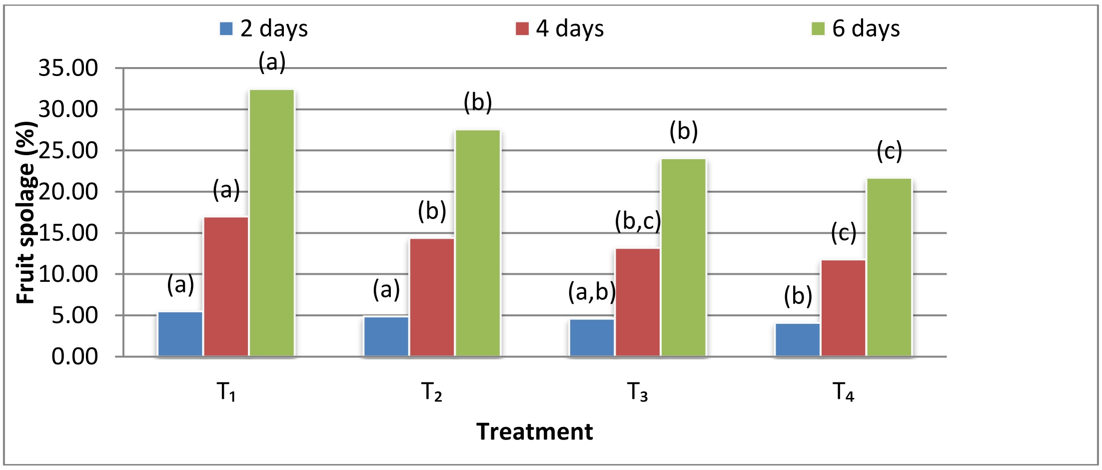

Fig. 2. Fruit spoilage (%) of strawberry cv. Chandler as affected by postharvest application of salicylic acid. Salicylic acid concentration:- T_1: 0 mM (control), T_2: 0.5, T_3: 1.0 mM T_4: 2.0 mM. Bars with same alphabets within same date of observation have no-significant difference

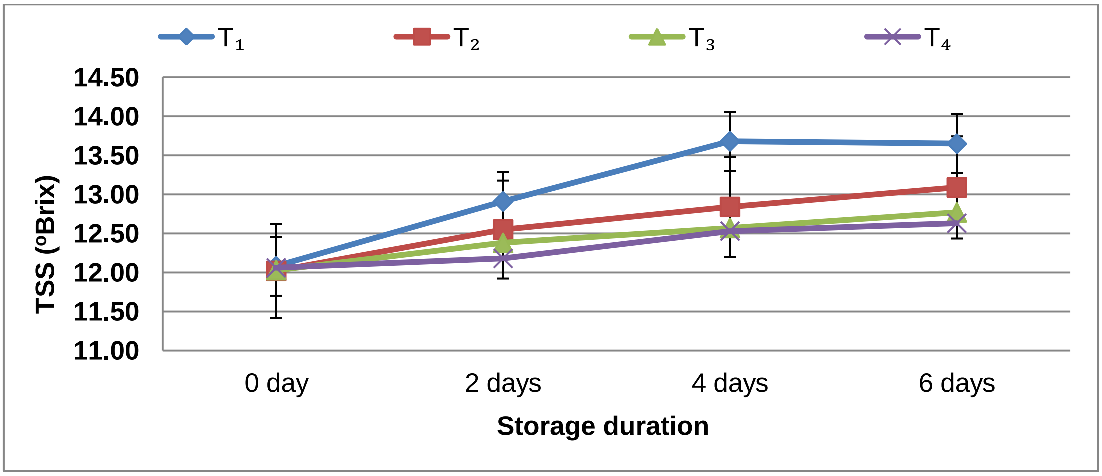

Fig. 3. Total soluble solids (TSS °Brix) of strawberry cv. Chandler as affected by postharvest application of salicylic acid treatments. Salicylic acid concentration:- T_1: 0 mM (control), T_2: 0.5, T_3: 1.0 mM T_4: 2.0 mM

