Article

FOOD SCIENCE AND TECHNOLOGY INTERNATIONAL

Investigating the effect of oxalic acid and salicylic acid treatments on the post-harvest life of temperate grown apricot varieties (*Prunus armeniaca*) during controlled atmosphere storage

Mariya Batool[1], Omar Bashir[2], Tawheed Amin[2], Sajad Mohd Wani[2], FA Masoodi[1], Nusrat Jan[2], Shakeel Ahmad Bhat[3] and Amir Gul[1]

Abstract

This study aimed at investigating the influence of different postharvest treatments with oxalic acid (OA) and salicylic acid (SA) on quality attributes and postharvest shelf life of temperate grown apricot varieties stored under controlled atmosphere (CA) storage conditions. After each treatment was given, the samples were stored in CA store maintained at a temperature of 0 °C, 90 ± 5% relative humidity, 5% oxygen and 15% carbon dioxide for 30 days. Results indicated that both OA and SA treatments significantly ($p \leq 0.05$) retained total soluble solids, titratable acidity, color profile, ascorbic acid content and total phenolic content of apricot varieties and had a positive effect on antioxidant activity and texture of samples compared to control. However, carotenoid content was found to be higher in control. Both the treatments reduced chilling injury index, weight loss and decay percentage of samples. Moreover, it was found that SA treatment was the most effective treatment in maintaining visual color of apricots while OA maintained fruit firmness and effectively decreased the decay percentage and chilling injury index of apricot varieties. In conclusion, it was found that both OA and SA have the potential to extend storage life of apricots and maintain quality attributes of the crop during CA storage.

Keywords

Apricot, phenolic content, controlled atmosphere storage, antioxidant activity, chilling injury

Date received: 25 October 2020; accepted: 23 June 2021

INTRODUCTION

Apricot (*Prunus armeniaca*) is a temperate fruit and belongs to plant family Rosaceae. These are cultivated worldwide but mostly distributed throughout the Northern temperate regions of globe. These contain a good amount of carbohydrates, minerals and vitamins (USDA, 2005), besides being rich in bioactive phytochemicals viz. polyphenols (gallic acid, chlorogenic

Food Science and Technology International 0(0) 1–13

DOI: 10.1177/10820132211032074
journals.sagepub.com/home/fst
SAGE

[1]Division of Food Science and Technology, University of Kashmir, Srinagar, India
[2]Division of Food Science and Technology, Sher e Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar, India
[3]College of Agricultural Engineering, Sher e Kashmir University of Agricultural Sciences & Technology of Kashmir, Srinagar, India

Corresponding authors:

Omar Bashir, Division of Food Science and Technology, Sher e Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar 190025, Srinagar, Jammu and Kashmir, India.
Email: abuumi786@gmail.com

Tawheed Amin, Division of Food Science and Technology, Sher e Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar 190025, Srinagar, Jammu and Kashmir, India.
Email: tawheed.amin@gmail.com

Sajad Mohd Wani, Division of Food Science and Technology, Sher e Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar 190025, Srinagar, Jammu and Kashmir, India.
Email: tawheed.amin@gmail.com

acid, neochlorogenic acid and caffeic acid) and carotenoids (β and γ-carotene, β-cryptoxanthin). These bioactive phytochemicals exhibit certain roles in the biological system and have found to be effective in preventing the oxidative stresses (Leccese et al., 2011). These compounds also confer color to plant tissues and therefore, largely contribute to the visual quality of fruits. Apricots are also embodied with a reasonable amount of dietary fibre and essential minerals such as potassium, phosphorus, calcium, magnesium, iron and selenium (Ali et al., 2011; USDA, 2005). Similarly, the vitamins found in apricots are pro-vitamin A, vitamin B, vitamin C, vitamin K and vitamin E (Haciseferogullari et al., 2007). The major organic acids present in apricots are malic acid (500-900 mg/100g) and citric acid (30-50 mg/100g) (Gurrieri et al., 2001). Owing to the presence of bioactive components of pharmacological importance, apricots have been found to be effective against chronic gastritis, oxidative intestinal damage, hepatic steatosis, atherosclerosis, coronary heart disease and tumor formation (Kim et al., 2003; We et al., 2004).

India ranks 35th in the world apricot production with Ladakh (Leh and Kargil districts) being the major apricot producing region followed by Himachal Pradesh. It is a highly perishable fruit with moisture content of 80-86% and a shelf life of only 2-5 days under ambient storage conditions (Akinci et al., 2004). Moreover, apricots are climacteric in nature with persistently higher rates of respiration and ethylene production that lead to various physiological and biochemical changes. This in turn causes quality deterioration of the fruit such as loss of water loss, volatile components, and decay during storage and transportation, thus causing massive commercial revenue losses (Undurraga et al., 2009). In order to reduce such losses in fruit and to maintain the physiological and quality attributes, the fruit needs to be stored in an appropriate storage environment. Amongst the successful operational storage techniques for fruits, controlled atmosphere (CA) storage have been extensively applied commercially (Undurraga et al., 2009). This technique provides different gas concentrations and appropriate temperature and relative humidity (RH) conditions for storage of fruits that reduces the respiration rate, delays senescence, reduces pathological invasions in turn extending the shelf life of fruits and vegetables (Dilley, 2006). However, CA stored horticultural crops suffer chilling injury (CI) when stored under sub-optimal or chilling temperature conditions. CI then leads to physiological and biochemical alterations resulting in the stimulation of ethylene production, increase in respiration rate, enzyme activation, alteration in cellular structure and cellular dysfunctions (Lurie and Crisosto, 2005). The immediate effects of CI include the development of pitting, discoloration, water soaked appearance, internal breakdown, browning, uneven ripening, off-flavour and decay of the stored crop (Valero and Serrano, 2010). It brings about significant deterioration of the produce and therefore, has a drastic effect on its final market value, leading to substantial economic losses (Aghdam et al., 2015).

Organic compounds like oxalic acid (OA) and salicylic acid (SA) that are found ubiquitously in plant species play a vital role in various physiological processes like fruit ripening, control of fruit decay by suppressing ethylene production, maintaining firmness and preserving fruit color (Barman et al., 2011). Both OA and SA have been reported to exhibit anti-senescence effect, an effect that delays postharvest ripening process (Gimenez et al., 2017) besides reduces chilling (Luo et al., 2011), enhances disease resistance (Zheng et al., 2007b) and extends the storability of horticultural crops (Valero et al., 2011). Moreover, dietary OA and SA from fruits and vegetables are described as bioactive molecules with health beneficial effects that are generally recognized as safe (GRAS) (Hooper and Cassidy, 2006).

As far as we could possibly know very scanty or no such study has been carried out wherein the effects of OA and SA-treatments on apricot varieties (*Rival, Harcot, New Castener and Erani*) under CA storage has been studied. This study is therefore, aimed to investigate the effects of postharvest treatments of OA and SA on physicochemical properties, bioactive compounds, storage stability and physiological disorders of some commonly temperate grown apricot varieties under controlled atmospheric conditions.

MATERIALS AND METHODS

Procurement of raw material

Apricot varieties viz. *Rival, Harcot, New Castener and Erani* (harvested at physiological maturity) were procured from Central Institute for Temperate Horticulture (CITH), Srinagar, Jammu and Kashmir, India. Fruits with signs of bruises, mechanical damage and diseased ones were discarded. Only those apricots which were uniform in color, size and shape were selected for the investigation. The chemicals used in the investigation were procured from Sigma-Aldrich, having purity of 99%.

Postharvest treatment of oxalic acid and salicylic acid and storage in controlled atmosphere store

The apricot samples were given postharvest treatments with OA and SA. Each of the four selected varieties

comprised of three groups viz. control, samples treated with OA and samples treated with SA. Each group comprised of 100 apricots. First group i.e. the control (T1) of each variety was dipped in a solution containing distilled water and 0.01% Tween-20 (a surfactant) for a period of 10 minutes. The second group (T2) of each variety was dipped into a solution of 8 mM OA and 0.01% Tween- 20 for duration of 10 minutes. The third group (T3) of each variety was treated with a solution of 4 mM SA solution and 0.01% Tween 20 for 10 minutes. The levels of the treatments have been selected based on some preliminary studies carried out by the authors. After each treatment, the samples were left to dry and kept at room temperature for 30 minutes. The samples were sealed in perforated plastic bags (the perforated bags were 36×19 cm in dimension with 20 holes having the size of 50 mm^2 for each pore) and stored at temperature of $0\,^{\circ}C$ and $90 \pm 5\%$ relative humidity for 30 days in controlled atmosphere store with oxygen and carbon dioxide levels maintained at 5% and 15%, respectively. The analysis was performed on the first day of harvest and thereafter at an interval of 10 days.

