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Aloe vera Gel and Sulfur Dioxide Fumigation Extend Postharvest Storage Life of Peach

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Peach fruits cannot be stored for a desirable length of time due to chilling injury and the incidence of decay during cold storage. The effects of *Aloe vera* gel and sulfur dioxide fumigation on physicochemical contents, chilling injury, decay index, and sensory quality of peach fruits during cold storage were investigated. Fruits were harvested at physiological maturity and stored at 0 °C ± 1 °C and 90% ± 5% RH for 30 d. The results showed that the combination of *Aloe vera* gel and sulfur dioxide fumigation significantly affected moisture, total soluble solids (TSS), pH, acidity, sugar-acid ratio, reducing sugars, non-reducing sugars, vitamin C, firmness, chilling injury, decay index and sensory attributes of peach fruits. The untreated fruits showed high incidence of chilling injury. Generally, the results indicated that the combination of *Aloe vera* gel and sulfur dioxide fumigation has the potential for maintaining the quality of peach fruits and for extending their shelf life during cold storage.

Key Words: *Aloe vera*, chilling injury, fumigation, physicochemical content, sensory attribute, sulfur dioxide

Abbreviations: TA – trtratable acidity, TSS – total soluble solids

INTRODUCTION

Peach is climacteric and the most important stone fruit grown in the temperate zones of the globe. In Pakistan, it is cultivated in the Peshawar region, Swat, South Wazeristan, Hazara and the Malakad division besides the Northern areas (Zaman et al. 2013; Khalil et al. 2012). The fruit is a rich source of vitamins, minerals, carotenoids, phenolic compounds (catechin, neochlorogenic acid, chlorogenic acid, and caffeic acid), and antioxidants, which are very important for human health (Khalil et al. 2012).

Postharvest diseases and chemical changes reduce the storage and market life of fresh peach during cold storage. Two other major problems of peach during cold storage are chilling injury and decay index (Jin et al. 2009). The main symptoms of chilling injury are flesh mealiness and internal browning. Due to its perishable nature and susceptibility to chilling injury, the postharvest life of fresh peach is very short and so the fruit cannot be supplied to the national and international markets (Murray et al. 2007; Eshun and He 2004).

Aloe vera inner gel is an edible bio-preservative which maintains the quality of fruits during storage (Marpudi et al. 2011). It also acts as a barrier against microorganisms (Puttalingamma et al. 2006). *Aloe vera* gel has a variety of positive effects on quality of fruits; it maintains color and texture, reduces weight loss, increases storage life, and reduces microbial growth (Dang et al. 2008; Castillo et al. 2010). The leaves of *Aloe vera* contain bioactive compounds such as antioxidants which are mostly used in food as a preservative (Eshun and He 2004). *Aloe vera* gel alleviates chilling injury and enhances ascorbic acid, firmness and overall quality of pineapple fruits (Marpudi et al. 2011).

Sulfur dioxide fumigation along with cold storage has been found to be effective in decreasing the extent of damage caused by all kinds of pathogens on grapes (Carter et al. 2015). Sulfur dioxide fumigation is an effective method to control postharvest fruit rots and is therefore used to increase the storage life of fresh figs (Cantín et al. 2011).

To the best of our knowledge, the combined effect of *Aloe vera* gel and sulfur dioxide fumigation on physicochemical contents, chilling injury, decay index, and sensory quality of peach fruits during cold storage has not been examined to date. Therefore, the overarching objective of the present study was to investigate the use of *Aloe vera* gel and sulfur dioxide fumigation as a potential postharvest shelf life extension technique for peach fruits during cold storage.

MATERIALS AND METHODS

Peach (cv. Indian Blood "Swat No. 8", late maturing variety) fruits of uniform size and color were chosen and divided

into different lots for various treatments. *Aloe vera* inner gel (100%) was obtained from the Agriculture Research Institute, Tarnab, Peshawar, Pakistan. *Aloe vera ge*l was diluted with 1:3 ratio of distilled water and peach fruits dipped at 25 °C for 5 min. Then the fruits were dried using the force air cooling method. During sulfur dioxide fumigation, 10 g of sulfur per kg of peach fruits was burnt in a closed chamber covered with plastic. This process was done at room temperature.

