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Effect of Calcium Chloride and Salicylic Acid Treatments on Quality Characteristics of Kiwifruit (*Actinidia deliciosa* cv. Hayward) During Storage

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ABSTRACT

Kiwifruit texture can deteriorate during cold storage, resulting in softness and mealiness. The purpose of this work was to estimate shelf-life and to study the behavior of 'Actinidia deliciosa cv. Hayward' kiwifruit kept at 1°C in a normal atmosphere. The effects of postharvest calcium chloride and salicylic acid applications on shelf-life and quality attributes of kiwifruits (Actinidia deliciosa cv. Hayward) after harvest or cold storage up to 60 days were determined. The experiment was started in season 2010-2011 and fruit weight losses, fruit firmness, total soluble solids (TSS), titratable acidity (TA), Peroxidase activity (POD) and ascorbic acid content (Vitamin C) were measured at 15, 30 and 60th days of postharvest life. The fruits were immersed in deionised water or at three calcium concentrations (0, 2 and 4% (W/V) and three salicylic acid concentrations (0, 2 and 4 mM). Results showed that fruit weight loss significantly decreased in combined treatment (calcium+salicylic acid) in comparison to control. Also, results showed that combined treatment (calcium+salicylic acid) increase fruit firmness and Peroxidase activity, while decreasing weight losses percentages and fruit decay percentage during cold storage at 1°C for 60 days ($p \leq 0.05$). Results showed that postharvest calcium chloride dips did not effect TA % in kiwifruit in during storage, while the fruits treated in SA solution for 5 min had higher TA and lower TSS than fruits that treated in control and Ca ($p \leq 0.05$). Furthermore, significant changes were observed in browning index and relative electrical conductivity during storage in all treatments ($p \leq 0.05$). The results showed that combined treatment (calcium+salicylic acid) application was influenced on Vitamin C value in comparison to control. In general, this experiment showed that post-harvest Salicylic acid (SA) and Ca treatments prevented fruit softening and decreased weight losses. This treatment can be easily used to improve of apple fruits during.

Key words: Postharvest life, salicylic acid, weight loss, firmness, calcium chloride

INTRODUCTION

Kiwifruit (*Actinidia deliciosa* cv. Hayward) is an important fruit produced in commercial scale in the north of Iran (Fattahi *et al.*, 2010). Kiwifruit can be air-stored for 4 to 6 months at 0°C, although extensive softening will occur (Antunes and Sfakiotakis, 2002). 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 (Fattahi *et al*., 2010). After harvest rapid ripening in fruits is responsible for short shelf life and represents a serious constraint for efficient handling and transportation. Though postharvest quality of a produce after harvest cannot be improved, it is possible to reduce the rate of quality loss. Surface treatments delay physiological decay in fruit tissues, stabilize the fruit surface and prevent degradation that affect the quality of the product (Akhtar *et al*., 2010). They also rinse the enzymes and substrates released from injured cells during cutting operations from the product surface. Calcium (Ca^{2+}) has been extensively reviewed as both an essential element and its potential role in maintaining postharvest quality of fruit and vegetable crops. The role of calcium in stabilizing cellular membranes and delaying senescence in horticultural crops is well known (Poovaiah *et al*., 1988). Pre- and postharvest application of calcium may delay senescence in fruits with no detrimental effect on consumer acceptance (Lester and Grusak, 2004). Exogenously applied calcium stabilizes the plant cell wall and protects it from cell wall degrading enzymes (White and Broadley, 2003). Postharvest calcium dips can increase calcium content considerably compared to preharvest sprays, without causing fruit injury, depending on salt type and calcium concentration. Postharvest calcium application maintains cell turgor, membrane integrity, tissue firmness and delays membrane lipid catabolism, extending storage life of fresh fruits (Garcia *et al*., 1996; Picchioni *et al*., 1998). Salicylic acid is known as a signal molecule in the induction defense mechanisms in plants. SA is a well known phenol that can prevent ACO activity that is the direct precursor of ethylene and decrease Reactive Oxygen Species (ROS) with increase enzyme antioxidant activity (Khan *et al*., 2003; El-Tayeb *et al*., 2006; Ansari and Misra, 2007; Mba *et al*., 2007; Mahdavian *et al*., 2007; Canakci, 2008). The objectives of this study were to determine the effect of postharvest fruit immersion in different calcium and SA concentrations on the quality and storage life of kiwifruit during storage.

