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 ORIGINAL ARTICLE

Effect Of Salicylic Acid On Post-Harvest Quantitative And Qualitative Traits Of Strawberry Cultivars

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ABSTRACT

Strawberry with scientific name (*Fragaria* spp.) belongs to the family of *Rosaceae* and genus of *Fragaria* that is a rich source of vitamin C and K. It has a little vitamin A folat (folic acid salts) and Ca. In order to study the effect of phenolic compounds (salicylic acid) on the post-harvest durability of fruits strawberry cultivars, a factorial study was carried out in Jiroft, Iran based on a completely randomized design which the factors included salicylic acid (SA) at five levels (0 as control, 1, 2, 3 and 4 mM) and cultivar at three levels (Paros, Kamarosa and Selva). The study consisted of 15 treatments with 3 replications. After putting the fruits in refrigerator, they were kept at 3±1°C for 12 days and then, they were transferred to a room with a temperature of 18-20°C for sampling. Results revealed that 4 mM SA treatment was in the highest vitamin C content. The highest rotten fruits percentage was obtained from control. In terms of storage durability, Paros cultivar had the highest healthy fruits percentage with vitamin C, TA and TSS conservation. Paros treated with 2 mM SA was superior over the other cultivars with respect to most quantitative and qualitative traits. This treatment had optimum acidity, vitamin C content and TSS/TA ratio. But, the interaction between cultivar and SA was not significant on healthy fruits percentage, rotten fruits percentage, fruit pH and TSS.

Key words: Paros, salicylic acid, strawberry.

Introduction

Advances in technology, techniques for determining harvest time, recognizing internal injuries, harvest methods, different methods of drying, initial cooling, non-chemical disinfection methods , various storages, chemical pre- and post-harvest treatments, application of ethylene absorbents and ethylene effect retardants, modern packaging methods with polyethylene films to prevent weight loss, rotting avoidance by thermotherapy methods and sustainable processes like compote and jam are effective ways for reducing the loss of the product. The application of salicylic acid (SA) is another method for post-harvest maintenance of products [4]. Strawberry is an herbaceous plant belonging to the family of *Rosaceae* and genus of *Fragaria*. Since it can propagate by adventitious stems, it is regarded as a permanent plant. The most domesticated variety of strawberry is a cross between *F. chlioensis* and *F. Virginiana* known as *F. ananassa* [4]. Duan *et al*. [2] reported that the treatment of grapes with SA had a positive effect of their hardness, appearance and the decrease in fungal infections which showed significant differences with control. Furthermore, they showed that post-harvest SA treatment had a better performance in controlling fungal rotting. Duan *et al*. [2] reported effective SA treatment on post-harvest of cherries caused in the retention of fruit acidity and the decrease in its pH and fungal infection, improved fruit storage durability and retained the quality of fruit appearance. Lipo oxigenase and Allen oxide synthesis directly or indirectly involve in ethylene biosynthesis and may participate in opposite direction of ethylene biosynthesis too, which can be adjusted by SA [3]. The effect of pre-storage SA treatment and storage duration on the activity of enzyme phenylalanine ammonia lyase, chilling and the quality of the fruits of pomegranate cultivars. Mals Saveh cultivar was studied and results revealed that the increase in SA concentration decreased chilling index and ion leakage and increased the activity of enzyme phenylalanine ammonia lyses. The highest enzymatic activity was observed at 2 mM SA. Vitamin C and titratable acidity (TA) of fruits treated with higher SA concentrations was higher than those of control fruits. The concentration of total suspended solids and pH increased during storage but vitamin C

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content and TA decreased [11]. Because of its decomposing structure, strawberry is highly susceptible to fungal attacks. Given their high metabolic activity, they rapidly lose their quality after harvesting [9]. The application of 2 mM SA effectively increased antioxidant compounds, ascorbic acid content and total suspended solids (TSS) and prevented fungal infection of strawberries [1]. SA prevents the softening of bananas and kiwis at maturity stage [16,13]. Amborabe [1] indicated that soaking strawberries Selva cultivar in SA resulted in the retardation of TSS loss. Vicente *et al*. [14] reported that post-harvest SA treatment increased TA compared to control. In a study on kiwi, Zhang *et al*. [18] found that SA levels decreased during maturity and that ethylene treatment accelerated ASA loss. Also, they proved that ethylene treatment increased its production and ethylene climacteric advanced and on the contrary, exogenous application of ASA markedly prevented ethylene production and retarded the commencement of ethylene climacteric. Wozniak *et al*. [17] reported that sugars and acids were important qualitative parameters of strawberries and varied in different cultivars. Shaw [12] revealed that total sugar, sucrose, glucose and fructose contents of strawberries depended upon genetic diversity. Kalt and McDonald [6] reported that the difference of strawberry cultivars in their sucrose levels depended on a combination of genetic and environmental factors. Kader [5] and Perkins-Veazie [10] reported that depending on cultivar and environmental factors, TSS and TA in commercial products of strawberry varied in the ranges of 5-12% and 0.5-1.78%, respectively. The current study was conducted to examine the effect of SA on post-harvest durability of three strawberry cultivars under cold storage conditions.

