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# Quality improvement and shelf life extension of fresh apricot fruit (*Prunus Armeniaca* cv. Shahroudi) using postharvest chemical treatments and packaging during cold storage

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**Abstract**
The main objective of this work was to assess the effectiveness of salicylic acid (SA), calcium chloride ($CaCl_2$) or sodium bicarbonate ($NaHCO_3$), and packaging on some qualitative properties of apricot fruit during cold storage. The experiments were conducted using a completely randomized design as factorial, with three replicates. Fruits were dipped in SA (0.1 or 0.5 mM), $CaCl_2$ (1 or 2%) or $NaHCO_3$ (0.2 or 0.5%) solutions for 3 min at 22°C. Then, fruits were placed into polyethylene trays and wrapped with cellophane films to create a passive modified atmosphere packaging, whilst the second group remained unwrapped. Fruits were stored in a cool room at 0.5 ± 0.5°C. Regardless of chemical treatments, total soluble solids (TSS), organoleptic characteristics, and shelf life were higher in packed fruit compare to unpacked fruit. The TSS, weight loss and firmness were lower in fruits covered with cellophane compared to unwrapped fruit. Fruits that treated with SA (0.5 mM) and covered with cellophane film had the lowest TSS while treated fruit with $CaCl_2$ (1%) with no cover indicated the highest TSS. Generally, there was a significant decrease in fruit firmness under the cellophane layer compare to unpacked fruits while in treated fruit with $CaCl_2$ (1%) firmness in packed fruit was obviously higher than unpacked fruits. The best visual quality and taste were obtained in treated fruit with $CaCl_2$ (2%), followed by SA (0.5 mM) when they were packed with cellophane film. The highest shelf life obtained in treated fruit with SA (0.1 mM), followed by $NaHCO_3$ (0.5%). Overall, a combination of chemical treatments and packaging with cellophane film improved fruit quality and extend shelf life significantly compared to the control.

**Keywords**: $CaCl_2$, $NaHCO_3$, salicylic acid.

## Introduction

Apricot is an important fruit in human nutrition, and can be used as fresh, dried or processed fruit. Mechanical injury, and above all impact bruising, is one of the most important factors in postharvest losses in terms of quality and quantity of fresh horticultural commodities (Cappellini and Ceponis, 1984; Kader, 2002). In order to reduce the risks of impact bruising and speed up the handling rate, growers today harvest apricots very early, compromising the attainment of full aroma development during distribution (Botondi *et al*., 2003). Temperature reduction has been seen not only to control bruising injury in different fruit such as apricots (De Martino *et al*., 2002) and apples (Saltveit, 1984), but also

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to delay ripening process in horticultural commodities, particularly in climacteric fruits, in order to be used as it is well known. Unfortunately, the use of low temperature on aromatic fruit such as apricots very often inhibits their aroma development, especially in combination with early harvest (Botondi *et al*., 1999).

Salicylic acid (SA) is a simple phenolic compound and recognized as a plant growth regulator, because of its external application effects on plant physiological processes (Raskin, 1992). The effect of SA on plant resistance to diseases has been discussed by several researchers, and it is known that SA is the signal molecule in plant systemic-acquired resistance induction (Raskin, 1992). Salicylic acid has been widely applied either at pre-harvest or post-harvest. It has been recently accepted that salicylic acid is a safe chemical, used to control post-harvest quantity or quality losses of perishable crops (Supapvanich and Promyou, 2013). The SA application either pre-harvest (Yao and Tian, 2005) or post-harvest reduced fungal decay in sweet cherry through induction of the defense resistance system (Chan and Tian, 2006) and stimulation of antioxidant enzymes (Xu and Tian, 2008). Also, pre- and post-harvest salicylic acid treatments alleviate internal browning and maintain quality of winter pineapple fruit (Lu *et al*., 2011). Post-harvest application of SA increased TSS and prolonged the storage life and preserved the valuable marketing characteristics of ‘Asgar-Abad’ apricot fruit (Hajilou and Fakhimrezaei, 2013).

