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The addition of rosehip oil improves the beneficial effect of *Aloe vera* gel on delaying ripening and maintaining postharvest quality of several stonefruit

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ABSTRACT

In this work *Aloe vera* gel (AV) alone or with the addition of 10 or 2% rosehip oil was used as fruit edible coatings in a wide range of *Prunus* species and cultivars: peaches ('Roma' and 'B-424-16' flat type), plums ('Red Beauty' and 'Songria'), nectarine ('Garofa') and sweet cherry ('Brooks'). Following treatments, fruit were stored at 20 °C for 6 days and analysed for the effect of treatments on fruit ripening and quality parameters compared with uncoated fruit (control). The addition of the rosehip oil to AV gel reduced respiration rate in all fruit, and ethylene production in the climacteric ones (peaches, plums and nectarine). In addition, all the parameters related with fruit ripening and quality, such as weight loss, softening, colour change and ripening index, were also delayed in treated compared with control fruit, the effect being generally higher when rosehip oil was added to AV, and especially in those fruit that exhibited the highest ethylene production rates ('Roma' and flat type peaches). Although the highest effect was obtained with AV + rosehip oil at 10%, the sensory panel detected an excess of gloss and oiliness on the fruit surface, which was considered as a negative attribute. Thus, 2% rosehip oil added to AV could be used as an innovative postharvest tool to increase the beneficial effect of AV as an edible coating, especially in climacteric fruit showing high ethylene production rates.

1. Introduction

Stonefruit including peach, nectarine, plum and sweet cherry are very appreciated by consumers due to their organoleptic and nutritive properties as well as their content of bioactive compounds with antioxidant activity (Díaz-Mula et al., 2008; Serrano et al., 2009, 2011; Legua et al., 2011). However, stonefruit deteriorate rapidly after harvest and lose their quality in a short period of time ranging from several days to 1–2 weeks, depending on plant species and cultivar (Valero and Serrano, 2010).

Low temperature storage is generally used to delay the postharvest deterioration process, although in some cases this treatment is not enough to maintain fruit quality during handling, transport and commercialization. In this sense, additional postharvest tools together with cold storage are necessary. In recent years, the use of *Aloe vera* gel (AV) has been used as an edible coating for raw produce such as mangoes (Dang et al., 2008), nectarines (Ahmed et al., 2009; Navarro et al., 2011), apples (Ergun and Satici, 2012), papaya (Marpudi et al., 2011), table grapes (Valverde et al., 2005), sweet cherries (Martínez-Romero et al., 2006), figs (Marpudi et al., 2013), strawberries (Singh et al., 2011), tomatoes (Chauhan et al., 2013), peaches and plums (Guillén et al., 2013). In all these fruit commodities, the AV treatment preserved physico-chemical parameters such as colour, firmness, total acidity (TA), and reduced respiration rates, ethylene production (in those climacteric fruit) and weight loss, leading to maintenance of the quality characteristics and extension of the shelf-life.

The gel of AV and other *Aloe* spp. is mainly composed of polysaccharides and soluble sugars followed by proteins, vitamins and minerals (Eshun and He, 2004), but are very low in lipid content, ranging from 0.07 to 0.42% depending on the *Aloe* spp. and climatic conditions during the growth cycle (Zapata et al., 2013). Thus, the gas barrier and hydrophobic properties of AV-based edible coatings could be improved with the addition of lipids, since the increase of lipid content in the composition of edible coatings leads to higher hydrophobic properties and barrier efficacy (Morillon et al., 2002). In this sense, rosehip seed is an inexpensive source of unsaturated fatty acids rich oil and is becoming very popular in cosmetic and other high valuable applications such as in the pharmaceutic industry, due to its antioxidant properties (Franco et al., 2007;

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Table 1
Fatty acid composition and relative concentration of rosehip oil ($n = 3$).

