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ORIGINAL ARTICLE

Effects of Pre-harvest Salicylic Acid Treatment on the Post-harvest Quality of Peach Cultivar Robin

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KEYWORDS

Antioxidant capacity;
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Total phenol

ABSTRACT: Peach is one of the most important horticultural crops and its storage and postharvest issues are increasingly taken into consideration. This experiment was conducted to the assessment of salicylic acid spray at 0, 1, 2, and 4 mmol concentrations, and salicylic acid submergence in 2 mmol concentrations on the post-harvest quality of peach cultivar Robin, and the measurement in the four storage times in 2014-2015. In this experiment, the weight loss, volume decrease, length decrease, diameter decrease, pH, total acidity, total soluble solids, vitamin c, antioxidant capacity, total phenol, total flavonoid, and fruit firmness were measured. The results suggested that the salicylic acid treatment caused the inhibition of the weight losses, volume decrease, length decrease, and diameter decrease over the storage period and maintained the fruit firmness. The best result obtained from 2 mmol spray of salicylic acid before harvest. The lowest total soluble solids and pH were observed in 2 mmol salicylic acid spray in all the storage times, while in the other treatments such as control, their contents increased. The results also demonstrated that the highest vitamin C content was in 2 and 4 mmol salicylic acid spray and 2 mmol salicylic acid submergence treatment, and the highest total phenol content resulted from 15 days after storing in all the salicylic acid treatments. The treatment of salicylic acid did not have much effect on the total flavonoid content and antioxidant capacity. Among all the treatments, the spray of 2 mmol salicylic acid, two weeks before the fruit harvest, revealed the best result and can be considered in the enhancement of peach postharvest shelf life.

INTRODUCTION

Fruits and vegetables, as an important part of the human food source, have special significance, and mankind from the very beginning have consumed these crops for providing a part of nutritional requirements. Nowadays the consumption of the horticultural products has extensively been considered [1]. Peach with the scientific name of *Prunus persica* belongs to the Rosaceae family and is native to the warm China regions. The cultivation area and production of peach in Iran in 2014 were 20 thousand hectors and 500 thousand tons, respectively, with an average yield of 25 tons per hectare [2].

Most fruits are perishable due to their high water content. Delay in the creation of appropriate condition to store these crops leads to abundant wastes. The demand increase for the agricultural fresh products, due to the higher nutritional value, requires more exact revision in the marketing of products. Incorrect marketing can cause the deterioration of a greater amount of crops, which remarkable time and investments have spent on their production. These wastes comprise about 25 up to 80 percent of fresh fruits and vegetables based on the estimation of different references [3]. Salicylic acid is a natural phenolic compound and

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androgenic hormone-like substances, which is synthesized through two pathways of coumaric acid and benzoic acid in most plants [4]. Salicylic acid is an effective substance regarding the increase of fruits and vegetables storage quality [5]. In keeping with its concentration, influence duration as well as the plant sensitivity, this acid can act as a stressful cofactor or brings about the resistance creation against abiotic stresses, and also motivates other genes expression stimulants associated with the secondary metabolites biosynthesis as well as the activity of the enzymes observed at plant defense mechanism [6, 7].

In a previous study, the postharvest application effect of chitosan and salicylic acid on some quantitative properties of jujube cultivar Sab was investigated [8]. The results demonstrated that in comparison to the control, salicylic acid at the concentration of 500 ml l^{-1} resulted in the significant increase of the fruit total soluble solids (TSS) and vitamin C, whereas it had the best result along with the control in the preservation of fruit apparent quality. Chitosan revealed the reduction of contamination rate and the lower weight loss in comparison to the other treatments. Another study assessed the efficacy of salicylic acid on the cold temperature injury and some of the qualitative and quantitative characteristics of mandarin cultivar Kinnow [9]. The results of this assessment indicated that with an increase in the storage period, the TSS rise and the titratable acidity as well as vitamin C decline. In total, the most effective treatment on the evaluated traits was 4 mmol salicylic acid.

In a study, it was observed that pre-harvest spray with salicylic acid significantly increased the contents of carotenoids (lycopene and alpha-carotene), ascorbic acid, glutathione, total phenol and total flavonoids in the fruit pulp and epicarp of orange (Navel) in the storage [10]. Moreover, the highest content of these antioxidant compounds was observed in the treated fruits with a high concentration of salicylic acid (1 and 2 mmol l^{-1}). Salicylic acid (2mmol l^{-1}) caused the reduction of ethylene, delay in moldiness and maintenance of strawberry over 15 days in the cold store [11]. But at higher concentrations, the strawberry rotting increased and some negative effect were seen.

