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EFFECTS OF EDIBLE COATING ON MINIMALLY PROCESSED POMEGRANATE FRUITS
UTICAJ JESTIVOG PREMAZA NA MINIMALNU DORADU NARA

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ABSTRACT

The pomegranate fruit is rich in many nutrients characterized by a variety of biologically-active and secondary metabolites. However, pomegranate fruits are prone to postharvest water loss, chilling injuries, physical disorders and fungal diseases. Various methods such as high hydrostatic pressure, ultrasound and gamma irradiation, synthetic fungicides, preservatives, controlled atmosphere and modified atmosphere storages, and edible coatings are used for preserving fruits and minimizing changes in their quality. New alternative technologies, such as the coating of agricultural commodities, have been employed to reduce the postharvest losses of fresh fruits and vegetables, and improve their shelf life. Edible films and coatings, including various chemicals, oils, essential oils, and/or a combination of oils and edible coatings, have been used to enhance the shelf life, quality and safety of minimally processed fruits. Therefore, the present study examines the efficacy of edible coating in maintaining the quality of pomegranate fruits and extending the shelf life of freshly dissected pomegranate arils.

Keywords: *decay, pomegranate aril, edible coating, minimally processed*

REZIME

Nar je bogat mnogim hranljivim sastojcima, koje karakterišu različiti bioaktivni i sekundarni metaboliti. Međutim, plodovi nara su skloni gubitku vode posle dodira, podhlađenja, fizičkim poremećajima i gljivičnim bolestima. Različite metode kao što su visoki hidrostatički pritisak, ultrazvuk i gama zračenje, sintetički fungicidi, konzervansi, kontrolisana atmosfera i skladištenje umodifikovanoj atmosferie, kao i jestivi premazi koriste se za očuvanje voća i minimiziranje promena u njihovom kvalitetu. Nove alternativne tehnologije, kao što je premaz poljoprivrednih proizvoda, korišćeni su za smanjenje gubitaka nakon ubiranja svežeg voća i povrća i produženje njihovog roka trajanja. Uljni filmovi i premazi, uključujući različite hemikalije, ulja, eterična ulja i/ili kombinaciju ulja i jestivih premaza, koriste se za produženje trajanja, poboljšanje kvaliteta i povećanje sigurnosti minimalno obrađenih plodova. Zbog toga, ova studija ispituje efikasnost jestivog premaza u održavanju kvaliteta plodova šipka i produženju roka trajanja sveže izrezanih aranžmana šipka.

Ključne reči: *rastur, aroma nara, jestivi premaz, minimalna dorada*

INTRODUCTION

The pomegranate is the fruit of *Punica granatum L.* (Punicaceae), which is widely produced in the Mediterranean area. Pomegranate seeds and juice are used in color, whereas seeds constitute the edible part of the fruit. Nevertheless, the consumption of pomegranates is limited due to considerable difficulties in removing seeds from the fruit (*Gil et al., 1996*). As the extraction of arils from the pomegranate fruit is time-consuming and poses a hindrance to consumption, the industrial production of ready-to-eat pomegranate arils is now possible using latest processing technologies (*Ayhan and Eştürk, 2009; Ojeda et al., 2014*).

In addition to other methods (storing under controlled or modified atmospheres, applying chemical agents and the UV irradiation), edible coating is one of the most accepted methods for prolonging the commercial shelf-life of fruits. The most important benefits of edible coatings are a decrease in the synthetic packaging waste and a contribution to food health and safety while meeting the environmental requirements (*Garcia et al., 2010*). In recent years, edible coatings have been comprehensively studied because of their positive effects on the quality of fruits and vegetables. The following functional benefits are associated with the use of edible films and coatings: reduced respiration rate (by exchanging O_2 and CO_2 between coated fruits and the environment), prolonged storage life, firmness retention, transportation of antimicrobials, antioxidants and other preservatives, and microbial growth control (*Ozdemir and Gökmen, 2017*). Materials that are commonly used as edible coatings or films are lipids, resins, polysaccharides and proteins. Relative to advantages and disadvantages of various coatings, the coating process can be performed using one type of material or a combination of different materials. A number of treatments have been applied to improve the quality and increase the shelf life of pomegranate fruits and minimally processed pomegranate arils. Materials commonly used for the coating of pomegranate arils are chitosan, starch with *N. sativa* oil acids (citric, ascorbic and acetic acid) and *Aloe vera* gel (*Ghasemnezhad et al., 2013; Oz and Ulukanli, 2011; Varasteh et al., 2012; Romeroa et al., 2012; Nabigol and Asghari (2013)*; *Ozdemir and Gökmen, 2017*). It was suggested in previous studies that further research should be conducted regarding the effect of edible coating materials on different cultivars grown in different geographical locations. Therefore, the present study examines the efficacy of edible coating in maintaining the quality and extending the shelf life of freshly dissected pomegranate arils.

