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Effect of salicylic acid treatment on fruit quality of Japanese plum (*Prunus salicina*) cv. Santa Rosa

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ABSTRACT

Santa Rosa plum (*Prunus salicina* Lindell) grows profitably under sub-temperate conditions of India but has a very limited postharvest life due to decay, mechanical injury and other ripening related changes. This necessitates searching for novel methods to make it available for longer period in the market. The plums were treated with salicylic acid (SA) (0.5, 1.0, 1.5 and 2.0 mM) aqueous dip treatments for 10 min at 20ºC, air-dried and packed in plastic punnets followed by storage at 2ºC and 90 ± 5 % RH. Among different treatments, SA (2.0 mM) was found to be the best for maintaining the fruit quality and overall acceptability. Likewise, SA treatments significantly influenced fruit quality. The colour of SA treated fruits was maintained for a significant period over control. This study reflects that salicylic acid dip treatment can be integrated as an effective postharvest practice in the supply chain management of Santa Rosa plums to extend their storage life while maintaining fruit quality during storage for 36 days.

Key words: Anthocyanin, Firmness, Fruit quality, Japanese plums, Salicylic acid

Santa Rosa is the commercial variety of plum (*Prunus salicina* Lindell) in India due to its self-fruitfulness, prolific bearing habit and characteristic flavour. Nevertheless, the availability of the plum fruit is restricted only to regions close to its places of production due to its very short postharvest life and heavy losses during transportation due to compression injury (Sharma *et al*. 2012 a, b). The plums have a limited shelf-life of about 3-4 days only at ambient temperatures (35± 2ºC and 70 ±5 % RH) and about 18-20 days in cold storage after ripening.

Among many ways of extending the postharvest life, salicylic acid (SA) has emerged as a new technique, which acts as an antagonist of ethylene and delays ripening and exhibits a high potential in controlling postharvest losses of horticultural crops (Asghari and Aghdam 2010).For instance, exogenous application of SA delayed ripening in banana and kiwifruit and increased host resistance to postharvest diseases of sweet cherry. However, no systematic studies have been conducted yet on the effect of SA treatment in Japanese plums in India. This prompted us to study the effect of SA on enzyme activities and quality of Santa Rosa plums during storage at 2 ± 0.5ºC and 90± 5% RH.

MATERIALS AND METHODS

These studies were conducted in the Division of Food Science and Postharvest Technology, Indian Agricultural Research Institute, New Delhi. Santa Rosa plums were harvested in the month of June from a private orchard at Katrain, Kullu (Himachal Pradesh) and transported by road. The plum fruits were given salicylic acid aqueous dip treatments (SA @ 0.5, 1.0, 1.5 and 2.0 mM) at IARI in Delhi. Salicylic acid was weighed as per treatment detail SA_1(0.5mM), SA_2 (1.0mM), SA_3 (1.5 mM) and SA_4 (2.0 mM). The treatment doses were conceived on the basis of prior studies done by other workers. This was then dissolved in small quantity of distilled water and then the solution poured in the 10 l container containing 5 l tap water. Fruits were dipped for 10 min in salicylic acid (SA) solution at 20°C. The fruits in control were also dipped in plain water. They were then air-dried for 30 min by spreading on blotting paper under fans. The treated and control fruits were then stored at 2ºC and 90±5% RH in plastic punnets (500 g capacity) having holes for ventilation and observations on different parameters were recorded at 4 days interval. SA treatment was given to 120 fruits with three replications in each treatment.

Physiological loss in weight (PLW) was calculated as the difference between the initial fruit weight and the final weight at the particular interval and expressed as percentage (%) of initial weight of the fruit.

Colour of plum was determined using the Hunter Lab System in Miniscan XE PLUS model. The colour value was expressed as L* (0: dark, 100: white), a* (negative value: green, positive value: red) and b* (negative value: blue, positive value: yellow). Four readings were taken from opposite positions of each fruit and the mean value

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calculated. These values were observed in three fruits per treatment. The hue angle and chroma were calculated as per Ranganna (1999).