Quality characteristics of apricots

Decay percentage. After every two days of storage, visually decayed fruits were removed and the decay percentage was calculated using equation (1) (El-Anany et al., 2009)

$$\text{Decay } (\%) = \frac{\text{Number } of \text{ decayed fruits}}{\text{Initial number } of \text{ fruits}} \times 100 \quad (1)$$

Percent weight loss and total soluble solids (TSS). Percent weight loss of samples was expressed as the percentage of weight loss with respect to the initial weight. TSS was determined using an Abbe Refractometer (RSRT-1) following the procedures of AOAC (1995) and the results were expressed as °Brix.

Titratable acidity and pH. TA was determined following the procedures of AOAC (2012). Briefly, 5 g sample was diluted with 100 mL distilled water and filtered. From this, 10 mL of aliquot was taken and a few drops of phenolphthalein indicator were added. The solution was titrated against 0.1 N NaOH until pink colour appeared which persisted for 15 sec. The results were expressed as the percentage malic acid. pH of the samples was determined using a digital pH meter (Inolab WTW Series, Germany) according to the standard methods described by AOAC (2005).

Ascorbic acid (AA) content. Ascorbic acid was determined following the protocols of AOAC (2005) by titrating sample aliquot with 2, 6-dichlorophenolindophenol sodium salt solution.

Carotenoids. Carotenoids were estimated according to the method of Rodriguez-Amaya (1999) with some modifications. Briefly, 5 g sample was homogenized with 100 mL of methanol:petroleum ether (1:9, v/v) and the mixture was transferred to a separating funnel. Petroleum ether layer was filtered through sodium sulphate, transferred to a volumetric flask and the total volume was made up to 100 mL with petroleum ether. Finally, total carotenoid content was measured using spectrophotometer (CE-2021, 2000 series CECIL Instruments Cambridge, England) at 450 nm and the results were expressed as carotene equivalents (mg/100 g of dry weight).

Antioxidant activity and total phenolic content. Antioxidant activity (DPPH assay) of methanol extract of apricot samples was determined spectrophotometrically at a wavelength of 517 nm according to the method described by Matthaus (2002), which involved the use of free radical, 2,2, diphenyl 1-picrylhydrazyl (DPPH). The total phenolic content of the samples was estimated according to the procedures as described by Amin et al. (2017).

Color profile (L, a* and b*).* Color was measured at ten different points on the surface of apricot sample, with a colorimeter (Labscan II CR-400, Japan). The values were expressed in terms of lightness (L^*), redness (a*) and yellowness (b*) (Parmar et al., 2007).

Textural characteristics-bio-yield point and firmness. Textural properties of apricot samples were determined using a TA-XT2 Plus texture analyzer (Stable Micro Systems, Surrey, UK). Fruits were placed on the platform in such a way that the aluminium probe penetrated to 5 mm and 10 mm distance after touching the surface of fruit. The maximum force (g) required to puncture the fruit surface (skin) was recorded as bio-yield point while as, firmness represents the force required by the probe to travel 5 mm or 10 mm distance inside the fruit. The loading speed was maintained at 10 mm/min and the compression disc of 50 mm diameter was used for the study.

Chilling injury (CI) index. The extent of chilling injury in control and treated samples during CA storage was assessed using chilling injury (CI) index. CI index used is based on a 4-point hedonic scale that takes into account the percentage of surface affected by CI symptoms (dehydration, browning and pitting etc.) (Sayyari

et al., 2009). The values of 0, 1, 2 and 3 reflect no symptom of chilling injury, 1-25% of the damaged area, 26–50% of the damaged area and ≥51% of the damaged area, respectively. CI index was calculated using the following equation (2)

$$\text{CI index} = \frac{\left(\sum \text{Value of hedonic scale} \times \text{number of fruits with corresponding scale number} \right)}{(4 \times \text{total number of fruits})} \quad (2)$$

Statistical analysis. All of the readings were taken as average of triplicates and the results were represented as mean±standard deviation. Source of variation were storage time (0, 10, 20, 30 days) and postharvest (OA and SA) treatments. Data was analyzed by analysis of variance (ANOVA) using SAS software (version 9.1). Mean comparisons were performed using least significant difference (LSD) tests at $p \leq 0.05$ level.

RESULTS AND DISCUSSIONS

Decay percentage

The percent decay in apricot samples treated with OA and SA was lower after 10 days of CA storage compared to the control that was moderately decayed. Incidence of decay was more pronounced after 20 days of storage, however, it was significantly ($p < 0.05$) lower in OA and SA- treated apricots compared to control. The percentage decay in control samples of different apricot varieties were 50% in *rival*, 60% in *harcot*, 70% in *new-castener* and 90% in *erani*. The study further revealed that OA was much effective in reducing the decay percentage compared to SA (Table 1). Furthermore, minimum decay percentage was reported in OA treated *rival* variety ($30 \pm 0.07\%$) during the storage period. OA and SA create acidic conditions over fruit surface, thereby making conditions unfavourable for micro-organisms to grow (Amborabe et al., 2002). The role of SA in controlling fungal decay may also be due to the activation of antioxidant defence response (Xu and Tian, 2008) in fruits or due to its direct antifungal effect (Amborabe et al., 2002).

Percent weight loss and total soluble solids (TSS)

Visual appearance, being the main quality parameters for marketing of apricots, is greatly affected by weight loss during the storage period. The results revealed the significant ($p < 0.05$) effect of CA storage on weight loss of apricot samples which progressively increased with the increase in storage period (Table 1). It was observed from the results that more weight loss occurred in control compared to the treated samples with highest weight loss reported in control of *harcot* variety ($7.90 \pm 0.03\%$). Amongst the treated samples, the highest weight loss ($4.90 \pm 0.04\%$) was observed in SA treated *erani* ($4.90 \pm 0.04\%$), whereas the lowest weight loss ($3.40 \pm 0.03\%$) was found in OA treated *rival* variety. Weight loss in fruits is mainly associated with the respiration and evaporation of moisture through skin. The thin skin of apricot fruits makes them susceptible to rapid loss of water, resulting in shrivelling and deterioration (Bin et al., 2014). The lower weight loss in treated samples is attributed to the stabilization or maintenance of cell integrity and permeability of tissues by these treatments (Mirdehghan et al., 2007). The suppressing effect of treatments on metabolic activity of fruit is also responsible for lower weight losses (Nanda et al., 2001).

The effect of storage time on TSS of both treated and control samples were statistically ($p \leq 0.05$) significant. TSS decreased significantly ($p \leq 0.05$) with storage amongst all the samples (Table 1). However, the decrease in TSS of OA- and SA- treated samples was significantly ($p \leq 0.05$) lower than that in control (Table 1). The lowering of TSS is believed to be due to the utilization of sugars during respiration (Ramesh et al., 2016). The anti-senescence effect of OA and SA is believed to help in the retention of TSS (Ahmad et al., 2013). Due to this anti-senescence effect, respiration rate lowers during storage which further decreases the production and utilization of metabolites resulting in the retention of TSS (Yaman and Bayoındırlı, 2002). The study reported maximum retention of TSS (11 ± 0.09 °B) in OA-treated *rival* variety. Retention of TSS in apricots and mango after OA treatment has also been reported by Koyuncu et al. (2018) and Zheng et al. (2007a), respectively.

Titratable acidity (TA) and pH

Titratable acidity (TA) and pH are directly related to the organic acid content present in fruit and are important factors in maintaining the quality of fruits. TA of control and treated samples, regardless of the treatments, decreased significantly ($p < 0.05$) over the storage period (Table 2). However, during the storage period, more decrease in TA was reported in control of all the varieties compared to treated ones. The lowest TA value was observed in control of *rival* variety ($0.12 \pm 0.03\%$). It is generally believed that the organic acids are used as substrates for glycolysis and tricarboxylic acid cycle pathway during fruit ripening (Diaz-Mula et al., 2009; Valero et al., 2011). Since OA- and SA-treatments delayed ripening process of apricots

Table 1. Effect of pretreatments on percentage decay, percent weight loss, and total soluble solid of different apricot varieties during CA storage.