MATERIAL AND METHOD

Plant material

Sweet-tasting 'Tarom', 'Hicaznar', 'Wonderful', 'Silifke Aşısı', 'Rabbab-e-Neyriz' *Punica granatum L. cv.* 'Mollar de Elche', *Punica granatum L. cv.* 'Malas Saveh' and 'Mollar de Elche' pomegranates were harvested at the commercial harvest stage (*Ergun and Ergun, 2009*; *Ghasemnezhad et al., 2013; Oz and Ulukanli, 2012; Varasteh et al., 2012; Romeroa et al., 2012; Öz et al., 2017*). Pomegranates were washed with clear tap water or sterile water, and arils were subsequently removed manually.

Experimental design

Ghasemnezhad et al. (2013) dipped arils in 0.25, 0.5 and 1% (*w/v*) chitosan aqueous solutions and distilled water (1% (*v/v*) acetic acid for the control) for 1 min. Each solution was adjusted to pH 5. After coating, arils were placed in rigid polyethylene boxes (10 cm × 6 cm × 5 cm) with lids that are not completely airtight. All boxes were stored at 4°C and 95% relative humidity for 12 days. *Nabigol and Asghari (2013)* dipped pomegranate arils in *A. vera* solutions, after which they were stored at 5 °C and 95% RH in permanent darkness for 3 weeks.*Oz and Ulukanli (2012*) prepared a coating solution by adding food-grade starch powder (2%) and glycerol as a plasticizer (1%) to sterilized distilled water. The solution (a starch: plasticizer ratio of 2:1) was heated and boiled until completely dissolved. Two concentrations (300 and 600 ppm) of cold-pressed seed oil of *N. sativa* were added into the coating solution and homogenized. The arils were immersed in the coating solution for 15 min at room temperature. After coating, coating solution residues were placed onto sterilized sieved trays at 20°C. The arils were placed into polypropylene bags and stored for 12 days. *Romeroa et al. (2012)* washed pomegranate arils in a solution containing 100 µL/L chlorine (NaOCL) for 5 min. Excess water was removed from arils with paper towels. The arils were divided into treatment group (Table 1). Thereafter, they were dipped in corresponding solutions for 5 minutes and left to dry subsequently. After coating, the arils (130 g) were placed in polypropylene boxes (280 mL) and covered with airtight lids (with a silicone septum for the gas extraction and the O_2 and CO_2 quantification). The boxes were stored for 12 days at 3°C and 90% relative humidity. *Özdemir and Gökmen (2017)* prepared aqueous solutions (*w/v*) of 1% chitosan + 1% ascorbic acid, 2% chitosan + 2% ascorbic acid, 1% ascorbic acid and distilled water for the control. The solutions were placed in an ultrasonic bath for 1 h to obtain a translucent solution. The sample arils were immersed in the coating solutions for 5 min. After the immersion, they were left to dry at 25 °C for 2 h. Then the arils (10 g) were transferred into sterilized packages and stored 28 days at 5°C.

RESULTS AND DISCUSSION

Effect of Coating Treatments on Pomegranate Aril Quality

Coating treatments provide fruits with a semi-permeable membrane, thus reducing the moisture loss from the surface of the fruit and modifying the atmosphere between the fruit and the environment (*Opara et al. 2015*). *Oz and Ulukanli (2012)* reported that there were statistically significant differences between the control and coating treatments throughout the storage. At the end of the storage, a 6% weight loss was measured in the control group, 3% in the starch coating itself, 2% in 300 ppm and 1% in 600 ppm oil + starch coating-treated arils (*Oz and Ulukanli, 2012*). While *Ghasemnezhad et al. (2013)* stated that chitosan coating significantly decreased the weight loss of pomegranate arils at 4 ◦C, *Ozdemir and Gökmen (2017)* stated that chitosan ascorbic acid coating did not affect weight loss as the control, 1% ascorbic acid and coated fruits lost similar weight during the 28 days of storage. While *Romeroa et al. (2012)* obtained no significant differences between coating treatments in regard to the total soluble solid content (TSS), *Ghasemnezhad et al. (2013)* reported that the highest TSS was observed in the control sample. Furthermore, *Oz and Ulukanli (2011)* stated that the application of 600 ppm oil plus starch coating seemed to be the most effective in reducing the TSS content when compared to the other treatments during storage. *Nabigol and Asghari (2013*) stated that the TSS was significantly higher in the *A. vera* treated arils than in the control arils. These findings were associated with the fact that edible coating reduced the respiration rate and weight loss, effectively maintaining the TSS and organic acid contents (*Pen and Jyang 2003; Ghasemnezhad et al. 2013*).