The fruits (except for the control) were treated with *Aloe vera* gel and sulfur dioxide fumigation as follows:

T_0 = Fruits with no treatment without distilled water (control, CK)
T_1 = Fruits treated with *Aloe vera* gel
T_2 = Fruits treated with sulfur dioxide fumigation
T_3 = Fruits treated with *Aloe vera* gel + sulfur dioxide fumigation

For sulfur dioxide fumigation, sulfur was burnt in a wood chamber, which was fully sealed with plastic in which the peach samples were placed. Ten grams (10 g) of sulfur/kg of peach fruits was used, and then the fruits were kept in a closed chamber for 2 h. The gas, which was produced by this process, $S + O_2 \Longrightarrow SO_2$, was circulated by a small fan situated at the top of the chamber.

All the treated and untreated fruits were packed in fruit carton boxes and stored at 0 °C ± 1 °C with 90% ± 5% RH. The data regarding various parameters were recorded at an interval of 10 d, i.e., 0, 10, 20 and 30 d and so on until 50% of the fruit samples were spoiled due to chilling injury or other reasons.

Physicochemical Content Analysis
Moisture content (%) of peach fruit was determined using the standard method (William and George 2000). Total soluble solids (°Brix) were determined with a digital refractometer (Atago-Palette PR 101; Atago Co., ItabashiKu, Tokyo, Japan). In accordance with the standard method used by William and George (2000), the following parameters were determined: (1) pH, (2) titratable acidity (%), (3) sugar-to-acid ratio (%), (4) reducing and non-reducing sugars (%), (5) ascorbic acid content by 2, 6-dichlorophenolindophenol titration, (6) ash content, (7) mineral content, and (7) beta carotene by high performance liquid chromatography (HPLC).

Total Phenolic Compounds
Total phenolic compounds in peach were determined with the Folin-Ciocalteu method as described by Ainsworth and Gillespie (2007) and the results were expressed as µg/100 g.

Fruit Firmness
Data pertaining to fruit firmness were recorded with the help of a penetrometer (Wagner Fruit Firmness Tester model FT-327) for five fruits per treatment (Jan et al. 2015). The results were expressed as kg/cm^2.

Chilling Injury
Chilling injury (%) was evaluated in each fruit with a 5-point hedonic scale based on the percentage of fruit surface affected by chilling injury symptoms as described by Junmatong et al. (2012) with slight modifications: 0 = none; 1 = 1% to 10% damaged area; 2 = 11% to 25% damaged area; 3 = 26% to 50% damaged area; 4 = 51% to 75%; and 5 = > 75% damaged area. Chilling injury = ∑ (value of hedonic scale) × (number of fruits with the corresponding scale number)/total number of fruits in the sample (Sayyari et al. 2009).

To determine chilling injury, fruits were transferred to room temperature (25 ± 2 °C, 70 ± 2% RH), and allowed to ripen. Fruits that have a chilling injury index above 2 were considered as unacceptable for marketing.

Decay
Decay (%) was measured by using a previously reported method (Tarabih et al. 2012) based on the formula:

$$\text{Decay (\%)} = \frac{\text{Weight of decayed fruits}}{\text{Initial fruit weight}} \times 100$$

Sensory Characteristics
Sensory attributes such as color, flavor, texture and overall acceptability were scored by 10 expert panel members using a 9-point hedonic scale as described by Larmond (1977).

Statistical Analysis
The data were analyzed statistically by using a complete randomized design, and means were separated by the LSD test at $P < 0.05$ level using Statistix Version 8.1.

RESULTS AND DISCUSSION

Moisture Content/Water Loss
A declining trend in the moisture content was observed in all the treatments (Fig. 1). The maximum decline in mean moisture content was found in T_0 (84.41) followed by T_2; whereas the minimum was found in T_3 followed by T_1. A significant decrease in moisture content was observed during storage. The moisture content decreased from 84.70 at day 0 to 81.79 at 30 d.