		Storage			
Variety	Treatment	Day 0	Day 10	Day 20	Day 30
Percentage decay (%)					
Rival	Control	0 ± 0.00aA	20 ± 0.10bA	50 ± 0.17cA	50 ± 0.20cA
	Oxalic acid	0 ± 0.00aA	2 ± 0.07bB	10 ± 0.04cB	30 ± 0.07 dB
	Salicylic acid	0 ± 0.00aA	5 ± 0.09**bC**	20 ± 0.10cC	40 ± 0.12dC
Harcot	Control	0 ± 0.00aA	30 ± 0.13bA	60 ± 0.18cA	60 ± 0.21cA
	Oxalic acid	0 ± 0.00aA	3 ± 0.00bB	20 ± 0.08cB	40 ± 0.09 dB
	Salicylic acid	0 ± 0.00aA	10 ± 0.09bC	30 ± 0.09cC	50 ± 0.10dC
New castener	Control	0 ± 0.00aA	40 ± 0.21bA	70 ± 0.25cA	70 ± 0.28dA
	Oxalic acid	0 ± 0.00aA	10 ± 0.04bB	30 ± 0.14cB	60 ± 0.21 dB
	Salicylic acid	0 ± 0.00aA	20 ± 0.10bC	50 ± 0.17cC	70 ± 0.25dC
Erani	Control	0 ± 0.00aA	60 ± 0.24bA	90 ± 0.23cA	90 ± 0.27dA
	Oxalic acid	0 ± 0.00aA	20 ± 0.17bB	55 ± 0.08cB	70 ± 0.30 dB
	Salicylic acid	0 ± 0.00aA	20 ± 0.24bC	60 ± 0.20cC	72 ± 0.32dC
Percent weight loss (%)					
Rival	Control	0 ± 0.02aA	3 ± 0.03bA	6 ± 0.03cA	7.2 ± 0.03dA
	Oxalic acid	0 ± 0.02aA	1.5 ± 0.02bB	2.3 ± 0.03cB	3.4 ± 0.03 dB
	Salicylic acid	0 ± 0.02aA	1.8 ± 0.05bC	3.1 ± 0.04cC	4.2 ± 0.05dC
Harcot	Control	0 ± 0.01aA	4.4 ± 0.03bA	5.6 ± 0.05cA	7.9 ± 0.03dA
	Oxalic acid	0 ± 0.01aA	1.6 ± 0.02bB	2.2 ± 0.03cB	4.3 ± 0.04 dB
	Salicylic acid	0 ± 0.01aA	1.2 ± 0.03bC	3.4 ± 0.03cC	4.45 ± 0.05dC
New castener	Control	0 ± 0.03aA	3.1 ± 0.04bA	4.4 ± 0.03cA	6.6 ± 0.03dA
	Oxalic acid	0 ± 0.03aA	2.1 ± 0.04bB	3.1 ± 0.05cB	4.3 ± 0.03 dB
	Salicylic acid	0 ± 0.03aA	0.9 ± 0.02bC	1.4 ± 0.04cC	3.5 ± 0.06dC
Erani	Control	0 ± 0.01aA	2.3 ± 0.03bA	3.4 ± 0.04cA	5.5 ± 0.03dA
	Oxalic acid	0 ± 0.01aA	1.3 ± 0.02bB	2.3 ± 0.03cB	4.5 ± 0.02 dB
	Salicylic acid	0 ± 0.01aA	1.2 ± 0.02bC	3.2 ± 0.02cC	4.9 ± 0.04dC
Total soluble solids (oB)					
Rival	Control	12 ± 0.21aA	10 ± 0.08bA	9 ± 0.05cA	8 ± 0.05dA
	Oxalic acid	12 ± 0.21aA	11 ± 0.07bB	11 ± 0.06bB	11 ± 0.09bB
	Salicylic acid	12 ± 0.21aA	11 ± 0.04bC	11 ± 0.07cC	10 ± 0.05dC
Harcot	Control	9 ± 0.06aA	11 ± 0.08bA	10 ± 0.04cA	9 ± 0.07dA
	Oxalic acid	9 ± 0.06aA	11 ± 0.10bB	10 ± 0.09cA	10 ± 0.04 dB
	Salicylic acid	9 ± 0.06aA	11 ± 0.07bC	11 ± 0.10cB	10 ± 0.02 dB
New castener	Control	10 ± 0.04aA	10 ± 0.03bA	9 ± 0.05cA	8 ± 0.35dA
	Oxalic acid	10 ± 0.04aA	11 ± 0.06bB	10 ± 0.04cB	10 ± 0.03cB
	Salicylic acid	10 ± 0.04aA	11 ± 0.07bC	10 ± 0.08cB	9 ± 0.03dC
Erani	Control	10 ± 0.06aA	9 ± 0.02bA	8 ± 0.01cA	7 ± 0.05dA
	Oxalic acid	10 ± 0.06aA	10 ± 0.02bB	9 ± 0.02cB	9 ± 0.05cB
	Salicylic acid	10 ± 0.06aA	9 ± 0.03bC	9 ± 0.04cB	9 ± 0.01cB

Results are expressed as Means ± standard deviation. Values with different alphabetical letters (small letters, a to d) within columns differ significantly ($p \leq 0.05$), representing the effect of storage period. Values with different alphabetical letters (capital letters, A to C) within rows, for each variety, differ significantly ($p \leq 0.05$), representing the effect of oxalic and salicylic acid during storage period.

(Gimenez et al., 2017), their TA was found to be higher than the control. Amongst the treated samples, OA-treated *new castener* recorded highest TA of 0.39 ± 0.03%. Similar results were reported by Koyuncu et al. (2018) for OA- treated apricots. Diaz-Mula et al. (2009) and Serrano et al. (2003) also reported similar results for OA-treated plums.

The pH of control and the treated samples increased significantly ($p < 0.05$) over the storage period, regardless of the treatments (Table 2). During storage, the highest pH of 4.90 ± 0.03 was recorded in control of new *castener* and lowest in OA-treated *erani* (3.60 ± 0.02). Similar findings have been reported by Zokaee Khosroshahi and Esna-Ashari (2007) for apricots and peaches. During storage, the rate of respiration was found higher in control than the treated samples. Higher respiration rate in control may have demanded the use of organic acids thereby decreasing their

Table 2. Effect of pretreatments on the titratable acidity TA (%), pH and ascorbic acid (AA) (mg/100g) of different apricot varieties during CA storage.

		Storage			
Variety	Treatment	Day 0	Day 10	Day 20	Day 30
Titratable acidity TA (%)					
Rival	Control	0.35 ± 0.02aA	0.25 ± 0.01bA	0.17 ± 0.03cA	0.12 ± 0.03dA
	Oxalic acid	0.35 ± 0.02aA	0.34 ± 0.02bB	0.30 ± 0.03cB	0.22 ± 0.01dB
	Salicylic acid	0.35 ± 0.02aA	0.33 ± 0.03bC	0.25 ± 0.02cC	0.19 ± 0.01dC
Harcot	Control	0.68 ± 0.06aA	0.49 ± 0.04bA	0.22 ± 0.02cA	0.17 ± 0.03dA
	Oxalic acid	0.68 ± 0.06aA	0.59 ± 0.03bB	0.44 ± 0.01cB	0.30 ± 0.01dB
	Salicylic acid	0.68 ± 0.06aA	0.52 ± 0.03bC	0.39 ± 0.02cC	0.29 ± 0.04dB
New castener	Control	0.63 ± 0.03aA	0.46 ± 0.01bA	0.29 ± 0.02cA	0.17 ± 0.05dA
	Oxalic acid	0.63 ± 0.03aA	0.56 ± 0.04bB	0.44 ± 0.01cB	0.39 ± 0.03dB
	Salicylic acid	0.63 ± 0.03aA	0.52 ± 0.05bC	0.48 ± 0.02cC	0.38 ± 0.02dB
Erani	Control	0.66 ± 0.04aA	0.52 ± 0.04bA	0.32 ± 0.01cA	0.27 ± 0.03dA
	Oxalic acid	0.66 ± 0.04aA	0.54 ± 0.07bB	0.44 ± 0.02cB	0.36 ± 0.04dB
	Salicylic acid	0.66 ± 0.04aA	0.57 ± 0.08bC	0.41 ± 0.01cC	0.32 ± 0.03dC
pH					
Rival	Control	3.4 ± 0.02aA	3.6 ± 0.03bA	4.2 ± 0.03cA	4.6 ± 0.03dA
	Oxalic acid	3.4 ± 0.02aA	3.6 ± 0.02bA	3.7 ± 0.03cB	3.8 ± 0.03 dB
	Salicylic acid	3.4 ± 0.02aA	3.5 ± 0.05bB	3.6 ± 0.04cC	3.7 ± 0.05dC
Harcot	Control	3.2 ± 0.01aA	3.4 ± 0.03bA	3.9 ± 0.05cA	4.2 ± 0.23dA
	Oxalic acid	3.2 ± 0.01aA	3.4 ± 0.02bA	3.6 ± 0.03cB	3.7 ± 0.04 dB
	Salicylic acid	3.2 ± 0.01aA	3.4 ± 0.03bA	3.5 ± 0.03cC	3.7 ± 0.05 dB
New castener	Control	3.8 ± 0.03aA	4.1 ± 0.04bA	4.4 ± 0.03cA	4.9 ± 0.03dA
	Oxalic acid	3.8 ± 0.03aA	3.9 ± 0.04bB	4.0 ± 0.05cB	4.2 ± 0.03 dB
	Salicylic acid	3.8 ± 0.03aA	3.9 ± 0.02bB	4.1 ± 0.04cC	4.2 ± 0.06dC
Erani	Control	3.1 ± 0.01aA	3.7 ± 0.03bA	4.2 ± 0.04cA	3.7 ± 0.03dA
	Oxalic acid	3.1 ± 0.01aA	3.3 ± 0.02bA	3.5 ± 0.03cB	3.6 ± 0.02 dB
	Salicylic acid	3.1 ± 0.01aA	3.4 ± 0.02bC	3.6 ± 0.02cC	3.8 ± 0.04dC
Ascorbic acid (AA) (mg/100g)					
Rival	Control	54.96 ± 0.10aA	58.96 ± 0.03bA	39.12 ± 0.09cA	35.12 ± 0.09dA
	Oxalic acid	54.96 ± 0.10aA	60.14 ± 0.14bB	55.16 ± 0.08cB	48.02 ± 0.05 dB
	Salicylic acid	54.96 ± 0.10aA	60.07 ± 0.02bB	54.63 ± 0.11cC	45.13 ± 0.05dC
Harcot	Control	56.21 ± 0.05aA	59.95 ± 0.04bA	38.82 ± 0.09cA	34.12 ± 0.09dA
	Oxalic acid	56.21 ± 0.05aA	62.81 ± 0.21bB	54.71 ± 0.01cB	47.20 ± 0.02 dB
	Salicylic acid	56.21 ± 0.05aA	61.23 ± 0.06bC	52.08 ± 0.04cC	46.71 ± 0.04dC
New castener	Control	55.71 ± 0.03aA	59.54 ± 0.07bA	34.18 ± 0.08cA	32.12 ± 0.09dA
	Oxalic acid	55.71 ± 0.03aA	61.71 ± 0.02bB	54.87 ± 0.11cB	48.09 ± 0.09 dB
	Salicylic acid	55.71 ± 0.03aA	60.20 ± 0.03bC	53.60 ± 0.04cC	46.61 ± 0.07dC
Erani	Control	57.81 ± 0.13aA	58.81 ± 0.08bA	32.12 ± 0.02cA	30.12 ± 0.09dA
	Oxalic acid	57.81 ± 0.13aA	62.71 ± 0.12bB	52.14 ± 0.09cB	47.02 ± 0.05 dB
	Salicylic acid	57.81 ± 0.13aA	60.71 ± 0.11bC	50.71 ± 0.05cC	43.12 ± 0.04dC

