

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

ABSTRACT

The present study aimed to determine the effect of postharvest salicylic acid (SA) treatments 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 solids, titratable acidity, ascorbic acid, reducing and total sugars) were recorded. Results showed that postharvest salicylic acid treatments significantly minimized the PLW and fruit spoilage. At 6 days of storage, the lowest PLW (14.43 %) and fruit spoilage (21.70 %) observed with SA at 2 mM. All three SA treatments effectively retained the biochemical quality (total soluble solids, titratable acidity, ascorbic acid, reducing and total sugars) of fruit and the SA concentrations were comparable. In conclusion, Salicylic acid at 1 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

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, and nutritional and health benefits. Globally China is leading in production, followed by USA, Mexico, Egypt, Turkey and Spain among others nations 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 renowned for commercial strawberry growing long back; but its commercial cultivation has increased substantially in subtropical plains and North-Eastern states of India in recent decades. Strawberries are commercially propagated by runners. Although, the extreme summer temperatures in the subtropical regions restricts the longer cropping season and runner production are very low [5].

Strawberry is a non-climacteric and highly perishable fruit. Highly perishability fruits have very short storage and shelf-life which is one of the primary bottlenecks in increasing the strawberries fresh market supply chain. The postharvest management practices greatly influence the shelf life and quality of strawberry fruits. Respiration rate and ethylene production does not increase during ripening [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 is developing countries.

Strawberry postharvest treatment strategies rely primarily on lowering respiration and water loss while preserving fruit firmness and preventing disease development. Several synthetic compounds have been used to extend the postharvest life of various fruits; nonetheless, public concern over fungicide residues is growing. 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, 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 spray on strawberry storability and fruit quality under ambient environments.

2. MATERIAL 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. Strawberry cv. Chandler fruits were for postharvest salicylic acid treatment at 0 (control), 0.5, 1 and 2 mM. 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 where fruits kept for 30 min to remove field heat under ambient conditions. In each treatment, 50 fruits were treated with salicylic acid and the treated fruits were kept in polypropylene terephthalate (PET) packaging under ambient conditions for 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 weight fruit from initial weight fruit weight and then divided by initial fruit weight in each treatment on specified days after storage using following formula:

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

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:

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

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 podded data of two years study were analysed using the Complete Randomized Design methodological approach [18]. The significance of the difference in treatment means a 5% level of significance was assessed using the critical differences (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 at all three dates of observations (Fig 1). Postharvest Salicylic acid treatment found effective in reducing the PLW of fruits (Fig 1). At 6 days of ambient storage, 2 mM salicylic acid provided the minimum PLW of 13.76 %. Highest PLW at 2, 4 and 6 days storage was recorded in control fruits (4.36, 11.04 and 15.94 %, respectively). 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.*, 2005 [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.

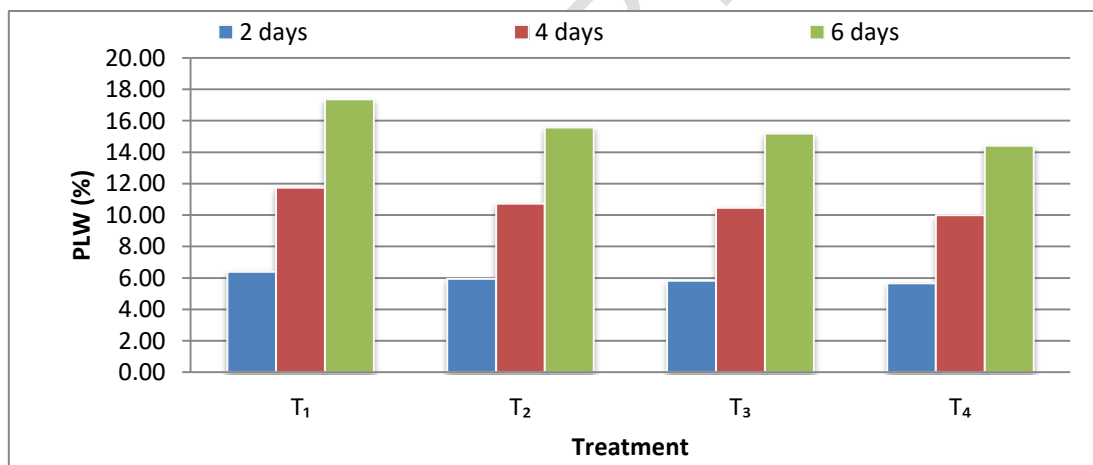


Fig 1: Physiological loss in weight (PLW) of strawberry cv. Chandler fruits as affected by postharvest salicylic acid treatments. Salicylic acid concentration:- T₁: 0 mM (control), T₂: 0.5, T₃: 1.0 mM T₄: 2.0 mM.