Total phenolics content of the fruit extracts were determined by the Singleton and Rossi method (1965) with some modifications, and expressed in microgram of gallic acid equivalent per g of fruit (µg GA equiv/g).

Antioxidant capacity was determined by following cupric reducing antioxidant capacity (CUPRAC) method (Apak *et al*. 2004) and results were expressed as µmol Trolox/g.

Total anthocyanin content was determined on a UV-visible spectrophotometer by the pH-differential method (Wrolstad *et al*. 2005) and expressed as mg/kg FW. These attributes were determined at each interval in 2 fruits per treatment, replicated 3 times.

Ascorbic acid content was quantitatively determined by 2,6-dichlorophenol indophenol dye method (Ranganna 1999). For each sample, 2 g pulp was homogenized with 10 ml of 3% metaphosphoric acid. The extract was made up to a volume of 50 ml and centrifuged at 3000 g for 15 min. at room temperature. Ten millilitres of supernatant were titrated against standard 2,6-dichlorophenol indophenol dye, which had already been standardized against standard ascorbic acid. Results were expressed as mg/100 g FW basis (Ranganna 1999).

SSC concentration was determined using FISHER hand refractometer at 20ºC and results were expressed as Degree Brix (ºB). TA was determined by using titration method (Ranganna 1999). To do that, 2 g of fruit sample was added to 50 ml distilled water plus a few drops of phenolphthalein solution as indicator and titrated with 0.1 N NaOH up to pH 8.1. The results were expressed as percentage (%).

Ten members of non-trained sensory panel rated the whole and cut pieces of plums using a 9-point hedonic scale with 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much and 9, like extremely (Ranganna 1999). The overall acceptability was evaluated based on colour, aroma, appearance, texture and taste of the fruits.

The experiments were laid out in factorial completely randomized (CRD) design with each treatment consisting of 120 fruits with 3 replications. The different treatments and storage time were the sources of variation. Values of different parameters were expressed as the mean ± standard error. The data obtained from the experiments were analyzed by following standard procedures and the results were compared from ANOVA by calculating the critical difference (CD) and standard error (SE) (Panse and Sukhatme 1984).

RESULTS AND DISCUSSION

Physiological loss in weight (PLW)

Physiological loss in weight is an important factor responsible for quantitative as well as qualitative loss of produce leading to shriveling and reduced consumer acceptance. SA treatments significantly influenced the PLW in Santa Rosa Japanese plums during low temperature storage at 2ºC (Fig 1). PLW increased with the advancement of the storage period regardless of whether the fruits were treated with SA or not. Untreated plums presented significantly higher PLW (1.8%) from the beginning of storage days, increased rapidly and reached 10.4% on 24th day of storage. Untreated plums recorded highest PLW (13.8%) on 36th day of storage (Fig 1). Shriveling was visually perceptible on fruits which lost 5-7% or more of their weight. However, plums treated with SA significantly slowed down the PLW during the entire storage period up till 36th day. Among the applied treatments, SA @ 2.0 mM and 1.5 mM) exhibited only 8.4% and 9.2% PLW loss, respectively on 36th day of storage. The interaction effect of treatment x duration was also significant. Higher PLW in untreated fruits may be because these fruits had more active metabolism in respect to respiration and transpiration thus losing higher amount of water during storage in comparison to SA treated fruits (Kumari *et al*. 2015). The lower weight loss in SA treated fruits may also be due to closing of stomata, which results in suppressed respiration and transpiration rate (Barman and Asrey 2014) thus minimizing weight loss of fruits. Malamy and Klessig (1992) have also restated that salicylic acid plays a pivotal role in promotion of plant disease resistance. Therefore, the fruit may have remained healthy and respired less and hence lower PLW in SA treated fruits. Grapes, persimmon, sugarapple, strawberry, apple and peach treated with SA also exhibited lower weight loss and quality maintenance compared to untreated fruits as reported by many workers (Shafiee *et al*. 2010).