Results are expressed as Means ± standard deviation. Values with different alphabetical letters (small letters, a to d) within columns differ significantly ($p \leq 0.05$), representing the effect of storage period. Values with different alphabetical letters (capital letters, A to C) within rows, for each variety, differ significantly ($p \leq 0.05$), representing the effect of oxalic and salicylic acid during storage period.

content in fruit, leading to an increase in pH (Diaz-Mula et al., 2009).

Ascorbic acid (AA) content

The effects of treatments on ascorbic acid during storage period are given in Table 2. AA content increased up to 10th day of storage, thereafter decreased until 30th day for both control and treated samples. Initially, the increase in ascorbic acid content of all the samples is due to the increase in ripening process as ascorbic acid is synthesized from uronic acid components of pectin degradation during ripening (Hegedus et al., 2011). The decrease in AA after 10th day of storage was higher in control. Our results corroborated well with the findings of Barman et al. (2014), in which a significant decrease in AA content of pomegranates has been reported during storage. The

decrease in AA during storage is ascribed to the conversion of dehydroascorbic acid to diketogulonic acid by oxidation (Ishaq et al., 2009). Similar findings were reported by Cao et al. (2009) in cucumber. Amongst the treated samples, more retention of AA was observed in OA- treated *new castener* variety (48.09 ± 0.09 mg/100g). The positive influence of SA and OA on AA retention during storage is due to their action against ascorbic acid oxidase (AAO) enzyme thereby, inhibiting its activity (Rao et al., 2011).

Carotenoids

Carotenoids possess antioxidant activity since these scavenge free radicals and thus provide health benefits (Leccese et al., 2011). Apricots contain sufficient amount of carotenoids that confer yellow orange color to the plant tissues, therefore, largely contribute to their visual quality (Mazza and Miniati, 1993). Results indicate more increase in carotenoid content in control of all the varieties compared to the treated samples (Table 3). This may be due to the higher rates of ripening in control samples and thus respiration, resulting in tissue softening thereby releasing pigments like carotenoids from cell structure (Oszmianski et al., 2011). Since ripening process was delayed in OA and SA-treated samples therefore, a lower increase in carotenoids while storage was observed in them. The more profound effect was reported in OA-treated *erani variety* compared to SA treated samples.

Total phenolic content (TPC) and antioxidant activity (DPPH assay)

Phenols possess free radical scavenging activity and also contribute to nutritional quality attributes of fruits and vegetables (Mushtaq and Wani, 2013). Storage period significantly ($p < 0.05$) affected TPC and antioxidant activity of samples (Tables 3). The results revealed that both OA and SA treatments significantly ($p < 0.05$) retained total phenolic contents with OA treated samples retaining higher TPCs than SA-treated samples. However, amongst the varieties, SA-treated *rival* variety had higher TPC (62.67 ± 0.18 mg GAE/100g) while as lower TPC was reported in control of *harcot* variety (43.41 ± 0.06 mg GAE/100g). Perez-Tortosa et al. (2012) have also reported the retention of TPC when SA was applied on thymus membrane shoots. Wang et al. (2009) have also reported the retention of total phenols and thus antioxidant activity in apricot fruit by application of exogenous salicylic acid.

Apricots are embodied with a wide variety of phytochemicals (phenols, carotenoids and ascorbic acid) that attribute to antioxidant activity. The DDPH radical scavenging activity of different apricot varieties was found to be significantly ($p \leq 0.05$) different amongst the selected apricot varieties (Table 3). The antioxidant activity of all the samples increased until 10th day of storage, thereafter it started to decrease. This increase up to 10th day of storage is due to the existence of natural antioxidants which in turn is ascribed to their hydrogen donating ability (Hajaji et al., 2010). At the end of the storage, the highest antioxidant activity was observed in *new castener* variety treated with OA (77.01 ± 0.17%) and lowest in the control of *harcot* (50.41 ± 0.16%). The less decrease in antioxidant activity of treated samples compared to control may be ascribed to the retention of phenolic compounds and ascorbic acid in treated samples. According to Mirdehghan and Rahimi (2016), the total antioxidant activity is highly correlated with total phenolic of fruits. Similar findings were reported by Sun et al. (2012) in Chinese kale.

Color profile

Skin color influences the consumer demand and is a very important quality parameter for determining the overall acceptability of apricots. The effects of OA and SA treatments on apricot skin color are given in Table 4. Lightness (L^*) decreased significantly ($p < 0.05$) during the storage period for both control and treated samples. OA-treated *new-castener* variety exhibited highest L^* value (18.48 ± 0.09) and lowest was shown by the control of *rival* (12.72 ± 0.01). Both OA and SA resulted in the retention of L^* values with the former retaining more. OA and SA treatments inhibit the degradation of chlorophyll and other pigments, thus preserving the skin color (Dokhanieh et al., 2013). However, more loss in lightness of control is related to higher water loss owing to more respiration during storage, compared to treated samples.

The a* value increased significantly ($p < 0.05$) with the storage duration, with control of *new-castener* variety having the highest value (26.11 ± 0.2). However, amongst the treated samples, highest a* value was found to be 23.15 ± 0.02 for OA treated *erani* and highest b* value of 41.61 ± 0.24 was reported in control of *new-castener*. The more increase in color values of control to dark reddish yellow have been associated with an increased ripening rate in apricots (Goncalves et al., 2004). However, the gradual increase in a* and b* values in treated samples was recorded due to the combined effect of the OA and SA on the rate of respiration that resulted in the delayed ripening of samples (Serrano et al., 2009). Our results corroborate well with the results of Koyuncu et al. (2018) for pomegranate.

Table 3. Effect of pretreatments on carotenoid content (mg/100 gm), total phenolic content (mg GAE/100g) and DPPH (%) of different apricot varieties during CA storage.

