

## THE EFFECTS OF POSTHARVEST TREATMENTS OF SALICYLIC ACID AND POTASSIUM PERMANGANATE ON THE STORAGE OF KIWIFRUIT

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### Abstract

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Kiwifruit (*Actinidia deliciosa* cv. Hayward) was used to investigate the effects of salicylic acid (0.5 mM, 1 mM) and potassium permanganate treatments on fruit quality and storage life during storage for two years. After treatments, kiwifruits were stored in MAP at 0°C with 85-95% RH for 200 days. At certain intervals, samples were collected from each treatment for physical and chemical analysis (e.g. flesh firmness, total soluble solids, titratable acid, total chlorophyll content, ascorbic acid content, reducing sugar content and degustation test). Salicylic acid treatment has been found to delay the ripening of kiwifruits. In salicylic acid and salicylic acid with potassium permanganate treated fruits, fruit softening, titratable acids, total chlorophyll concentration, ascorbic acid content decreased and total soluble solid, reducing sugar content and degustation test score increased slowly than control fruits during storage. Control fruits decreased faster than other treatments. At end of the 200 days in both years, in these treatments were also found moderate (marketable) in taste assessment.

*Key words:* Kiwifruit, salicylic acid, potassium permanganate, fruit quality

### Introduction

Kiwifruit, a climacteric fruit, is commonly stored for long periods at low temperatures. During cold storage, the main factor limiting storage is fruit softening and water loss (Beever and Hopkirk, 1990; Pekmezci et al., 2004). An extreme case is kiwifruit in which even a very low ethylene concentration induces flesh softening, limiting long-term cold storage (Crisosto et al., 2000). Fruit softening and ripening can be enhanced with different applications or may be blocked.

Removal of ethylene from storage rooms is very important for climacteric fruits. Modified atmosphere packaging plus use of ethylene absorbent is a useful

technique for maintaining postharvest quality. In common commercial use to remove ethylene from the atmosphere is to absorb and oxidize it with potassium permanganate (KMnO<sub>4</sub>). Several studies have shown that KMnO<sub>4</sub> applications delay fruit softening and increase postharvest life (Illeperuma and Jayasuriya, 2002; Castro et al., 2005; Correa et al., 2005).

Salicylic acid (SA) is a plant hormone inhibiting ethylene biosynthesis and delaying the senescence (Ozeker, 2005). SA has been shown to inhibit the conversion of ACC into ethylene (Leslie and Romani, 1988) by suppressing ACC oxidase activity (Fan et al., 1996). SA is also involved in local and systemic resistance to pathogens (Yalpani et al., 1994; Kang

et al., 2003). Exogenous supplied SA has been reported to delay the ripening of apple (Yan et al., 1998), peach (Han et al., 2003), persimmon (Li and Han, 2000), banana (Srivastava and Dwivedi, 2000). Both SA and its derivative acetylsalicylic acid (ASA) have been shown to inhibit ethylene production in cultured pear cells (Leslie and Romani, 1988) and carrot cell suspension cultures (Roustan et al., 1990). Zainuri et al. (2001) attributed the effects of SA to inhibition of mango skin ripening.

This work was conducted to examine the effect of SA and  $\text{KMnO}_4$  treatments on cold storage period and physico-chemical changes in kiwifruits.

## **Material and Methods**

### *Plant material*

Hayward kiwifruit the first year (07.11.2006) on average 6.5% total soluble solids and fruit firmness average 7.5 kg, the second year (01.11.2007) on average 6.2% total soluble solids and fruit firmness was reached average 7.8 kg were harvested in Tekirdag, Turkey. Kiwifruits uniform in shape and size and free of fungal infection were selected.

### *Treatments and storage*

Kiwifruits were subjected to the following treatments:

Group 1. Control

Group 2. Potassium permanganate sachet ( $\text{KMnO}_4$ )

Group 3. 0.5 mM salicylic acid

Group 4. 1 mM salicylic acid

Group 5. 0.5 mM salicylic acid +  $\text{KMnO}_4$  sachet

Group 6. 1 mM salicylic acid +  $\text{KMnO}_4$  sachet

### *Application of salicylic acid*

SA was applied by immersing fruit for 5 min in a solution of 0.5 mM and 1 mM SA. After immersion, the fruit were dried.

