

POSTHARVEST QUALITY OF KIWIFRUIT (*Actinidia deliciosa* cv. Hayward) AFFECTED BY PRE-STORAGE APPLICATION OF SALICYLIC ACID

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Abstract: *Kiwifruit (Actinidia deliciosa cv. Hayward) is commonly cultivated in the north part of Iran. In this research, fruits at commercial maturity stage were immersed in 1mM salicylic acid (SA) solution for 3.5, 5, 7.5 and 10 min, stored at 0.5 °C up to 90 days. Physicochemical properties of fruits including weight losses, skin and flesh color, firmness, total soluble solids (TSS), titratable acidity (TA), pH and sensory properties were monitored during storage. The results showed that fruit weight loss significantly decreased in all dipping time in comparison to control. Dipped fruits in SA solution for 5, 7.5 and 10 minutes had higher firmness and lower TSS than 3.5 min dipping time and control. Furthermore, no significant changes were observed in TA and pH during storage in all treatments. A high levels of skin and flesh L* values were observed in fruits which maintained for one month than those stored for two and three months. Besides, a* and b* values of flesh and skin at each sampling date had not significant differences with control. Generally, flesh L* value decreased during storage at 90 days. Flesh a* value was more negative in the first month that referred to enhancement of flesh green color in all treatments. SA application was not influenced on b* value in comparison to control. The content of vitamin C was not changed in response to different dipping time of SA solutions. In the sensory test, fruits which dipped in SA solution for 5 and 7.5 min appeared an Overall Liking appearance as commented by assessors.*

Key words: kiwifruit, salicylic acid, quality, storage.

INTRODUCTION

Kiwifruit (*Actinidia deliciosa* cv. Hayward) is an important fruit produced in commercial scale in the north of Iran. Kiwifruit is a climacteric fruit with a long post-harvest life in cool storage. Losses in fruit quality are mostly due

to its relatively high metabolic activity during storage. Cool storage is widely used to reduce respiration rate and extend the shelf-life of kiwifruit. This slow down metabolism must be prior to transportation or storage. Hayward kiwifruit is usually stored under cool storage at 0°C and 90-95% RH conditions (Zhang et al. 2003, Fisk et al. 2008, Solaimani et al. 2009).

Moreover, postharvest life and quality of kiwifruit can also be extended by some other techniques in combination with cool storage (Fallik 2004). Among these, heat treatments have already been used to control postharvest decays and improving storage quality of kiwifruits (Femenia et al. 2009).

Salicylic acid (SA), calcium dips, edible coating and modified atmosphere packaging are other choices to reduce moisture losses, restriction of oxygen uptake, reduction in respiration, retardant ethylene production that will be result in retardant of discoloration and will also inhibit microbial growth (Fisk et al. 2008, Yao & Tian 2005, Montanaro et al. 2006).

Salicylic acid is known as a signal molecule in the induction defense mechanisms in plants (Horvath et al. 2007, Cao et al. 2006, Huang et al. 2008). It delays the ripening of banana fruit (Srivastara & Dwivedi 2000), inhibit ethylene production in cultured pear cells (Leslie & Romani 1988) and carrot cell suspension cultures (Roustan et al. 1990).

As Zhang et al. (2003) reported, application of SA on kiwifruit increased superoxide free radical and Lipoxygenase (LOX) activity. In that case, climacteric rise in ethylene production was retarded. So, fruit ripening and senescence were delayed (Zhang et al. 2003). Application of exogenous methyl salicylate (MeSA) vapor on kiwifruits led to prevent the softening process of fruit flesh, kept ascorbic acid content and firmness during 5 months storage (Solaimani et al. 2009).

Fruit visual quality has been correlated with various physical attributes like fruit skin color, flesh color, firmness, fruit shape and size. Maintaining the natural color in processed and stored fruits has been a major challenge to enhance fruits quality (Mohammadi et al. 2008).

Most studies on changes in green color due to time and temperature treatments only mention a decrease of green color. Several color scales have been used to describe color among which the most used in fruits are the Hunter color L^* , a^* , b^* CIE system (Giese 2000). Warrington et al. (1990) suggested $L^* = 34$, $a^* = -5$ and $b^* = 16$ as flesh fruit color index for standard ripened kiwifruits.