		Storage			
Variety	Treatment	Day 0	Day 10	Day 20	Day 30
Carotenoid content (mg/100 g)					
Rival	Control	13 ± 0.02aA	14 ± 0.03bA	15 ± 0.03cA	16.2 ± 0.03dA
	Oxalic acid	13 ± 0.02aA	13.5 ± 0.02bB	13.3 ± 0.3cB	13.8 ± 0.03 dB
	Salicylic acid	13 ± 0.02aA	13.6 ± 0.05bC	13.9 ± 0.04cC	14.1 ± 0.05dC
Harcot	Control	12 ± 0.01aA	14.4 ± 0.03bA	14.9 ± 0.05cA	15.1 ± 0.03dA
	Oxalic acid	12 ± 0.01aA	12.6 ± 0.02bB	12.9 ± 0.03cB	13.7 ± 0.04 dB
	Salicylic acid	12 ± 0.01aA	12.3 ± 0.03bC	13.4 ± 0.03cC	13.9 ± 0.05dC
New castener	Control	14 ± 0.03aA	15.1 ± 0.04bA	15.8 ± 0.03cA	16.6 ± 0.03dA
	Oxalic acid	14 ± 0.03aA	14.6 ± 0.04bB	15.1 ± 0.05cB	15.3 ± 0.03 dB
	Salicylic acid	14 ± 0.03aA	14.4 ± 0.02bC	14.9 ± 0.04cC	15.2 ± 0.06dC
Erani	Control	11 ± 0.01aA	12.3 ± 0.03bA	13.4 ± 0.04cA	15.5 ± 0.03dA
	Oxalic acid	11 ± 0.01aA	11.9 ± 0.02bB	12.3 ± 0.03cB	12.8 ± 0.02 dB
	Salicylic acid	11 ± 0.01aA	12 ± 0.02bC	12.9 ± 0.02cC	13.9 ± 0.04dC
Total phenolic content (mg GAE/100 g)					
Rival	Control	66.02 ± 0.13aA	61.06 ± 0.17bA	49.41 ± 0.10cA	46.42 ± 0.10dA
	Oxalic acid	66.02 ± 0.13aA	67.81 ± 0.25bB	63.44 ± 0.52cB	61.73 ± 0.32 dB
	Salicylic acid	66.02 ± 0.13aA	68.08 ± 0.44bC	64.59 ± 0.28cC	62.67 ± 0.18dC
Harcot	Control	67.91 ± 0.32aA	68.45 ± 0.20bA	53.41 ± 0.16cA	43.41 ± 0.06dA
	Oxalic acid	67.91 ± 0.32aA	65.20 ± 0.31bB	63.30 ± 0.25cB	60.24 ± 0.52 dB
	Salicylic acid	67.91 ± 0.32aA	64.91 ± 0.45bC	61.15 ± 0.65cC	58.36 ± 0.13dC
New castener	Control	62.71 ± 0.52aA	64.13 ± 0.34bA	50.98 ± 0.11cA	46.98 ± 0.11dA
	Oxalic acid	62.71 ± 0.52aA	65.72 ± 0.28aB	59.91 ± 0.37cB	55.01 ± 0.17 dB
	Salicylic acid	62.71 ± 0.52aA	64.14 ± 0.19bC	57.87 ± 0.30cC	53.43 ± 0.27dC
Erani	Control	70.60 ± 0.42aA	68.71 ± 0.81bA	53.87 ± 0.54cA	45.87 ± 0.54dA
	Oxalic acid	70.60 ± 0.42aA	74.71 ± 0.79bB	64.06 ± 0.62cB	60.41 ± 0.47 dB
	Salicylic acid	70.60 ± 0.42aA	72.83 ± 0.90bC	64.40 ± 0.75cC	62.06 ± 0.33dC
DPPH (%)					
Rival	Control	86.02 ± 0.13aA	87.06 ± 0.17bA	58.41 ± 0.10cA	54.41 ± 0.10dA
	Oxalic acid	86.02 ± 0.13aA	90.81 ± 0.25bB	84.44 ± 0.52cB	72.73 ± 0.32 dB
	Salicylic acid	86.02 ± 0.13aA	89.08 ± 0.44bC	80.59 ± 0.28cC	68.67 ± 0.18dC
Harcot	Control	84.91 ± 0.32aA	85.45 ± 0.20bA	53.41 ± 0.16cA	50.41 ± 0.16dA
	Oxalic acid	84.91 ± 0.32aA	88.20 ± 0.31bB	79.30 ± 0.25cB	71.24 ± 0.52 dB
	Salicylic acid	84.91 ± 0.32aA	85.91 ± 0.45bC	76.15 ± 0.65cC	66.36 ± 0.13dC
New castener	Control	87.71 ± 0.52aA	88.13 ± 0.34bA	59.98 ± 0.11cA	57.98 ± 0.11dA
	Oxalic acid	87.71 ± 0.52aA	90.72 ± 0.28bB	83.91 ± 0.37cB	77.01 ± 0.17 dB
	Salicylic acid	87.71 ± 0.52aA	89.14 ± 0.19bC	80.87 ± 0.30cC	76.43 ± 0.27dC
Erani	Control	89.60 ± 0.42aA	91.71 ± 0.81bA	60.87 ± 0.54cA	53.27 ± 0.54dA
	Oxalic acid	89.60 ± 0.42aA	94.71 ± 0.79bB	80.06 ± 0.62cB	73.41 ± 0.47 dB
	Salicylic acid	89.60 ± 0.42aA	92.83 ± 0.90bC	79.40 ± 0.75cC	69.06 ± 0.33dC

Results are expressed as Means ± standard deviation. Values with different alphabetical letters (small letters, a to d) within columns differ significantly ($p \leq 0.05$), representing the effect of storage period. Values with different alphabetical letters (capital letters, A to C) within rows, for each variety, differ significantly ($p \leq 0.05$), representing the effect of oxalic and salicylic acid during storage period.

Texture characteristics-bio-yield point and firmness

Most of the fruits lose firmness and soften as the ripening process accelerates resulting in the loss of quality during storage. The textural properties (bio-yield point and firmness) of samples are presented in Table 5. Bio-yield point of all the samples, control as well as treated apricots, decreased significantly ($p < 0.05$) with storage. However, the bio-yield point and flesh firmness of treated samples was retained more compared to control during CA storage. OA-treated *rival* variety exhibited maximum bio-yield point of 692.21 ± 1.19 g in comparison to SA-treated samples. Lowest bio-yield point was reported in control of *new castener* (336.17 ± 2.87 g).

While looking at the firmness values (Table 5), OA-treated *rival* variety exhibited highest firmness value

Table 4. Effect of pretreatments on color profile (*L**, *a** and *b**) of different apricot varieties during CA storage.

		Storage			
Variety	Treatment	Day 0	Day 10	Day 20	Day 30
*L** values					
Rival	Control	54.70 ± 0.23aA	43.68 ± 0.05bA	33.76 ± 0.01cA	12.72 ± 0.01dA
	Oxalic acid	54.70 ± 0.23aA	48.58 ± 0.08bB	35.94 ± 0.05cB	18.12 ± 0.10dB
	Salicylic acid	54.70 ± 0.23aA	47.21 ± 0.03bC	37.41 ± 0.26cC	17.77 ± 0.10dC
Harcot	Control	53.11 ± 0.15aA	42.71 ± 0.40bA	31.77 ± 0.12cA	11.76 ± 0.01dA
	Oxalic acid	53.11 ± 0.15aA	47.92 ± 0.05bB	34.09 ± 0.06cB	16.95 ± 0.20dB
	Salicylic acid	53.11 ± 0.15aA	46.79 ± 0.02bC	32.36 ± 0.12cC	14.34 ± 0.20dC
New castener	Control	52.50 ± 0.18aA	42.45 ± 0.04bA	31.47 ± 0.26cA	12.76 ± 0.01dA
	Oxalic acid	52.50 ± 0.18aA	49.45 ± 0.15bB	36.99 ± 0.06cB	18.48 ± 0.09dB
	Salicylic acid	52.50 ± 0.18aA	46.39 ± 0.27bC	36.41 ± 0.03cC	18.36 ± 0.01dC
Erani	Control	53.70 ± 0.20aA	43.20 ± 0.21bA	30.92 ± 0.08cA	11.76 ± 0.01dA
	Oxalic acid	53.70 ± 0.20aA	47.37 ± 0.02bB	33.63 ± 0.12cB	16.26 ± 0.10dB
	Salicylic acid	53.70 ± 0.20aA	48.92 ± 0.16bC	34.46 ± 0.07cC	14.36 ± 0.03dC
*a** values					
Rival	Control	10.93 ± 0.03aA	15.23 ± 0.02bA	21.45 ± 0.02cA	24.45 ± 0.2dA
	Oxalic acid	10.93 ± 0.03aA	11.25 ± 0.04bB	18.40 ± 0.01cB	21.24 ± 0.2 dB
	Salicylic acid	10.93 ± 0.03aA	12.96 ± 0.01bC	19.22 ± 0.01cC	20.20 ± 0.5dC
Harcot	Control	7.32 ± 0.04aA	17.46 ± 0.02bA	20.73 ± 0.04cA	25.25 ± 0.2dA
	Oxalic acid	7.32 ± 0.04aA	12.51 ± 0.01bB	16.00 ± 0.02cB	19.14 ± 0.3 dB
	Salicylic acid	7.32 ± 0.04aA	13.39 ± 0.02bC	17.62 ± 0.01cC	20.04 ± 0.4dC
New castener	Control	10.38 ± 0.02aA	13.75 ± 0.05bA	23.62 ± 0.01cA	26.11 ± 0.2dA
	Oxalic acid	10.38 ± 0.02aA	12.63 ± 0.02bB	19.34 ± 0.02cB	19.18 ± 0.3 dB
	Salicylic acid	10.38 ± 0.02aA	12.89 ± 0.01bC	20.31 ± 0.03cC	21.81 ± 0.2dC
Erani	Control	7.97 ± 0.03aA	16.32 ± 0.03bA	22.46 ± 0.06cA	25.49 ± 0.2dA
	Oxalic acid	7.97 ± 0.03aA	15.14 ± 0.04bB	21.61 ± 0.02cB	23.15 ± 0.2 dB
	Salicylic acid	7.97 ± 0.03aA	14.09 ± 0.02bC	19.40 ± 0.01cC	22.27 ± 0.3dC
*b** values					
Rival	Control	26.88 ± 0.14aA	31.45 ± 0.20bA	34.31 ± 0.24cA	38.31 ± 0.24dA
	Oxalic acid	26.88 ± 0.14aA	29.63 ± 0.08bB	31.07 ± 0.31cB	33.98 ± 0.32 dB
	Salicylic acid	26.88 ± 0.14aA	28.79 ± 0.10bC	32.42 ± 0.15cC	33.16 ± 0.09dC
Harcot	Control	27.69 ± 0.09aA	32.71 ± 0.28bA	38.16 ± 0.16cA	40.31 ± 0.24dA
	Oxalic acid	27.69 ± 0.09aA	28.96 ± 0.02bB	32.43 ± 0.41cB	34.36 ± 0.21 dB
	Salicylic acid	27.69 ± 0.09aA	29.88 ± 0.17bC	33.25 ± 0.05cC	35.84 ± 0.34dC
New castener	Control	25.98 ± 0.11aA	33.18 ± 0.18bA	38.36 ± 0.23cA	41.61 ± 0.24dA
	Oxalic acid	25.98 ± 0.11aA	28.95 ± 0.41bB	33.66 ± 0.07cB	36.10 ± 0.13 dB
	Salicylic acid	25.98 ± 0.11aA	29.09 ± 0.16bC	34.42 ± 0.32cC	37.25 ± 0.40dC
Erani	Control	27.25 ± 0.12aA	32.61 ± 0.20bA	37.96 ± 0.36cA	41.31 ± 0.24dA
	Oxalic acid	27.25 ± 0.12aA	29.58 ± 0.16bB	33.64 ± 0.25cB	35.28 ± 0.27 dB
	Salicylic acid	27.25 ± 0.12aA	29.96 ± 0.10bC	34.69 ± 0.09cC	37.51 ± 0.13dC

