Food Chemistry 217 (2017) 585–592

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

The addition of rosehip oil to *Aloe* gels improves their properties as postharvest coatings for maintaining quality in plum

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ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 5 September 2016
Accepted 5 September 2016
Available online 7 September 2016

Keywords:
Fruit quality
Storage
Polyphenols
Anthocyanins
Carotenoids
Antioxidant activity

ABSTRACT

The effect of *Aloe vera* gel (AV) and *Aloe arborescens* gel (AA) alone or in combination with rosehip oil (RO) at 2% on ethylene production, respiration rate, quality parameters, bioactive compounds and antioxidant activity during plum postharvest storage was studied. Coated plums showed a delay in ethylene production and respiration rate at 20 °C and during cold storage and subsequent shelf life, the main effect being observed for those fruits coated with AA + RO. Quality parameters such as softening, colour and maturity index was also delayed during storage by the use of the coatings, which led to a 2-fold increase in plum storability. Accumulation of bioactive compounds was also delayed although at the end of the experiment the content of bioactive compounds was higher than those found for control fruits at the estimated shelf life. The most effective coating for maintaining plum quality and bioactive compounds was AA + RO.

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1. Introduction

Fruits from 'President' cultivar (*Prunus domestica* L.) have an oval in shape with a deep purple skin and yellow flesh. This cultivar has a rich sweet flavour and used mainly for fresh consumption but also in jams, jellies and prunes. 'President' plums are considered to have a climacteric-ripening pattern, in which ethylene is the hormone responsible for triggering the ripening and senescence processes (Valero, Martínez-Romero, Valverde, Guillén, & Serrano, 2003). The main consequences are a reduced shelf life and a decrease in the quality parameters, such as skin and mesocarp colour changes, weight and acidity losses, softening and decay (Menniti, Gregori, & Donati, 2004; Valero & Serrano, 2010; Valero et al., 2004).

Several postharvest strategies have been reported to extend the plum storability for longer periods in order to maintain quality parameters, such as force air-cooling (Martínez-Romero, Castillo, & Valero, 2003), cold storage alone (Serrano et al., 2009) or combined with 1-methylcyclopropene (Minas, Crisosto, Holcroft, Vasilakakis, & Crisosto, 2013; Valero et al., 2003, 2004) alginate coating (Valero et al., 2013), polyamines (Serrano, Martínez-Romero, Guillén, & Valero, 2003) and modified atmosphere packaging (Díaz-Mula, Martínez-Romero, Castillo, Serrano, & Valero, 2011), among others.

Previous reports have shown that *Aloe vera* gel (AV) can be used as an edible coating in mango (Dang, Singh, & Swinny, 2008), nectarine (Ahmed, Singh, & Khan, 2009; Navarro et al., 2011), apple (Ergun & Satici, 2012), papaya (Marpudi, Abirami, Pushkala, & Srividya, 2011), table grape (Valverde et al., 2005), sweet cherry (Martínez-Romero et al., 2006), pomegranate arils (Martínez-Romero et al., 2013), fig (Marpudi, Ramachandran, & Srividya, 2013), strawberry (Singh, Singh, Kingsly, & Sharma, 2011), tomato (Chauhan et al., 2013), and peach and plum (Guillén et al., 2013). The coating based on AV was effective on reducing respiration rate, weight loss, colour changes and total acidity (TA), as well as ethylene production in climacteric fruits. Overall, maintenance of quality attributes and extension of shelf-life was obtained by using AV coating.

Eshun and He (2004) reported that the composition of AV gel is mainly polysaccharides followed by soluble sugars, proteins, vitamins and minerals, while the lipid content is very low, ranging in between 0.07 and 0.42% depending on the *Aloe* spp. (Zapata et al., 2013). In a recent paper, Guillén et al. (2013) noted that the effects of *Aloe arborescens* gel (AA) were higher than those from AV gel on maintaining fruit quality properties when applied as postharvest coating to plums or peaches, which were attributed to the higher lipid concentration of *Aloe arborescens* gel. In this

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http://dx.doi.org/10.1016/j.foodchem.2016.09.035
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sense, it is possible to increase the hydrophobic properties of *Aloe* gels by adding to the composite a source of lipids and then to enhance the barrier efficacy of the coating. Among the possible sources, the oil extracted from rosehip seeds could be a good alternative which is rich in unsaturated fatty acids, mainly oleic, linoleic and linolenic acids (Grajzer et al., 2015). In addition, rosehip oil has high content of vitamin C, minerals, carotenoids, tocopherols, phytoesterols, flavonoids, tannins, pectin, sugars, organic acids, amino acids, essential oils and health beneficial properties (Franco, Sineiro, Pinelo, & Núñez, 2007; Machmudah, Kawahito, Sasaki, & Goto, 2007). For this reason, rosehip oil is becoming very popular in cosmetic and pharmaceutic industries due to its antioxidant properties, and also could be used in the food industry (Fromm, Bayha, Kammerer, & Carle, 2012). In fact in a recent paper, rosehip oil (at 2 or 10%) was added to AV gel and the coating applied to a wide range of *Prunus* species and cultivars (peach, plum, nectarine and sweet cherry), the main results being a reduction in respiration rate for all fruits, lower ethylene production in climacteric fruits, and a delay in the changes of fruit quality parameters, such as softening, loss of weight and acidity, colour and ripening index (Paladines et al., 2014). However, in this study the fruits were stored at 20 °C for a shorter period of time (6 days), and there is no information about the effect of this coating during prolonged cold storage.