MATERIALS AND METHODS

The experiment was started in season 2010-2011 and Fruit Weight Losses, Fruit Firmness, Total soluble solids, Titratable acidity, Peroxidase activity (POD) and ascorbic acid content (Vitamin C) were measured at 15, 30 and 60th days of postharvest life. Kiwifruit (*Actinidia deliciosa* cv. Hayward) were harvested at commercial maturity stage from an experiment orchard at the kiwifruit Research Institute of Iran (Babol, Iran). Fruits were subsequently transferred to laboratory and sorted based on size and the absence of physical injuries or infections. Fruits were randomly divided into six groups, each group containing 100 fruits in four replicates and immersed into solution of (0, 2, 4 mM) SA, 0, 2, 4% (w/v) calcium chloride and distilled water as control for 5 min. Fruits were then dried for about 24 h and then stored at 1°C and 85-90% relative humidity for two months. After 15, 30 and 60th days storage, 30 fruits per treatment were taken from cool storage for fruit quality assessment.

Weight loss: Weight loss was determined by using Tefera *et al*. (2007) method, by periodical weighing of kiwifruit 15, 30 and 60 days after storage.

Fruit firmness: 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 $kg/7.9\ mm^2$.

Total soluble solid: Total Soluble Solids (TSS) were measured by the method described by Dong *et al.* (2001).

Titratable acidity: 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 0.1 N 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. Ascorbic acid content (Vitamin C).

Ascorbic acid (AA) content of kiwifruit was determined by the 2,6-dichlorophenolindophenol method (Tefera *et al.*, 2007).

Browning index: Browning index was assessed by measuring the extent of browning area as described by Wang *et al.* (2005).

Relative electrical conductivity: Relative electrical conductivity was measured by the method described by Fan and Sokorai (2005).

Peroxidase activity (POD): Peroxidase activity (POD) was measured by the method described by Chance and Maehly (1955).

Experimental design and statistical analysis: Experiment was arranged in complete randomized design with four replications. Analysis of variance was performed on the data collected using the General Linear Model (GLM) procedure of the SPSS software) Version 16, IBM Inc.). The mean separation was conducted by tukey analysis in the same software (p = 0.05).

RESULTS AND DISCUSSION

Weight loss: Effect of SA , Ca or SA+Ca on weight losses of stored fruits are listed in Table 1. Results showed that Dipped fruits in SA, Ca or SA+Ca solution at different concentration prevented weight loss in comparison with control ($p \leq 0.05$). Maximum weight loss occurred in control, while lowest loss was recorded in 4 mM SA+ 4% (w/v) Ca (Table 1). Calcium applications have known to be effective in terms of membrane functionality and integrity maintenance which may be the reason for the lower weight loss found in Calcium treated fruits (Lester and Grusak, 1999). Mahajan and Dhatt (2004) reported that pear fruit treated with $CaCl_2$ proved to be most effective in reducing weight loss compared to non treated fruit during a 75 days storage period. It's thought that SA can decrease respiration through inhibition of ethylene biosynthesis or action (Srivastava and Dwivedi, 2000). Salicylic acid also caused decrease in respiration rate and fruit weight losses by closing stoma (Zheng and Zhang, 2004). The above mentioned results are agreed with those recorded by Fattahi *et al.* (2010), they found that Dipped fruits in SA solution at different concentration reduce kiwifruit weight losses percentages.

Firmness: It is clear from the obtained data in Table 1 that dipping kiwifruit in 4 mM SA with 4% (w/v) Ca were effective in Firmness for 60 day more than the other treatments in during storage. The results indicate that maximum firmness was recorded in 4 mM SA with 4% (w/v) Ca as compared to control, while minimum firmness was recorded in control during 60 day ($p \leq 0.05$). The retention of firmness in calcium treated fruits might be due its accumulation in the cell walls leading to facilitation in the cross linking of the pectic polymers which increases wall strength and

Table 1: Mean comparison of fruit weight loss, Firmness, TA, Ascorbic acid, Browning index, REC and POD in different concentration SA and Ca solution during 60 days storage at 1°C

