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Effect of Pre- and Postharvest Treatment of Salicylic Acid on Ripening of Fruit and Overall Quality of Strawberry (*Fragaria ananasa* Duch cv. Camarosa) Fruit

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ABSTRACT

This experiment was conducted to study the effect of salicylic acid (SA) as pre- and postharvest treatments on the strawberry fruit quality (Fragaria ananasa Duch. cv. Camarosa). The experiment was carried out in a factorial randomized complete block design with three replications. This factor included the inclusive of SA in 4 levels (0, 3, 5 and 7 mM) applied on 60 shrubs. The results showed that SA delays the ripening of strawberry fruits. Pre- and/or post-harvest treatment of SA had higher titratable acidity (TA) values than the control. Fruits dipped in SA solution had less weight loss, decay and higher vitamin C and redness than the control. SA treatment delayed the onset of the climacteric peak of respiration and also inhibited respiration and ethylene production. A signification difference was seen among the three levels of SA. SA affected on the quality of strawberry fruit and increased its storekeeping.

Key words: ripening, salicylic acid, strawberry, fruit quality

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INTRODUCTION

Salicylic acid (SA), a ubiquitous plant phenolic compound, regulates a number of processes in plants [25]. SA is a natural phenolic compound presented in many plants and is an important component in the signal transduction pathway. SA is also involved in local and systemic resistance to fungal pathogens [20]. It is known that SA, as a plant growth regulator, can enhance disease resistance of a few growing plants or detached plant organs [20, 24]. Strawberries are very sensitive against fungal attack because of their perishable structure. Due to the high metabolic activity, their quality decrease rapidly after harvesting [23]. Exogenous application of SA at nontoxic concentrations to susceptible plants could enhance their resistance to fungal pathogens [21]. Furthermore, exogenous application of SA has been found to enhance the efficacy of the bio-control of yeast *Cryptococcus laureate* in pear fruit [33], cherry fruit [24] and apple fruit [34]. SA delays fruit ripening [29]. Influence of SA on fruit softening, fruit ripening and senescence are accompanied by changes in several quality aspects such as softening, decrease in total acidity and increase in sugar contents, color development and aroma production [22]. Exogenous application of SA at

nontoxic concentrations to susceptible fruits and vegetables could enhances resistance to pathogens and delays post-harvest decay [3, 5]. SA and its derivative, acetyl salicylic acid (ASA), inhibited ethylene production in pear [14]. Marissen et al. [19] proposed the role of SA as an antagonist to ethylene action. The concentration of 1-2 mmolL^{-1} SA effectively reduced fungal decay in strawberry cv. Selva fruit [5]. In contrast, it has also been shown that high concentrations of SA increases oxidative damage generated by NaCl in *Arabidopsis* [6] and decreases drought tolerance in *Zea mays* [22]. SA inhibited flowering in Arum lilies [26]. It has been demonstrated that SA in a concentration dependent manner effectively reduces respiration in plants and harvested fruits [28, 29]. Me-SA delayed post-harvest decay in Hayward kiwifruit. Decay incidence in fruits treated with 32 mL was 6.3%, whereas it was 34.2% in the control fruits [1]. The aim of the study was to evaluate the effect of pre- and postharvest treatment of SA on ripening of strawberry (*Fragaria ananasa* Duch. cv. Camarosa) fruit and its overall quality.

MATERIALS AND METHODS

Plant Material and Growth Conditions

The experiment was conducted during 2011 and 2012 on strawberry plants at a greenhouse located in Gorgan city, Golestan province, Iran (latitude 36°50´N, longitude 24°44´E). Three month old strawberry (*Fragaria ananasa* Duch. cv. Camarosa), propagated by cutting runners from mother plants were planted in 25-cm plastic pots filled with sterilized pit mass and perlite (1:2) and hydroponically grown in a greenhouse under high light and at a constant temperatures (17-19°C night and 24-27°C day).