The value of pH did not change significantly and almost remained constant during storage (*Oz and Ulukanli, 2011*) in both the coated and uncoated aril samples. Similarly, *Ozdemir and Gökmen (2017)* stated that TA (titrable acidity) and pH did not change significantly during storage in both the control and coated samples (1% chitosan-1% ascorbic acid).

Fruit firmness has been accepted as one of the most important factors that affect the quality of fruit commodities during postharvest storage. *Oz and Ulukanli (2012)* and *Romeroa et al. (2012)* found that the highest softening aril ratio (%), which may mainly derive from the hydrolysis of starch to sugar and the degradation of pectin in the fruit cell wall associated with fruit ripening, was in the control arils. The coatings of *A. vera* gel (at 50 or 100%) alone or in a combination with acids (*Romeroa et al., 2012*) and the coatings of starch and *N. sativa* oil (*Oz and Ulukanli, 2012*) showed a significant delay of softening. Calcium chloride treatments (0.5% and 1%) maintained the highest firmness of arils, indicating significant differences between the treated and untreated arils (Shaarawi *et al.*, 2016). *Oz and Ulukanli (2011)* reported that the most effective treatment for inhibiting browning was the application of 300 and 600 ppm oil plus starch coating and starch coating itself. Pomegranate arils coated with chitosan and ascorbic acid showed no signs of deterioration, which rendered them acceptable for consumption. The findings obtained also showed that the a* value, which is related to the color stability and redness was significantly higher in the chitosan coated arils than in the control samples after 12 days of storage (*Özdemir and Gökmen, 2017*). It has been reported that the coating with chitosan and ascorbic acid significantly reduced bacteria, yeast and mold populations throughout the storage time (*Ozdemir and Gökmen, 2017*). The total yeast and mold counts were also below the detection limits in the 300 ppb and 600 ppb oil + starch coating samples (*Oz and Ulukanli, 2011*), whereas the lowest bacterial growth was observed on the arils coated with 1% chitosan during storage (*Ghasemnezhad et al., 2013*). *Nabigol and Asghari (2013*) immersed arils which were dipped in a spore suspension of pathogens (*A. niger* and *P. digitatum*) in different *A. vera* solutions. They reported that for both fungi, the inhibition of mycelium growth rate increased with the *A. vera* concentration. In another study, the total microbial population was lower in the arils treated with salicylic acid compared to those treated with calcium chloride, calcium lactate, as well as the control arils (*Shaarawi et al., 2016*)

Effects of Coating Treatments on the Anthocyanin Content (TAC) and Antioxidant Activity of Pomegranate Arils

The attractive colour is one of the most important sensory characteristics of pomegranate arils (*Ghasemnezhad et al., 2013*). *Ozdemir and Gökmen (2017)* argued that the anthocyanin synthesis was reduced by the reduction of gas metabolism and significantly inhibited by a combination of chitosan and ascorbic acid barriers (*Özdemir and Gökmen 2017*). Similarly, *Varasteh et al. (2012)* reported that the total anthocyanin content of the chitosan-coated (2%) pomegranate fruit stored at 2 °C, was 1.56-fold higher than that recorded in the control sample stored at 5 °C at the end of the trial duration. Moreover, *Oz and Ulukanli (2012)* asserted that the high edible starch coating, including *Nigella* oil, significantly influenced the anthocyanin content of arils, and that the TAC was the highest in the treatment with 300 ppm oil + starch coating, followed by 600 ppm and starch coating itself compared to the control samples (*Oz and Ulukanli, 2012*). Furthermore, chitosan coating suppressed a decline in the aril anthocyanin content during storage, and the highest anthocyanin content was recorded after 12 days of storage at 4 °C in the pomegranate arils coated with 1% chitosan (*Ghasemnezhad et al., 2013*).

