Postharvest Treatment with Edible Bio-Materials to Preserve the Quality of 'Shahvar-e-Shirin' Pomegranate Arils

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Summary

The present study was conducted to investigate the effects of salicylic acid (SA) and chitosan (CH) pre-treatments on the bioactive compounds and quality of pomegranate arils. The statistical design of the experiment was factorial based on a completely randomized design (CRD). It included 5 levels of treating solutions (CH at 0.5 and 1%, SA at 1 and 2 mmol L^{-1}, and distilled water as control) × 3 levels of evaluation time (days 0, 7 and 14 of storage). Each 250 g randomly mixed 'Shahvar-e-Shirin' pomegranate aril served as an experimental unit with three replicates for each treatment. Treatments included 5 min dips in CH and SA aqueous solutions. Following air drying, arils of each experimental unit were packed in a clear hinged pet plastic clamshell container and stored for 14 days at 5 °C with a relative humidity of 90 ± 5%. Pre-treatments with SA and CH, especially at higher doses, reduced weight loss (WL) and respiration rate, improved firmness retention, and resulted in more preferred BrimA (consumer acceptability index; CAI) and TSS/TA ratio (maturity index; MI) as well as higher ascorbic acid content (AAC), total anthocyanin content (TAC), total phenolic content (TPC), and radical-scavenging activity (RSA) in the juice and assigned better sensory evaluation scores at the time of consumption compared to the control. Finally, it was predicted that these treatments would be a promising postharvest tool in optimum storage of minimally processed (MP) arils from commercial pomegranate cultivars, which needs to be evaluated.

Key words

antioxidant activity, chitosan, minimal processing, *Punica granatum* L., salicylic acid, total phenolic content

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Introduction

Pomegranate (*Punica granatum* L.) is a member of the Punicaceae family, with its origin in Iran. Iran is also one of the world's leading producers and exporters of this horticultural superfruit (Varasteh and Arzani, 2009). Pomegranate, a nutrient-dense fruit rich in phytochemical compounds (Mokhtarzadeh and Shahsavar, 2020), is widely available or used in minimally processed (MP) ready-to-eat arils, and it is recognized as a novel food with an innovative concept that meets modern consumers' lifestyle needs for healthy, more convenient fresh products (Bhatia et al., 2013). According to the International Fresh-Cut Produce Association (IFPA), MP produce is "any fresh fruit or vegetable or any combination thereof that has been physically altered from its original form but remains in a fresh state" (Garrett, 1999). Pomegranate arils, which account for 52% of the total fruit (w/w), with 78% juice and 22% seeds (Bhatia et al., 2015), are a highly perishable and rapidly deteriorating produce, with unfavorable physiological and biochemical changes occurring at a faster rate than intact fruit during storage (Bhatia and Asrey, 2019). As a result, preserving the quality of pomegranate arils is a critical challenge for extending product shelf life (Abdel Fattah et al., 2016). The majority of pomegranate research is concerned with whole fruit, including the physiochemical changes that occur during development, ripening, and postharvest storage (Özdemir and Gökmen, 2017). As a result, few reports on the development of safe and profitable techniques for preserving MP pomegranate arils during storage have been published. Some researchers, for instance, propose using edible bio-materials like salicylic acid (SA) or chitosan (CH), either alone or in combination, to extend the shelf life of this produce. In this regard, treatments with CH 1% (Ghasemnezhad et al., 2012; Varasteh et al., 2012) and 1.5% (Ramezanian et al., 2018), CH 1% in combination with ascorbic acid (AA) 1% (Özdemir and Gökmen, 2017), and SA at 2 mmol L^{-1} (Bhatia and Asrey, 2018) are among the elite methods that provide advantages for extending the shelf-life of produce while also positively influencing its bioactive compounds and nutritional value.

SA is a naturally occurring safe phenolic compound with anti-ripening and anti-senescence properties, as well as the ability to improve crop stress resistance systems. Its practical and useful application in the postharvest management of horticultural crops has been proved (Asghari and Aghdam, 2010). CH, on the other hand, is a carbohydrate biopolymer and deacetylated derivative of chitin with unique properties such as biocompatibility, biodegradability, and nontoxicity, which make its applications in the food industry profitable, mainly for food preservation as edible coating (Tian and Liu, 2020). CH-coated foods have a lower rate of respiration and membrane permeation in the cells, resulting in greater stability and shelf life (Tian and Liu, 2020).