Water loss (shriveling) had been identified as the most significant cause of commercial loss in kiwifruit (Hassall et al. 1998). By 3-4 percent water loss, fruit may appear shriveled symptoms mainly in stem end of fruit (Fisk

2006). Some chemical parameters, like soluble solids content (TSS), titratable acidity (TA), Electrical conductivity (EC) and vitamin C, have also been used to determine fruit quality (Marsh et al. 2004, Jha et al. 2007). Fisk et al. (2006) reported that titratable acidity decreased and TSS increased when Hardy kiwifruit stored under refrigerated conditions. Also in this experiment, TA of fruits continuously decreased from about 1.26% to less than 1% at 42 days after storage, while pH continuously increased from 3.61 to 3.75 (Fisk et al. 2006).

Kiwifruit is small caloric and has high amounts of vitamin C which is higher than that determined in orange, strawberry, lemon and grapefruits. Tavarini et al. (2008) recorded that vitamin C concentration in fruits of cv. Hayward decreased at the end of the long cool storage (6 months).

Descriptive sensory testing supplies information about the quality attributes of a samples. Generally, panelists rate the amount of appearance, texture, aroma, flavor and basic descriptors using line or number scales (Fisk et al. 2006). Harder et al. (2009) evaluated changes in aspects analyzed (color, aroma, flavor, texture and overall acceptance) of kiwifruit nectar. They observed no significant differences between treatments (gamma radiation) relative to the control. Also, Amos (2007) studied the sensory properties of skins from novel kiwifruit (*Actinidia*). The kiwifruit skins ranged from the edible skins of grape-sized *Actinidia arguta* through to the brown hairy toughened skin of *A. delisiosa*, which is usually considered inedible (Amos, 2007).

The aims of this study was to determine the effect of salicylic acid application with different dipping times on the quality and storage life of Hayward kiwifruit by monitoring physicochemical parameters and evaluating the sensory properties.

MATERIALS AND METHODS

1. Fruit materials

Fruits were harvested at commercial maturity stage (TSS=7%) from an experiment orchard at the Citrus Research Institute of Iran (Ramsar). Fruits were subsequently transferred to laboratory and sorted based on size and the absence of physical injuries or infections.

2. Treatments

Fruits were randomly divided into five groups, each group containing 120 fruits in three replicates and immersed into solution of 1 mM SA and in distilled water as control for 3.5, 5, 7.5 and 10 min. Fruits were then dried for about 24 h and then stored at 0.5 °C and 85-90 % relative humidity for three months. After 1, 2 and 3 months storage, 30 fruits per treatment were taken from cool storage for fruit quality assessment.

3. Physicochemical analysis

Firmness was determined by measuring compression using a hand-held Effegi penetrometer with a 7.9 mm probe after removal of skin to a vertical depth of 1 mm on two sides of the fruit. The firmness considered as an average peak force of 10 fruits and expressed as $\text{kg}/7.9 \text{ mm}^2$. Moreover, 3 fruits per replicate were weighed at the beginning of storage and throughout storage period to calculate weight loss percentage. Titratable acidity was determined using 5 ml of fruit puree from five fruits mixed with 25 ml of distilled water, with two drops of phenolphthalein (1%) as indicator, titrated with 0.1N NaOH to an endpoint pink (pH 8.2). The results were expressed as percent anhydrous citric acid since it is the dominant acid in kiwifruit. Total soluble solids (TSS) were then measured using an ATC-1E ATAGO hand-held refractometer on the translucent part of the juice. The pH of the samples were measured by a pH meters (Inolab pH 720, WTW, Germany).

The skin and flesh color was evaluated with a Minolta chromometer CR-400, which provided measurements of Hunters L^* , a^* and b^* . L^* measures lightness and varies from 100 for perfect white to zero for black. a^* measures redness when its value is positive, gray when zero, and greenness when negative, and b^* measures yellowness when positive, gray when zero, and blueness when negative.