Table 1. Edible coating treatments of pomegranate fruits and arils

References	Coating Materials	Treatment Description
Mirdehghan et al., 2007	- control (distilled water) (by pressure infiltration) - 1 mM putrescine - 1 mM spermidine - control (distilled water) (by immersion) - 1 mM putrescine - 1 mM spermidine	Fruits were harvested when fully mature. Fruits were randomized and divided into six lots of 125 fruits. Half of the lots were treated by pressure (0.05 bar for 4 min at 25 °C) and the other half was treated by dipping at 25 °C for 4 min. The fruits were placed on the desiccant Kraft paper and were allowed to dry (rt*, in a dark place). The fruits were stored for 60 days at 2 °C, in a temperature-controlled chamber, in permanent darkness, and with relative humidity of 90%.
Ergun and Ergun, 2009	- sterile water (control) - 10% honey solution (*w/v*) - 20% honey solution (*w/v*)	Arils were manually extracted. The arils were dipped into water or diluted honey solutions, after which they were removed with a plastic strainer and drained. 50 g of arils per treatment were placed in loosely closed plastic containers (130 mL) and stored at 4 °C for 10 days.
Oz and Ulukanli, 2012	- starch coating (starch + glycerol, 2:1, *v/v*) - 300 ppm oil + starch coating (starch + glycerol, 2:1, *v/v* and *N. sativa* oil, 300 ppm) - 600 ppm oil + starch coating (starch + glycerol, 2:1, *v/v*, *N. sativa* oil, 600 ppm)	Immersing of arils for 15 min at rt* Let to drip off in laminar flow at rt* Packaging with PP* (250 g aril/0.5 L) Storage of 12 days
Varasteh et al., 2012	- 1% acetic acid (control) - 1% aqueous chitosan solutions (*w/v*) - 2% aqueous chitosan solutions (*w/v*) - 1% acetic acid (*v/v*).	Dipping of pomegranates, Drying [illegible] 12 h at [illegible] Storing at 2±0.5 C and 5±0.5 °C, at 90%±5 RH* f[illegible]35 days, Plac[illegible]g under shelf life conditions, for 20 °C after 45 da[illegible]
Romeroa et al., 2012	- water (control washed arils) - acids 0.5% (citric acid 0.5% + ascorbic acid 0.5%) - acids 1.0% (citric acid 1.0% + ascorbic acid 1.0%) - *A. vera* 50% (*A. vera* gel diluted with distilled water 50–50 *v/v*) - *A. vera* 100% (*A. vera* gel) - *A. vera* 50% + acids 0.5% (treatments b + d) - *A. vera* 100% + acids1.0% (treatments c + e)	Immersing of arils [illegible] 5 min Drying Packaging [illegible] rigid PP [illegible]xes (1[illegible]g aril/280 mL) Storage [illegible] days at 3 °C, [illegible]% [illegible]*
Nabigol and Asghari, 2013	- control (distilled water) - *A. vera* 60 ml/L - *A. vera* 125 ml/L - *A. vera* 250 ml/L	[illegible] were manually [illegible]racted and washed. Rinsing with tap water at 5 ◦C. Dipping arils in a spore suspension of pathogens. Immersion for 5 min in the [illegible] *vera* solution. Storing at 5 ◦C and 95% RH in permanent. [illegible]kness for 3 weeks.
Ghasemnezhad et al., 2013	- distilled water with 1% (*v/v*) acetic acid. - 0.25% (*w/v*) chitosan, - 0.5% (*w/v*) chitosan, - 1% (*w/v*) chitosan.	[illegible]shing at 5 °C for 2 min. Rinsing excess water. Dipping arils in coat[illegible]olutions for 1 min. Packaging with rigid PP* boxes. Storing in a cold room at 4 ◦C and 95% RH* for 12 days
Barman et al., 2014	- control (distilled water) - 2 mM putrescine - 2 mM putrescine +carn[illegible]a wax	Fruits were randomized and divided into 3 lots. Treatments were performed by dipping. After treatments, fruits were air-dried and stored in a chamber (3and 5 °C, 90±5%.RH). The fruits were stored for 60+3 days. The peel was carefully cut, arils were taken out and juice was manually extracted for analysis.
Zahran et al., 2015	- control (distilled water) - 0.5%, unirradiated chitosan - 0.5%, 25 kGy irradiated chitosan - 1.0%, unirradiated chitosan - 1.0%, [illegible]5 kGy irradiated chitosan - 1.0%, 50 kGy irradiated chitosan	Fruits were washed in sterilized water with a 200 µL/L sodium hypochlorite (NaOCl) solution. The fruits were manually peeled. Arils were treated by immersion for 2 min. Arils were dried, packed in self-sealed 250 g PP trays and refrigerated at 5 °C and RH 75% for up to 15 days
Meighani et al., 2015	- control (distilled water) - 1 % chitosan (*w/v*) + 1 % acetic acid (*v/v*) - [illegible] % chitosan (*w/w*)+ 1 % acetic acid (*v/v*) - carnauba wax - resin	The fruits were dipped in a chitosan solution (2 min.) and the resin and carnauba waxes were manually applied by brush. Coated fruits were allowed to dry at ambient temperature. Thereafter, fruits were stored at 4.5±0.5 °C with 90±5 % RH
Shaarawi et al., 2016	- sterile water (control) - [illegible]5% calcium chloride - 1% calcium chloride - 0.5% calcium lactate - 1% calcium lactate - 1 mM salicylic acid - 2 mM salicylic acid	Fruits were washed in sterilized water with a 200 µl l^{-1} of NaOCl solution. The arils were gently removed by hand. The arils were divided into six portions and dipped in one of the two for 5 min. The arils were drained using a colander and left to dry on clean cloth absorbent paper. The pomegranate arils were packaged in previously sterilized rigid plastic containers (PET) and then kept in cold storage at 5±1 °C and 95±2% RH for up to 12 days.
Özdemir and Gökmen, 2017	- distilled water (control) - 1% chitosan and 1% ascorbic acid - 2% chitosan and 2% ascorbic acid - 1% ascorbic acid	Immersing of arils (100 g) in coating solutions (200 mL) for 5 min. Drying for 2 h at 25 °C. Sterile packaging (10 g aril). Storage for 28 days at 5 °C
Öz et al., 2017	- distilled water (control) - 2.5 mM oxalic acid - 5 mM oxalic acid - 2.5 mM gaba - 5 mM gaba	Pomegranates were washed with clear water. The arils were removed from peel manually. The arils were immersed in solutions (5 min at rt). After dipping, solution residues were removed onto sterilized sieved trays at 20 °C. The arils were stored for 20 days in PP bags.