Despite the fact that a large number of pomegranate cultivars, the majority of which are native to Iran, are grown in various parts of the country, there is little published data on their characteristics or different pre- or postharvest requirements for crop production and quality improvement. In other words, many Iranian pomegranate cultivars are unknown even to local growers, exporters, academic scientists, and researchers. This is also true for Shahvar-e-Shirin pomegranate. According to published data, Shahvar-e-Shirin pomegranate fruit is one of the major cultivars produced in Iran's important production areas of Yazd, Fars, Esfahan, Zanjan, Semnan, and Markazi provinces (Mohseni, 2009). The main fruit characteristics are yellow peel, sour-sweet pink arils, and semi-soft seeds (Zarei and Sahraroo, 2018). Because of the relatively large, juicy and tasty arils, Shahvar-e-Shirin MP produce is likely to be an ideal and popular choice for consumers and commercial markets. The current study aimed to address a knowledge gap regarding the effect of postharvest SA- and CH pre-treatments on the physiological and quality attributes of stored Shahvar-e-Shirin MP arils.

Materials and Methods

Plant Materials and Treatments

Commercially matured pomegranate fruits cv. 'Shahvar-e-Shirin' were harvested from a commercial orchard in Khafr, Fars province, Iran, and immediately transported to the laboratory. Fruits with similar shape and diameter which were free of mechanical damage, disease, or pests were chosen and washed with distilled water. Fruits were then air-dried at 23 ± 1 °C. The outer skins of the fruit were carefully cut with a sharpened knife at the equatorial zone, and the arils were manually separated. Each 250 g randomly mixed aril served as an experimental unit with three replicates for each treatment. For 5 min at room temperature, arils were dipped in different aqueous solutions of SA (1 and 2 mmol L^{-1}, named SA1 and SA2, respectively) and CH (0.5 and 1% w/v, named CH1 and CH2, respectively; containing 1% acetic acid (v/v), and adding 0.1 mol L^{-1} NaOH for pH adjustment to 5.0). As a surfactant, two g L^{-1} Tween-20 was added to the solutions. Arils in the control group were dipped in distilled water. The aqueous solutions of CH were made using the Varasteh et al. (2012) method. The treated and control arils were air-dried at room temperature. Following that, arils of each experimental unit were packed in a clear hinged pet plastic clamshell container and stored for 14 days at 5 °C and 90 ± 5% RH. Following preliminary aril assessments for harvested fruit, additional evaluations were performed at seven-day intervals during storage.

Chemical Materials

CH (crab shells) with a medium molecular weight and a deacetylation degree of 75-85%, SA (≥99%), and all other chemicals used were Sigma-Aldrich (Germany) brand.

Weight Loss (WL)

To determine the weight, both treated and control experimental units were weighed at sampling intervals using a FZ-300iWP precision scale (AandD Co.). The WL (%) was then calculated by subtracting the weight at the time of measurement from the initial weight (250 g).

Respiration Rate

The rate of respiration was measured using a closed system and expressed as mL CO_2 kg^{-1} h^{-1}. In an airtight plastic container, a known weight of arils was placed. CO_2 levels were measured twice, once at the beginning (D_1) and again after 1 hour (D_2), using the testo 440 air measuring instrument and a bluetooth CO_2 probe, and respiration rate was calculated using the following equation

(Asghari et al., 2020): (ΔC × V)/(t × W); where ΔC, V, t and W are the percentage change in CO_2 (%), container volume, time (h), and the aril weight (kg), respectively.

Firmness

The firmness of 20 arils was measured individually (as maximum compression force (N) required to rupture) and averaged for each replicate. A texture analyzer (TAXT Plus, Stable Micro Systems, Surrey, England), a 35 mm diameter cylindrical probe, a test speed of 1.0 mm s^{-1}, and a distance of 9.5 mm were used.

Total Soluble Solids (TSS), Titratable Acidity (TA), pH, TSS/TA (Maturity Index; MI), and BrimA (Consumer Acceptability Index; CAI)

Juice TSS was quantified using a digital refractometer (Milwaukee MA871, Hungary), and expressed as % (°Brix). TA (% citric acid) was evaluated using the potentiometry method with 0.1 N NaOH, with pH 8.1 as the endpoint. The pH value was measured using a pH meter (Metrohm model 827, Switzerland). The MI was calculated as the TSS/TA ratio. BrimA, also known as CAI (consumer acceptability index), was calculated as TSS – k × TA, where k represents the tongue's sensitivity, which was assigned a value of 2 for pomegranate (Fawole et al., 2020; Obenland et al., 2009).

Ascorbic Acid Content (AAC)

The AAC was determined using the method described by Sogvar et al., (2020). Using a 3% metaphosphoric acid solution, ten grams of aril were homogenized and diluted to 100 mL. Following centrifugation, 10 mL of the supernatant was titrated against 2,6-dichlorophenol indophenol to obtain a stable pink color. Results were expressed as mg AA 100 mL^{-1} juice.