The objective of this study was to determine the best salicylic acid concentration to the increase of storage period peach cultivar Rubin and the physicochemical properties of fruits in the store.

MATERIALS AND METHODS

Plant materials

The present experiment was conducted in 2014 on peach cultivar Rubin in an orchard located in Kordkuy, Golestan Province with an altitude of 51 m above sea level, latitude 36.79N, and longitude 54.11E. This semi-humid region located in the north east of Iran between Caspian sea in the north and Alborz mountain chain in the south. For this experiment, 10-year-old trees with suitable physiological condition were selected. The orchard irrigation, fertilization, pruning and pest, and weed control performed according to the advice of official experts. A factorial experiment was conducted with three replications. The first treatment was salicylic acid (in five levels including the spray at the concentrations of 0, 1, 2, and 4 mmol and the salicylic acid submergence in 2 mmol solutions) and the second factor was the storage time (in four levels including the harvesting day (day 0), and 5, 10, and 15 days after harvesting). Two weeks before the fruit harvest, the spray of the whole tree crown by salicylic acid was performed early in the morning. For salicylic acid submergence treatment, the fruits were first washed and then immersed in 2 mmol salicylic acid for 5 minutes and were dried in the laboratory after one hour, then all the fruits were transferred into the refrigerator at the temperature of 4˚c.

Fruit properties

In order to measure of the fruit weight, the digital scale with the precision of 0.0001 g were used. To measure the fruit length and diameter the digital caliper with the precision of 0.0001 cm used. For measuring the volume, a calibrated Beaker was used. The fruit firmness was measured with a pressure gauge (Effegi, Italy). For this, at first, the fruit peeled off along with a thin layer of pulp and

then the pressure into the fruit's pulp was calculated in kilogram per square centimeter.

The pH of the fruit juice was determined using the pH meter (pH 110 meter, EUTECH/OAKTON Instruments, USA). The TSS using the digital refractometer (Digital Abbe refractometer, model Quartz, Ceti, Belgium), and the acidity rate by the titration with sodium hydroxide (N= 0.01) [12] were determined. The antioxidant activity was measured according to Sun and Ho [13] and the total phenol content of the juice measured by Folin–Ciocalteu phenol indicator using spectrophotometer (Spectrophotometer, SQ 2800 UV/VIS, UNICO, USA). Total flavonoid was measured using the method of Fawole and Opara [14] and vitamin C was measured according to Kashyap and Gautam [15] method.

Data analysis

The experiment data was conducted using SAS 9.0 software as a factorial in a completely randomized design with three replications. The mean comparison of each trait was accomplished using the LSD test, depending on the case at 1% or 5% probability levels.

RESULTS AND DISCUSSION

The results of the analysis of variance suggested that the interaction effect of the storage time and salicylic acid on all the apparent traits including weight loss, volume decrease, length reduction, diameter decrease, and fruit firmness (Table 1) was significant at 1% probability level. Therefore the interaction effect of time and salicylic acid was only evaluated.

Table 1. The analysis of variance of the salicylic acid treatment and storage time effect on some apparent traits of peach cultivar Rubin

Sources of variation	df	Mean of squares				
		Weight loss	Volume decrease	Length reduction	Diameter decrease	Fruit firmness
Time	3	72.387**	4292.604**	0.796**	0.853**	3.052**
Salicylic acid	4	8154.538**	328.335**	28.538**	32.428**	51.838**
Time × Salicylic acid	12	390.094**	24.263**	3.725**	4.266**	8.031**
Error	40	46.297**	0.830**	0.735**	0.637**	5.665*

**Significant difference at 1% probability level, *significant difference at 5% probability level, ^{ns} no significant difference

The means comparison results demonstrated that the highest weight loss (21.28 g), volume decrease (17.01 cm^3), length reduction (1.65 cm), and diameter decrease (1.70 cm) were observed at control treatment 15 days after storage, and the lowest amount of the mentioned traits were observed in 2 mmol salicylic acid 15 days after storage, but this treatment had no significant difference with 2 and 4 mmol salicylic acid spray 10 days after storage (Table 2). Likewise the results represented that the highest fruit firmness was observed in 2 mmol salicylic acid spray at day 0 (at fruit harvest), and the lowest amount was at 0 and 1 mmol salicylic acid spray and 2 mmol salicylic acid submergence 15 days after storage, which had no significant difference with some other treatments (Table 2).