Fruit colour

Colour is an important maturity index and indicator of physiological status of fruits. Consumers buy and choose mainly with their eyes and colour is the most important criterion determining acceptability. The L*, a*, b*, hue and chroma values of plums were significantly affected by SA treatments during cold storage (data for L*, a*, b* values not shown; Table 1). As ripening ensues, there is a continuous decrease in L*, a* and b* values in plums. However, SA treatments significantly delayed colour development. Untreated plums developed colour faster than SA treated fruits. L*, a* and b* values showed a gradual decrease

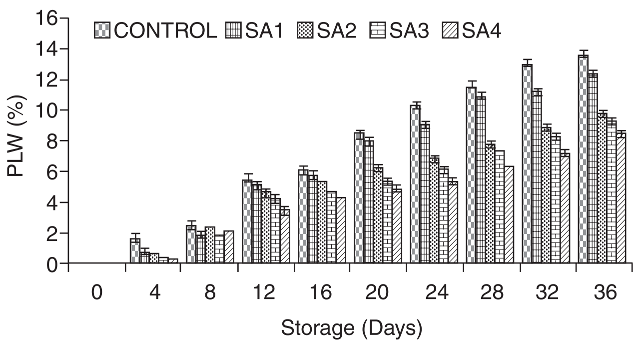

Fig 1 Effect of salicylic acid treatments on PLW (%) in Santa Rosa plums duringcold storage conditions

Table 1 Effect of salicylic acid treatments on fruit colour (Hue and Chroma) of Santa Rosa plums during cold storage conditions

Treatment	Hue									
	Storage duration (Days)									
	4	8	12	16	20	24	28	32	36	Mean
Control	3.35	3.91	4.49	5.28	4.74	5.02	5.81	3.18	4.29	4.45
SA_1 (0.5 mM)	1.43	1.27	1.11	1.14	1.10	1.20	1.30	1.48	1.89	1.32
SA_2 (1.0 mM)	0.93	1.17	1.08	1.22	1.03	1.31	1.03	1.25	1.31	1.15
SA_3 (1.5 mM)	1.12	1.04	1.05	1.11	1.31	1.28	1.60	1.63	2.07	1.36
SA_4 (2.0 mM)	0.89	0.94	0.96	0.97	1.09	1.20	1.81	2.07	1.90	1.32
Mean	1.54	1.66	1.74	1.95	1.85	2.00	2.31	1.92	2.29	1.92
CD	Treatment = 0.132, Duration =0.177, duration × treatment = 0.396									
SE (d)	Treatment = 0.066, Duration =0.089, duration × treatment = 0.199									
SE (m)	Treatment = 0.047, Duration =0.063, duration × treatment = 0.141									
	Chroma									
Control	21.47	19.39	21.74	17.08	14.68	14.26	12.73	12.34	10.58	16.03
SA_1 (0.5 mM)	44.19	36.81	32.42	31.75	26.57	23.94	19.37	16.50	14.94	27.39
SA_2 (1.0 mM)	44.39	39.88	34.57	31.60	25.47	22.29	19.47	17.24	14.98	27.77
SA_3 (1.5 mM)	41.04	38.60	36.65	35.37	31.53	28.29	24.82	22.09	18.78	30.79
SA_4 (2.0 mM)	46.55	44.39	42.20	39.06	35.16	29.03	24.70	23.33	20.60	33.89
Mean	39.53	35.81	33.52	30.97	26.68	23.56	20.22	18.30	15.98	27.17
CD	Treatment = 0.611, Duration =0.820, duration × treatment = 1.833									
SE (d)	Treatment = 0.307, Duration =0.412, duration × treatment = 0.921									
SE (m)	Treatment = 0.217, Duration =0.291, duration × treatment = 0.651									