Time storage (day)	Treatment Ca% (w/v	SA (mM)	Weight loss (%)	Firmness (kgf)	TSS (brix %)	TA (%)	Ascorbic acid mg/ 100 g FW	Browning index (%)	REC (%)	POD activity (Units/g. fresh weight)
15	0	0	0.51^{a}	1.00^{b}	14.15^{a}	0.51^{b}	21.00^{c}	31.14^{a}	28.14^{a}	51.12^{c}
		2	0.22^{b}	0.90^{b}	13.00^{b}	0.43^{b}	23.14^{b}	22.30^{b}	22.70^{b}	55.16^{b}
		4	0.21^{b}	2.00^{a}	10.21^{c}	1.11a	25.00^{a}	16.14^{c}	20.00^{c}	60.00^{a}
	2	0	0.21^{a}	1.17^{a}	15.00^{a}	0.61^{a}	22.13^{a}	15.15^{a}	22.11^{a}	65.14^{b}
		2	0.20^{a}	1.64^{a}	14.21^{a}	0.57^{a}	22.60^{a}	14.00^{b}	20.00^{b}	66.11^{b}
		4	0.20^{a}	1.70^{a}	14.12^{a}	0.63^{a}	22.80^{a}	13.80^{c}	19.70^{c}	67.15^{a}
	4	0	0.17^{a}	1.90^{b}	13.14^{a}	0.54^{a}	22.17^{c}	14.00^{a}	17.17^{a}	70.12^{b}
		2	0.17^{a}	2.00^{b}	12.67^{a}	0.49^{a}	23.17^{b}	12.80^{b}	16.00^{b}	70.68^{b}
		4	0.11^{b}	2.41^{a}	12.50^{a}	0.56^{a}	24.00^{a}	11.00^{c}	15.10^{c}	75.16^{a}
30	0	0	0.50^{a}	0.97^{b}	13.14^{a}	0.41^{c}	20.00^{b}	33.14^{a}	31.15^{a}	70.16^{c}
		2	0.43^{b}	0.90^{b}	14.18^{b}	0.61^{b}	26.14^{a}	20.11^{b}	24.70^{b}	72.14^{b}
		4	0.40^{b}	1.16^{a}	15.80^{c}	1.00^{a}	26.15^{a}	16.17^{c}	22.00^{c}	75.60^{a}
	2	0	0.33^{a}	1.81^{a}	12.14^{a}	0.41^{a}	28.12^{a}	18.60^{a}	23.80^{a}	77.16^{a}
		2	0.30^{a}	1.95^{a}	12.61^{a}	0.47^{a}	27.89^{a}	16.80^{b}	20.17^{b}	77.90^{a}
		4	0.30^{a}	2.00^{a}	12.80^{a}	0.50^{a}	28.71^{a}	16.00^{b}	17.30^{c}	77.84^{a}
	4	0	0.24^{a}	1.90^{b}	13.74^{a}	0.61^{a}	30.14^{b}	16.14^{a}	17.16^{a}	80.11^{b}
		2	0.22^{a}	1.92^{b}	14.00^{a}	0.70^{a}	30.89^{b}	15.00^{b}	16.00^{b}	80.00^{b}
		4	0.20^{a}	2.17^{a}	13.69^{a}	0.69^{a}	26.14^{a}	11.17^{c}	16.10^{c}	85.61^{a}
60	0	0	0.67^{a}	0.31^{b}	15.14^{a}	0.51^{c}	32.17^{b}	38.17^{a}	36.70^{a}	80.30^{b}
		2	0.58^{b}	0.41^{b}	12.11^{b}	0.69^{b}	33.70^{b}	19.14^{b}	18.18^{b}	81.00^{b}
		4	0.53^{b}	1.00^{a}	10.00^{c}	1.12^{a}	36.17^{a}	10.91^{c}	13.17^{c}	87.60^{a}
	2	0	0.43^{a}	1.00^{a}	13.16^{a}	0.67^{a}	38.11^{a}	27.14^{a}	27.14^{a}	90.00^{b}
		2	0.41^{a}	1.30^{a}	12.89^{a}	0.80^{a}	38.59^{a}	26.14^{b}	25.17^{b}	91.11^{b}
		4	0.41^{a}	1.45^{a}	113.00^{a}	0.87^{a}	38.70^{a}	22.30^{c}	25.00^{b}	93.17^{a}
	4	0	0.21^{a}	1.30^{b}	15.00^{a}	0.91^{a}	40.12^{b}	20.16^{a}	18.14^{a}	100.00^{b}
		2	0.21^{a}	1.45^{b}	14.87^{a}	0.87^{a}	40.60^{b}	18.70^{b}	16.14^{b}	101.14^{b}
		4	0.15^{b}	1.67^{a}	14.13^{a}	0.90^{a}	54.15^{a}	9.17^{c}	10.34^{c}	118.36^{a}
F-test probabilities										
	SA		0.001	0.001	0.004	0.01	0.003	0.001	0.020	0.001
	Ca		0.010	0.030	0.600	0.59	0.010	0.040	0.003	0.020

Means in each column followed by similar letters are not significantly different at 5% level

cell cohesion (White and Broadley, 2003). This result was in agreement with the report of Aghdam *et al*. (2009) that suggested postharvest application of kiwifruit by MeSA decreased softening and kept firmness during storage. Zhang *et al*. (2003) reported that rate of fruit ripening related to internal SA concentration.