Materials and Methods

In order to study the effect of salicylic acid (SA) on post-harvest durability of three strawberry cultivars, a factorial study was carried out in Jiroft, Iran based on a completely randomized design in which the factors included salicylic acid (SA) at five levels (0 as control, 1, 2, 3 and 4 mM) and cultivar at three levels (Kamarosa, Paros and Selva). After preparing the solutions with predetermined ratios, the fruits of strawberry were soaked in it for 2 minutes. Then, they were dried and about 30 fruits were packed in transparent bags with the dimensions of $5\times10\times13$ cm^3. After that, they were weighed and put in refrigerator after labeling. Before the study, the fresh fruits were sampled to measure their pH, total suspended solids (TSS), vitamin C content and titratable acidity (TA). The study was included 15 treatments with 3 replications. Control treatment consisted of fruits which were not treated with hormone. After putting the fruits in refrigerator, they were kept at 3±1°C for 12 days. Next, they were transferred to a room with a temperature of 18-20°C for sampling. The measured traits included the number of healthy and rotten fruits counted visually and then, their percentages were determined. The secondary weight was determined with a 0.1precision digital scale. The weight loss percentage was specified by subtracting the initial weight (pre-study weight) from the secondary one. TSS was determined with a refractometer (Tagoa, ATC-1E made in Japan), pH was determined with a pH-meter, and vitamin C content and TA were measured by titration method in laboratory of Agriculture Research Center, Jiroft, Iran. Meanwhile, the initial and secondary volume of the fruits was measured by graduated cylinder and then, volume loss percentage was calculated. TA was calculated by titration method with soda 1.0 normal in terms of citric acid. So, vitamin C content was calculated by titration method and after titration with potassium iodide. The collected data were statistically analyzed by software MSTAT-C and the diagrams were drawn by software Excel.

Results and Discussion

After conducting all experimental stages on the effect of SA on post-harvest quantitative and qualitative traits of strawberries, the variance of the data was analyzed. Results revealed that the effect of SA on healthy fruit percentage, weight loss percentage and vitamin C content was very significant. There wasn't a significant difference for effect of SA in rotted fruits percentage, fruit volume loss percentage, TA, pH, TSS and TSS/TA ratio. Effect of cultivar healthy fruits percentage, rotted fruits percentage, fruit weight loss percentage, fruit volume loss percentage, TA, vitamin C content and TSS/TA ratio at $P\leq0.01$and TSS at $P\leq0.05$probability level, but its influence on fruit pH was not significant (Table 1).The interaction between SA and cultivar was very significant on fruit weight and volume loss percentage and vitamin C content at $P\leq0.01$ probability level and on TA and TSS/TA ratio at $P\leq0.05$ probability level. But it was not significantly on healthy fruits percentage, rotted fruits percentage, TSS and pH (Table 1). Healthy fruits percentage had the highest negative correlation with rotted fruits percentage and pH (r = - 0.926), but it exhibited a positive correlation with TA, TSS and TSS/TA ratio (Table 5).The most of healthy fruits percentage (60.81%) was observed in plants treated with 2 mM SA and the lowest one (43.6%) in control, i.e. plants treated with no SA (Table 2). In a study on strawberries, Li *et al*. [7] reported the inhibiting effect of SA on TSS accumulation in injured fruits. According to the table of means comparison, Paros cultivar had great healthy fruits percentage as two other cultivars (77.22%) and the lowest healthy fruits percentage was observed in Kamarosa cultivars