These results correspond well with the results of previous experiments. In another study, the efficacy of chitosan and salicylic acid postharvest application on some quantitative characteristics of Jujube fruit was assessed [8]. The results suggested that salicylic acid at the concentration of 500 mg l^{-1} had the best result in the preservation of the fruit apparent quality in comparison to the control. Similarly, the salicylic acid pre-harvest spray treatment at the concentration of 3 mmol inhibited the weight loss during storage period in comparison to the control and the concentration of 1 mmol [16]. It has been reported that salicylic acid treatment can prevent weight loss during storage through stomatal closure and respiration reduction [17].

Table 2. The interaction effect of salicylic acid and storage time on some apparent traits of peach cultivar Rubin

Salicylic acid (mmol)	Storage time (day)	Weight loss (g)	Volume decrease (cm^3)	Length reduction (cm)	Diameter decrease (cm)	Fruit firmness ($kg\ cm^{2-1}$)
0 (Control)	0	0.00 i	0.00 k	0.00 h	0.00 g	1.14 ef
	5	10.64 g	7.83 g	0.89 d	0.95 de	0.30 hi
	10	15.81 d	10.00 e	1.40 b	1.46 b	0.05 i
	15	21.28 a	17.01 a	1.65 a	1.70 a	0.00 i
1 (Spray)	0	0.00 i	0.00 k	0.00h	0.00 g	1.22 de
	5	9.04 h	6.67 h	0.73 e	0.81 ef	0.94 fg
	10	13.69 ef	8.66 f	0.97 cd	1.00 de	0.43 hi
	15	19.31 b	15.75 b	1.32 b	1.35 bc	0.00 i
2 (Spray)	0	0.00 i	0.00 k	0.00 h	0.00 g	4.36 a
	5	6.81 i	4.60 j	0.22 g	0.23 fg	1.87 b
	10	8.75 h	6.72 h	0.45 f	0.49 fg	1.36 cde
	15	14.33 e	11.58 d	0.65 e	1.00 de	0.58 fg
4 (Spray)	0	0.00i	0.00 k	0.00 h	0.00 g	1.48 cde
	5	8.19 h	5.92 i	0.57 f	0.60 fg	1.74 bcd
	10	12.56 f	8.08 fj	0.66 e	0.67 fg	0.74 fg
	15	17.87 c	14.16 c	1.10 c	1.13 cd	0.54 ghi
2 (Submergence)	0	0.00 i	0.00k	0.00 h	0.00 g	1.31 cde
	5	9.39 h	6.92 h	0.73 e	0.76 ef	0.40 hi
	10	13.65 ef	8.59 f	0.94 d	0.96 de	0.13 i
	15	18.48 bc	16.25 b	1.35 b	1.39 b	0.00 i

The similar letters in each column indicate non-significant difference.

The results of the analysis of variance also indicated that the interaction effect of the storage time and salicylic acid was significant at 1% probability level on the TSS, pH, and vitamin C and at 5% probability level on total phenol, but it was not significant on acidity, total flavonoid, and antioxidant capacity. The simple effect of the storage time on acidity and antioxidant capacity was significant at 1% and 5% probability levels respectively, but it was not significant on total flavonoid (Table 3).

Table 3. The analysis of variance of the salicylic acid and storage time effect on some of the physicochemical traits of peach cultivar Rubin

		Mean of squares						
Sources of variation	df	TSS	Acidity	pH	Vitamin C	Total phenol	Total flavonoid	Antioxidant capacity
Time	3	20.002**	0.178**	0.162**	18.561**	11418.95**	0.002^{ns}	267.09*
Salicylic acid	4	33.819**	0.599**	0.065**	9.7**	4576.95**	0.003*	1285.89**
Time × Salicylic acid	12	2.592**	0.024^{ns}	0.029**	1**	357.53*	0.001^{ns}	37.36^{ns}
Error	40	0.565	0.039	0.015	0.326	176.543	0.001	110.84

**Significant difference at 1% probability level, *significant difference at 5% probability level, ^{ns} no significant difference

The highest content of TSS was observed at 0 and 1 mmol salicylic acid spray 10 and 15 days after storage and in 2 mmol salicylic acid submergence of 5 and 15 days after storage. Its lowest content also resulted from 2 mmol salicylic acid spray at all storage times (Table 4). On the other hand, the content of TSS increases during storage. The rise of TSS during fruits storage might be due to the fruit juice decrease and degradation of complex sugars into

simple sugars [18]. But all the salicylic acid treatments partially lower this enhancement. The highest impact was by 2 mmol salicylic acid spray treatment. These results were similar to the result obtained before [19]. They found that the efficacy of salicylic acid was significant at 1% probability level on TSS. The result might due to the salicylic acid impact on respiration decrease and consequently the decline of complex sugars degradation which has also been observed in strawberry [20] and kiwifruit [21].