### *Application of potassium permanganate*

This application and the natural clay were obtained from a mixture of potassium permanganate granules

used BI-ON is a trademark. High gas permeability bags (sachets) embedded and packaged with 9 grams of  $\text{KMnO}_4$  (average 9 g/kg) of granules were placed into one of the packages.

After treatments, 8 kiwifruits were put in polyethylene container and packed with polyethylene bags (LDPE-low density polyethylene, 13  $\mu$  thicknesses) and stored at 0°C and 85-95% relative humidity for 200 days.

### *Quality evaluation*

Physical and chemical quality factors were measured periodically after treatment and every 40 day. Kiwifruit firmness was determined by penetrometer with a tip radius of 8 mm and expressed as kg unit. Percentage of total soluble solid (TSS) content was determined with hand refractometer. Titratable acids (TA) was determined by titration with 0.1 N NaOH and expressed as mg/100 ml citric acid. Total chlorophyll content was analyzed according to Arnon (1949). Ascorbic acid measurement was made following the indophenol dye titration method (Cemeroglu, 2007). Reducing sugar content was determined according to Rose (1959). Degustation test was evaluated by 5 panelist using a 5 point scale (1: very bad, 2: bad, 3: moderate, marketable, 4: good, 5: very good).

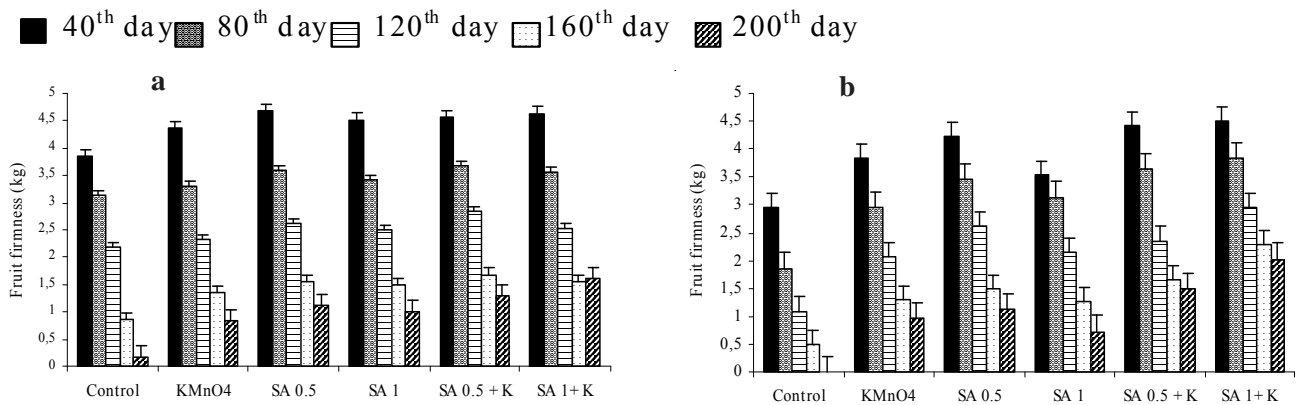
### *Statistical analysis*

The data for the experiment was analyzed as completely randomized blocks design with three replicates and each replicate consisted of 3 packages. An analysis of variance was used to analyze difference between means and the LSD test was applied for mean separation at  $P \leq 0.05$ . All analyses were done by means of MSTAT-C statistical software.

## **Results**

### *Fruit firmness*

The fruit firmness of the kiwifruits continuously decreased during storage. Fruits of all treatments had a great decrease in firmness especially in 40<sup>th</sup> day and slower thereafter (Figure 1). Control fruits firmness decreased faster than other treatments and softened



**Fig. 1.** Fruit firmness of kiwifruit treated  $KMnO_4$  and SA during storage in the first year (a)(initial: 7.6 kg) and second year (b)(initial :7.45 kg) of the experiment. Vertical bars represent  $\pm$  SE

excessively at the end of storage period. In first and second year of the experiment  $KMnO_4$  treated kiwifruit maintained firmness than non- $KMnO_4$  treated. At the end of 200<sup>th</sup> day, SA 1+K and SA 0.5+K treatments were firmer in both years.