Total Anthocyanin Content (TAC)

TAC quantification (as mg Cyd-3-glucoside equivalent (C_3gE) 100 mL^{-1} juice) was performed through pH differential method as described by Fawole et al. (2011). Aril juice was mixed (1:9) with pH 1.0 and pH 4.5 buffers, then absorbance at 520 and 700 nm was measured for the mixtures, and total absorbance (A) was calculated as: $(A_{520}\text{-}A_{700})_{pH\ 1.0} - (A_{520}\text{-}A_{700})_{pH\ 4.5}$. TAC calculation equation was: [(A×MW×DF)/ε×L)], in which A, MW, DF, ε and L were absorbance, the molecular weight of anthocyanin (449.2), dilution factor, the molar absorbance of cyanidin 3-glucoside (26900), and cell path-length (1 cm), respectively.

Total Phenolic Content (TPC)

The Folin-Ciocalteu (Folin C) method (Fawole et al., 2020) was used to determine the TPC of samples (as mg gallic acid equivalent (GAE) 100 mL^{-1} juice). One mL of juice was extracted in a centrifuge tube with 50% methanol. The mixture was then sonicated in cold water (10 min). After centrifugation, a mixture of 50 µL of methanolic extract, 450 µL of 50% methanol, 500 µL of Folin C reagent and 2.5 mL of sodium carbonate solution was prepared, vortexed and incubated in the dark for 40 min at room temperature. Finally, the mixture's absorbance was measured at 725 nm.

Radical-Scavenging Activity (RSA)

The DPPH method, as described by Kulkarni and Aradhya (2005), was used to assess the antioxidant capacity of aril juice in terms of RSA. A mixture was prepared adding 100 mmol L^{-1} Tris–HCl buffer (0.9 mL, pH 7.4) and 1 mL of DPPH (500 µM in ethanol) to 0.1 mL juice, which was shaken and set aside for 30 min. At 517 nm, the absorbance (A) of the resulting solution was measured. For background correction, the reaction mixture lacking DPPH was used. Finally, the following equation was used:

$$\text{The juice RSA (\%)} = \frac{\text{A control (517 nm)} - \text{A sample (517 nm)}}{\text{A control (517 nm)}} \text{x } 100$$

Sensory Evaluation

At the end of the storage period, 10 semi-trained panelists rated the overall acceptability of arils on a scale of 1–10 based on their general feelings of texture, color, taste, aroma, and juiciness, with 1 indicating poor and 10 indicating excellent acceptability, respectively.

Experimental Design and Statistical Analysis

The design of the experiment was factorial, based on a completely randomized design (CRD) with three replicates per each treatment. It included 5 levels of treating solutions (CH at 0.5 and 1%, SA at 1 and 2 mmol L^{-1} and distilled water as control) × 3 levels of evaluation time (days 0, 7 and 14 of storage). All data were subjected to two-way analysis of variance (ANOVA) performed with the SAS 9.1.3 service pack 4 software, and the means were separated by the LSD test at $P \leq 0.05$.

Results and Discussion

Quality Parameters

Aril Weight Loss (WL), Respiration Rate and Firmness

WL is regarded as an important quality index for the postharvest life of horticultural commodities. As shown in Fig. 1a, during the storage period, all treated and control arils lost less weight than the commercial limit for MP products, which is 4-6% (Özdemir and Gökmen, 2017). According to the literature, this could be due in part to the clamshell packaging's high efficiency in reducing aril WL (O'Grady et al., 2014). Packaging has been shown in the literature to be effective in extending the shelf life and maintaining the quality of pomegranate arils by reducing shriveling, WL, and maintaining bioactive compounds (Bhatia and Asrey, 2019).

According to the findings (Fig. 1a), WL increased significantly but at a slower rate in arils treated with SA or CH than in control arils during storage. After one week of storage, SA2-treated arils had the lowest WL, with no difference between SA1- and SA2-treated ones. Furthermore, after two weeks of storage, the SA2-treated arils had the lowest WL, while the other treated arils were statistically the same. Moreover, arils pre-treated with CH and SA had lower respiration rates than controls during storage; higher doses had a greater effect. Finally, SA2-treated arils had the lowest respiration rate (Fig. 1b). On the other hand, pre-treatments with CH and SA resulted in better aril firmness preservation than the control, with SA2-treated arils having the highest firmness at the end of storage, followed by CH2-treated arils (Fig. 1c).