Ascorbic acid was determined using the Dye method (Ranganna 1977). The kiwifruit puree samples (30 g) were homogenized with 30 ml of 3% metaphosphoric acid (HPO_3). Five ml of aliquot was titrated with a standard dye solution (2, 6-dichlorophenol-indophenol) to a pink color that persisted for 15 seconds using an autotitrator calibrated using standard ascorbic acid. The ascorbic acid content (Vitamin C) was expressed as $\text{mg}^{-1} 100 \text{ g FW}$.

4. Sensory analysis

For the sensory evaluation of taste and appearance, 20 assessors without any training were randomly selected from volunteer personal working at Citrus Research Institute of Iran. For skin and flesh appearance, aroma, flavor, sweetness, sourness and overall liking characteristics, the assessors tested samples and rated using a 9 pointed hedonic scale (1= dislike extremely, 5= neither like nor dislike and 9= like extremely).

5. Statistical analysis

Physicochemical data were analyzed with MSTAT-C statistical software (Michigan State University, USA). Treatments were arranged in completely randomized design, and Tukey's test ($p < 0.5$) was used to reveal any differences.

RESULTS AND DISCUSSION

1. Fruit Weight Losses

Dipped fruits in SA solution at different times prevented weight loss in comparison with control (Table 1). The loss of weight in fresh fruit and vegetable is mainly due to the loss of water caused by transpiration, respiration and VPD between fresh produce and surrounding air. It's

thought that SA can decrease respiration through inhibition of ethylene biosynthesis or action (Srivastava & Dwivedi 2000). Salicylic acid also caused decrease in respiration rate and fruit weight losses by closing stoma (Zheng & Zhang 2004).

2. Fruit Skin and Flesh color

Changes in the skin color of kiwifruit were monitored by measuring L^* , a^* and b^* values. A high levels of L^* value (skin and flesh) were observed in fruits which maintained for one month than those stored for two and three months. There were not literatures about the effect of post-harvest application of SA on skin color changes. On the other hand, the use of SA solution did not change a^* and b^* values of fruit skin in comparison to control (Table 1). However, skin color values significantly decreased during the storage period ($p < 0.05$).

Fruit flesh color changed during kiwifruit storage. L^* value of flesh generally decreased during the 90 days of storage. The decrease in L^* value represented formation of dark color in the pulp due to oxidative browning reactions or increasing brown pigment concentrations. Flesh a^* value was more negative in the first sampling date that showed an enhancing greenness of flesh fruit than the second and third months of storage (Table 1). The SA application did not affect b^* value in comparison with control. Based on the work of Zhang et al. (2003), the improved retention of green color of fruit flesh is mainly due to the lower rate of chlorophyll destruction during the first month of storage. In this experiment, we observed an accelerated a^* and b^* values at all treatments mainly in the first month of storage that were in accordance with Zhang et al. (2003) report.

3. Fruit Firmness

Loss of texture is one of the main factors limiting quality and the post-harvest shelf life of Kiwifruit. In the present study, fruits dipped in SA solution for 5, 7.5 and 10 minutes were firmer than 3.5 min dipping time and control (Table 2). This result was in agreement with the report of Solaimani et al. (2010) that suggested postharvest application of kiwifruit by MeSA decreased softening and kept firmness during storage. Softening pattern of kiwifruit includes an early slow stage followed by a rapid decline in firmness (Chen et al. 1999). We observed similarly pattern for all treatments but it was slower in SA treatments than non treatment fruits. Zhang et al. (2003) reported that rate of fruit ripening related to internal SA concentration. Also, Wang et al. (2006) found that rapid softening of fruits during ripening were in coincident with rapid decrease in endogenous SA of fruits. As seen in

Table 1.
 Mean comparison of fruit weight loss, skin and flesh color in different dipping time
 of fruit in 1mM SA solution during 90 days storage at 0.5°C