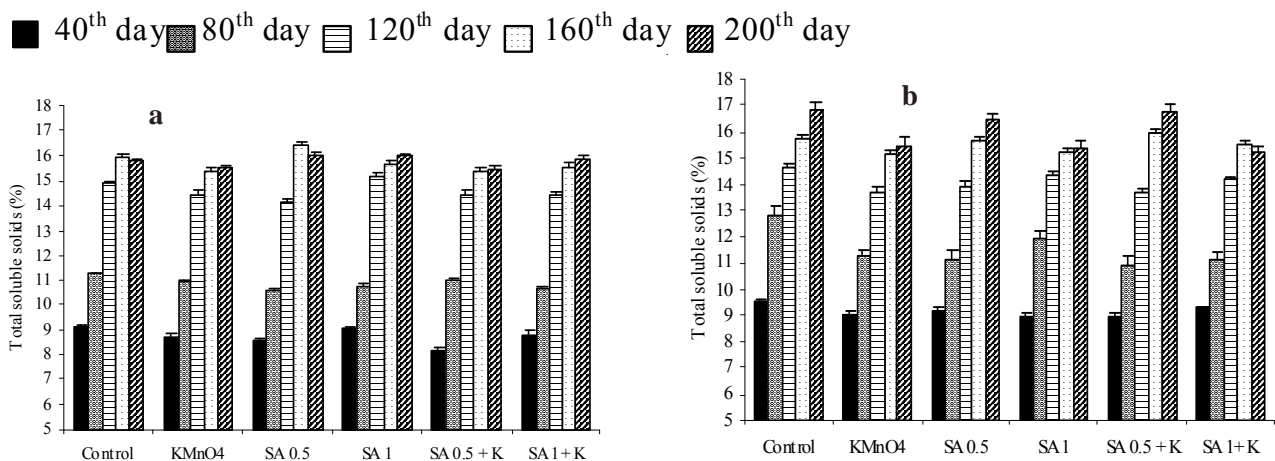
**Total soluble solids**

In all treatments, total soluble solids increased during storage. The increase of soluble solids was more pronounced until 160<sup>th</sup> day and after that period it was almost stable in both years (Figure 2). First year, at the end of 200<sup>th</sup> day, while the highest TSS content of kiwifruits was detected in SA 0.5 treatments, the lowest TSS content was determined in  $KMnO_4$  and

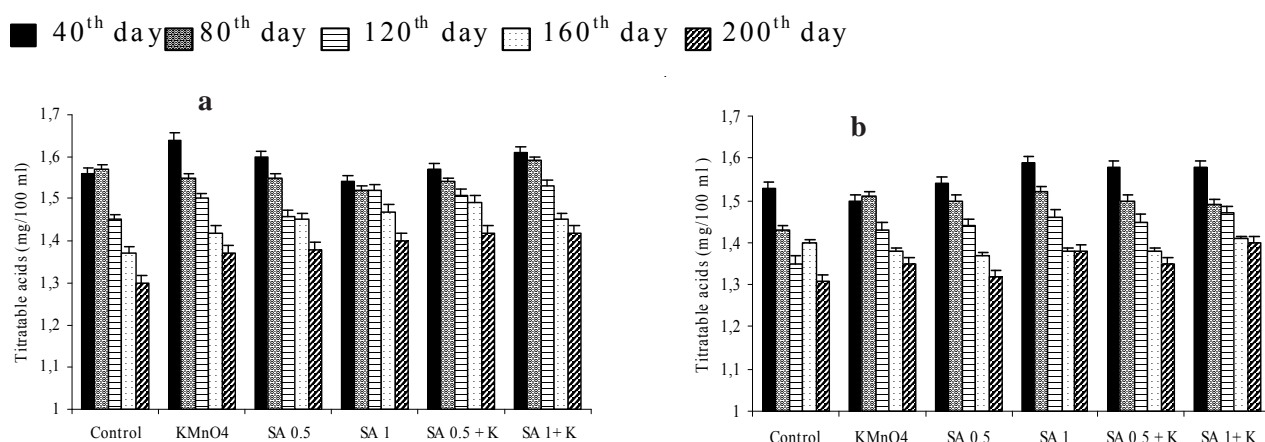
in SA 0.5+ K treatments. At the end of 200<sup>th</sup> day of second year, TSS content of kiwifruits in control showed highest values and the lowest TSS content was detected for SA 1+K treatment.