The moisture losses of the fruits treated with *Aloe vera* gel along with sulfur fumigation were less than those of the control samples and other treatments. This decrease of moisture losses in treated fruits might be due to the decrease in the transpiration and respiration rate, which, in turn, could be due to *Aloe vera* gel. These results are in agreement with earlier findings (Marpudi et al. 2011; Hu et al. 2011; Carter et al. 2015). *Aloe vera* gel also

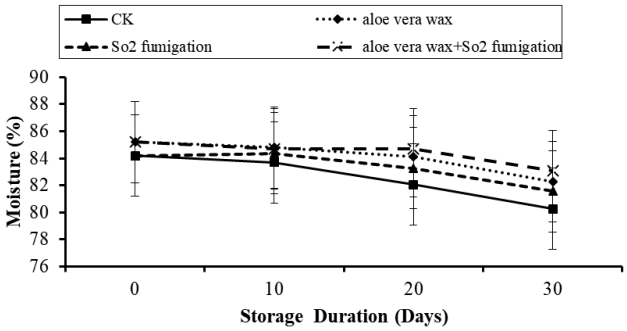

Fig. 1. Effect of *Aloe vera* gel, SO_2 and storage intervals on the moisture content (%) of peach fruits.

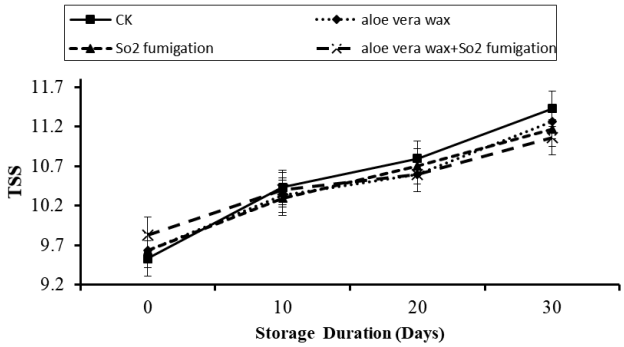

Fig. 2. Effect of *Aloe vera* gel, SO_2 fumigation and storage intervals on the total soluble solids (TSS, °Brix) of peach fruits.

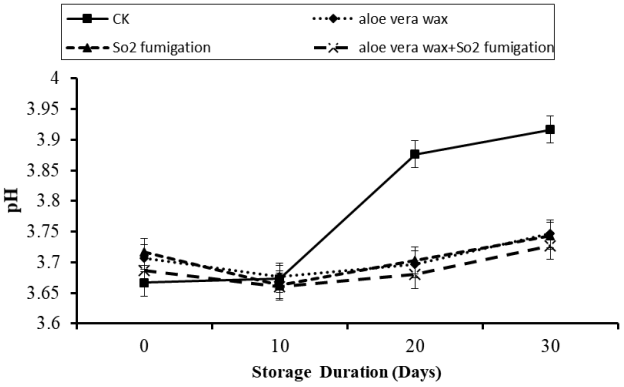

Fig. 3. Effect of *Aloe vera* gel, SO_2 and storage intervals on the pH of peach fruits.

significantly delayed the postharvest water loss in sweet cherry (Martínez-Romero et al. 2006). *Aloe vera* gel in polysaccharides has been found to be extremely efficient as a water barrier and as a reducer of postharvest transpiration and respiration rates in fruits (Ni et al. 2004; Alonso and Alique 2004).