(35.91%) twelve days after storage (Table 3). Also, Wang and Zhang, [16] reported that strawberry contained a high level of antioxidant compounds like anthocyanins and flavonoids which played protective role against oxygen and free radicals activation and were markedly influenced by genotype factors and environmental conditions. The highest and lowest percentage of rotted fruits was observed in Kamarosa and Paros cultivars 12 days after storage at 3±1°C respectively (Table 3), which can be related to the fact that the fruits of Paros cultivar were harder during harvesting or they had higher acidity which is regarded as an appropriate trait favoring the storage of fruits. As the table of correlation between traits showed as rotted fruits percentage had a negative correlation with fruits vitamin C content and also, it had a more negative correlation with healthy fruits percentage (r = -0.926) (Table 5). Because increase of rotted fruits percentage caused, decrease of vitamin C content of fruits. Amborabe *et al*. [1] reported that SA can play a central role in the resistance of crops to diseases, particularly during acquired systemic resistance. The highest weight loss (3.48%) was observed in the treatment with 4 mM SA and the lowest one (2.17%) in the treatment with 1 mM SA which can be related to the strong effect of SA on the compounds inside the fruit tissue. Treatments of SA on weight loss percentage strawberry fruits hadn't significant differences (Table 2).The highest fruit weight loss percentage was observed in Paros cultivar but the weight losses percentage of Kamarosa and Selva cultivars was lower than Paros cultivar (Table 3). Chilling during storage period reduced fruits weight and the cultivars varied in their resistance. Also, Sayari *et al*. [11] reported that chilling increased during storage period and consequently, fruits weight and volume decreased. Interaction between cultivars and SA showed the highest fruits weight loss percentage belonged to Paros cultivar (70%) and the lowest one was observed in Selva cultivar (7%) which treated with 3 mM SA and 1 mM SA respectively (Table 4). According to the table of correlation traits, there was a highest positive correlation between fruits weight loss percentage and fruits volume loss percentage(r = 0.823) because SA can activate enzymes oxidase and peroxidase by intensifying lignifications of fruits cellular walls which results in the loss of the weight and volume of the fruits (Table 5).The effect of cultivars on fruit volume loss percentage revealed that Paros cultivar had the highest loss (18%) compare with two other cultivars meanwhile there wasn't significant differences between them (Table 3). Different cultivars of strawberry lose their volume and consequently, their weight during storage whose amount is different in them. The highest fruit volume loss percentage was observed in Paros cultivar (27%) treated with 3 mM SA and the lowest one was observed in Selva cultivar (5%) treated with 1 mM SA (Table 4).

The comparison of correlation coefficient between studied traits indicated a positive, significant correlation between fruits volume loss and healthy fruits percentage (Table 5). The increase in SA suberized the cellular wall and resulted in the loss of volume and weight. Paros cultivar had the highest TA (7%) while the other two cultivars did not show significant differences with each other (Table 3). Also, Kader [5] reported that various strawberry cultivars had different TA depending on cultivar and environmental factors. Interactions between cultivar and SA, the highest TA was obtained by Paros cultivar (10%) which treated with 3 mM SA although it did not have significant difference with that of Paros cultivar treated with 2 mM SA and the lowest TA was observed in Selva cultivar (5%) without TA treatment (Table 5).The highest vitamin C content was produced by treatment with 4 mM SA (86.48 mg/100 g), while the lowest one was observed in control treatment (62.7 mg/100 g) (Table 2). In a study on pomegranate, Sayari *et al.* [11] stated that it had higher vitamin C content under the treatment with higher SA comparison than control. the effect of cultivar on vitamin C content revealed that Paros cultivar had the highest vitamin C content (84.35 mg/100 g) and Kamarosa cultivar had the lowest one (56.54 mg/100 g) (Table 3). Also, Stanchev (1974) reported that strawberry fruits varied in their vitamin C contents. The study of the interaction between cultivar and SA treatment showed that Selva and Paros cultivars treated with 4 mM SA had the highest vitamin C content (90.85 and 89.71 mg/100 g) respectively and Kamarosa cultivar without receiving SA treatment had the lowest one (45.7 mg/100 g) (Table 4). It shows that without treated with chemicals, Kamarosa cultivar rapidly lost its vitamin C content during storage. Paros cultivar had the highest TSS (62%) and Selva cultivar had the lowest one (5.8%) (Table 3).The highest TSS/TA ratio was in Paros cultivar (1.3 %) and was the lowest in Kamarosa cultivar (0.9%) although it did not exhibit statistically significant difference with Selva cultivar (Table 3). Among the interactions, Paros cultivar treated with 3 and 4 mM SA had the highest TSS/TA ratio and Kamarosa cultivar treated with 2 mM SA had the lowest one (Table 4).