Results are expressed as Means ± standard deviation. Values with different alphabetical letters (small letters, a to d) within columns differ significantly ($p \leq 0.05$), representing the effect of storage period. Values with different alphabetical letters (capital letters, A to C) within rows, for each variety, differ significantly ($p \leq 0.05$), representing the effect of oxalic and salicylic acid during storage period.

(208.98 ± 1.16 g) compared to SA-treated samples. The lowest value of firmness was shown by the control of *new castener* variety (114.26 ± 1.42 g). Previous studies on apricots (Koyuncu et al., 2018), peach (Razavi and Hajilou, 2016; Zheng et al., 2007b) and mango (Zheng et al., 2007a) have also advocated the ability of OA in maintaining the flesh firmness, delaying softening and extending the postharvest life of fruit. The firming effect of OA and SA treatments could be ascribed to the delaying effect on peak activity of cell wall loosening enzyme expansion and hydrolyzing enzyme (polygalactouronase and pectin methyl esterase) (Kant et al., 2013). Similar results have been reported by Zheng (2007b) for peach, Zheng et al. (2007a) for mango and Wang et al. (2009) for *jujube*. The results further indicate that the firming effect is accompanied by improved water holding capacity due to a more cross-linked pectin network and decreased pectin

Table 5. Effect of pretreatments on bio-yield (g), firmness (g) and chilling injury (CI index) of different apricot varieties during CA storage.

		Storage			
Variety	Treatment	Day 0	Day 10	Day 20	Day 30
Bio-yield (g)					
Rival	Control	994.87 ± 3.89aA	781.21 ± 2.26bA	536.17 ± 2.87cA	506.17 ± 2.87dA
	Oxalic acid	994.87 ± 3.89aA	884.74 ± 1.87bB	726.80 ± 2.19cB	692.21 ± 1.19dB
	Salicylic acid	994.87 ± 3.89aA	810.43 ± 1.94bC	716.44 ± 2.67cC	611.14 ± 1.27dC
Harcot	Control	925.10 ± 2.86aA	604.37 ± 2.17bA	489.16 ± 2.74cA	436.17 ± 2.87dA
	Oxalic acid	925.10 ± 2.86aA	844.09 ± 1.57bB	720.16 ± 3.32cB	687.95 ± 2.98dB
	Salicylic acid	925.10 ± 2.86aA	792.43 ± 1.95bC	689.53 ± 1.12cC	598.93 ± 1.69dC
New castener	Control	748.28 ± 2.71aA	587.98 ± 1.34bA	347.61 ± 1.05cA	336.17 ± 2.87dA
	Oxalic acid	748.28 ± 2.71aA	616.73 ± 1.09bB	534.45 ± 2.71cB	476.33 ± 1.87dB
	Salicylic acid	748.28 ± 2.71aA	608.91 ± 2.87bC	523.20 ± 2.02cC	449.82 ± 2.67dC
Erani	Control	898.10 ± 1.74aA	621.28 ± 1.98bA	476.10 ± 2.31cA	436.27 ± 2.87dA
	Oxalic acid	898.10 ± 1.74aA	873.80 ± 3.61bB	683.82 ± 1.89cB	553.14 ± 1.43dB
	Salicylic acid	898.10 ± 1.74aA	823.13 ± 2.61bC	622.91 ± 1.56cC	525.88 ± 2.71dC
Firmness (g)					
Rival	Control	379.50 ± 1.32aA	256.07 ± 1.87bA	164.96 ± 1.42cA	144.96 ± 1.42dA
	Oxalic acid	379.50 ± 1.32aA	301.61 ± 2.04bB	239.08 ± 2.41cB	208.98 ± 1.16 dB
	Salicylic acid	379.50 ± 1.32aA	291.80 ± 2.43bC	218.08 ± 2.12cC	195.37 ± 1.09dC
Harcot	Control	332.71 ± 1.09aA	218.81 ± 1.08bA	157.41 ± 1.15cA	144.96 ± 1.42dA
	Oxalic acid	332.71 ± 1.09aA	277.47 ± 2.09bB	228.01 ± 2.18cB	204.27 ± 1.06 dB
	Salicylic acid	332.71 ± 1.09aA	265.45 ± 1.11bC	214.62 ± 2.81cC	189.89 ± 2.09dC
New castener	Control	263.48 ± 2.65aA	178.80 ± 1.97bA	120.53 ± 1.03cA	114.26 ± 1.42dA
	Oxalic acid	263.48 ± 2.65aA	228.23 ± 1.98bB	192.16 ± 2.13cB	160.57 ± 1.43 dB
	Salicylic acid	263.48 ± 2.65aA	204.07 ± 1.13bC	187.03 ± 1.71cC	140.86 ± 2.13dC
Erani	Control	281.95 ± 1.09aA	198.08 ± 1.19bA	137.32 ± 1.54cA	124.96 ± 1.42dA
	Oxalic acid	281.95 ± 1.09aA	239.49 ± 2.07bB	203.41 ± 2.41cB	184.37 ± 1.08 dB
	Salicylic acid	281.95 ± 1.09aA	234.57 ± 2.17bC	198.63 ± 1.13cC	172.87 ± 1.67dC
Chilling injury (CI index)					
Rival	Control	0 ± 0.02aA	0.3 ± 0.03bA	0.6 ± 0.03cA	0.8 ± 0.03dA
	Oxalic acid	0 ± 0.02aA	0.1 ± 0.02bB	0.2 ± 0.03cB	0.4 ± 0.03 dB
	Salicylic acid	0 ± 0.02aA	0.1 ± 0.05bC	0.3 ± 0.04cC	0.4 ± 0.05dC
Harcot	Control	0 ± 0.01aA	0.4 ± 0.03bA	0.6 ± 0.05cA	0.9 ± 0.03dA
	Oxalic acid	0 ± 0.01aA	0.1 ± 0.02bB	0.2 ± 0.03cB	0.3 ± 0.04 dB
	Salicylic acid	0 ± 0.01aA	0.2 ± 0.03bC	0.4 ± 0.03cC	0.45 ± 0.05dC
New castener	Control	0 ± 0.03aA	0.1 ± 0.04bA	0.4 ± 0.03cA	0.5 ± 0.03dA
	Oxalic acid	0 ± 0.03aA	0.1 ± 0.04bB	0.1 ± 0.05cB	0.2 ± 0.03 dB
	Salicylic acid	0 ± 0.03aA	0.2 ± 0.02bC	0.4 ± 0.04cC	0.4 ± 0.06cC
Erani	Control	0 ± 0.01aA	0.3 ± 0.03bA	0.4 ± 0.04cA	0.5 ± 0.03dA
	Oxalic acid	0 ± 0.01aA	0.3 ± 0.02bB	0.3 ± 0.03cB	0.6 ± 0.02 dB
	Salicylic acid	0 ± 0.01aA	0.2 ± 0.02bC	0.2 ± 0.02cC	0.3 ± 0.04dC

Results are expressed as Means ± standard deviation. Values with different alphabetical letters (small letters, a to d) within columns differ significantly ($p \leq 0.05$), representing the effect of storage period. Values with different alphabetical letters (capital letters, A to C) within rows, for each variety, differ significantly ($p \leq 0.05$), representing the effect of oxalic and salicylic acid during storage period.

solubilisation. The firming effect of OA is attributed to maintaining membrane integrity and consequently increased cell turgor (Kant et al., 2013). Further, the reduction of fruit softening by the application of OA and SA can be ascribed to ACO (1-aminocyclopropane-1-carboxylic acid oxidase) activity inhibitory, and therefore on ACC (1-aminocyclopropane-1-carboxylic acid) conversion to ethylene Kazemi et al. (2011). The inhibition of fruit softening is also found to be associated with the decreased polygalacturonase (PG) and pectin methyl esterase (PME) activities thereby retarding pectin solubilization/degradation (Razavi and Hajilou, 2016).