during storage (data not shown). Lowest a* value (10.31) was recorded in control fruits while the highest (18.54) in SA@ 2.0 mM treated fruits (data not shown). For b* value also, highest value was recorded with SA @ 2.0 mM (8.98) and control (2.36) treated fruits indicating faster ripening (data not shown). The control fruits recorded higher hue angle values at each storage interval among the treatments and it also increased with storage period, with highest hue angle on 28th day (5.81) showing slight decline at the end of storage (4.29). SA treatments showed lower hue angle values than control throughout the storage period (Table 1). The chroma values declined with the advancement in storage period and were higher in SA treated plums over untreated plums at all the intervals. The maximum chroma value (46.55) was recorded in SA4 treated plums after 4 days of storage (Table 1). The slower colour development in SA treated plums may be due to suppression of ethylene evolution and reduced biosynthesis of anthocyanins. The delayed colour development with SA treatments is also reported earlier in strawberry by Shafiee *et al.* (2010). The chroma value of partially ripe plums was always higher than ripe fruit during storage as also reported earlier in sweet cherries.

Total phenolics content (TPC)

The SA treatments maintained significantly higher total phenol content in Santa Rosa plums than untreated plums (Fig 2). However, the maximum total phenol content (107 mg/100 g pulp) was recorded in SA (2.0 mM) treated plums at the end of 36 days of storage. Other treatments of SA (0.5, 1.0 and 1.5 mM) showed intermediate results for total phenol content during the storage. Further, the phenolic content in plums decreased progressively with the increase in storage period, the minimum being on 36th day of storage (65.0 mg/100 g pulp) in untreated fruits (Fig 2). Higher levels of total phenol content in SA treated fruits might be due to retention of higher amount of organic compounds like sugars, ascorbic acid etc., in such fruits than untreated ones (Kumari *et al*. 2015, Barman and Asrey 2014). Higher retention of phenolics in SA treated litchi fruit was ascribed to the lower activities of PPO and POD enzymes, which might have in turn delayed the oxidation of phenolics (Kumari *et al*. 2015). The reduction in phenols may be due to the strong relationship with ascorbic acid and an increase in antioxidant capacity during low-temperature storage may

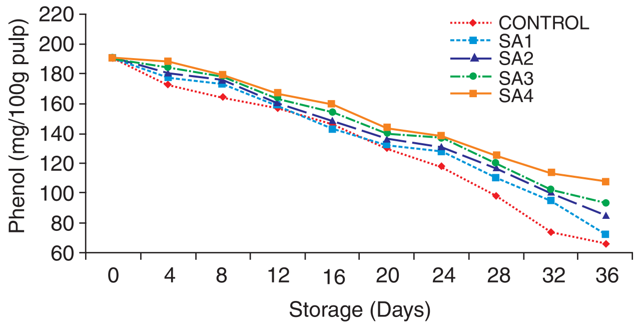

Fig 2 Effect of salicylic acid treatments on total phenolics content (TPC) (mg/100g pulp) in Santa Rosa plums during cold storage conditions.

be possible only in fruit in which the contribution of total phenolics is greater than vitamin C.

Total antioxidant capacity (TAC)

All SA treatments significantly influenced the antioxidant capacity of plums during storage, and a decrease in antioxidant capacity was observed with subsequent storage period (Fig 3). However, fruit treated with SA (2 mM) slowed the decreasing trend up to 36th day of storage and maintained higher values than other treatments and control. At the end of the storage period, untreated fruit showed lowest (10.4 µmol Trolox/g) antioxidant capacity than SA treated fruit. Among the treatments, highest (15.2 µmol Trolox/g) antioxidant capacity was found in fruit, which were treated with SA @ 2.0 mM, followed by SA @ 1.5 mM treatment (Fig 3). Antioxidant capacity of plum is mainly due to the presence of phenolic compounds, ascorbic acid and anthocyanin pigments. The higher antioxidant capacity in SA treated fruit might be attributed to higher content of anthocyanins, ascorbic acid and phenolic compounds. Further, the antioxidant capacity decreased progressively with the increase in storage period in all the treatments. The reduction in antioxidant capacity may be related with the decrease in phenolics and ascorbic acid, with progressive increase in storage period. Our results are in line with Sayyari *et al*. (2011) who found higher antioxidant capacity in SA treated pomegranates. Others workers have also reported that pre-harvest SA treatments could maintain *Citrus* fruit antioxidant activity. Our result is in line with Barman and Asrey (2014) who attributed higher antioxidant activity in SA treated Chausa mangoes to higher content of phenolics and carotenoids.