These results are in agreement with those obtained by Fattahi *et al*. (2010). They reported that Dipped fruits in SA solution at different concentration increased kiwifruit Firmness percentages.

Total soluble solids and titratable acidity: Table 1 show that the storage period has a significant effect on TSS% and TA of fruits ($p \le 0.05$). The results indicate that minimum TSS was observed in 4 mM salicylic acid, the highest TSS was recorded in control during 60 day ($p \le 0.05$). 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. Also, The results indicate that maximum TA was observed in 4 mM salicylic acid and lowest TA was recorded in control.

Titratable acidity is directly related to the concentration of organic acids present in the fruit which are an important parameter in maintaining the quality of fruits. results showed that postharvest calcium chloride dips did not effect TA % in kiwifruit in during storage, while the results showed that fruits treated in SA solution for 5 min had higher TA and lower TSS than fruits that treated in control and Ca. Manganaris *et al.* (2005) has also reported that postharvest calcium chloride dips did not effect TA % in peaches during storage. Delay in fruit ripening and extended shelf-life after SA treatment also reported in banana fruit by Srivastava and Dwivedi, 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.

Ascorbic acid (Vit C) content and POD activity: The results indicate that maximum ascorbic acid (Vit C) content was recorded in 4 mM SA+ 4% (w/v) Ca as compared to control and other treatment. Minimum ascorbic acid (Vit C) was recorded in control during 60 day (Table 1). Also, the results indicate that the values of Vitamin C significantly increased with increasing POD activity in the storage duration. All treatments had significant effect on the values of vitamin C except control ($p \le 0.05$). Previous studies (Lamikanra and Watson, 2001) indicated the ascorbate dependency of peroxidase (POD) enzymes in a number of commonly fresh-cut processed fruits whose activities appear to be related to the level of oxidative stress in cut fruit. Ascorbic acid is an important nutrient quality parameter and is very sensitive to degradation due to its oxidation compared to other nutrients during food processing and storage (Veltman *et al.*, 2000). These results showed that SA and Ca treatments had a significant effect on retaining ascorbic acid content in kiwifruit. As Zhang *et al.* (2003) reported, application of SA on kiwifruit increased superoxide free radical and enzyme antioxidant activity. In that case, climacteric rise in ethylene production was retarded. So, fruit ripening and senescence were delayed (Zhang *et al.*, 2003). Present result showed that of SA and Ca delayed the rapid oxidation of ascorbic acid with increasing POD activity in the storage duration.

Browning Index (BI) and Relative Electrical Conductivity (REC): Table 1 show that the storage period has a significant effect on BI and REC of fruits ($p \le 0.05$). The results indicate that maximum BI and REC was observed in control, while, the lowest BI and REC was recorded in 4 mM salicylic acid+ 4% (w/v) Ca. Oxidative membrane injury allows the mixing of the normally separated enzyme (PPO) and oxidizable substrates (polyphenols) which lead to browning (Hodges, 2003). High calcium concentrations result in decreased flesh browning symptoms which are directly associated with calcium content in fruits (Hewajulige *et al.*, 2003). Decreased electrolyte leakage by calcium application increases the cell wall integrity and stability (Mortazavi *et al.*, 2007). 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, REC, BI and senescence were delayed (Zhang *et al.*, 2003).

CONCLUSION

In general, this experiment showed the effectiveness of Salicylic acid and calcium chloride on keeping quality and shelf-life of kiwifruit. Application of SA and calcium chloride improved characteristics like Fruit Firmness, Peroxidase activity and ascorbic acid content (Vitamin C). The post-harvest SA and calcium chloride treatment prevented weight losses percentages and fruit decay percentage during cold storage at 1°C for 60 days. Further studies are required, especially to validate some antioxidant enzyme activity, antioxidant capacity and proline concentrations.

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