Fatty acid	Chemical name	Concentration (%)
Myristic acid	C14:0	2.26 ± 0.15
Palmitic acid	C16:0	6.70 ± 0.34
Palmitoleic acid	C16:1	2.32 ± 0.09
Stearic acid	C18:0	2.78 ± 0.11
Oleic acid	C18:1	16.04 ± 1.12
Linoleic acid	C18:2	43.47 ± 2.45
Linolenic acid	C18:3	23.77 ± 1.06
Arachidic acid	C20:0	2.65 ± 0.23

Machmudah et al., 2007). However, there is no evidence of the use of rosehip oil in the agro-food industry. Thus, the objective of this research was to analyse the beneficial effect of the addition of rosehip oil to AV gel on delaying the ripening process and maintaining quality in a wide range of *Prunus* species and cultivars. As far as we know, this is the first time in which rosehip oil is being used as postharvest fruit treatment.

2. Materials and methods

2.1. Experimental design

Several stonefruit were manually harvested from commercial orchards in Southern Spain on year 2012 at the commercial ripening stage. The fruit were: peach (*Prunus persica* [L.] Batsch cv. Roma), flat peach (*Prunus persica* [L.] Batsch cv. B-424-16), nectarine (*Prunus persica* [L.] Batsch cv. Garofa), plums (*Prunus salicina* Lindl. cv. Red Beauty and Songria) and sweet cherry (*Prunus avium* L. cv. Brooks). For peach and plum species, 15 lots of 5 fruit each homogeneous in colour and size were selected, while for cherries the lots were composed of 20 fruit. Three lots were used to determine the fruit properties at harvest and the remained 12 for the following treatments in triplicate: control (distilled water), *Aloe vera* gel at 100% (AV), *Aloe vera* gel at 100% + rosehip oil 2% (AVR2), and *Aloe vera* gel + rosehip oil 10% (AVR10). The AV gel was obtained according to previous reports (Navarro et al., 2011; Zapata et al., 2013). Briefly, freshly AV 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 (*Rosa rubiginosa* L. or its synonymous *Rosa eglanteria*) was purchased from Guinama, Valencia, Spain). Chemical composition of free fatty acids from rosehip oils is shown in Table 1. AVR2 and AVR10 were prepared by dissolving the corresponding concentration of rosehip oil (2 or 10%) to Tween-80 and then added to AV gel by vigorous shaking. Treatments were performed by dipping the fruit in the corresponding solution for 10 min. After treatments, fruit were left to dry at room temperature and stored in a controlled-chamber at 20 °C and 85% of relative humidity (RH) for 6 days. For analytical determinations, ethylene production and respiration rate were measured individually on a daily basis (with the exception of sweet cherry for which 20 cherries were used), while quality parameters, weight loss, colour, fruit firmness, total soluble solids (TSS) and total acidity (TA) were measured at day 0 and after 6 days of storage.

2.2. Analytical determinations

Weight loss of individual fruit was calculated as % with respect to the weight on day 0. Ethylene production and respiration rate were measured by placing each fruit in a 0.5 L glass jar hermetically sealed with a rubber stopper, for 30 min. Ethylene was quantified using a Shimadzu™ GC-2010 gas chromatograph (Kyoto, Japan), equipped with a flame ionisation detector (FID) and CO_2 using Shimadzu™ GC-2010 with thermal conductivity detector (TCD). Results are the mean ± SE and expressed as nL g^{-1} h^{-1} and mg CO_2 kg^{-1} h^{-1} for ethylene and respiration rate, respectively.

Colour parameters (L^*, a^* and b^*) were determined individually on each fruit using the CIE Lab System in a Minolta colorimeter CR200 model (Minolta Camera Co., Japan). Two determinations were performed on opposite side of each fruit, the Hue angle index (arctan = (b^*/a^*) was calculated and results are the mean ± SE. Fruit firmness was measured on the fruit shoulder using a flat steel plate coupled with a texturometer (TX-XT2i Texture Analyzer, Stable Microsystems, UK) interfaced to a personal computer. A bevelled holder prevented bruising of the opposite side. For each fruit, the diameter was measured and then a force that achieved a 3% deformation of the fruit diameter was applied. Results are expressed as the force-deformation (N mm^{-1}) and are the mean ± SE. After firmness determination, fruit from each treatment and replicate were manually peeled to separate the peel from the flesh. The flesh tissue from each lot was cut into small pieces and used to determine total soluble solids concentration (TSS) and titratable acidity (TA) in duplicate. TSS were measured with a digital refractometer Atago PR-101 (Atago Co. Ltd., Tokyo, Japan) at 20 °C and expressed as % (g 100 g^{-1}). Total acidity (TA) was determined by automatic titration (785 DMP Titrino, Metrohm) with 0.1 N NaOH up to pH 8.1, using 1 mL of diluted juice in 25 mL of distilled H_2O, and results expressed as g malic acid equivalent per 100 g^{-1} fresh weight. The ripening index (ratio between TSS and TA) was calculated and results are expressed as the mean ± SE.