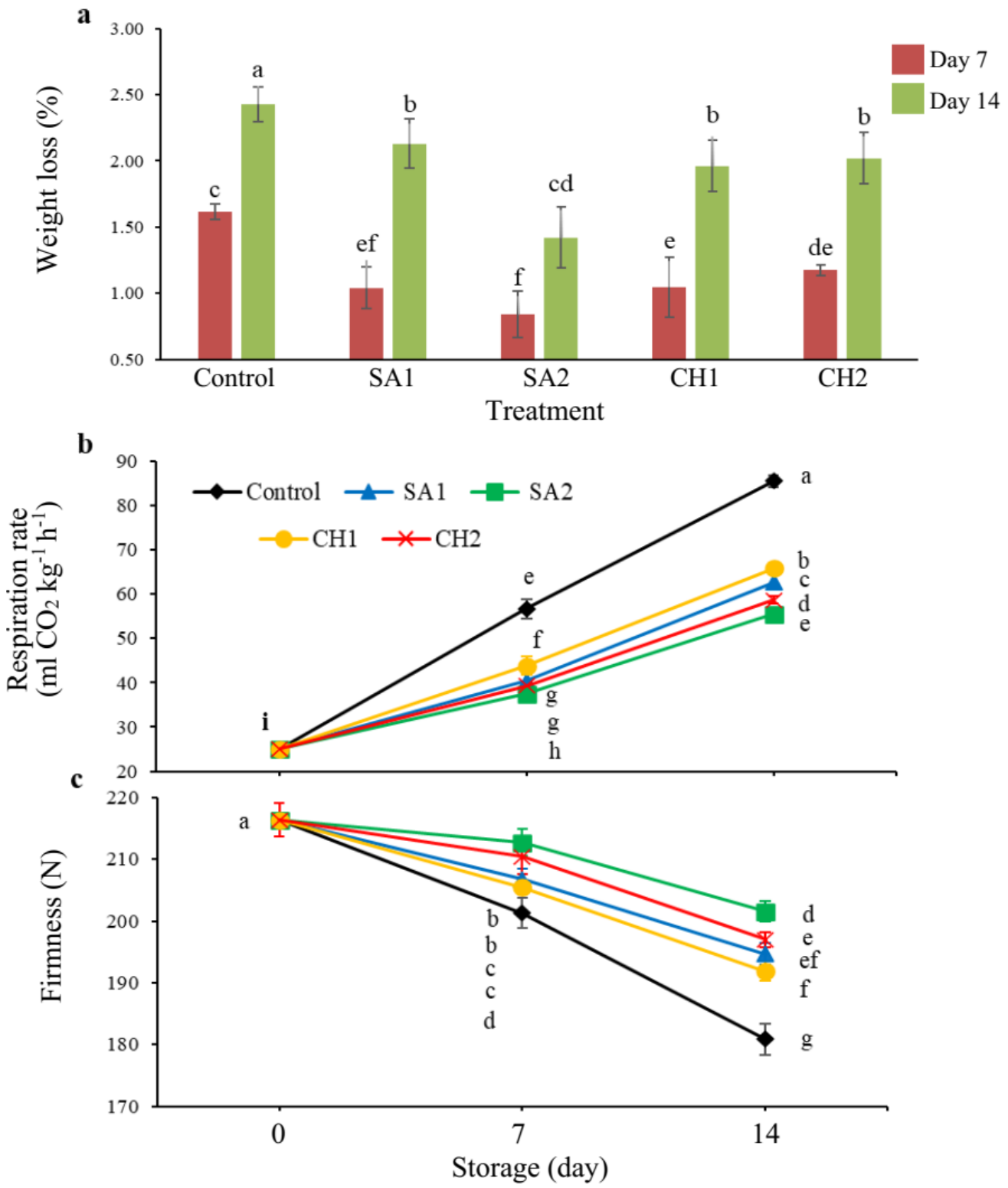

Figure 1. Changes in (a) weight loss, (b) respiration rate, and (c) firmness of pre-treated pomegranate arils during 14 days storage at 5 °C and 90 ± 5% RH. SA1 and SA2: salicylic acid at 1 and 2 mmol L^{-1}, respectively. CH1 and CH2: chitosan at 0.5 and 1%, respectively. Vertical bars represent the standard deviation (n = 3). The means with the same letter in each part are not significantly different by LSD test at $P \leq 0.05$