Total Soluble Solids (TSS)

The data on the influence of *Aloe vera* gel and sulfur dioxide fumigation on total soluble solids of peach fruits during a storage period of 30 d are shown in Fig. 2. The maximum mean TSS (10.54) was observed in T_0; whereas the minimum was found in T_3. A significant increase in TSS was observed during storage. TSS increased from 9.66 at day 0 to 11.23 at 30 d. In the control samples, TSS increased rapidly compared with that of the treated fruits. Increase in TSS was slower and gradual in the samples treated with *Aloe vera* gel along with sulfur dioxide fumigation. This result might due to the decline in the ripening and respiration processes. The present results are in line with those of earlier studies (Cheah et al. 1993; Adetunji et al. 2012; Carter et al. 2015) which reported a slow increase of TSS content in gel-treated samples. Similar results were also observed previously (Marpudi et al. 2011). On the other hand, a significant increase in TSS was observed in the control samples, while wax-treated fruits maintained lower TSS levels (Hu et al. 2011).

pH

The pH of the peach fruits treated with *Aloe vera* gel in combination with sulfur dioxide fumigation gradually increased during storage (Fig. 3). The control fruits had higher pH, while a slow increase in pH was observed in the treated samples. The slow increase in pH of treated fruits might be due to modified internal atmosphere, i.e., internal O_2 and CO_2 concentrations in the fruit which slow down the ripening process (Ahmed et al. 2009; Cantín et al. 2011; Ergun and Satici 2012; Arowora et al. 2013).

Titratable Acidity (TA)

In terms of the effect of *Aloe vera* gel and sulfur dioxide fumigation treatment on acidity (%) of peach fruits during cold storage, the treatments had less significant effects on acidity (Fig. 4). Fruits treated with *Aloe vera* gel and sulfur dioxide fumigation maintained higher acidity than untreated fruits. Acidity gradually decreased in all treatments during cold storage. The slow decrease of titratable acidity in treated samples might be related to slow ripening and respiration as affected by *Aloe vera* gel and sulfur dioxide fumigation. The decrease in titratable acidity in *Aloe vera* gel-treated fruits was also observed by Ahmed et al. (2009) and Ergun and Satici (2012).

Sugar-Acid Ratio

A significant increase in sugar-acid ratio was observed during cold storage (Fig. 5). The sugar-acid ratio increased from 12.76 at day 0 to 15.60 at 30 d. The maximum mean sugar-acid ratio (14.20) was noticed in T_2 followed by T_1; whereas the minimum was found in T_3. The slow increase in sugar-acid ratio in treated fruits might be due to delay in respiration and ripening. The finding in this study was similar to that of the work carried out by Arowora et al. (2013), Cantín et al. (2011) and Ahmed et al. (2009) who observed an increasing

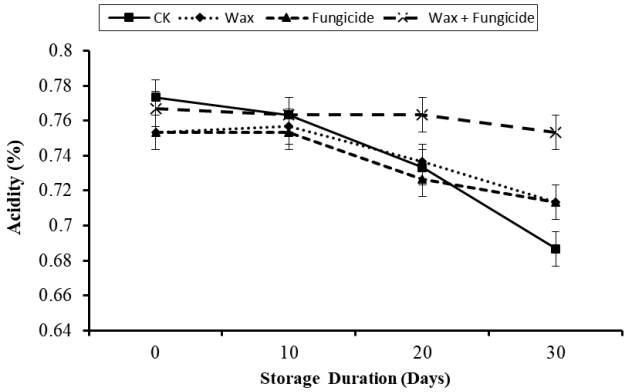

Fig. 4. Effect of *Aloe vera* gel, SO_2 and storage intervals on the acidity (%) of peach fruits.

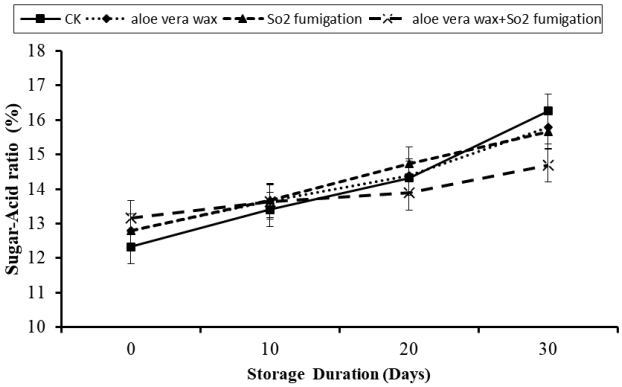

Fig. 5. Effect of *Aloe vera* gel, SO_2 and storage intervals on the sugar-acid ratio of peach fruits.