Treatment of Salicylic Acid

Different concentrations of SA (0, 3, 5 and 7 mM) were applied. SA solutions were prepared by dissolving powdered SA in hot water and then applied on plants and fruits in different combinations and different time durations. Plants were divided into 3 groups; each group consisted of 20 plants and received SA treatments at different plant and fruit development stages (Table 1). Therefore, different concentrations of SA were used for experiments as pre- and post-harvest treatments. A number of fruits were also sprayed with distilled water as the control. Spray was done three times at 10-day intervals before harvesting. At harvesting time, each of the groups of fruits with or without treatment SA were divided into further two groups; some fruits were immersed into the SA solutions for 15 min, and the others in distilled water, accordingly. All the fruits were air-dried for approximately 30 min, and then stored at 10°C and 90% relative humidity (RH) for 21 days. Each treatment contained three replicates of 80 fruit for this experiment. Sampling (5 fruits from each replicate) for fruit quality assessment was carried out at 3 times with 7 days intervals. The control plants, during the vegetative growth and fruit development stages were dipped only in pure water [29].

Fruit Selection

Strawberries were harvested early in the morning and rapidly transferred to the laboratory. Strawberries were sorted on the basis of size, color (70% full red color) and absence of physical damage, and were randomly divided into lots of ten fruits.

Measurement of Titratable Acidity (TA)

The 10 ml of extracted fruit juice was diluted with 100 ml distilled water and were titrated with 0.1 N of sodium hydroxide to a pH 8.1. Titratable acidity was calculated as percentage of citric acid [27].

Measurement of Total Soluble Solid (T.S.S.)

Total soluble solid (T.S.S) in the extracted fruits juice was measured by a refractometer [ATAGO (Brix=0-32%)] and the results were expressed as °Brix.

Measurement of Vitamin C (Ascorbic Acid)

Fruit vitamin C was measured by titration with iodide and iodide potassium [17].

Statistical Analysis

All data obtained were subjected to one-way analysis of variance (ANOVA) and the mean differences were compared using Duncan's multiple range test (DMRT) when the *F*-test indicated significant difference at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of SA on T.S.S.

All treatments decreased the level of T.S.S. Thus, the highest T.S.S content (7.1%) was obtained in control plants (Table 4). Overall quality is the most important factor in fruit marketability assessment. T.S.S. may be increased during fruit ripening due to the action of sucrose-phosphate synthesis (SPS), a key enzyme in sucrose biosynthesis [11]. This enzyme is activated by ethylene and the ripening process itself during storage [13]. Treatment of kiwifruits with 32 ml L^{-1} Me-SA maintained a lower T.S.S. content than the control fruits at the end of cold storage [1]. Study of Lu et al. [16] on pineapple fruit showed that the application of SA as pre- and postharvest treatment resulted in a decreased T.S.S. Shafiee et al. [27] reported that postharvest treatment of strawberry with ASA resulted in a lower T.S.S than the control. There is only one report [2] which showed SA decreased T.S.S. in strawberry cv. Selva.

Effect of SA on Fruit Weight Loss

The results showed that fruits dipped by salicylic acid (SA) had less weight loss. The greatest fruit weight loss (9.4 g) was calculated in plants treated with 7 mM. All treatments induced more fruit weight loss in comparison with the control (Table 4). Garcia et al. [9] found similar results in strawberry fruits cv. Tudla. SA can also decrease the respiration rate and fruit weight loss [18, 36].

Effect of SA on Delay of Ripening

Fruits dipped by SA had less delay than the control fruits (Table 4). Fruit ripening decreased as the concentration of SA increased (Table 4). The same results were obtained from pre- and post-harvest SA application on strawberry [27]. Study of El-Ghaouth et al. [8] on apple and citrus fruits showed that the fruits dipped by SA had less delay than the control. Some other studies showed that SA can delay fruit ripening and/or reduce decay of banana, nectarine, peach, apple, pear, strawberry, kiwifruit and citrus [15, 28, 32, 35], also alleviate chilling injury of tomato and cucumber stored at low temperature [10]. Decrease in fruit metabolic activities resulted in a decrease in fruit water loss and carbohydrate depletion rate and consequently, effectively delays fruit senescence process [30]. Ethylene production was reduced by the SA treatment, and this has also been reported for strawberry fruit [5]. Treatment of green tomato fruits with SA during the pre-climacteric phase has been shown to delay their ripening. It has been shown that Me-SA treatment significantly decreased ethylene production in kiwifruits [1]. Zhang et al. [35] reported that postharvest treatment of kiwifruit with ASA resulted in a lower ACO and ACS (Two enzymes interfere in ethylene and respiration production) activity and decreased ethylene production during the early stages of fruit ripening. The researches proposed that SA reduces ethylene production that may be resulted in decreased SPS enzyme activity leading to decrease in sucrose synthesis [4].