Table 4. The interaction effect of the salicylic acid treatment and the storage time on some physicochemical traits of peach cultivar Rubin

Salicylic acid (mmol)	Storage time (day)	TSS (Brix)	pH	Vitamin C (mg/100 ml)	Total phenol (mg Gallic acid/100 ml)
0 (Control)	0	9.29 def	4.32 bc	5.91 fg	16.38 f
	5	10.70 cd	4.36 abc	6.10 fg	23.44 ef
	10	11.87 bc	4.11 de	6.55 ef	24.22 ef
	15	12.77 ab	4047 ab	5.32 fg	90.05 ab
1 (Spray)	0	8.53 efg	4.55 a	7..65 de	43.50 cde
	5	10.13 de	4.37 ab	7.97 cde	41.99 cde
	10	12.70 ab	4.36 abc	7.30 de	31.55 de
	15	12.47 ab	4.40 ab	5.76 fg	97.27 ab
2 (Spray)	0	6.84 g	4.35 abc	9.56 a	87.33 ab
	5	7.93 fgh	4.33 bc	9.06 ab	82.61 ab
	10	7.57 fgh	3.95 e	8.49 abc	76.28 b
	15	8.10 fgh	4.24 cd	6.74 ef	105.70 a
4 (Spray)	0	8.98 efg	4.39 ab	8.65 abc	52.22 c
	5	9.93 def	4.39 ab	8.53 abc	49.72 cd
	10	9.23 efg	4.04 de	7.28 de	45.22 cde
	15	9.67 def	4.29 cd	5.65 fg	101.30 a
2 (Submergence)	0	9.29 def	4.32 bc	8.80 abc	16.38 f
	5	12.10 ab	4.32 bc	8.13 bcd	27.49 ef
	10	13.40 a	4.31 bc	7.83 de	31.83 de
	15	11.87 bc	4.25 cd	4.98 g	97.83 ab

The similar letters in each column indicate non-significant difference.

The results indicated that the highest fruit pH was observed in 1 mmol salicylic acid spray, which did not have any significant difference with some other treatments. The lowest pH value was observed in 2 and 4 mmol salicylic acid spray 10 days after storage (Table 4). These results correspond well with the results obtained in another study [16]. They reported through the study of salicylic acid and calcium chloride pre-harvest spray effect on the barberry storage life that the higher the salicylic acid concentration the lower the pH value. Likewise, the results of the experiment suggested that the pH value increased during the storage period. The similar results attained in strawberry [22]. The climb in pH value might be due to the changes in organic acids during storage, but this rise varies depending on the fruit type, because the alteration in other substances such as sugars may also be effective [23].

The results also revealed that the highest content of vitamin C was observed in 2 mmol salicylic acid sprays on the first day and 5 and 10 days after storage, 4 mmol salicylic acid spray on the first day and 5 days after storage, and 2 mmol salicylic acid submergence on the first day (Table 4). All the salicylic acid concentrations enhanced vitamin C content; however, it reduced during the storage period. These results correspond well with the previous experiments results. It was reported that the navel orange pre-harvest treatment with salicylic acid led to the increase of ascorbic acid content in the fruit epicarp and pulp [10]. Moreover, similar research in pineapple proved that salicylic acid prevents the diminution of ascorbic acid [24]. Salicylic acid can inhibit the oxidation of ascorbic acid or decline its velocity through the rise of ascorbate peroxidase enzyme activity [25]. The diminution of ascorbic acid during storage might be due to fruit senescence [26].

The highest content of fruit total phenol was observed in all the salicylic acid treatments 15 days after storage and also in 2 mmol salicylic acid spray on the first day and 5 days after storage. The lowest content was observed in control and 2 mmol salicylic acid submergence treatment on the

first storage day (table 4). Based on the results, the total phenol content increased during storage and the treated fruits with salicylic acid pre-harvest spray represented the highest total phenol content that corresponds well with the other results. It was previously observed that salicylic acid enhanced the content of carotenoids, total phenol, and total flavonoids in fruit epicarp and pulp, significantly [10].