Postharvest calcium dips can increase calcium content considerably compared to pre-harvest sprays, without causing fruit injury, depending on salt type and calcium concentration of the dip. Calcium chloride ($CaCl_2$) has been widely used as preservative and firming agent in the fruits and vegetables industry for whole and fresh-cut commodities. In kiwi fruit, SA and $CaCl_2$ application significantly decreased weight loss during storage (Kazemi *et al*., 2011). Storage life of pomegranate fruit that were treated with $CaCl_2$ increased significantly compared to control (Moradinezhad *et al*., 2013; Moradinezhad and Khayyat, 2014). Beneficial effects of pre- (Tzoutzoukou and Bouranis, 1997) and post-harvest (Antunes *et al*., 2003; Ali *et al*., 2013; Hajilou and Fakhimrezaei, 2013) application of calcium treatments on the storage life of apricot fruit have been reported previously.

Apricot fruit is also susceptible to post-harvest pathogens during storage, handling and marketing mainly due to fast ripening. The use of fungicides has been becoming increasingly more restricted because of health concerns due to contamination with chemical residues (Ragsdale and Sisler, 1994). In addition, there are no post-harvest fungicides registered for apricots, but post-harvest pathogens continue to cause significant losses. It is therefore necessary to find alternatives to control both post-harvest pathogens and maintaining fruit quality during storage and marketing. An alternative is sodium bicarbonate ($NaHCO_3$, SBC), which is a commonly used food additive, and a compound that is generally regarded as safe. Immersing fruit in solutions of SBC to control the post-harvest incidence of *Penicillium digitatum* on citrus fruit was first described by Barger (1928) and has since been used to control post-harvest decay of lemons in California because it is inexpensive, readily available and can be used with little risk of fruit injury (Palou *et al*., 2001).

The apricot is a climacteric fruit that displays a narrow ethylene peak in time. It should be noted that the time period from commercial ripening to appearance of senescence symptoms, depends on the apricot variety. It is known that the atmosphere generated by modified atmosphere packaging (MAP) also delays ripening of fruits, including mango (Kader, 1994) and apricot (Pretel *et al*., 2000).

Although, there are some reports on the positive effects of postharvest treatments on improvement of post-harvest quality of apricot (Botondi *et al*., 2003; De Martino *et al*., 2006; Ibrahim, 2005; Koyuncu and Can, 2000; Mencarelli *et al*., 2006; Pala *et al*., 1994; Pretel *et al*., 2000; Souty *et al*., 1995; Tzoutzoukou and Bouranis, 1997); however, there is no report on the effects of pre-storage treatments applying SA or $NaHCO_3$, alone or combined with packaging, on the post-harvest life of 'Shahroudi' apricot fruit. It has also been reported that the respiratory behavior of different cultivars of apricot (Pretel, 2000) varies in MAP to some extent. The main objectives of this study; therefore, are to assess the effectiveness of SA, $NaHCO_3$ or $CaCl_2$ and packaging on quality improvement and shelf life extension of apricot fruit kept in cold storage (0.5°C).

## Material and Methods

### *Plant Material and Preparation*

About 400 mature (45-50 g) 'Shahroudi' apricots were harvested early in the morning from a commercial apricot orchard in Birjand, South Khorasan, Iran, and immediately transferred to the post-harvest laboratory of Department of Horticultural Science, University of Birjand, late in May 2013. Harvest was according to peel color of apricots (light-green background with slightly yellow color), and a total soluble solid content equivalent to 10.5 Brix. Fruits with defects were discarded, and uniform fruit were selected and used for the following treatments in triplicate (12 fruit per replicate). Fruits were dipped in SA (0.1 or 0.5 mMol $L^{-1}$), $CaCl_2$ (1 or 2%) or $NaHCO_3$ (0.2 or 0.5%) solutions for 3 min at 22°C. Control fruit just washed with distilled water at 22°C. Next, fruits were allowed to completely dry in air at room temperature (22 ± 1°C). Thereafter, four fruits from each replicate were placed into polyethylene trays of 140mm × 100mm × 50mm and 80 µm thicknesses and wrapped with cellophane films (20 µm thicknesses) to create a passive modified atmosphere packaging, whilst the second group remained unwrapped. The fruits were then stored in a cool room at 0.5 ± 0.5°C and approximately 80% RH. After 3 weeks of storage, both physico-chemical and sensory properties were evaluated. Shelf life was evaluated daily. Temperature and relative humidity of storage were recorded using datalogger (Extech Instruments, Model RHT20, Humidity and Temperature Datalogger, USA) during the experiment.