Postharvest WL in horticultural commodities and MP products is considered to be caused by water loss due to continuous respiration and transpiration processes after harvest (Hanif et al., 2020). Furthermore, according to several reports in the literature, the firmness of pomegranate MP arils decreases significantly during storage, depending on which variation has been linked to the rate of water loss incidence (Bhatia and Asrey, 2018; Bhatia et al., 2013; Bhatia et al., 2015; Martínez-Romero et al., 2013; Oz and Ulukanli, 2012). There are some reports in the literature on significant reductions in the rate of postharvest WL of SA-treated horticultural commodities such as Ponkan and Kinnow mandarins (Zheng and Zhang, 2004), papaya (Hanif et al., 2020), strawberry (Shafiee et al., 2010), sweet cherry (Valero et al., 2011), apricot (Satraj et al., 2013), and peach (Tareen et al., 2012), as well as pomegranate (Koyuncu et al., 2019). Bhatia and Asrey (2018) investigated the effect of different SA concentrations on the functional and sensory quality of MP pomegranate arils. Our findings are consistent with their reports that using 2 mmol L^{-1} SA reveals the best results in terms of aril respiration rate and firmness. Moreover, our findings are consistent with the findings of Ghasemnezhad et al. (2012) that CH coating significantly reduces the WL of pomegranate arils stored at 4 °C for 12 days. In another studies, it has been found that the CH coatings reduce WL of various fruit such as plum (Bal, 2013), apricot (Ghasemnezhad et al., 2010), pear (Lin et al., 2008), sapota (Ahlawat et al., 2015), Longan (Jiang and Li, 2001) and red kiwifruit (Kaya et al., 2016), as well as whole pomegranate fruit (Varasteh et al., 2017). When compared to controls, the CH and SA treatments' positive results could be ascribed to preservative effects on cell integrity and the permeability, as well as decreased metabolic activity in the affected tissues (Bhatia and Asrey, 2018; Koyuncu et al., 2019). SA treatments that inhibit the activities of senescence-related enzymes reduce the respiration rate and, as a result, WL of stored products (Khademi and Ershadi, 2013; Korkar 2013). Abbasi et al. (2019) revealed a negative correlation between SA concentration and WL in the peach fruit, which was attributed to its anti-senescence properties. Furthermore, SA treatments reduce ethylene synthesis, and promote auxin and cytokinin production, all of which result in a delay in product aging and softening and a longer shelf life (Hosseinifarahi et al., 2020). On the other hand, the positive effect of CH on reducing the WL, preserving firmness and alleviating the respiration rate is thought to be caused by the thin layer film that forms on the surface of the MP product, creating a modified atmosphere and restricting gas exchange while also acting as an effective barrier, delaying the rate of transpiration and moisture loss during storage (Khaliq et al., 2016). Varasteh et al. (2017) report that CH coating reduces the pomegranate's respiration rate and WL, with better results obtained by increasing the CH dose applied. Similarly, they conclude that CH, as a preservative coating material, performs the same function as modified atmosphere packaging. Similar to the proposed mechanisms of action for coating with CH, there is evidence in the literature on the efficacy of other bio-material coatings through a reduction in respiration rate and WL, as well as extending the time required for softening of stored MP arils (Martínez-Romero et al., 2013; Oz and Ulukanli, 2012).

Total Soluble Solids (TSS), Titratable Acidity (TA), pH, TSS/TA (Maturity Index; MI), and BrimA (Consumer Acceptability Index; CAI)

During storage, there was a continuous statistical increase in juice TSS, which was significantly higher in control arils than in treated arils at each sampling time. On the other hand, there were no differences between different treated arils in each evaluation time (Fig. 2a).