Thus, the objective of this work was to study the effect of the addition of rosehip oil (at 2%) to *Aloe vera* and *Aloe arborecens* gels as coating with improved barrier properties, on 'President' plum quality attributes during 28 days of cold storage (at 2 °C) and subsequent shelf life (2 days at 20 °C), as well as the content of bioactive compounds (phenolics, anthocyanins, carotenoids) and antioxidant activity in both peel and pulp.

2. Material and methods

2.1. Plant material and experimental design

Plum fruits (*Prunus domestica* L., cv. 'President') were harvested in mid-August 2013 at commercial ripening stage from 10-year-old trees grown in an orchard in Murcia (Spain). Over 1500 fruits were manually picked to avoid mechanical damage, and once in the laboratory 720 fruits were selected according to size and colour, randomised and divided into 69 lots of 10 fruits. Three lots were used to determine the fruit properties at harvest, 18 lots were used for "Experiment I" and the remaining 48 were used for "Experiment II". In both experiments, treatments were performed in the same way. All lots were treated in triplicate: control (distilled water), rosehip oil 2% (RO), *Aloe vera* gel (AV), *Aloe vera* gel + rosehip oil 2% (AA + RO), *Aloe arborescens* gel (AA) and *Aloe arborescens* gel + rosehip oil 2% (AA + RO). The AV and AA gels were obtained according to previous reports (Navarro et al., 2011; Zapata et al., 2013). Briefly, freshly AV and AA leaves (harvested 3 h after sunrise) were transferred to the laboratory and then the parenchymatous tissue was manually removed to obtain the gel from each leaf, which was filtered to discard fibrous tissue. Rosehip oil (RO) (*Rosa rubiginosa* L. or its synonymous *Rosa eglanteria*) was purchased from Guinama Laboratory, Valencia, Spain. The coatings containing RO were prepared by dissolving the RO to Tween-80 and then added to distilled water (RO coating), AV (AV + RO coating) or AA (AA + RO coating) by vigorous shaking to give a final concentration of 2% RO. Treatments were performed by dipping the fruit in the corresponding coating for 10 min. After treatments, fruit were left to dry at room temperature and further stored in a controlled-chamber at 20 °C providing a RH of 85% by the use of humidification automatic system (Experiment I) or at 2 °C and 90% RH and subsequent shelf life of 2 days at 20 °C and RH 85% (Experiment II).

For the Experiment I, ethylene production and respiration rate were measured individually in each fruit at 0, 1, 2, 3, 4, 7 and 14 days of storage. The quality parameters, weight loss, fruit firmness, and total acidity (TA) were measured at day 0 and after 14 days of storage. For the experiment II, after 7, 14, 21 and 28 days cold storage, six lots from each treatment were taken randomly, three was immediately analysed and the others were stored for a further 2 days at 20 °C to simulate commercial procedure (shelf-life, SL), in which the same analytical determinations were carried out as follows.

For each lot, fruit firmness and colour were measured individually. Following these determinations, two subsamples of five fruits each were made from each lot, in which ethylene production and respiration rate were quantified. The fruit from each subsample were then manually peeled to separate the peel from the pulp. The flesh tissue was cut in small pieces and a portion used to determine soluble solids concentration and titratable acidity. The separate peel and pulp were then immediately frozen and ground in liquid N_2. The samples were stored in at −40 °C until analysis of total phenolics, total anthocyanins, total carotenoids and total antioxidant activity was carried out in the samples from day 0 and after 14 and 28 days of cold storage plus 2 days more at 20 °C.

2.2. Ethylene production and respiration rate

Ethylene production and respiration rate were determined inside the chambers and measured by placing each fruit in a 0.5-L glass jar (Experiment I) or each subsample of five fruit in a 2-L glass jar (Experiment II) hermetically sealed with a rubber stopper for 30 min. One mL of the holder atmosphere was withdrawn with a gas syringe, and the ethylene was quantified using a Hewlett-Packard™ model 5890A gas chromatograph (Wilmington, DE) equipped with a flame ionization detector and a 3 m stainless steel column with an inner diameter of 3.5 mm containing activated alumina of 80/100 mesh. Chromatographic conditions were previously reported (Navarro et al., 2011). Ethylene production (nL g^{-1} h^{-1}) was expressed as the mean ± SE.

For respiration rate determination, another sample of 1 mL of the same atmosphere was withdrawn and CO_2 quantified using a Shimadzu™ 14A gas chromatograph (Kyoto, Japan), with a thermal conductivity detector and a molecular sieve 5A column, 80–100 mesh (Carbosieve SII. Supelco Inc., Bellefonte, USA). Chromatographic conditions were previously reported (Navarro et al., 2011), and results (mg CO_2 kg^{-1} h^{-1}) were the mean ± SE.

2.3. Fruit firmness and colour

Firmness and colour were determined as previously (Martínez-Romero et al., 2003). Briefly, firmness was measured as force–deformation (N mm^{-1}) on the fruit shoulder by applying a 3% deformation of the fruit diameter using a flat steel plate coupled with a texturometer (TX-XT2i Texture Analyzer, Stable Microsystems, UK).

For colour after measuring the L^*, a^*, b^* coordinates using the CIE Lab System in a Minolta colorimeter CR200 model using D65 illuminant (Minolta Camera Co., Japan), colour was expressed as Hue angle (mean ± SE).

2.4. Soluble solids concentration, titratable acidity and ripening index

Total soluble solids (TSS) concentration was determined in duplicate from the juice obtained for each subsample with a digital refractometer Atago PR-101 (Atago Co. Ltd., Tokyo, Japan) at 20 °C, and expressed as %. Titratable acidity (TA, g of malic acid equivalent per 100 g^{-1} fresh weight) was determined also in duplicate by automatic titration (785 DMP Titrino, Metrohm) with 0.1 N

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