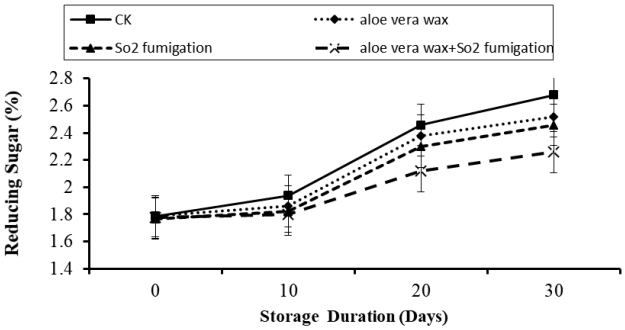

Fig. 6. Effect of *Aloe vera* gel, SO_2 and storage intervals on the reducing sugar (%) of peach fruits.

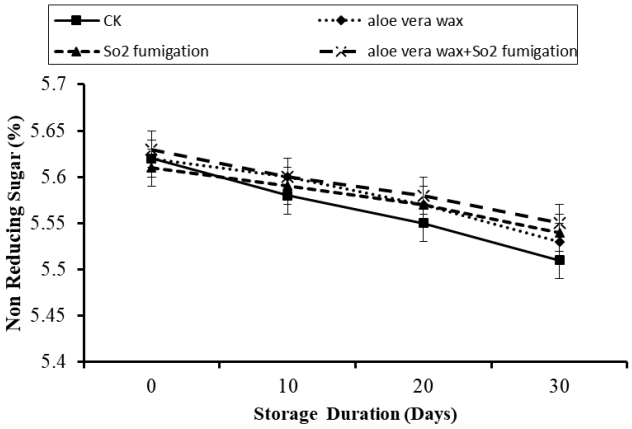

Fig. 7. Effect of *Aloe vera* gel, SO_2 and storage intervals on the non-reducing sugar (%) of peach fruits.

trend in sugar-acid ratio in treated fruits. The increase in sugar-acid ratio level could be attributed mainly to the breakdown of starch into water, soluble sugars, sucrose and glucose during ripening (Arowora et al. 2013).

Reducing Sugars (%)

An increasing trend in reducing sugars was observed in all the treatments during cold storage (Fig. 6). Maximum increase in reducing sugars was found in the control fruits, and the minimum in treated fruits. Increase in reducing sugars in treated samples might be due to the decrease in conversion of complex carbohydrates into simpler carbohydrates. A similar trend in reducing sugars has also been reported in the literature (Gabler et al. 2010; Tarabih et al. 2012; Carter et al. 2015).

Non-Reducing Sugars (%)

Aloe vera gel and sulfur dioxide fumigation significantly affected the non-reducing sugars (Fig. 7). A decreasing trend in non-reducing sugars was observed in all the treatments during cold storage. The decrease might be due to the decrease in ripening and respiration and to the conversion of complex carbohydrates into simple carbohydrates. These results are in agreement with previous findings (Gabler et al. 2010; Tarabih et al. 2012; Carter et al. 2015).

Ascorbic Acid

Peach fruits treated with *Aloe vera* gel and sulfur dioxide fumigation were evaluated in comparison with control samples for ascorbic acid content after every 10-d interval up to 30 d (Fig. 8). A decreasing trend in ascorbic acid was found in all the samples. Decrease in ascorbic acid might be attributed to respiration and oxidation. The maximum retention of ascorbic acid in the treated fruit samples might be due to the role of *Aloe vera* gel and sulfur dioxide fumigation that efficiently reduced ripening and respiration. These results are in agreement with previous work carried out by Arowora et al. (2013), who found that ascorbic acid of coated fruits was high compared with that of uncoated fruits. Veltman et al. (2000) observed that Vitamin C content decreases with increase in storage intervals. Ahmed et al. (2009) also recorded that Vitamin C content was reduced by the action of enzymes during storage.