Anthocyanin content

The major anthocyanins found in plums are cyanidin-3-rutinoside, peonidin-3-rutinoside, cyaniding-3-glucoside, cyaniding-3-xyloside and peonidin-3-glucoside. Anthocyanins are natural phenolic compounds which give reddish-blue colour to the plants. Colour of the fruit decides not only the proper harvesting time but also the acceptance by the consumer. Anthocyanin content was significantly influenced by different SA treatments in the Japanese plum cv. Santa Rosa. The minimum anthocyanin content (581 mg/kg FW) was observed in 2.0 mM SA treated plums, followed by other SA treatments (0.5, 1.0 or 1.5 mM) and the maximum (606.7 mg/kg FW) in untreated fruits on the last day of storage. The anthocyanin content increased with the progressive increase in storage period which may be due to gradual ripening and increase in colour of fruits (Sharma *et al*. 2012 a,b). The anthocyanin content was less in SA treated fruits primarily because of delayed ripening in such fruits (Luo *et al*. 2011). Application of SA and chitosan were found highly effective in retaining anthocyanin pigments in the litchi fruit pericarp (Kumari *et al*. 2015).

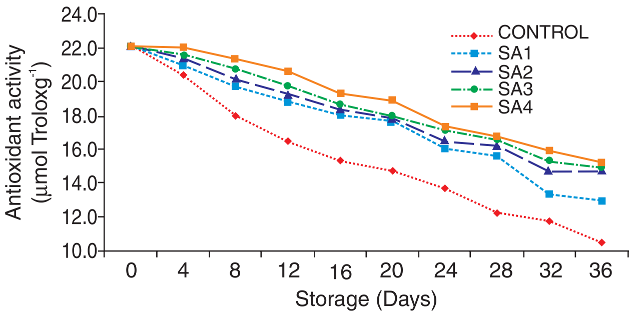

Fig 3 Effect of salicylic acid treatments on antioxidant capacity (µmol Trolox/g) in Santa Rosa plums during cold storage conditions.

Ascorbic acid content (AAC)

AAC of Santa Rosa fruits shows a clear decline from the beginning of storage period. The reduction in AAC was much more in untreated plums than SA treated ones. Fruits treated with SA @ 2.0 mM showed the maximum retention at all intervals of storage than all other concentrations of SA. On the final day of storage, the different doses of SA (0.5, 1.0, 1.5 and 2.0mM) retained 20.8, 22.2, 26.5 and 26.6 mg/100 g pulp, respectively compared to the control which had only 17.5 mg/100 g pulp. The ascorbic acid retention was higher in plums treated with progressively higher doses of SA exhibiting a linear relationship between the two. The higher content of ascorbic acid might be elucidated by the slow ripening and higher acidity retention in Santa Rosa fruits (Sharma *et al*. 2012a). The loss in ascorbic acid content is slowed by the application of salicylic acid in a variety of fruit crops including plum.

Soluble solids content (SSC)

SSC includes mainly sugars along with other salts, pigments and organic acids. The untreated plums presented a rapid increase in SSC from the beginning of the storage period than SA treated fruits. The control plums attained maximum SSC value (16.7ºB) on 16th day of storage and declined thereafter. Higher SSC in control plums may be due to faster ripening and the hydrolysis of starch into simple sugars. The quicker decline may be due to higher respiration rate of untreated fruits. SA @ 1.5 mM and 2.0 mM treated plums exhibited continual slow increase in SSC till the final day of storage. The SA @ 1.5 and 2.0 mM treatments recorded 16.4ºB and 16.2ºB SSC while the lowest (14.5ºB) was noted in untreated plums at final day of storage. SA @ 0.5 mM and 1.0 mM treatments showed increase in SSC till 16th day followed by a continuous drop. Other workers have also reported delayed increase in SSC in SA treated kiwifruit and apple fruit. The SSC: TA ratio increased with storage in all the treatments with control fruits showing maximum values consistently and highest value was recorded as 18 on 36th day of storage. SA4 treatment showed lowest values and it was 12.5 on the last day of the storage.