2.3. Fatty acid composition of rosehip oil

Rosehip oil (2 mL) was submitted to methylation of fatty acids by adding 1 mL boron trifluoride/methanol at boiling temperature for 10 min. Methylated fatty acids were extracted with hexane, taken to dryness and redissolved in 200 μL chloroform before injection. Fatty acids were separated and quantified by gas chromatography (GC, Hewlett-Packard model 6890) equipped with flame ionisation detector (FID). Five microliters in split mode was injected into a capillary column (HP-Innowax Polyethylene glycol, 30 m × 250 μm × 25 μm). A gradient of temperature was used for fatty acid separation: initial temperature 120 °C for 2 min and then a rate at 4 °C/min to 190 °C which was held 5 min, and final rate at 4 °C/min to 242 °C. Identification of fatty acids was performed by comparing retention times with authentic standards (purchase from Sigma, Sigma–Aldrich, Madrid, Spain). The results of fatty acid composition are shown in Table 1.

2.4. Sensory evaluation

Sensory analyses to compare the external visual aspect of treated and control stonefruit after 6 days of storage at 20 °C were carried out by 10 trained adults, aged 25–50 years (5 female and 5 male). The panel was trained in a pre-test for evaluating the colour of these fruit. A laboratory of sensory analyses with an individual booth for each panellist was used. Each judge evaluated 1 sample for each treatment. Samples were blind labelled with random three digit codes, and the sample order was randomised. The rating for external visual aspect was based on a five-point scale (5 to 1) with 5 = like extremely (very characteristic of the fruit), 4 = like moderately, 3 = neither like nor dislike like (limit of acceptance for consumers), 2 = dislike moderately and 1 = dislike extremely (non-characteristic of the product).

2.5. Statistical analysis

Experimental data were subjected to ANOVA analysis. Sources of variation were treatment and storage. The overall least significant differences (Fisher's LSD procedure, $P < 0.05$) were calculated and