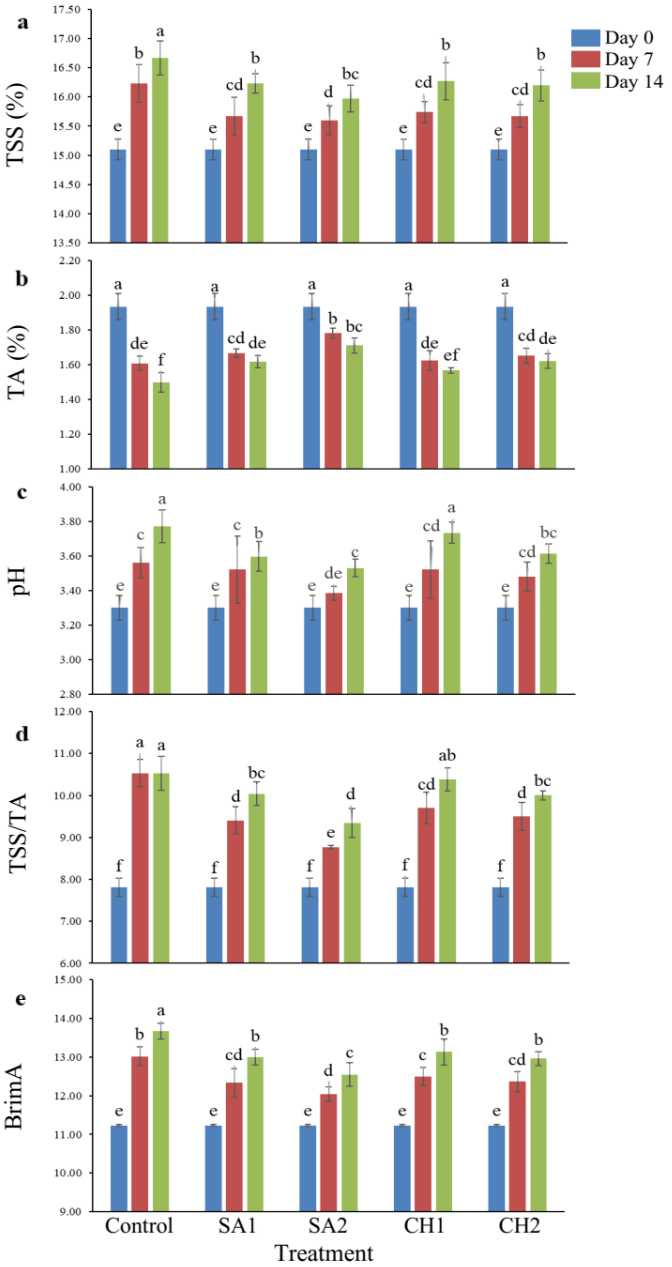

Figure 2. Changes in (a) TSS, (b) TA, (c) pH, (d) TSS/TA, and (e) BrimA of pre-treated pomegranate arils during 14 days storage at 5 °C and 90 ± 5% RH. SA1 and SA2: salicylic acid at 1 and 2 mmol L^{-1}, respectively. CH1 and CH2: chitosan at 0.5 and 1%, respectively. Vertical bars represent the standard deviation (n = 3). The means with the same letter in each part are not significantly different by LSD test at $P \leq 0.05$

As mentioned earlier, significant WL of pomegranate MP arils is via significant amounts of water loss during the storage period. As a result, an increase in the juice TSS percentage could happen with progress in storage time (Koyuncu et al., 2019). The slower rate of increase in juice TSS in treated arils could be attributed to the significant role of SA and CH in reducing water loss from treated arils compared to controls.

Overall, during the first week of storage, all treated and control arils showed a significant decrease in juice TA, followed by a non-significant slower rate for treated arils than controls during the second week. Except for the SA2-treated arils, which had a statistically higher amount of TA at both evaluation times during storage, all of the other treated arils had the same amount of TA as the control on day 7, while only the CH1-treated arils were the same as the control at the end of the storage period (Fig. 2b). With the exception of SA2-treated arils, the pH value in the juice of all treated and untreated arils increased significantly and similarly during one week of storage. However, at the end of storage, SA2- and CH2-treated arils had statistically the lowest pH values, while CH-1 and control arils had the highest. The pattern of change in pH value corresponds to the pattern of change in TA value (Fig. 2c). The decrease in juice TA observed during storage could be ascribed to the conversion of acids to other compounds as well as a progressive decrease in the product's ability to synthesize them (Shaarawi and Nagy, 2017). Moreover, it is proportional to the rate of increase in respiration of the MP product during storage, and could be considered as a strong indicator of ongoing metabolism resulting in higher pH values (Fawole and Opara, 2013; Jitareerat et al., 2007). It can be concluded that higher TA and lower pH values detected at the end of the storage period in SA- and CH2-treated arils could be attributed to the high suppressive effects of these treatments on the metabolism and senescence process of the treated arils. According to this viewpoint, CH at lower dose lacked sufficient and desirable efficiency.

Generally, the TSS/TA ratio and BrimA index of MP arils increased progressively over the storage time, but statistically at a slower rate in treated arils than in controls. SA2-treated arils had the lowest TSS/TA ratio and BrimA index compared to the other treated arils at each evaluation time during storage; for the first index, all differences were significant; for the second, significant differences were detected only with CH1-treated arils after one week of storage and with all treated arils at the end of storage time (Fig. 2d, e). TSS and TA levels are important determinants of the MI and CAI indices. According to the aforementioned results, better organic acid and TA level maintenance, as well as a slower rate of increase in WL and TSS percentage detected in SA2-treated arils, resulted in a significantly lower increase in the MI and CAI indices when compared to other treated or untreated arils. The lower fluctuation in the MI and CAI indices of SA2-treated arils could be an important indicator of SA2's greater efficiency in preserving the quality of this produce during storage when compared to other treatments.