Chilling injury (CI) index

The OA and SA-treated samples were least affected by chilling injury during the 30 days of storage (Table 5)

with minimum and maximum CI index values of 0.20 ± 0.03 in OA treated *new castener* and 0.60 ± 0.02 in OA treated *erani,* respectively. However, CI index for control were higher compared to treated samples, with highest value reported in *harcot* (0.90 ± 0.03). SA treatments boost membrane fluidity of cells thereby diminishing their tendency to phase transition from flexible liquid-crystalline to rigid sol-gel stages, resulting in improved resistance of cells against CI (Aghdam et al., 2016). It has also been reported that OA and SA treatments enhance arginine pathway which results in the accumulation of signalling molecules (polyamines) with pivotal roles in chilling tolerance (Jubault et al., 2008). Generally, CI occurs primarily at the cell membrane and changes fatty acid phospholipid composition (Lurie et al., 1987; Stainley, 1991). This membrane damage initiates a cascade of secondary reactions leading to the distribution of cell structures (Ezzat et al., 2017).

CONCLUSION

The results of this study envisaged that OA and SA treatments contributed to maintaining the quality attributes of apricot varieties, relative to the control, during CA storage. Moreover, OA treatment was found to be much effective in retaining the firmness and delaying the decay percentage of apricots compared to SA treatment, during CA storage. Since OA and SA are generally recognized as safe (GRAS), their application to the fruit crop will not pose any threat to the humans. The use of such biological compounds retard the chilling injury and respiration rate of stored crop thereby making the applications of OA and SA treatments as a promising postharvest tool for enhancing the physicochemical characteristics and prolonging the storability of fruits.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iDs

Omar Bashir https://orcid.org/0000-0002-4981-8458
Tawheed Amin https://orcid.org/0000-0003-2919-7065

REFERENCES

Aghdam MS, Asghari M, Babalar M and Sarcheshmeh MAS. (2016). Impact of salicylic acid on postharvest physiology of fruits and vegetables. In *Eco-Friendly Technology for Postharvest Produce Quality* pp. 243–268.

Aghdam MS, Sevillano L, Flores FB and Bodbodak S. (2015). The contribution of biotechnology to improving post-harvest chilling tolerance in fruit and vegetables using heat-shock proteins. *The Journal of Agricultural Science* 153(1): 7–24.

Ahmad S, Singh Z, Khan AS and Iqbal Z. (2013). Preharvest applications of salicylic acid maintain the rind textural properties and reduce fruit rot and chilling injury of sweet orange during cold storage. *Pakistan Journal of Agricultural Science* 50: 559–569.

Akinci I, Ozdemir F, Topuz A, Kabas O and Canakci M. (2004). Some physical and nutritional properties of *Juniperus drupacea* fruits. *Journal of Food Engineering* 65(3): 325–331.

Ali S, Masud T and Abbasi KS. (2011). Physico-chemical characteristics of apricot (*Prunusarmeniaca* L.) grown in Northern areas of Pakistan. *Scientia Horticulturae* 130(2): 386–392.

Amborabe BE, Lessard PF, Chollet JF and Roblin G. (2002). Antifungal effects of salicylic acid and other benzoic acid derivatives towards *Eutypalata*: Structure–activity relationship. *Plant Physiology and Biochemistry* 40(12): 1051–1060.

Amin T, Naik HR, Hussain SZ, Jabeen A and Thakur M. (2017). In-vitro antioxidant and antibacterial activities of pumpkin, quince, muskmelon and bottle gourd seeds. *Journal of Food Measurement and Characterization* 12(1): 182–190.

AOAC. (1995). *Official Method of Analysis*. 16th ed. Washington DC: Association of Official Analytical Chemists.

AOAC. (2005). *Official Method of Analysis*. 18th ed. Washington DC, USA: Association of Official Analytical Chemists.

AOAC. (2012). *Association of Official and Analytical Chemists*. Washington, DC: Official methods of analysis.

Barman K, Asrey R and Pal RK. (2011). Putrescine and carnauba wax pretreatments alleviate chilling injury, enhance shelf life and preserve pomegranate fruit quality during cold storage. *Scientia Horticulturae* 130(4): 795–800.

Barman K, Asrey R, Pal RK, Kaur C and Jha SK. (2014). Influence of putrescine and carnauba wax on functional and sensory quality of pomegranate (*Punica granatum* L.) fruits during storage. *Journal of Food Science and Technology* 51(1): 111–117.

Bin W, Qin G, Gang XW, Xin YP, Ji-de W and Feng-bin C. (2014). Effects of different postharvest treatments on the physiology and quality of 'Xiaobai' apricots at room temperature. *J Food Sci Technol* 52(4): 2247–2255.

Cao SF, Hu ZC and Wang HO. (2009). Effect of salicylic acid on the activities of anti-oxidant enzymes and phenylalanine ammonia-lyase in cucumber fruit in relation to chilling injury. *The Journal of Horticultural Science and Biotechnology* 84(2): 125–130.

Diaz-Mula HM, Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Serrano M, et al. (2009). Changes in hydrophilic and lipophilic antioxidant activity and related bioactive

compounds during postharvest storage of yellow and purple plum cultivars. *Postharvest Biology and Technology* 51(3): 354–363.

Dilley DR. (2006). Development of controlled atmosphere storage technologies. *Stewart Post Harvest* 2(6): 1–8.

Dokhanieh AY, Aghdam MS, Rezapour FJ and Hassanpour H. (2013). Postharvest salicylic acid treatment enhances antioxidant potential of cornelian cherry fruit. *Scientia Horticulturae* 154: 31–36.

El-Anany AM, Hussan GFA and Rehab Ali FM. (2009). Effects of edible coatings on the shelf life and quality of Anna Apple during cold storage. *Journal of Food Technology* 7(1): 5–11.

Ezzat A, Ammar A, Zabo Z and Holb IJ. (2017). Salicylic acid treatment saves quality and enhances antioxidant properties of apricot fruit. *Horticulture Scientific* 44(2): 73–81.

Gimenez MJ, Serrano M, Valverde JM, Martinez-Romero D, Castillo S, Valero D, et al. (2017). Preharvest salicylic acid and acetylsalicylic acid treatments preserve quality and enhance antioxidant systems during postharvest storage of sweet cherry cultivars. *Journal of the Science of Food and Agriculture* 97(4): 1220–1228.

Goncalves B, Landbo A-K, Knudsen D, Silva AP, Moutinho-Pereira J, Rosa E, et al. (2004). Effect of ripeness and postharvest storage on the phenolic profiles of cherries (*Prunus avium* L.). *Journal of Agricultural and Food Chemistry* 52(3): 523–530.

Gurrieri F, Audergon JM, Albagnac G and Reich M. (2001). Soluble sugars and carboxylic acids in ripe apricot fruit as parameters for distinguishing different cultivars. *Euphytica* 117(3): 183–189.

Haciseferogullari H, Gezer I, Ozcan MM and Murat AB. (2007). Postharvest chemical and physical-mechanical properties of some apricot varieties cultivated in Turkey. *Journal of Food Engineering* 79(1): 364–373.

Hajaji H, Naadya L, Katem A and Yehyya C. (2010). Antioxidant activity phytochemical screening and total phenolic content of extracts from carob tree barks. *Arabian Journal of Chemistry* 4(3): 321–324.

Hegedus A, Pfeiffer P, Papp N, Abrankó L, Blázovics A, Pedryc A, et al. (2011). Accumulation of antioxidants in apricot fruit through ripening: Characterization of a genotype with enhanced functional properties. *Biol Res* 44(4): 339–344.