**Titrateable acids**

Titrateable acidity of kiwifruit at harvest was determined 1.63 mg/100 ml for the first year and 1.56 mg/100 ml for the second year. Then TA in kiwifruits decreased with storage duration as presented in Figure 3. After 200<sup>th</sup> day of storage, TA content was lower in controls than other treated fruits in both years. First year, the highest values of TA detected in fruit treated with SA 1+K and SA 0.5+K in 200<sup>th</sup> day, the second



**Fig. 2.** Total soluble solids of kiwifruit treated  $KMnO_4$  and SA during storage in the first year (a) (initial: %6.52) and second year (b) (initial: %6.71) of the experiment. Vertical bars represent  $\pm$  SE



**Fig. 3.** Titratable acids content of kiwifruit treated  $\text{KMnO}_4$  and SA during storage in the first year (a) (initial: 1.63 mg/100 ml) and second year (b) (initial: 1.56 mg/100 ml) of the experiment. Vertical bars represent  $\pm$  SE

year the highest values of TA determined in fruit treated with SA 1+K.

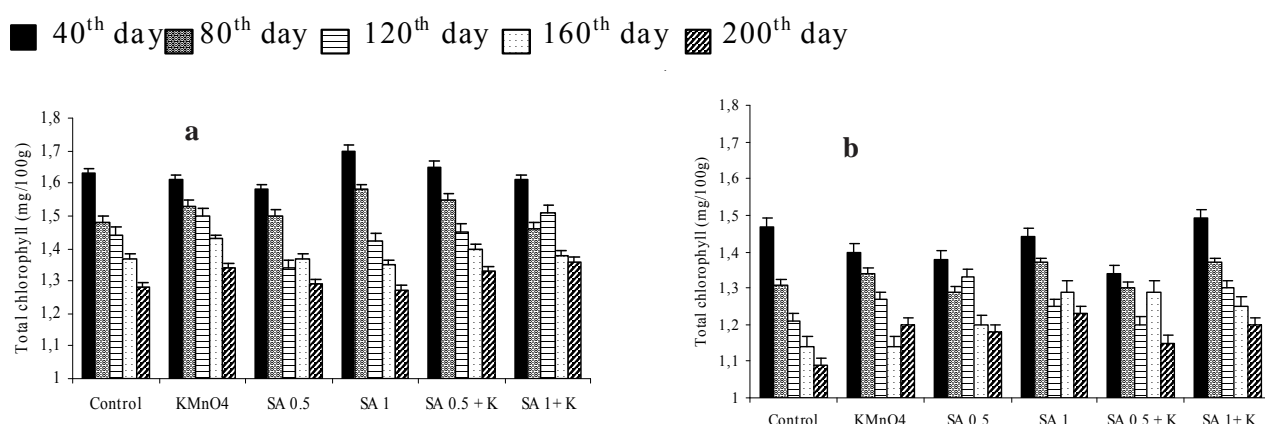
**Total Chlorophyll**

The total chlorophyll concentrations varied between treatments in both years and according to the harvest values generally decreased with storage duration (Figure 4). However, in both years irregular changes were detected between applications. First year, after 200<sup>th</sup> day storage period the highest values of total chlorophyll detected in fruit treated with SA 1+K and lowest value detected in SA 1 treatment followed by con-