time storage (day)	SA dipping time (min)	Weight loss (%)	Skin color index			Flesh color index		
			L*	a*	b*	L*	a*	b*
30	3.5	0.21 b	41.2 a	6.11 abc	22.86 b	53.62 a	-12.73 e	34.34 a
	5	0.21 b	42.82 a	7.01 a	25.9 a	52.61a	-12.42 ed	32.03 a
	7.5	0.22 b	43.28 a	6.53 ab	24.67 ab	54.52 a	-11.66 d	31.69 a
	10	0.2 b	41.08 a	6.72 a	24.3 ab	53.67 a	-12.2 ed	33.19 a
	control	0.36 a	42.21 a	6.16 abc	24.23 ab	50.8 ab	-12.3 ed	32.13 a
60	3.5	0.20 b	30.71 bc	5.46 c	13.06 c	44.36 bc	-7.46 a	17.94 d
	5	0.16 b	29.14 c	5.36 c	12.9 c	47.36 b	-7.59 ab	20.54 bcd
	7.5	0.14 b	29.34 c	5.22 c	12.48 c	49.36 b	-7.48 a	18.24 cd
	10	0.17 b	29.32 c	5.25 c	12.48 c	51.36 ab	-8.18 abc	19.2 bcd
	control	0.35 a	31 bc	5.51 c	13.09 c	41.1 c	-7.45 a	17.27 d
90	3.5	0.15 b	32.69 b	5.61c	13.95 c	45.54 bc	-8.85 c	20.66 bcd
	5	0.16 b	30.72 bc	5.63 bc	13.06 c	46.87 b	-8.81 c	21.15 b
	7.5	0.13 b	30.76 bc	5.27 bc	13.42 c	45.44 bc	-8.56 bc	21.06 bc
	10	0.15 b	32.98 b	5.51 c	13.767 c	45.49 bc	-8.56 abc	20.56 bcd
	control	0.21 b	31.5 b	5.36 c	13.72 c	42.35 c	-8.25 abc	19.33 d

Mean separation within a column by Tukey's test at P = 0.05

Table 2.

Mean comparison of fruit firmness, TSS (%), TA (%), pH and vitamin C in different fruit dipping time in 1mM SA solution during 90 days storage at 0.5°C

time storage (day)	SA dipping time (min)	Firmness (kg/7.9 mm ²)	TSS (%)	TA (%)	pH	VC (mg/100 g FW)
30	3.5	1.56 b	14.54 b	0.71 b	3.61 abc	24.89 de
	5	2.51 a	13.933c	0.96 ab	3.48 c	23.49 e
	7.5	2.41 a	12.63 c	0.79 ab	3.63 ab	25.44 de
	10	1.37 b	12.57 c	1.2 a	3.60 abc	27.43 de
	control	1.24 b	14.31b	0.64 b	3.59 abc	27.29 de
60	3.5	1.24 b	15.05 ab	0.69 bc	3.66 ab	36.51 b
	5	2.55 a	14.59 b	0.75 bc	3.71 a	36.4 b
	7.5	2.07 a	13.09 c	0.79 ab	3.61abc	36.4 cd
	10	2.24 a	13.87 bc	0.97a	3.59 abc	36.4 bc
	control	1.22 b	14.5 b	0.52 c	3.63 ab	40.58 ab
90	3.5	0.6 c	15.01 ab	0.62 c	3.63 ab	52.33 a
	5	1.58 b	15.11 a	0.62 c	3.56 bc	54.43 a
	7.5	1.61 b	14.75 b	0.7 bc	3.56 bc	33.21 bc
	10	1.46 b	14.75 b	0.73 bc	3.61abc	54.45 a
	control	0.59 c	15.07 ab	0.51 c	3.61 abc	52.44 a

Mean separation within a column by Tukey's test at $P = 0.05$

Table 2, there are a well correlation between the extent of dipping time and fruits firmness. Our results suggested that firmness caused by SA associated with ethylene production inhibitory. This suppression may mostly due to inhibitory effect of SA on ACC conversion to ethylene (Li et al. 1992).

4. Total soluble solids, Titratable acidity and pH

Total soluble solids content of fruits during storage is considered an index of fruit ripening and an increase in TSS corresponds to a conversion of starch to soluble sugars (Fisk et al. 2006).

Fruits dipped in SA solution for 5, 7.5 and 10 min had lower TSS than those dipped for 3.5 min and control during the first and second month of storage (Table 2). This result was disagreement with Babalar (2007) who reported that use of salicylic acid (2 mM) increased total soluble solids of strawberry fruits. Delay in fruit ripening and extended shelf-life after SA treatment also reported in banana fruit by Srivastava & Dwived (2000). Similarly, Zhang et al. (2003) found that the rate of softening in kiwifruit treated by SA reduced because had remained relatively high levels of SA concentrations.