### *Fruit Weight Loss and Firmness Measurement*

In order to calculate weight loss, fruit weight was measured just after harvest and at the end of experiment and data expressed as percentage, relative to initial value. Fruit firmness was measured using a digital penetrometer (Extech Co., Fruit Hardness Tester, Model FHT 200, USA), fitted with a 3 mm diameter tip and data showed as Newton.

### *Total Soluble Solids (TSS) and Titratable Acidity (TA)*

Total soluble solid in the extracted juice of fruits was measured by a hand-held refractometer (Extech Co., Model RF 10, Brix, 0–32%, USA), and the results were expressed as Brix. In order to measure titratable acidity, 2 ml of extracted fruit juice was titrated with 0.1 N sodium hydroxide. Titratable acidity was calculated as percentage of malic acid by the following formula (Nielsen, 2010):

$$\% \text{ acid (wt vol}^{-1}) = N \times V1 \times Eq\ wt / V2 \times 10$$

where N = normality of titrant, usually NaOH (mEq $mL^{-1}$), V1 = volume of titrant (mL), Eq. wt. = Equivalent weight of predominant acid (mg $mEq^{-1}$), V2 = volume of sample (mL)

### *Shelf life*

Shelf life was based on the physical appearance of the fruit as judged by the retention of freshness, color, and glossy appearance of fruit without any desiccation, pathogenic decay and chilling injury.

### *Organoleptic evaluation*

The perceived sensorial quality for fruit color and taste was evaluated by a panel of five assessors at the end of experiment. The evaluation was done on a scale of 1–5, where score 5 indicated as very good (evident harvest freshness and absence of off-flavor) and score 1 considered as very bad degree (dislike completely, desiccated fruits with brown tough peel, with low juiciness and becoming dry). Scores of 3 (like moderately with retention of freshness, color and taste of flesh) and above were considered acceptable for commercial purposes.

### *Statistical analysis*

The experiments were conducted using a completely randomized design as factorial, with three replications. Data from the analytical determinations were subjected to analysis of variance (ANOVA). Mean comparisons were performed using LSD test ($P<0.05$). All analyses were performed with Genstat program (Discovery Edition, Version 7.2, 2008, VSN International, Ltd., UK).

## Results

### *Fruit weight loss and firmness*

Regardless of the chemical treatments, weight loss of apricot fruits slightly decreased in fruit packed with cellophane compared to the unpacked fruit. Packaging fruit in cellophane significantly reduced weight loss compared to the control (Table 1). The highest weight loss was obtained in control unpacked fruit (37.7%), while the lowest weight loss (8.8%) was recorded for apricots that were treated with SA at concentration of 0.5 mM prior to packaging. Treatment of apricot fruits with SA or $NaHCO_3$ at both concentrations and $CaCl_2$ (2%) in all cases significantly reduced fruit weight loss.

Packaging fruit with cellophane or treatment with SA, $CaCl_2$ or $NaHCO_3$ reduced fruit firmness. However, unpacked fruit had greater firmness after 3 weeks of cold storage. The lower firmness observed in treated fruit with SA (0.5 mM) or $CaCl_2$ (2%), 19, and 26.3%, respectively (Table 1).

### *Total Soluble Solids (TSS) and Titratable Acidity (TA)*

The TSS of apricot fruits is significantly affected by the packaging. After 3 weeks of cold storage unpacked fruit exhibited a higher TSS than cellophane packed fruit (Table 1). SA treated fruit exhibited the lowest TSS (10.5%) for both of the SA concentrations applied.

The TA percentage of juice slightly but significantly increased in packed fruit compared to unpacked fruit (Table 1). However, $CaCl_2$ (1%) treated fruit did not increase the percentage TA.