Fruit TSS at harvest ranged from 12.02 to 12.08 ^{0}Brix (Fig. 3). It increased with the progression of storage duration and rate of increase was higher in control fruits compared to salicylic acid treated fruits (Fig. 3). At 6 days of storage, control fruits had 13.65 ^{0}Brix TSS while it was 13.09, 12.77 and 12.63 ^{0}Brix in the 0.5, 1 and 2 mM salicylic acid treated fruits, respectively. Results also indicated that all three salicylic acid doses had similar effects on TSS determined at 2, 4 and 6 days of storage study. The higher value of total soluble solids in control fruits might be due to the decrease in fruit water content and the conversion of cell wall components such as starch, protein, pectin, and hemicelluloses into simple soluble sugars during storage, resulting in the higher TSS value. Wills et al. [24] reported that starch is hydrolyzed into mono and disaccharides, resulting in an increase in the soluble solid content of tin fruits. Salicylic acid is an ethylene inhibitor; which slow down the ripening process by lowering respiration rates and metabolic activities [25, 26]. Our findings are consistent with those of Sayyari et al. [27] and Salari et al. [28] who found that salicylic acid treatment, resulted in a considerably sluggish increase in total sugar content in pomegranate fruit during storage. Awad [29] recorded that the total sugar of Flordaprince peaches in cold storage settings reduced due to the application of a higher salicylic acid concentration. Use of salicylic acid have also been reported to slow down the rate of respiration, prolonging the increase in SSC content in strawberry [9] and banana [30].

Titratable acidity in fruits at harvest ranged from 0.419 to 0.429 ^{0}Brix (Table 1). It decreased with the progression of storage duration and rate of decrease was slow in salicylic acid treated fruits compared to control (Table 1). At 2 day of storage, no significant different was found in fruit acidity due to salicylic acid treatment. At 6 days of storage, 0.5, 1 and 2 mM salicylic acid treated fruits had 0.292, 0.307 and 0.316 % titratable acidity while control fruits showed the lowest acidity of 0.269 %. The effect of salicylic acid at 1 and 2 mM on acidity was statistically at par at both 4 and 6 days of storage (Table 1). It has been reported that fruit uses the acids during maturity, hence organic acids in fruits diminish while storage [31,32]. Because salicylic acid inhibits ethylene biosynthesis [33], it aids in slowing the rate of respiration and the conversion of acids into sugars while storage. Our findings correspond with those reported in banana [30] and apple [34].

Fruit ascorbic acid content at harvest ranged from 60.05 to 60.74 mg 100 g^{-1} (Table 1). It decreased with the increase in the storage duration and rate of decrease was higher in control fruits compared to salicylic acid treated fruits. Data revealed that the salicylic acid treatment significantly minimized decrease of ascorbic acid in fruit (Table 1). Salicylic acid at 2 mM resulted the significantly the highest ascorbic acid content (59.42, 56.30 and 49.25 mg 100 g^{-1}) at 2, 4 and 6 days of storage, respectively. The lowest ascorbic acid content at all three dates of study was noted in control fruits (54.26, 49.73 and 41.48, respectively). According to Awad et al*.* [29], changes in fruit ascorbic acid concentration during storage dropped rapidly as storage duration increased. Earlier reports also reveal that post-harvest salicylic acid treatments have been shown to be beneficial in maintaining ascorbic acid in fruits [35]. Salicylic acid slow down the drop of ascorbic acid content and prevent ascorbic acid dissolution in pineapple [36], hence high ascorbic acid amounts in treated fruit might improve fruit quality.