Table 1: Analysis of variance

Treatment	df	Means of squares								
		Healthy fruits percentage	Rotten fruits percentage	Weight loss percentage	Volume loss percentage	TA	Vitamin C	pH	TSS	TSS/TA
SA	4	680.217^{**}	491^{ns}	2.759^{**}	0.237^{ns}	0.046^{ns}	708^{**}	0.285^{ns}	0.448^{ns}	0.001

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Cultivar	2	4352**	5866**	18.5**	4.21**	0.194**	3122**	0.211^{ns}	0.650*	0.004**
SA × cultivar	8	149.685^{ns}	414^{ns}	8.13**	0.78**	0.051*	141**	0.224^{ns}	0.111^{ns}	0.0015*
Error	30	168.599	196.2	0.500	0.228	0.018	19.101	0.200	0.188	0.0005
Coefficient of variations (%)		2.2	3.32	2.13	2.56	2.75	2.12	1.37	7.5	1.64

Not: *, ** and ^{ns} significance at P≤0.05, P≤0.01 and non-significance, respectively.

Table 2: Means Comparison of measured traits mean in strawberry fruits by SA treatment

Treatment	Healthy fruits percentage	Weight loss percentage	Vitamin C content (mg/100 g)
0 mM SA	43.60 ^{c}	2.72 ^{bc}	62.70 ^{d}
1 mM SA	52.64 ^{ab}	2.17 ^{c}	68.33 ^{c}
2 mM SA	60.81 ^{a}	3.09 ^{b}	71.18 ^{bc}
3 mM SA	44.4^{abc}	2.26 ^{c}	74.62 ^{b}
4 mM SA	48.59 ^{bc}	3.48 ^{a}	86.48 ^{a}

Note: Means follow by similar letters in each column are not significant by DNMTR test at P≤0.05.

Table 3: Comparison of measured traits mean in strawberry fruits by cultivar

Treatment	Healthy fruits percentage	Rotten fruits percentage	Weight loss percentage	Volume loss percentage	TA	Vitamin C (mg/100g)	TSS (°brix)	TSS/TA
Paros	77.22 ^{a}	23.66 ^{c}	4.02 ^{a}	1.87 ^{a}	0.79^{a}	83.35 ^{a}	6.27 ^{a}	0.13 ^{a}
Kamarosa	35.91 ^{c}	64.42 ^{a}	1.99 ^{b}	0.99 ^{b}	0.58 ^{b}	56.54 ^{b}	6.17 ^{ab}	0.09 ^{b}
Selva	62.75 ^{b}	38.19 ^{b}	2.22 ^{b}	0.92 ^{b}	0.61 ^{b}	77.10 ^{c}	5.87 ^{b}	0.11 ^{b}

Note: Means follow by similar letters in each column are not significant by DNMTR test at P≤0.05.

Table 4: Comparison of measured traits mean in strawberry fruits by the interaction between SA and cultivar