### *Shelf life*

The interaction of SA, $CaCl_2$ or $NaHCO_3$ treatments and packaging was significant regarding the shelf life of apricot fruit (Table 2). The highest shelf life of the treated-fruits was obtained with SA at 0.1 mM (19.6 d), followed by $NaHCO_3$ at 0.5% (18.5 d) and SA at 0.5 mM (17.7 d) in packed fruit compared to control (12 d). However, there was no significant different between the shelf life of treated-fruit with SA at 0.1 mM or $NaHCO_3$ at 0.5% when they packed in cellophane.

### *Organoleptic evaluation*

Organoleptic assessments showed that packaging the apricot fruits in cellophane significantly increased both the color as well as the perceived taste of apricot fruits after 3 weeks of cold storage (Table 2). However, treated-fruit with $CaCl_2$ (1 or 2%) or $NaHCO_3$ (0.2%) had better quality and acceptable fruit from sensorial assessments as judged by panelists.

**Table 1. Effect of salicylic acid, $CaCl_2$ and $NaHCO_3$ dipping and packaging on weight loss, firmness and chemicals of fresh 'Shahroudi' apricot fruit after 3 weeks of cold storage at 0.5°C**

| Pre-storage Treatments | Packaging | Weight loss (%) | Firmness (N) | TSS (°Brix) | TA (%) |
|---|---|---|---|---|---|
| Control | Unpacked† | 37.7d | 54.3a | 14.7b | 3.8cd |
| | Cellophane | 10.0a | 46.2a | 10.3de | 4.0b |
| SA (0.1 mMol/L) | Unpacked | 32.2c | 36.8b | 14.4b | 3.3d |
| | Cellophane | 9.9a | 30.5b | 10.2de | 3.4d |
| SA (0.5 mMol/L) | Unpacked | 28.7b | 33.8b | 14.2b | 3.9cd |
| | Cellophane | 8.8a | 19.0c | 9.7de | 4.3bc |
| $CaCl_2$ (1%) | Unpacked | 36.9d | 22.5b | 19.6a | 3.1e |
| | Cellophane | 10.5a | 37.2b | 11.7d | 3.0e |
| $CaCl_2$ (2%) | Unpacked | 28.7b | 42.0a | 13.7bc | 4.2bc |
| | Cellophane | 9.1a | 26.3b | 12.1d | 4.7a |
| $NaHCO_3$ (0.2%) | Unpacked | 33.5c | 41.0a | 14.6b | 3.6c |
| | Cellophane | 11.2a | 31.8b | 12.4d | 3.8c |
| $NaHCO_3$ (0.5%) | Unpacked | 32.8c | 43.9a | 14.8b | 3.9c |
| | Cellophane | 9.6a | 34.0b | 12.0d | 4.1bc |

† Columns with different letters indicate significant differences at $P < 0.05$ according to LSD test (n =12).

**Table 2. Effect of salicylic acid, $CaCl_2$ and $NaHCO_3$ dipping and packaging on sensory assessments and shelf life of fresh 'Shahroudi' apricot fruit after 3 weeks of cold storage at 0.5°C**

| Pre-storage Treatments | Packaging | Organoleptic Score† | | Shelf life (day) |
|---|---|---|---|---|
| | | Colour | Taste | |
| Control | Unpacked | 0.65e | 1.65e | 9.0g |
| | Cellophane | 1.95d | 2.55c | 12.2f |
| SA (0.1 mMol/L) | Unpacked | 2.06d | 1.96d | 10.0g |
| | Cellophane | 2.90a | 2.93a | 19.6a |
| SA (0.5 mMol/L) | Unpacked | 2.00d | 1.98d | 8.0gh |
| | Cellophane | 2.95a | 2.98a | 17.7b |
| $CaCl_2$ (1%) | Unpacked | 1.76e | 1.92d | 9.0g |
| | Cellophane | 3.06a | 2.73b | 17.3b |
| $CaCl_2$ (2%) | Unpacked | 1.90d | 1.90d | 10.3g |
| | Cellophane | 3.10a | 2.70b | 16.3bc |
| $NaHCO_3$ (0.2%) | Unpacked | 2.10d | 1.88d | 9.5g |
| | Cellophane | 3.04a | 2.86a | 16.4bc |
| $NaHCO_3$ (0.5%) | Unpacked | 1.94d | 1.76e | 9.5g |
| | Cellophane | 2.85a | 2.95a | 18.5ab |

† Score: 1, very bad; 3, acceptable; 5 very good
Columns with different letters indicate significant differences at $P < 0.05$ according to LSD test (n =12).