Reducing sugar in fruit at harvest ranged from 4.50 to 4.63 % (Table 2). It increased with the progression of storage duration and rate of increase was higher in control than salicylic acid treated fruits. The salicylic acid treatment didn't influenced the reducing sugars in fruits at 2 days of storage, but it had substantial impact later on 4 and 6 days on storage studies (Table 2). At 4 days of storage, the reducing sugars estimated in salicylic acid at 0.5, 1 and 2 mM treated fruits were statistically at par. At 6 days of storage, the highest reducing sugars in fruits was estimated in control fruits while 0.5, 1 and 2 mM salicylic acid treated fruits had reducing sugar value of 5.72, 5.49 and 5.32 %, respectively (Table 2). Total sugars in fruit at harvest ranged from 7.93 to 8.03 % (Table 2). It also increased with the progression of storage duration and rate of increase was higher in control than salicylic acid treated fruits. The effect of salicylic acid significantly influenced the total sugars in fruits at 2, 4 and 6 days of storage studies (Table 1). At 2, 4 and 6 days of storage, the highest total sugars 9.42, 10.05 and 10.24, respectively were observed in control fruits followed by salicylic acid treatment at 0.5 mM, 1 mM and 2mM. At 6 days of storage, total sugars in fruits treated with 0.5, 1 and 2 mM salicylic acid were 10.15, 10.15 and 9.44 %, respectively Table 2.

Respiration process breakdown the acids into sugars thereby titrable acidity in fruits diminishes and sugars increases during storage [32]. Bhattatai and Gautam [31] also pointed out that fruit uses the acids during maturity and organic acids in fruits diminish in storage. Because salicylic acid inhibits ethylene production [33], it slows the rate of respiration and acid-to-sugar conversion during storage. Our findings are in accordance with the results reported in apple [34].

Table 1. Effect of postharvest application of salicylic acid on titratable acidity and ascorbic Acid of strawberry cv. Chandler fruits

Treatment	Titratable acidity (%)				Ascorbic Acid (mg 100g^{-1})			
	0 day	2 days	4 days	6 days	0 days	2 days	4 day	6 days
T_1-0.00 mM	0.429	0.379	0.331	0.269	61.17	54.26	49.73	41.48
T_2-0.50 mM	0.420	0.379	0.346	0.292	60.05	55.38	53.01	46.56
T_3-1.00 mM	0.419	0.379	0.357	0.307	60.30	57.58	54.46	46.83
T_4-2.00 mM	0.424	0.399	0.365	0.316	60.74	59.42	56.30	49.25
SEd±	0.13	0.120	0.10	0.008	1.88	1.76	1.54	1.42
CD(0.05)	NS	NS	0.022	0.019	NS	3.91	3.36	3.10

Table 2. Effect of postharvest application of salicylic acid on reducing sugars and Total sugars of strawberry cv. Chandler fruits

Treatment	Reducing sugars (%)				Total sugars (%)			
	0 day	2 days	4 days	6 days	0 days	2 days	4 day	6 days
T_1-0.00 mM	4.50	5.19	5.73	6.00	8.03	9.42	10.05	10.24
T_2-0.50 mM	4.51	5.11	5.33	5.72	7.93	9.02	9.84	10.15
T_3-1.00 mM	4.62	4.96	5.23	5.49	7.93	8.85	9.27	9.94
T_4-2.00 mM	4.63	4.87	5.13	5.32	7.96	8.29	8.92	9.44
SEd±	0.14	0.15	0.16	0.18	0.24	0.28	0.28	0.31
CD(0.05)	NS	NS	0.34	0.38	NS	0.63	0.62	0.68

4. CONCLUSION

Postharvest salicylic acid treatments on strawberry cv. Chandler fruit considerably reduced the PLW and fruit spoilage. After 6 days of storage under ambient conditions, SA at 2 mM had the lowest PLW and fruit spoilage. Also, the SA treatment found effective in maintaining the biochemical quality (TSS, acidity, ascorbic acid, reducing sugars and non-reducing sugars) of the fruits during storage. Hence, postharvest salicylic acid treatment of strawberry fruits at 2 mM can help to reduce PLW and fruit spoilage while also maintaining the biochemical quality of the fruits under ambient storage conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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