Beta Carotene

Peach fruits were analyzed for beta carotene content after *Aloe vera* gel and sulfur dioxide treatments (Fig. 9). The treatments significantly affected the beta carotene content. A decreasing trend in beta carotene was observed during

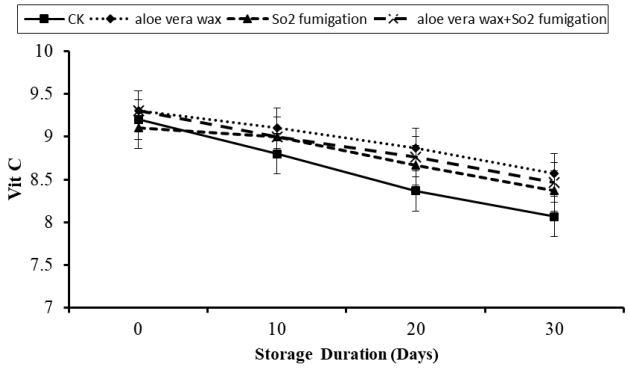

Fig. 8. Effect of *Aloe vera* gel, SO_2 and storage intervals on vitamin C (mg/100 g) of peach fruits.

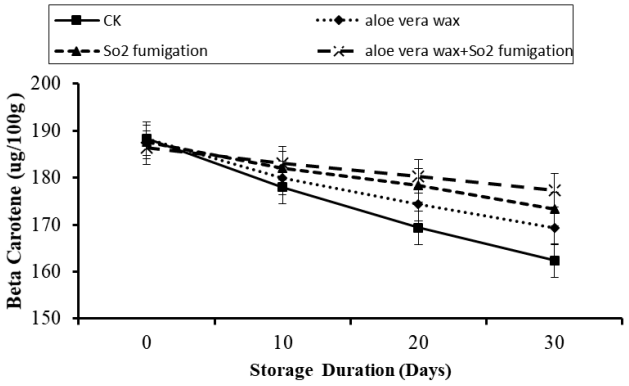

Fig. 9. Effect of *Aloe vera* gel, SO_2 and storage intervals on beta carotene (µg/100 g) of peach fruits.

cold storage. In the control lot, maximum decrease in beta carotene with the storage intervals might be due to certain enzyme activities such as polyphenol oxidase and polygalacturonase, which might be responsible for the breakdown of carotenoids into simple compounds. A similar trend was observed in previous studies (Gabler et al. 2010; Tarabih et al. 2012; Asghari et al. 2013; Vanaei et al. 2014; Carter et al. 2015).

Total Phenolic Content

Peach fruits treated with *Aloe vera* gel and sulfur dioxide were evaluated in comparison with the control lot for total phenols after every 10-d interval up to 30 d (Fig. 10). A decreasing trend in total phenolic compounds was observed during storage intervals. The maximum decrease was observed in the control samples and the minimum in the treated samples. In a previous study, it was found that *Aloe vera* gel effectively reduced the rate of decrease in phenolic content, which inhibited the activity of polyphenol oxidase enzymes and retained the total phenolic compounds (Asghari et al. 2013). This might be due to the oxidation or enzyme activities. These results are in agreement with the findings of previous authors (Park 1999; Gabler et al. 2010; Tarabih et al. 2012;

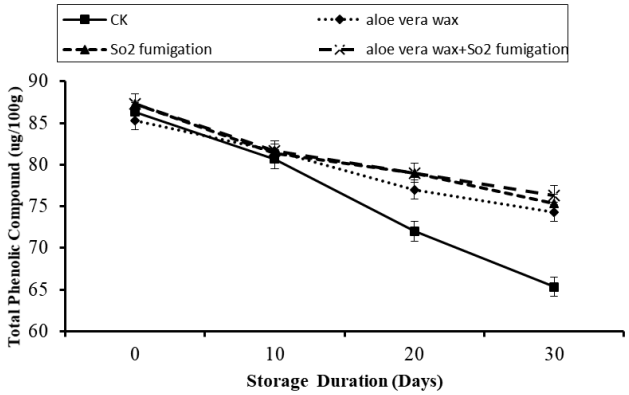

Fig. 10. Effect of *Aloe vera* gel, SO_2 and storage intervals on total phenolic compound (µg/100 g) of peach fruits.