The acid concentrations varied between treatments. No significant changes were observed in TA during storage among treatments, exception in fruits dipped for 10 minute which was relatively high. For that reason, TA slightly increased after 30 (1.2 %) and 60 (0.97 %) days of storage (Table 2). Similar results have also been reported by Babalar (2007) on SA dipping Selva strawberry fruits.

Moreover, no significant changes were observed in TA of pomegranate fruit which had treated by SA at different concentrations (0.7, 1.4 or 2 mM) during storage (Sayyari et al. 2009). In our study, fruit pH retained relatively stable during 3 months storage. There were no significant differences between SA treatment and control fruits (Table 2).

5. Vitamin C

It is well known that kiwifruit, as well as citrus fruits are excellent sources of vitamin C. As shown in Table 2, the vitamin C content only showed significant differences between interval month sampling during 3 months of cool storage.

In all treatments, the vitamin C significantly increased during storage (Table 2). Our results were in agreement with Shafiee et al. (2010) who reported that strawberry fruit vitamin C content did not show changes in response to SA solution. The accumulation of vitamin C during ripening depends on type of fruit. There are some reports that mentioned vitamin C

content decreased in apple and mango but increased in apricot, peach, pepper and papaya with ripening, and in strawberry during storage (Tavarini et al. 2008, Elwan & El-Hamahmy 2009, Babalar 2007). The results were not in agreement with previous reports (Antunes et al. 2007), which suggested that vitamin C content decreased during ripening and storage of kiwifruit.

6. Sensory analysis

The assessors tested and rated samples using a 9 pointed hedonic scale for selection terms. Table 3 shows the results of the sensory consumer test on fruits.

Table 3.
Sensory properties of fruit dipped in 1mM SA solution for different time after 90 days storage at 0.5°C.

Sensory parameters Dipping time (min.)	Skin appearance	Flesh appearance	Aroma	
3.5	4.33 b	4.33 b	4 b	
5	7.67 a	8 a	8 a	
7.5	9 a	6.33 ab	6.67 a	
10	5.67 b	4.67 b	4 b	
Control	3.33 c	3.67 bc	2 c	

Sensory parameters Dipping time (min.)	Flavor	Sweetness	Sourness	Overall liking
3.5	3.67 c	3.67 b	3.67 b	2.67 c
5	8.67 a	8.67 a	5.5 ab	8 a
7.5	6.67 ab	5 b	7 a	7 a
10	4 bc	3.33 b	3.67 b	5 b
Control	4.67 b	4.33 b	2.67 c	4.33 bc

Mean separation within a column by Tukey's test at $P = 0.05$

The assessors tested samples and rated using a 9 pointed hedonic scale (1= dislike extremely, 5= neither like nor dislike, and 9= like extremely).

Regarding the results of panel monitoring, the parameters were well liked by consumers achieved from fruits which dipped in SA solution for 5

and 7.5 min. Means ratings for skin and flesh appearance were 9 (like extremely) and 8 (like very much) for 7.5 and 5 min dipping time, respectively.

The aroma, flavor and sweetness means ranged from 8 to 8.2 (8 = like very much) for 5 min dipping time in comparison with control which ranged from 2 to 4.6 (dislike). In addition, fruits which dipped in SA solution for 5 and 7.5 min appeared to have overall liking appearance as commented by assessors in the sensory test (Table 3).

The use of qualified panels applying specific evaluation methods for sensory quality increases the reliability of the results (Etaio et al. 2010). Hayward kiwifruit is a relatively important fruit cultivated in the north parts of Iran. The information generated from this sensory analysis would be very important for growers who currently export most of their fruits.

CONCLUSION

In general, this experiment showed the effectiveness of SA dipping treatments (5-10 min) on Hayward kiwifruit quality. Application of SA improved characteristics like TSS, TA, skin and flesh appearance, aroma, flavor and sweetness.

The post-harvest SA treatment prevented fruit softening and decreased weight losses. This treatment can be easily used to improve kiwifruit quality.

Further studies are required, especially to validate some antioxidant enzyme activity, antioxidant capacity and flavonoid concentrations.

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