## Discussions

According to the experimental results, regardless to the effects of different treatments on the surveyed quality attributes of the apricot fruits, we observed differences in the percentage weight loss, the firmness, TSS, perceived taste and shelf life in fruits that were covered with cellophane film compared to unwrapped fruits. However, combination of chemical treatments with cellophane film improved the measured quality attributes, and extends the shelf life of 'Shahroudi' apricot fruit significantly compared to unwrapped fruit.

Generally, cellophane wrapping alters the enclosed atmosphere around the packed fruits and vegetables. These alterations included, a decreasing $O_2$ and an increase in $CO_2$ level that can resulting in an increase in the storage life of products (Pretel *et al.*, 2000) due to a decrease in ethylene synthesis and a reduction in the respiration rate of the products (Burg and Burg, 1967).

With the increase in respiration rate, it accelerates the conversion of starch to sugar. Therefore, the main index in Brix enhance and TSS increases (Ganji moghadam and Shikh-eslami, 2006). In current research, lower amount of TSS was obtained in packed fruits compared to unpacked fruits. It may be associated to reduction in respiration rate under the cellophane film. It is also likely that reduction of weight loss and the extension of shelf life in packed fruits relate to a lower respiration rate and a higher relative humidity in the atmosphere around the fruits. Similar results were also obtained in a study conducted with pear fruits (Mahajan *et al*., 2013). The Food and Agriculture Organization (1989) reported to keep water loss from fresh produce as low as possible, it should be kept in a moist atmosphere (Zewter *et al*., 2012). It is known that an optimum moisture content for storage of apricot is about 90 to 95%. In the present study, the highest moisture content in a cool room was approximately 80%. A plastic layer around the product can affect the water evaporation/transpiration of the product involved by an increase in relative humidity around the product. Since, moisture loss is primarily due to difference between vapor pressure of water in the atmosphere and the products involved, it is important to minimized weight loss as much as possible through either higher relative humidity during storage or using a suitable cover around the product, particularly in apricot fruit which has a thin and soft peel. In this study, cellophane film prevented weight loss of the apricot fruit significantly compared to the other treatments. This is in agreement with the observation of Zewter *et al*. (2012) who reported a lower weight loss from fruits placed under polyethylene covers.

The color changes of apricot fruit during the storage period of 3 weeks showed significant difference among the treatments. Apricot fruits wrapped in cellophane film exhibited a better visual quality, and perceived taste compared to unpacked fruits and all treatments. The highest observed quality concerning the attribute “color” was observed in fruits that were treated with $CaCl_2$ (2%) and wrapped with cellophane. The observed desirable color of apricot fruits that were packed with cellophane as compared to those stored under air could be due to retarded respiration because of the modified atmosphere by the cellophane cover. Previous studies have reported similar results showing that polyethylene packaging can extent the shelf life and favor the quality attribute color due to modifying the atmosphere by reducing the $O_2$:$CO_2$ ratio (Gonzalez-Aguilar *et al*., 1999; Zewter *et al*., 2012). Next, to polyethylene film, calcium treatment (2%) had a significant positive effect on the preservation of fruit color. Calcium chloride has been widely used as preservative and firming agent in the fruits and vegetables industry (Martin-Diana *et al*., 2007). Ali *et al*. (2013) showed that 3% $CaCl_2$ dip improved quality and post-harvest life of ‘Habi’ apricot fruits in ambient storage. They found that treated fruits with $CaCl_2$ (3%) significantly maintained freshness and quality attributes up to 12 d. Moreover, post-harvest application of $CaCl_2$ prolonged the storage-life of ‘Asgar-Abad’ apricot fruit stored at 1°C (Hajilou and Fakhimrezaei, 2013). Post-harvest calcium application can impact on maintains cell turgor, membrane integrity, tissue firmness and delay membrane lipid catabolism. In addition, calcium ions form cross-links or bridges between free carboxyl groups of the pectin chains, resulting in strengthening of the cell wall. This cross linking is thought to have a positive effect on the storage life of fresh fruits (Manganaris *et al*., 2007).