**rt: room temperature, PP: Polypropilene, RH: Relative Humidity, h: hour*

Romeroa et al. (2012) found that the *Aloe* 100%+Acids 1% coating arils showed the highest anthocyanin content after a storage period of 8 days at 3°C. Previous reports showed that the chitosan edible starch coating, including *Nigella* oil and *A. vera* coating with acids, had beneficial effects in maintaining the anthocyanin content of pomegranates.

According to the total phenolics, the concentration during storage indicated no significant changes in those arils treated with *A. vera* gel (50 or 100%) (*Romeroa et al., 2012*). *Ghasemnezhad et al. (2013)* stated that the concentration of total phenolics decreased significantly during storage in both the chitosan-coated and uncoated arils. Therefore, chitosan coating suppressed a decline in the aril phenolic content during storage. The pomegranate arils coated with 1% chitosan maintained the higher total content of phenolics after 12 days of storage (*Ghasemnezhad et al., 2013*). The highest antioxidant activity was recorded in the pomegranate arils coated with 1% chitosan, whereas the lowest was recorded in the uncoated group after 12 days of storage at 4 °C. Moreover, chitosan coating exhibited beneficial effects in maintaining the antioxidant activity of pomegranate arils. Previous studies showed that there was a positive correlation between the antioxidant activity and total phenolic content. Therefore, a high total antioxidant capacity could be attributed to a high total phenolic content (*Ghasemnezhad et al., 2013*).

Effect of Coating Treatments on the Sensory Quality of Pomegranate Arils

The pomegranate arils treated with the 300 ppm oil + starch coating showed the best aroma quality. The panelists did not perceive any off-flavors in pomegranate arils as a consequence of the chitosan and ascorbic acid treatment (*Özdemir and Gökmen, 2017*). *Romeroa et al. (2012)* stated that the highest scores were given to the arils treated with a combination of *A. vera* gel and acids. Higher sensory scores of the coated arils may result from the fact that edible coatings served as a barrier which reduced the loss of volatiles, i.e. affected the metabolism of volatile production (*Olivas et al., 2007*).

CONCLUSION

The use of edible coating or film packaging materials is an innovative method for controlling the quality of fruits and vegetables, as well as minimizing microbial postharvest losses. The application of coating materials to fruits and vegetables affects the nutritional composition and appearance of fresh commodities. There are a number of treatments applied to enhance the quality, storage and shelf life of pomegranates and minimally processed pomegranates. The shelf life of pomegranate arils can be prolonged by edible coating treatments in exchange for chemical treatments or modified atmosphere packaging. According to previous studies, the most marked effects of edible coating on pomegranate arils are as follows: browning inhibition, weight loss and decay reduction, maintaining firmness, and higher sensory scores, as well as anthocyanin and phenolic contents. Admittedly, the effects of different types of coating materials on pomegranate arils require further research, as well as their effect on fresh pomegranate arils and other fruit quality parameters.

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