Effect of SA on Titratable Acidity (TA)

Pre-harvest application of SA in nutrient solution changed fruit TA. At harvest time, SA treatment increased the rate of TA, but did not differ significantly as compared to the control (Table 4). Pre- and/or post-harvest SA treatments induced higher TA values than the control. After 3 week, the rate of TA in fruits treated with SA was less than control. During shelf-life, the TA content of the strawberry fruit initially increased significantly and reached to a peak value at 7 days then underwent a downward trend, following a similar pattern in all treatments. Lu et al. [16] reported that pre- and post-harvest treatment of strawberry with SA resulted in an increased TA of fruit.

Effect of SA on Vitamin C Content

The results showed that the content of vitamin C in strawberry did not show changes in response to SA in nutrient solution. The highest dose (7 mM) was more effective than the lower dose (3 mM). After 3 weeks, ascorbic acid amount was decreased (Table 4). Jing-Hua et al. [12] reported that the application of SA can increase vitamin C and then decrease anti-oxidant in fruit and increase resistance to chilling damage in strawberry. Also, study of Dat et al. [7] showed the role of SA on increasing of total ascorbic acid amount in mustard. Our study revealed that SA could increase the rate of vitamin C in strawberry that resulted in increasing the fruit quality and decreasing physiology disease.

Table 1: Analysis of variance of the effect of different concentrations of SA on ripening of fruit, T.S.S, fruit weight, TA and vitamin C percent of strawberry (*Fragaria ananasa* Duch. cv. Camarosa) in different times

Traits		Ripening of fruit (%)			T.S.S (%)			Fruit weight (g)			TA (%)			Vitamin C (%)	
Time	First Week	Second Week	Third Week	First Week	Second Week	Third Week	First Week	Second Week	Third Week	First Week	Second Week	Third Week	First Week	Second Week	Third Week
df (Between-Within Group)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)	(3-8)
Mean Square	(210.750 - 1.000)	(130.750-1.000)	(101.000-1.000)	(0.648-0.258)	(0.488-0.10)	(0.260-0.10)	(5.348-0.10)	(3.710-0.505)	(4.468-0.10)	(0.001 – 0.00)	(0.001 – 0.00)	(0.001-0.000)	(12.928-0.10)	(11.228-0.258)	(23.148-0.10)
F	210.750***	130.750***	101.000***	2.515^{ns}	48.750***	26.000***	534.750***	7.347^{ns}	44.740***	8.750^{ns}	5.000sx^{ns}	10.000^{ns}	1292.750***	43.602***	231.750***

****: Significant at P≤0.05 probability level, ns: Non significant*

Table 1: Mean comparison of the effect of different concentrations of SA on ripening of fruit, T.S.S, fruit weight, TA and vitamin C percent of strawberry (*Fragaria ananasa* Duch. cv. Camarosa) in different times

SA concentration (mM)	Ripening of fruit (%)	T.S.S. (%)	TA (%)	Vitamin C (%)	Fruit weight (g)
			First Week		
0	61a	7.1a	0.94c	70.3d	12.4a
3	50b	7.0a	0.95bc	72.6c	11.6b
5	47c	6.5b	0.96b	73.8b	10.3c
7	41d	6.1b	0.98a	75.2a	9.4d
			Second Week		
0	63a	7.3a	0.90c	58.9c	11.2a
3	54b	7.1b	0.91bc	60.4b	11.0a
5	53b	6.7c	0.92ab	62.5a	9.4b
7	47c	6.4d	0.93a	63.1a	9.0b
			Third Week		
0	64a	7.4a	0.84b	51.2d	10.7a
3	56b	7.3a	0.86a	53.4c	10.5b
5	57c	6.9b	0.83b	55.7b	8.9c
7	50d	6.8b	0.87a	57.6a	8.2d

Within each column, same letter indicates no significant difference among treatments (P<0.05).

CONCLUSION

In conclusion, the experiment conducted here indicated that the application of SA, especially at pre-harvest and post-harvest times effectively increased the fruit quality and maintained quality of strawberry fruit during shelf-life.

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