Titratable acidity (TA)

Both untreated and SA treated plums registered a continual decrease in TA. However, SA treated plums

Table 2 Effect of salicylic acid treatments on overall acceptability (sensory quality) of Santa Rosa plums during cold storage conditions

Treatment	Storage duration (Days)				
	0 + 3	10 + 3	20 + 3	30 + 3	Mean
Control	8.0	9.0	3.0	2.0	5.5
SA_1 (0.5 mM)	6.0	7.0	7.0	6.0	6.5
SA_2 (1.0 mM)	6.0	8.0	8.0	6.0	7.0
SA_3 (1.5 mM)	6.0	7.0	7.0	8.0	7.0
SA_4 (2.0 mM)	5.0	7.0	8.0	9.0	7.3
Mean	6.2	7.6	6.6	6.2	6.7
CD	Treatment = 0.283, Duration =0.253, duration × treatment = 0.566				
SE (d)	Treatment = 0.139, Duration =0.125, duration × treatment = 0.279				
SE (m)	Treatment = 0.099, Duration =0.088, duration × treatment = 0.197				

showed a significant slow decline over control fruits. SA @ 2.0 mM treated plums recorded the highest TA (1.3%) compared to 1.5, 1.0 and 0.5 mM SA treatments, 1%, 1%, 0.9%, respectively on the 36^{th} day of storage. Minimum TA (0.8%) was noted in untreated Santa Rosa fruits. The retention of higher acidity in plums was more in subsequently higher doses of SA. SA @ 2.0 mM treatment on plums was most effective and contained 63% higher TA over the untreated plums on the last day of storage. Delay in ripening and senescence processes in SA treated plums may be attributed to higher retention of TA. SSC: TA ratio showed a continuous rise with progression in storage in all the SA treatments as well as control fruits. SA4 treatment showed consistently higher SSC:TA ratio with minimum values of 12.5 on 36^{th} day of the storage.

Sensory evaluation

The overall acceptability of Santa Rosa plums was higher initially for control fruits during storage. The control fruits had a sensory score of 9 after 10 days of cold storage followed by 3 days storage at ambient conditions which then declined to 2 after 30 days of cold storage and 3 days ambient storage (Table 2). In general, SA treated plums recorded consistently higher values throughout the storage period. The plums treated with SA_4 @ 2.0 mM showed better score at each subsequent storage interval (Table 2). Untreated plums had better overall score initially primarily because these plums have attractive, colour, flavour and taste than treated fruits which show slower rate of ripening than untreated plums. However, decline in score of control fruits with increase in storage period might be due to decline in all factors contributing to acceptability. SA treated Santa Rosa plums did not have better colour or taste or flavour initially in comparison to untreated plums, however later such plums acquired better score with the progressive increase in taste, colour or quality. Kumari *et al*. (2015) in litchi fruits and Barman and Asrey (2014) in mango fruits also recorded higher fruit quality and overall acceptability in SA treated fruits over control during postharvest storage.

Our study demonstrated that different concentrations of salicylic acid (0.5 mM, 1.0 mM, 1.5 mM and 2.0 mM) not only extended the postharvest life of Santa Rosa plums significantly but also maintained the postharvest quality during storage at 2 ± 0.5ºC. However, among different concentrations of SA @ 2.0 mM treatment was most effective in delaying ripening and maintaining high quality of plums. Hence, SA which is a natural phenolic compound can be safely used in place of other chemicals for enhancing shelf life and increasing availability of plums in the market.

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