Bioactive Compounds and Antioxidant Capacity

Ascorbic Acid Content (AAC), Total Anthocyanin Content (TAC), Total Phenolic Content (TPC) and Radical-Scavenging Activity (RSA)

Aril, an edible part of the pomegranate fruit, is high in antioxidants including phenolics such as AA and anthocyanins, and its value varies depending on the cultivar (Koyuncu et al., 2019). These bioactive compounds are mainly responsible for the antioxidant capacity of pomegranate arils (Sayyari et al., 2011).

In general, as storage time progressed, the AAC, TAC, TPC and RSA in aril juice decreased significantly, but statistically at a slower rate in pre-treated arils than in controls (Fig. 3a, b, c, d).

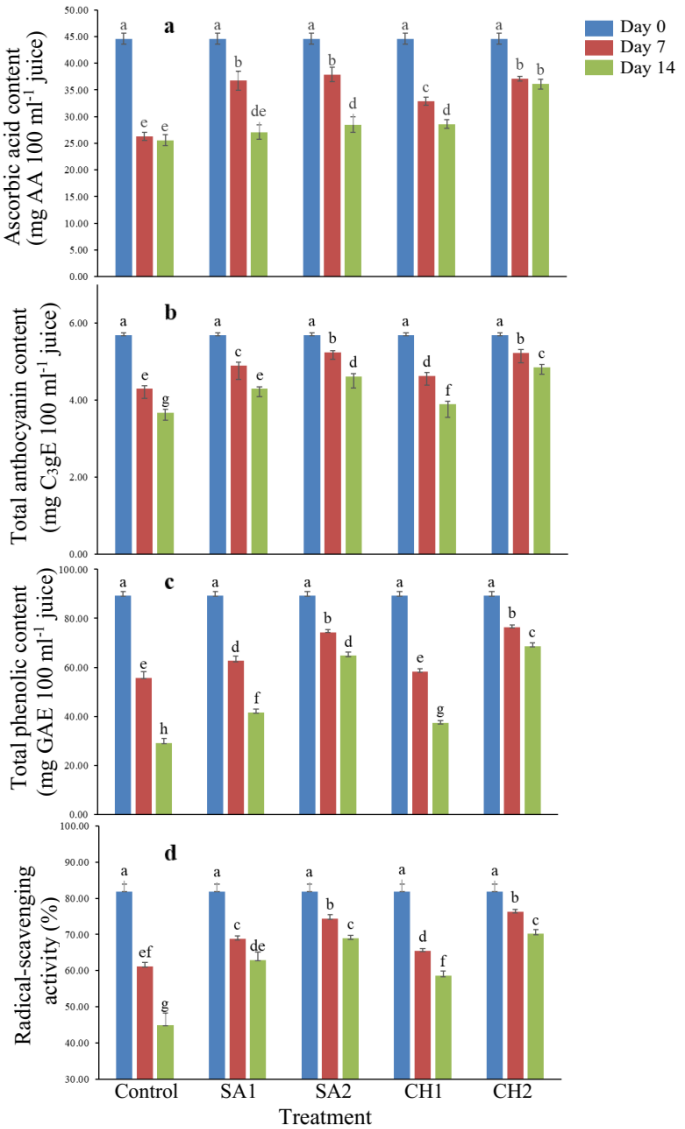

Figure 3. Changes in (a) ascorbic acid content, (b) total anthocyanin content, (c) total phenolic content, and (d) radical-scavenging activity of pre-treated pomegranate arils during 14 days storage at 5 °C and 90 ± 5% RH. SA1 and SA2: salicylic acid at 1 and 2 mmol L^{-1}, respectively. CH1 and CH2: chitosan at 0.5 and 1%, respectively. Vertical bars represent the standard deviation (n = 3). The means with the same letter in each part are not significantly different by LSD test at $P \leq 0.05$

Our findings on significant decrease in different bioactive compounds and antioxidant activity corroborate the previous findings on pomegranate whole fruit or arils (Aarabi et al., 2008; Artes et al., 1996; Barman et al., 2014; Nanda et al., 2001; Ramezanian et al., 2018). The highest measured AAC was detected at the end of the first week of storage in SA1-, SA2-, and CH2-treated arils, with the value remaining stable for CH2-treated arils until the end of the storage period and the other treated ones at the following step. At this time, there was no statistically significant difference between SA1-treated and control arils (Fig. 3a). TAC changes in treated and control arils followed a statistically similar pattern to TPC changes during storage. In other words, when compared to the control, a lower concentration of SA was more effective than a lower concentration of CH in preserving TAC and TPC in aril juice. Nevertheless, after 7 days of storage, arils pre-treated with higher doses of SA and CH had the highest TAC and TPC values, with CH2-treated arils leading the way until the end of the experiment, followed by SA2-treated ones in the following step (Fig. 3b, c). Changes in RSA during storage followed a similar pattern to TPC, with the exception of a similarity at the end of the storage period between SA2- and CH2-treated arils (Fig. 3d).