Fruit spoilage was observed to be increased with increase in storage duration and recorded the highest in un-treated fruit at all three dates of observations (Fig 2). The fruit spoilage was greatly minimized with the salicylic acid treatment (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. Although, the effect of salicylic acid doses of 1 mM and 2 mM were comparable. 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 stimulated the defense system by increasing the activity of antioxidant enzymes, resulting in better resistance to fungal assault in treated sweet cherry fruits.

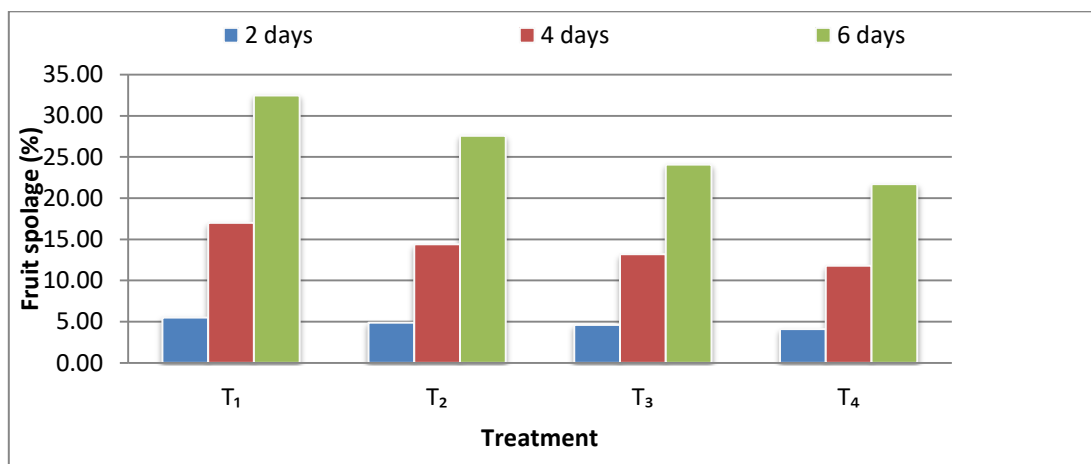


Fig 2: Fruit spoilage (%) of strawberry cv. Chandler as affected by postharvest application of salicylic acid treatments. Salicylic acid concentration:- T₁: 0 mM (control), T₂: 0.5, T₃: 1.0 mM T₄: 2.0 mM.

Fruit TSS at harvest ranged from 12.02 to 12.08 °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 °Brix TSS while it was 13.09, 12.77 and 12.63 °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. As so Awad [29], 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].

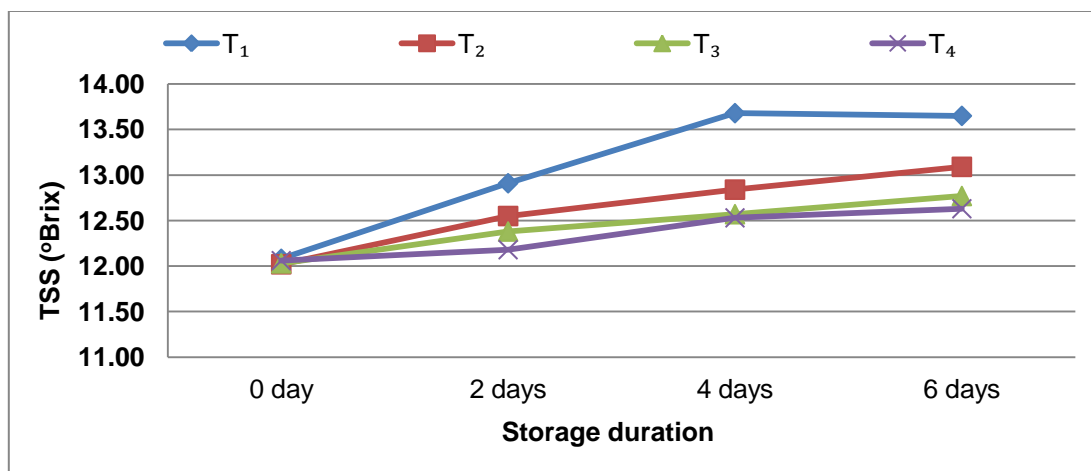


Fig 3: Total soluble solids (TSS °Brix) of strawberry cv. Chandler as affected by postharvest application of salicylic acid treatments. Salicylic acid concentration:- T₁: 0 mM (control), T₂: 0.5, T₃: 1.0 mM T₄: 2.0 mM.

Titrateable acidity in fruits at harvest ranged from 0.419 to 0.429 °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 % titrateable 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]. 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].

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

Treatment	Titrateable 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

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.

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

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].

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. SA treatments found effective in maintaining the biochemical quality 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.

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