Hooper L and Cassidy A. (2006). A review of the health care potential of bioactive compounds. *Journal of the Science of Food and Agriculture* 86(12): 1805–1813.

Ishaq S, Ahmed Rath H, Majeed S, Awan S and Ali Shah SZ. (2009). The studies on the physico-chemical and organoleptic characteristics of apricot (*Prunus armeniaca* L.) produced in Rawalakot, AzadJammu and Kashmir during storage. *Pakistan Journal of Nutrition* 8(6): 856–860.

Jubault M, Hamon C, Gravot A, Lariagon C, Delourme R, Bouchereau A, et al. (2008). Differential regulation of root arginine catabolism and polyamine metabolism in clubroot-susceptible and partially resistant *arabidopsis* genotypes. *Plant Physiology* 146(4): 2008–2019.

Kant K, Arora A, Singh VP and Kumar R. (2013). Effect of exogenous application of salicylic acid and oxalic acid on post harvest shelf life of tomatoes. *Indian Journal of Plant Physiology* 18(1): 15–21.

Kazemi M, Aran M and Zamani S. (2011). Effect of salicylic acid treatments on quality characteristics of apple fruits during storage. *American Journal of Plant Physiology* 6(2): 113–119.

Kim DO, Jeong W and Lee SCY. (2003). Antioxidant capacity of phenolic phytochemicals from various cultivars of plums. *Food Chemistry* 81(3): 321–326.

Koyuncu MA, Erbas D, Onursal CE, Secmen T, Guneyli A and Uzumcu SS. (2018). Postharvest treatments of salicylic acid, oxalic acid and putrescine influences bioactive compounds and quality of pomegranate during controlled atmosphere storage. *Journal of Food Science Technology* 13197: 3495–3491.

Koyuncu MA, Secmen T, Onursal CE, Erbas D, Guneyli A, Uzumcu SS, et al. (2018). Effect of postharvest oxalic acid treatment on cold storage of apricot cv. 'aprikoz'. *Scientific Papers. Series B, Horticulture* LXII: 147–152.

Leccese A, Viti R and Bartolini S. (2011). The effect of solvent extraction on antioxidant properties of apricot fruit. *Open Life Sciences* 6(2): 199–204.

Luo Z, Chen C and Xie J. (2011). Effect of salicylic acid treatment on alleviating postharvest chilling injury of "qingnai" plum fruit. *Postharvest Biology and Technology* 62(2): 115–120.

Lurie S, Sonego L and Ben-Arie R. (1987). Permeability, microviscosity and chemical changes in the plasma membrane during storage of apple fruit. *Scientia Horticultuae* 32: 73–83.

Lurie S and Crisosto CH. (2005). Chilling injury in peach and nectarine. *Postharvest Biology and Technology* 37(3): 195–208.

Matthaus B. (2002). Antioxidant activity of extracts obtained from residues of different oilseeds. *Journal of Agriculture and Food Chemistry* 50: 3444–3452.

Mazza G and Miniati E. (1993). *Anthocyanins in Fruits, Vegetables and Grains*. Boca Raton, FL: CRC Press.

Mirdehghan SH, Rahemi M, Martinez-Romero D, Guillen F, Valverde JM, Zapata PJ, et al. (2007). Reduction of pomegranate chilling injury during storage after heat treatment: Role of polyamines. *Postharvest Biology and Technology* 44(1): 19–25.

Mirdehghan SH and Rahimi S. (2016). Pre-harvest application of polyamines enhances antioxidants and table grape (*Vitis vinifera*) quality during postharvest period. *Food Chemistry* 196: 1040–1047.

Mushtaq M and Wani SM. (2013). Polyphenols and human-health – a review. *International Journal of Pharmacy and Biological Science* 4: 338–360.

Nanda S, Sudhakar Rao DV and Krishnamurthy S. (2001). Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits cv. Ganesh. *Postharvest Biology and Technology* 22(1): 61–69.

Oszmianski J, Wojdyło A and Kolniak J. (2011). Effect of pectinase treatment on extraction of antioxidant phenols

from pomace, for the production of puree-enriched cloudy apple juices. *Food Chemistry* 127(2): 623–631.

Parmar N, Singh N, Kaur A and Thakur S. (2007). Comparison of color, anti-nutritional factors, minerals, phenolic profile and protein digestibility between hard-to-cook and easy-to-cook grains from different kidney bean (*Phaseolus vulgaris*) accessions. *Journal of Food Science and Technology* 54(4): 1023–1034.

Perez-Tortosa V, Lopez-Orenes A, Martinez-Pérez A, Ferrer MA and Calderon AA. (2012). Antioxidant activity and rosmarinic acid changes in salicylic acid-treated Thymus membranaceus shoots. *Food Chemistry* 130(2): 362–369.

Ramesh NK, Monahar PD, Veena J, Padmavathamma AS and Syamraj NC. (2016). Effect of antioxidants on shelf life and quality minimally processed pomegranate arils cv. *Bhagwa*. *Advances in Life Science* 5: 4678–4682.

Rao TVR, Gol NB and Shah KK. (2011). Effect of postharvest treatments and storage temperatures on the quality and shelf life of sweet pepper (*Capsicum annum* L.). *Scientia Horticulturae* 132: 18–26.

Razavi F and Hajilou J. (2016). Enhancement of postharvest nutritional quality and antioxsidant capacity of peach fruits by preharvest oxalic acid treatment. *Scientia Horticulturae* 200: 95–101.

Rodriguez-Amaya DB. (1999). *A Guide to Carotenoid Analysis in Foods*. Washington: ILSI Press.

Sayyari M, Babalar M, Kalantari S, Serrano M and Valero D. (2009). Effect of salicylic acid treatment on reducing chilling injury in stored pomegranates. *Postharvest Biology and Technology* 53(3): 152–154.

Serrano M, Díaz-Mula H, Zapata PJ, Castillo S, Guillen F, Martinez-Romero D, et al. (2009). Maturity stage harvest determines the fruit quality and antioxidant potential after storage of sweet cherry cultivars. *Journal of Agricultural and Food Chemistry* 57(8): 3240–3246.

Serrano M, Martinez-Romero D, Guillen F and Valero D. (2003). Effects of exogenous putrescine on improving shelf life of four plum cultivar. *Postharvest Biology and Technology* 30(3): 259–271.

Stanley DW. (1991). Biological membrane deterioration and associated quality losses in food tissues. *Critical Reviews in Food Science and Nutrition* 30(5): 487–553.

Sun B, Yan H, Zhang F and Wang Q. (2012). Effects of plant hormones on main health-promoting compounds and antioxidant capacity of Chinese kale. *Food Research International* 48(2): 359–366.

Undurraga PL, Olaeta JA, Retamales JB, Escobar J and Toso AM. (2009). Effect of maturity and storage temperature on the development of peteca in lemons (*Citrus limon* (L.). *Scientia Horticulturae* 122(1): 56–61.

USDA (2005). *Database for Flavonoid Content of Selected Foods*. USA: United States Department of Agriculture.

Valero D, Diaz-Mula HM, Zapata PJ, Castillo S, Guillen F, Martinez-Romero D, et al. (2011). Postharvest treatments with salicylic acid, acetylsalicylic acid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. *Journal of Agricultural and Food Chemistry* 59(10): 5483–5489.

Valero D and Serrano M. (2010). *Postharvest Biology and Technology for Preserving Fruit Quality*. Boca Raton, USA: CRC Press-Taylor and Francis.

Wang Q, Lai T, Qin G and Tian S. (2009). Response of jujube fruits to exogenous oxalic acid treatment. *Plant & Cell Physiology* 50(2): 230–242.

We YT, Liu DW, Ding LY and Liq Xiao YH. (2004). Therapeutic effects and molecular mechanical of antifibrosis herbs and selection on rats with hepatic fibrosis. *World Journal of Gastroenterology* 10(5): 703–706.

Xu X and Tian S. (2008). Salicylic acid alleviated pathogen induced oxidative stress in harvested sweet cherry fruit. *Postharvest Biology and Technology* 49(3): 379–385.

Yaman Ö and Bayoındırlı L. (2002). Effect of edible coating and cold storage on shelf life and quality of cherries. *LWT – Food Science and Technology* 35(2): 146–150.

Zheng X, Tian S, Gidley MJ, Yue H and Li B. (2007a). Effects of exogenous oxalic acid on ripening and decay incidence in mango fruit during storage at room temperature. *Postharvest Biology and Technology* 45(2): 281–284.

Zheng X, Tian S, Meng X and Li B. (2007b). Physiological and biochemical responses in peach fruit to oxalic acid treatment during storage at room temperature. *Food Chemistry* 104(1): 156–162.

Zokaee Khosroshahi MR and Esna-Ashari M. (2007). Postharvest putrescine treatments extend the storage-life of apricot (*Prunus armeniaca* L.) 'Tokhm-sefid' fruit. *The Journal of Horticultural Science and Biotechnology* 82(6): 986–990.