In this research, the higher color retention with $CaCl_2$ and cellophane cover may be due to the slower change of chlorophyll into carotenoids in the presence of firming agent as $CaCl_2$ in a modified atmospheric storage in the covered polyethylene packages. The results of the researchers' present study are in agreement with findings of Ishaq *et al*. (2009) who showed that treatments with $KMnO_4$, $CaCl_2$ and polyethylene bags were most effective in the retention of sensory perceived parameters like color in apricot fruit during the storage.

Fruits that were treated with SA (0.1 mM) and placed under the cellophane film were observed to exhibit the most optimal shelf life during storage compared with all other treatments discussed above. Salicylic acid is a beta-hydroxy acid of phenolic acid that functions as a plant hormone. In addition to its medicinal and cosmetic applications, it also applied as food preservative, bactericide and antiseptic agent. Similar results as described above have been obtained from research on kiwi fruit treated with salicylic acid (Fatemi *et al*., 2013). It was shown that SA has significant positive impact on post-harvest decay and fruit quality. The application of SA significantly decreased the percentage weight loss and increased the storage life of these fruits (Fatemi *et al*., 2013). 'Asgar-abad' apricot fruit that were treated with SA at 2 mM had less fruit weight loss and maintains fruit quality during 3 weeks cold storage (Hajilou and Fakhimrezaei, 2013) in agreement with our results.

In our study, it is observed that sodium bicarbonate (SBC) plays an important role in the preservation of organoleptic characteristics and the extension of the shelf life of the apricot cultivar researched. The SBC has been used to reduce postharvest decay, mainly on citrus fruits. It is inexpensive, readily available, and poses little risk of phytotoxicity at concentration 1-4% (Williams *et al*., 1980). This chemical component is approved as food additives throughout the world. It has been shown that this compound enhances the extension of the fruit shelf life by delaying its decay (Williams *et al*., 1980; Mahmoud *et al*., 2011; Hong *et al*., 2014). Thus, far there is no report concerning the effects of this compound on the organoleptic properties of SBC treated apricots. In the current study, a higher quality was obtained in apricots treated with SBC. This observation can be related to the inhibitory effect of this chemical on pathogens growth and development. Although infection of apricot fruits by pathogens was not assessed in this study, the visual quality of stored fruits was evaluated at a regular basis as indicator of microbial deterioration of the apricots under study.

The results indicated that the effect of cellophane film were obvious retarding the retardation of the titratable acidity loss. Majidi *et al*. (2011) also found that modified atmosphere packaging slowed down the diminishing trend of TA in tomatoes. Respiration is the main metabolic route for the consumption of organic acids resulting into a decline in fruit acidity during storage (Jan and Rab, 2012). As mentioned before, enhanced $CO_2$ concentrations and decreased $O_2$ concentrations inside the film covered packages made can affect the respiratory rate. Therefore, a decrease in respiration rate inside the plastic bags resulted in higher TA than to unpacked fruits. The higher TA in packed fruits is in agreement with the results reported by Błaszczyk *et al*. (2010).

## Conclusions

The benefits of modified atmosphere packaging in combination with SA, $CaCl_2$ or $NaHCO_3$ treatments are extension of the shelf life of 'Shahroudi' apricot fruit to meet market demand through reduction of both metabolic activities and pathological deterioration. The combined approach based on chemical or natural compounds added in combination with active or passive MAP, was designed to respond to a number of issues related to food quality deterioration during refrigerated storage. In particular, in the case of apricot, the use of these chemical compounds in combination with MAP improves the product overall quality in terms of maintenance of organoleptic and other quality properties and reduces the postharvest losses. Apricot fruit treated with SA, $CaCl_2$ or $NaHCo_3$ prior to packaging with cellophane could be stored for a longer period during cold storage with a minimum deterioration in quality compared to untreated and non-packed reference apricots. The shelf life nearly doubled when a combination of pre-storage chemical treatments and wrapping were used. It is; therefore, concluded that passive MAP in combination with SA, $CaCl_2$ or $NaHCO_3$ is a valuable, simple and low-cost method which can improve storability of 'Shahroudi' apricot fruit during cold storage including market conditions when proper cold chain is available.

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