The results of simple effects demonstrated that the highest value of the acidity (1.90 mg/100 ml juice) was observed in 2 mmol salicylic acid spray treatment, and the lowest amount was observed in control (0 mmol) and 2 mmol salicylic acid submergence treatment (1.30 and 1.44 mg/100 ml juice). Similarly, the results suggested that the highest fruit acidity was observed at the storage days of 0 and 5 (1.69 and 1.59 mg/100 ml juice, respectively), and the lowest amount was observed at the storage days of 10 and 15 (1.47 and 1.46 mg per 100 milliliter juice, respectively), but they did not show any significant difference with 5 days storage (Table 5). These results correspond well with the previous results. The highest titratable acidity in barberry was observed in 1 and 3 mmol salicylic acid treatments [16]. In other fruits like tomato [27] and strawberry [11], salicylic acid increased the acidity in comparison to the control. Also, the fruit acidity lessened during the storage. The decrease of acidity occurs due to the biochemical changes of fruit compounds during respiration [28].

Table 5. The simple effect of salicylic acid treatment and storage time on some of the chemical traits of peach cultivar Rubin

	Acidity (mg/100 ml)	Total flavonoid (mg Gallic acid/100 ml)	Antioxidant capacity (free radicals percentage)
salicylic acid (mmol)			
0 (Control)	1.30 d	5.03 a	84.67 a
1 (Spray)	1.51 bc	3.32 ab	78.25 ab
2 (Spray)	1.90 a	1.59 b	58.08 c
4 (Spray)	1.61 b	1.74 b	74.19 b
2 (Salicylic acid submergence)	1.44 cd	3.77 ab	81.17 ab
Storage time (day)			
0	1.69 a	4.20	80.17 a
5	1.59 ab	1.71	74.70 ab
10	1.47 b	2.93	69.96 b
15	1.46 b	3.53	76.24 ab

The similar letters in each column indicate non-significant difference.

The highest total flavonoid was observed in control (0 mmol salicylic acid), however, it did not have any significant difference with some other treatments. According to the results, the highest antioxidant capacity was observed in 0 and 1 mmol salicylic acid spray as well as in the 2 mmol salicylic acid submergence, and the lowest content was observed in 4 mmol salicylic acid spray. Similarly the highest antioxidant capacity was observed at the first storage day and also 5 and 15 days after storage, and the lowest content was observed 10 days after storage, however it had no significant difference with some other treatments (Table 5). Based on the results of this experiment, salicylic acid had no significant effect on total flavonoid and antioxidant capacity. On the contrary, in another study, the pre-harvest spray of navel orange with salicylic acid was assessed [10]. It was found that these treatments significantly increased the contents of carotenoids, glutathione, total phenol, and total flavonoids in the fruit epicarp and pulp during the storage. Furthermore, the highest quantity of these antioxidant compounds was observed in the treated fruits with higher salicylic acid concentrations (1 and 2 mmol). In another experiment, the researchers assessed the antioxidant capacity changes and the postharvest quality of two orange cultivars 60 days after storage at the temperature of 7˚c and 90% relative humidity [29]. Their results revealed that the

antioxidant capacity of citrus fruits decreased during the storage, which is similar to the results of the present research.

CONCLUSIONS

The application of salicylic acid in peach using the pre-harvest spray and postharvest submergence enhanced the storage period of the fruits. It also caused higher fruit quality at the end of the period. According upon the conducted experiment, the salicylic acid spray had a significant effect on the fruit firmness, volume decrease, weight loss, acidity, TSS, pH, total phenol, and vitamin C. The pre-harvest and postharvest salicylic acid treatments resulted in the fruit quality maintenance against weight loss, volume decrease, length reduction, and diameter decrease. The best result obtained with 2 mmol salicylic acid spray. Salicylic acid was also very effective in the preservation of the fruit firmness. The results also demonstrated that 2 mmol salicylic acid spray perfectly maintained the TSS and pH as in preliminary condition at the harvest. The salicylic acid treatment led to the increase of vitamin C, total phenol, and titratable acidity. Based on the acquired results, the best result was gained by the pre-harvest spray of salicylic acid at the concentration of 2 mmol, and this treatment can be used to increase peach storage quality.

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Conflict of interests

The authors declare that there are no conflicts of interest.

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