AA as an unstable organic acid could be oxidized and converted to dehydroascorbic acid by the ascorbate oxidase enzyme (Khaliq et al., 2016; Singh et al., 2005). AA destruction is recognized as a result of product senescence, and it is well established that pre-treatment with SA, due to its antisenescence property, can reduce AA loss in stored products (Saurabh et al., 2019). Moreover, CH coating has the potential to reduce AA oxidation by restricting the required O_2 for the oxidation reaction (Ramezanian et al., 2018; Saurabh et al., 2019; Tokatlı and Demirdöven, 2020). Sayyari et al. (2009) reported a decrease in AA content for control and low dose SA-treated pomegranate fruit (0.7 and 1.4 mmol L^{-1}), but a stable value for fruit treated with the highest dose (2 mmol L^{-1}). In another report on pomegranate, while control fruit lost about half of the AA content at the end of storage, the fruit treated with 0.1 mmol L^{-1} Acetyl salicylic acid (ASA) suffered no changes (Sayyari et al., 2011). The authors claimed that these effects were proportional to the free SA content because ASA immediately converts to SA in treated fruit.

The rate of decrease in anthocyanin content of pomegranate juice is proportional to the rate of water loss (Ramezanian et al., 2018) as well as the rate of increase in pH during storage (Bhatia and Asrey, 2018). It is reasonable to conclude that all of the pre-treatments had the desired effect of preserving this bioactive compound from destruction due to beneficial effects on minimizing produce water loss. Furthermore, the highest doses of CH and SA resulted in a slower increase in pH value and better anthocyanin retention during storage. In this regard, we agree with Bhatia and Asrey (2018) and Ghasemnezhad et al. (2012) on the desirable efficiency of 2 mmol L^{-1} SA and 1% CH treatments, respectively. On the other hand, similar to the protective role of CH coating against AA oxidation, CH-treated produce has less enzymatic oxidation of anthocyanins than untreated produce (Ghasemnezhad et al., 2012; Varasteh et al., 2012).

When compared to controls or those treated with lower doses of SA and CH, the higher RSA in the juice of arils pre-treated with higher doses of SA and CH could be explained by a slower rate of loss of phenolics like ascorbic acid and anthocyanins. (Barman et al., 2014).

Sensory Evaluation

Sensory evaluation by panelists at the end of the storage period revealed that pre-treated arils with SA and CH, especially at higher doses, were preferable and scored higher than control (Fig. 4). As previously stated, SA2- and CH2-treated arils had lower WL and respiration rate, higher firmness, more preferred CAI and MI indices and higher AAC, TAC, and TPC in juice. As a result, they experienced less quality loss and better preservation of important bioactive compounds during storage.

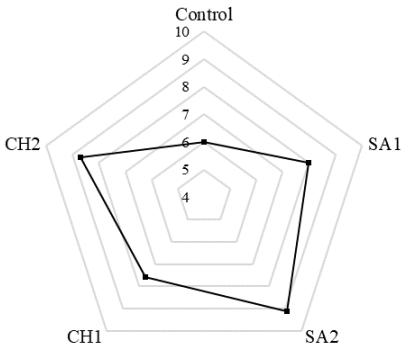

Figure 4. Sensory evaluation of the overall acceptability of pre-treated pomegranate arils after 14 days storage at 5 °C and 90 ± 5% RH. SA1 and SA2: salicylic acid at 1 and 2 mmol L^{-1}, respectively. CH1 and CH2: chitosan at 0.5 and 1%, respectively

Conclusion

The current study revealed that pre-treatments of pomegranate arils with SA and CH, especially at higher doses, reduced WL and respiration rate, improved firmness retention, and resulted in more preferred BrimA and TSS/TA ratio at the end of storage period when compared to the control. Furthermore, these pre-treated arils had higher levels of AAC, TAC, TPC, and RSA than controls, as well as higher scores from panelists at the time of consumption. Finally, it was predicted that these treatments would be a promising postharvest tool in optimum storage of MP arils from commercial cultivars, which needs to be evaluated.

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