Asghari et al. 2013; Carter et al. 2015) who also observed a decreasing trend in total phenolic content in fruits and vegetables during storage.

Ash

Results on the impact of *Aloe vera* gel and sulfur dioxide on the ash content of peach fruits during cold storage are presented in Fig. 11. Both treatments and storage intervals had no significant effect on ash content of the fruits.

Phosphorus, Potassium, Magnesium and Calcium

Peach fruit samples were evaluated for phosphorus, potassium, magnesium and calcium contents after *Aloe vera* gel and sulfur dioxide treatments (Fig. 12). Both treatments and storage intervals had no significant effect on the mineral content of the samples.

Fruit Flesh Firmness (kg/cm^2)

A significant variation in flesh firmness was found in all the treatments (Fig. 11). In terms of firmness, a declining trend was observed in all treatments. Decrease in the firmness during storage intervals might be due to cellular degradation and respiration. *Aloe vera* gel in combination with sulfur dioxide treatments has been observed to be useful in delaying the ripening process and production of ethylene. Similar observations have also been recorded previously by Arowora et al. (2013) and Ahmed et al. (2009) who reported that coated fruits have more firmness retention compared with control fruits during cold storage.

Chilling Injury (%)

Figure 12 shows the effect of *Aloe vera* gel along with sulfur dioxide treatments on chilling injury (%) of peach fruits during storage. Control fruits showed high incidence of chilling injury with moderate and severe symptoms compared with treated fruits. At 30 d, the chilling injury index was significantly lowered in treated fruits compared with the control samples. This result

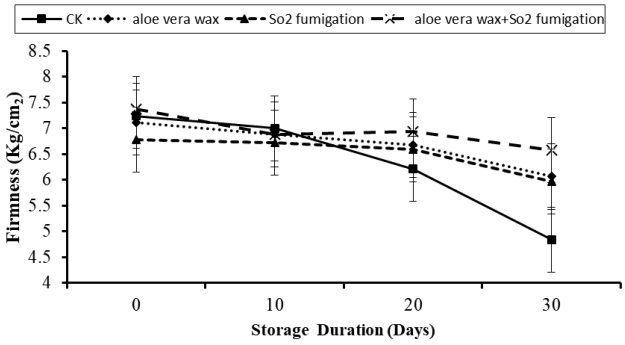

Fig. 11. Effect of *Aloe vera* gel, SO_2 and storage intervals on firmness (kg/cm^2) of peach fruits.

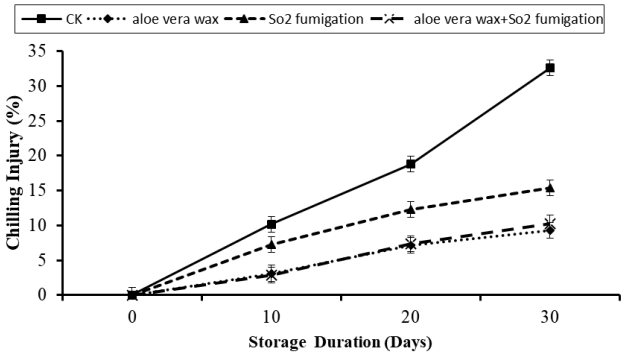

Fig. 12. Effect of *Aloe vera* gel, SO_2 and storage intervals on chilling injury (%) of peach fruits.

might be due to the *Aloe vera* gel which protects the fruit skin and decreases the extent of damage of the cellular wall while the sulfur dioxide treatments controlled postharvest decay. Similar observations have also been reported previously (Park 1999; Lurie and Crisosto 2005; Gabler et al. 2010; Junmatong et al. 2012; Tarabih et al. 2012; Asghari et al. 2013; Hu et al. 2011; Vanaei et al. 2014; Carter et al. 2015).