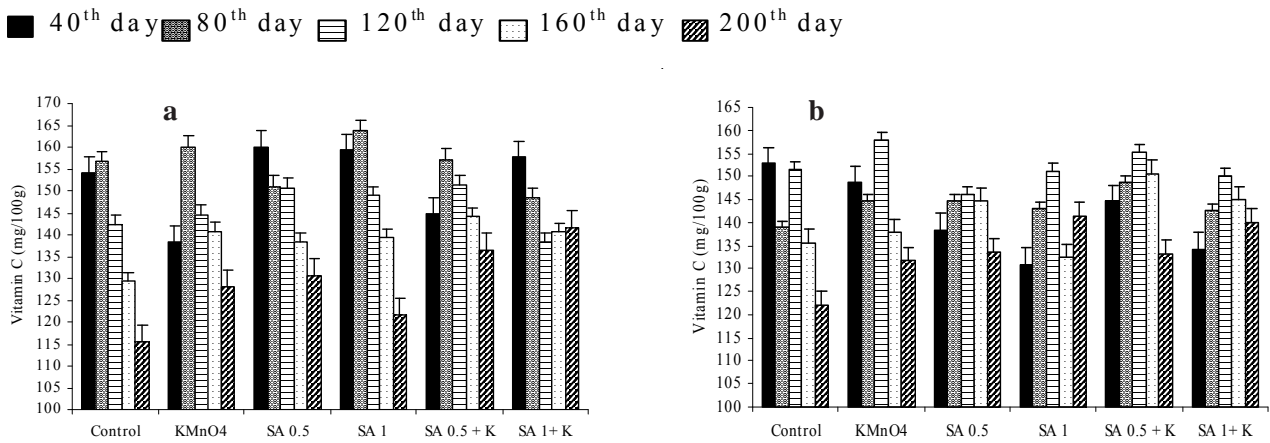
trol. Second year, after 200<sup>th</sup> day storage period the highest values of total chlorophyll determined in SA 1 treatment and lowest value determined in control fruits.

**Ascorbic Acid**

The ascorbic acid content in kiwifruit increased initially with the advancement of storage period and declined thereafter as presented in Figure 5. During the storage period in first year, the highest ascorbic acid content of kiwifruits was detected in SA 1 in 80<sup>th</sup> day and control treatment had the lowest ascorbic acid content in 200<sup>th</sup> day. In the second year of study,



**Fig. 4.** Total chlorophyll content of kiwifruit treated  $\text{KMnO}_4$  and SA during storage in the first year (a) (initial: 1.81 mg/100g) and second year (b) (initial: 1.60 mg/100g) of the experiment. Vertical bars represent  $\pm$  SE



**Fig. 5. Vitamin C content of kiwifruit treated KMnO<sub>4</sub> and SA during storage in the first year (a) (initial: 143.8 mg/100g) and second year (b) (initial:132.5 mg/100g) of the experiment. Vertical bars represent ± SE**

the highest values of ascorbic acid determined in fruit treated with KMnO<sub>4</sub> in 80<sup>th</sup> and ascorbic acid content of kiwifruits in control showed lowest values in 200<sup>th</sup> day. At the end of the storage period, SA1+K treatment for first year and SA1 treatment for second year had the highest ascorbic acid content.

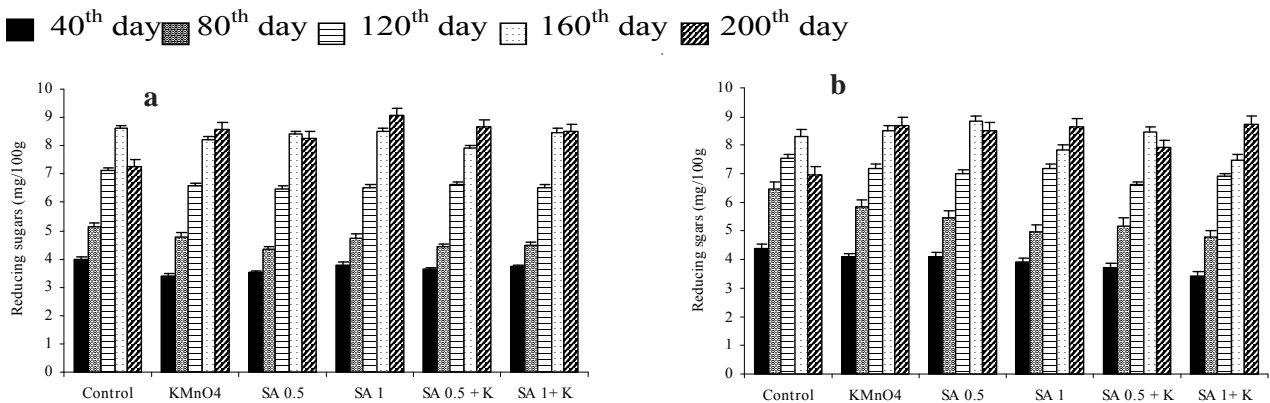
fruits was detected in SA 1 treatments in 200<sup>th</sup> day, second year the highest reducing sugar content of kiwifruits was detected in SA 0.5 treatments in 160<sup>th</sup> day (Figure 6). In both years, after 200 days of storage period, the lowest reducing sugar was obtained at control fruits.