Treatment	Weight loss percentage	Volume loss percentage	TA (%)	Vitamin C (mg/100g)	TSS/TA
Paros × 0 mM SA	2.18 ^{d}	1.23 ^{b}	0.54 ^{d}	76.69 ^{b}	0.09 ^{c}
Kamarosa × 0 mM SA	2.37 ^{d}	1.32 ^{b}	0.60 ^{cd}	45.70 ^{e}	0.11 ^{b}
Selva × 0 mM SA	3.60 ^{c}	1.10 ^{b}	0.50 ^{d}	58.64 ^{d}	0.11 ^{b}
Paros × 1 mM SA	3.82 ^{c}	1.71 ^{ab}	0.72 ^{b}	83.74 ^{a}	0.11 ^{b}
Kamarosa × 1 mM SA	1.93 ^{de}	1.17 ^{b}	0.57 ^{cd}	52.70 ^{f}	0.09 ^{c}
Selva × 1 mM SA	0.75 ^{f}	0.58 ^{c}	0.65 ^{c}	75.50 ^{b}	0.10 ^{c}
Paros × 2 mM SA	5.37 ^{b}	2.47 ^{a}	0.70 ^{b}	84.45 ^{a}	0.11 ^{b}
Kamarosa × 2 mM SA	1.97 ^{de}	0.87 ^{c}	0.55 ^{d}	51.14 ^{e}	0.08 ^{c}
Selva × 2 mM SA	1.93 ^{de}	0.77 ^{c}	0.72 ^{b}	77.49 ^{b}	0.12 ^{b}
Paros × 3 mM SA	7.07 ^{a}	2.72 ^{a}	1.01 ^{a}	87.17 ^{a}	0.16 ^{a}
Kamarosa × 3 mM SA	1.48 ^{e}	0.80 ^{c}	0.63 ^{c}	54.14 ^{d}	0.10 ^{c}
Selva × 3 mM SA	1.89 ^{de}	0.93 ^{c}	0.63 ^{c}	82.55 ^{b}	0.11 ^{b}
Paros × 4 mM SA	1.66 ^{e}	1.23 ^{b}	0.99 a	89.71 ^{a}	0.16 ^{a}
Kamarosa × 4 mM SA	2.18 ^{d}	0.80 ^{c}	0.59 ^{cd}	78.88 ^{b}	0.09 ^{c}
Selva × 4 mM SA	2.94 ^{cd}	1.22 ^{b}	0.52 ^{d}	90.85 ^{a}	0.09 ^{c}

Note: Means follow by similar letters in each column are not significant by DNMTR test at P≤0.05.

Table 5: Correlation coefficients of measured traits

Traits	Healthy fruits percentage	Rotten fruits percentage	Weight loss percentage	Volume loss percentage	TA	Vitamin C	pH	TSS	TSS/TA
Healthy fruits percentage	1								
Rotten fruits percentage	-0.926**	1							
Weight loss percentage	0.410*	-0.385*	1						
Volume loss percentage	0.393*	-0.386*	0.823**	1					
TA	0.311^{ns}	-0.340^{ns}	0.347^{ns}	0.337^{ns}	1				
Vitamin C	0.562**	-0.536**	0.325^{ns}	0.288^{ns}	0.409*	1			

pH	-0.124^{ns}	0.099^{ns}	-0.129^{ns}	-0.093^{ns}	0.050^{ns}	-0.181^{ns}	1		
TSS	0.115^{ns}	-0.021^{ns}	-0.021^{ns}	0.055^{ns}	0.149^{ns}	0.124^{ns}	0.372^{*}	1	
TSS/TA	0.278^{ns}	-0.341^{ns}	0.356^{ns}	0.298^{ns}	0.952	0.381^{*}	-0.014^{ns}	-0.138^{ns}	1

Note:*, ** and ^{ns} Correlation is significant at the 0.01 level (2-tailed).

Conclusion:

Given the susceptibility of strawberries in storage and its short storage durability, phenolic compounds like SA can increase its storage durability and can be effective in maintaining their quantitative and qualitative traits. In the current study, the effect of SA treatment on strawberry traits were examined which showed that the treatment of strawberries with 2 mM SA was effective in increasing healthy fruits percentage. Although the increase in SA concentration up to 4 mM could play more effective role in maintaining their vitamin C content, higher healthy fruits percentage in 2 mM SA treatment was more important. On the other hand, strawberry cultivars are different from each other in terms of storage durability. Also, the results showed in terms of storage durability, Paros cultivar had higher healthy fruits percentage than two other cultivars because of its higher toughness at harvest time. It had higher vitamin C content, acidity and TSS too; i.e. Paros cultivar had better performance in maintaining its fruits content owing to its higher preservative enzymes content. Kamarosa cultivar was readily influenced by chilling during storage because of its more fragile tissue. Its phenylalanine ammonia lyase enzyme content decreased and it suffered from ion leakage which resulted in the loss of its vitamin C content and TA but its TSS remained in high level. Therefore, it was specified that Kamarosa cultivar had higher metabolic activity and consequently, rapidly lost its quality. Furthermore, the storage of strawberries is very expensive and given its short post-harvest lifetime, the application of phenolic compounds on some certain cultivars can make its storage economical. Results of the current study revealed that treatment with 2 mM SA and Paros cultivar had higher quantitative and qualitative traits than other cultivars in most cases and it had optimum TA, vitamin C content and TSS/TA ratio. But the interaction between cultivar and SA was not significant on healthy and rotten fruits percentage, fruit pH and TSS.

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