Chilling injury during low temperature storage in peach, plum, apricot and nectarine is a major physiological disorder the symptoms of which are expressed during ripening under non-stressed conditions (Crisosto and Labavitch 2002).

Decay Index (%)

Evaluation after every 10-d interval up to 30 d (Fig. 13) showed that untreated fruits had a high incidence of decay compared with treated fruits, indicating that *Aloe vera* gel along with sulfur dioxide fumigation are the most effective techniques in reducing total decay (%) in peach fruits during storage. This result might be due to the destruction of microorganisms or the inactivation of enzymes due to *Aloe vera* gel and sulfur dioxide. These results are in agreement with the findings of previous authors (Park 1999; Gabler et al. 2010; Tarabih et al. 2012; Asghari et al. 2013; Hu et al. 2011; Jiang et al. 2013; Vanaei et al. 2014; Carter et al. 2015) who also observed that *Aloe vera* gel along with sulfur dioxide treatments are effective to control the decay in fruits. In the case of berry fruits, SO_2 fumigation significantly controlled decay during storage (Cantín et al. 2012).

Overall Acceptability

Overall acceptability scores showed a decreasing trend throughout cold storage (Fig. 14). The lowest scores were recorded for the control samples while fruits treated with *Aloe vera* gel in combination with sulfur dioxide got the highest scores throughout storage. This trend clearly showed that *Aloe vera* gel in combination with sulfur dioxide maintained overall sensory quality of fruits during storage period. These results are in agreement with the findings of previous workers (Park 1999; Gabler et al. 2010; Tarabih et al. 2012; Asghari et al. 2013; Hu et al. 2011; Vanaei et al. 2014; Carter et al. 2015). Martínez-Romero et al. (2006) mentioned that *Aloe vera* gel is an edible coating in fruits, and that it is an alternative for use in postharvest chemical treatments to improve the overall acceptability of fruits.

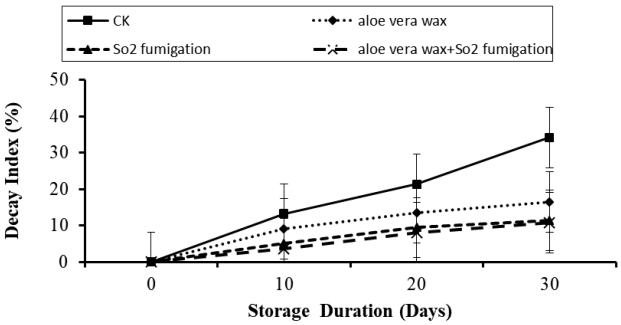

Fig. 13. Effect of *Aloe vera* gel, SO_2 and storage intervals on decay index of peach fruits.

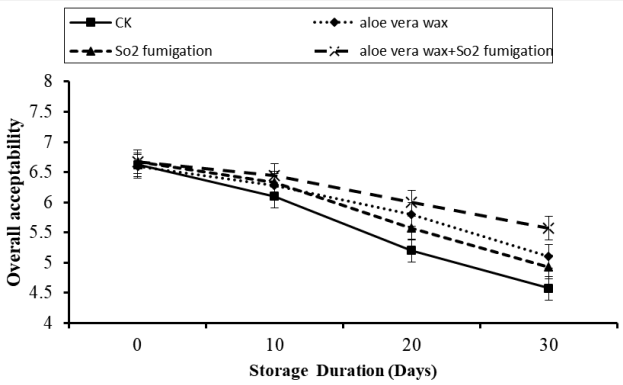

Fig. 14. Effect of *Aloe vera* gel, SO_2 and storage intervals on overall acceptability of peach fruits.

CONCLUSION

Aloe vera gel and sulfur dioxide fumigation could be used as a promising postharvest strategy to reduce chilling injury and decay index and to extend the storage life of peach during cold storage. The treated fruits showed high retention of vitamin C, beta carotene and total phenolic content along with firmness.

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