**Reducing sugars**

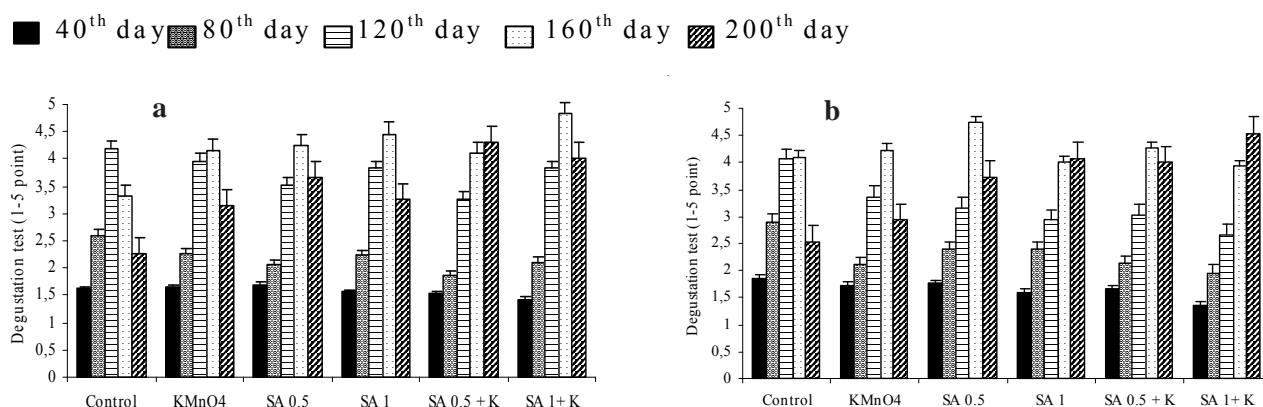
In the study, at the beginning of storage, reducing sugar of kiwifruits was around %2.1-%2.5. With kiwifruit maturity, increasing reducing sugar changed depending on storage period and treatments. First year, while the highest reducing sugar content of kiwi-

**Degustation test**

In the present study, with maturity in taste assessment was determined to increase the test points. Towards the end of the storage period, excessive maturity of fruit was determined to reduce the taste scores. First year; while SA1+K treatment in 160<sup>th</sup> day had



**Fig. 6. Reducing sugars content of kiwifruit treated KMnO<sub>4</sub> and SA during storage in the first year (a) (initial: 2.18 mg/100g) and second year (b)(initial:2.53 mg/100g) of the experiment. Vertical bars represent ± SE**



**Fig. 7. Degustation test of kiwifruit treated  $\text{KMnO}_4$  and SA during storage in the first (a) (initial: 1) and second year (b) (initial: 1) of the experiment. Vertical bars represent  $\pm$  SE**

the highest degustation test point, second year the highest degustation test point was determined at SA 0.5 treatments in 160<sup>th</sup> day (Figure 7). First year in 200<sup>th</sup> day, control fruits were found less than 3 point which was represented moderate (marketable), in case second year, control and  $\text{KMnO}_4$  treatments were found less than 3 point. Other treatments were placed above three points in 200<sup>th</sup> day.

### Discussion

The results showed that during storage, in treated SA and SA with  $\text{KMnO}_4$  fruits, fruit firmness, TA, total chlorophyll concentration, ascorbic acid content decreased and TSS, reducing sugar concentration and degustation test score increased slowly than control fruits.

In the present study, control kiwifruit rapidly softened when stored at low temperature, as evidenced by a rapid decrease in fruit firmness within the first 40 days. This result was in agreement with the previous reports (Arpaia et al., 1987; Beaver and Hopkirk, 1990; Kaynas et al., 1999; Oz, 2006). Packages of fruit with ethylene absorbent sachet retained the more firmness than other treatments. In previous studies, Castro et al. (2005) in mango, Kim (1997) in apples, Correa et al. (2005) in papaya fruit reported that  $\text{KMnO}_4$  treatment has slowed fruit to soften. In treated SA with  $\text{KMnO}_4$  fruits firmer in both years. Han et al. (2003) and Li and Han (2000) found that immersions

of persimmon in low concentrations of SA, compared to control fruits, delayed the decline of firmness of stored fruits.

In both years treated and non-treated kiwifruits showed similar behavior. The results indicated that effect of treatments on TSS was not regular. The TSS increased mostly in 160 day storage, and remained almost constant thereafter for all treatments in both years. In research, flavor acceptability of kiwifruit was found to increase with increasing TSS. Mitchell et al. (1992) identified consumers preferring sweeter (TSS > 13%) fruit rather than less sweet fruit (TSS < 13%). At the end of the storage, although TSS value of unmarketable fruits were found around 15-16%, had below 3 point (marketable) on degustation test. These findings are corroborated by Rossiter et al. (2000). According to these results, it may be misleading to determine simply TSS value for consumption eligibility.

In general, it is known that there is a reduction in citric acid content of kiwifruit during the storage period (Marsh et al., 2003). In study, TA content of kiwifruits exhibited reduction dependence on ripening and treatments towards the end of storage period. These results are similar to those of Kaynas et al. (1999) and Namdar and Ozcan (2006). Especially, SA with  $\text{KMnO}_4$  treatments was more effective to maintain TA than control. Similar observations were reported with SA treated grapes (Bal and Kok, 2007) and with  $\text{KMnO}_4$  treated mangos (Illeperuma and



Jayasuriya, 2002).

The total chlorophyll content is an important quality parameter of kiwifruit and decrease in ripening period (Fuke et al., 1985; Karacali, 2002). In the first period of storage, rapid increase in chlorophyll destruction decreased towards the end of the storage. These findings are corroborated by Thompson (2003). The lower rate of decrease in chlorophyll content of SA and  $\text{KMnO}_4$  treated fruits could be attributed to be slower ripening. Ozer et al. (1997) pointed out that storage of MA and CA conditions, chlorophyll content of kiwifruit significantly decreased with storage time.

The data concerning ascorbic acid content of kiwifruits increased initially and then decreased with the increases in storage period. These results confirmed those of other workers (Manolopoulou and Papadopoulou, 1998; Ozer et al., 1997). SA 1+K treatment in first year and SA 1 treatment in second year had the highest ascorbic acid contents at the end of the storage. In these treatments decreased slower ascorbic acid content may be related to be lowered the activity of the enzymes and prevented oxidation of ascorbic acid. Tsay et al. (1984) showed that continuing of respiration in kiwifruits lead increase in ethylene content and decrease in ascorbic acid content.

During the storage, starch is converted to soluble sugars in kiwifruits. After harvest and during storage and ripening of the fruits the content in reducing sugars was increased in parallel with the TSS content. Results are consistent with those reported by Manolopoulou and Papadopoulou (1998). There was a slower increase in reducing sugar in SA and  $\text{KMnO}_4$  treatments which caused slowdown of ripening. Similar observation was reported with SA treated banana (Srivastava and Dwivedi, 2000).

Preferred tasting kiwifruit have an ideal combination of sugars, organic acids and aroma volatiles in the ripe fruit (Lancaster, 2002). In study, SA and  $\text{KMnO}_4$  treatments inhibited ethylene biosynthesis and delayed the senescence. SA 0.5 +K and SA 1+K treatments had the highest points in degustation tests in both years. This work supports studies that showed SA treatments can retard ripening in storage of ba-

nana and peach (Srivastava and Dwivedi, 2000; Han et al., 2003).  $\text{KMnO}_4$  absorbed ethylene gas in MAP and increased postharvest life of kiwifruits. These results confirmed those of other workers (Illeperuma and Jayasuriya, 2002; Kucuk, 2006).

## Conclusions

In conclusion, the research indicates that SA and  $\text{KMnO}_4$  treatments, alone or in combination, is effective methods of extending the shelf life of kiwifruits in storage. The most effective treatment in reducing losses of fruit quality was found to be SA 1+K and SA 05+K treatments during the long storage period of kiwifruit. It was determined that under these conditions Hayward kiwifruit can be stored for 200 days without losing much of its quality.

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