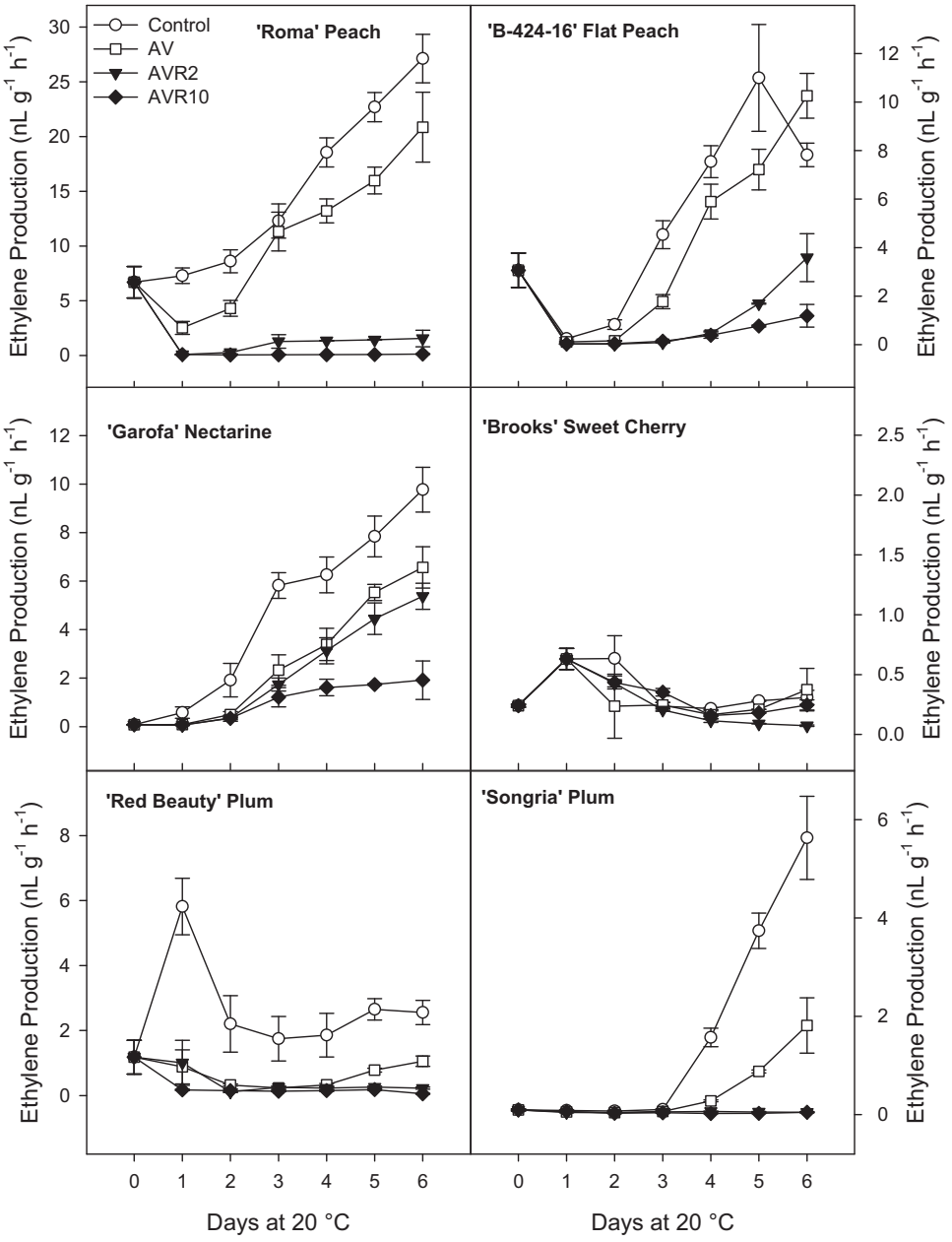

Fig. 1. Ethylene production (nL g^{-1} h^{-1}) of several *Prunus* species and cultivars during storage at 20 °C after treatments with *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Data are the mean ± SE. LSD values for 'Roma' and 'B-424-16' peaches, 'Garofa' nectarine, 'Brooks' sweet cherry, 'Red Beauty' and 'Songria' plums were 1.18, 0.64, 0.49, 0.08, 0.40 and 0.21, respectively.

used to detect significant differences among treatments and storage time. All analyses were performed with SPSS software package v. 11.0 for Windows.

3. Results and discussion

The change in ethylene production for the 6 stonefruit is shown in Fig. 1. Control peaches ('Roma' and flat B-424-16), nectarine and plums ('Red Beauty' and 'Songria') exhibited significant increases in ethylene production and remained unchanged in 'Brooks' sweet cherry (ethylene rates below 1 nL g^{-1} h^{-1}). The climacteric ethylene peak of control fruit was reached on day 1 for 'Red Beauty' plum, on day 5 for flat peach, while for 'Roma' peach, 'Garofa' nectarine and 'Songria' plum, this peak was reached on day 6 or later. Thus, plum, peach and nectarine cultivars behaved as climacteric fruit, as has been observed for other cultivars of these plant species (Valero and Serrano, 2010). However, for all climacteric fruit, the increase in ethylene production was delayed in *Aloe vera* (AV) treated fruit, the effect being higher when rosehip oil was added to AV gel. Interestingly, AV in combination with rosehip oil at 10% (AVR10) resulted in a total inhibition of the ethylene production in all the climacteric fruit. As expected, in 'Brooks' sweet cherry, ethylene production was very low in both control and treated fruit, given the non-climacteric behaviour of this fruit. With respect to respiration rate (Fig. 2), all fruit species treated with AV showed lower respiration rates than control fruit during storage, with the exception of 'Roma' peach in which no significant differences were obtained between control and AV-treated peaches. However, the use of AV + rosehip oil (AVR) led to significant reductions in respiration rates compared with those treated with AV alone for all plant species, the effect being generally higher for 10 than 2%.

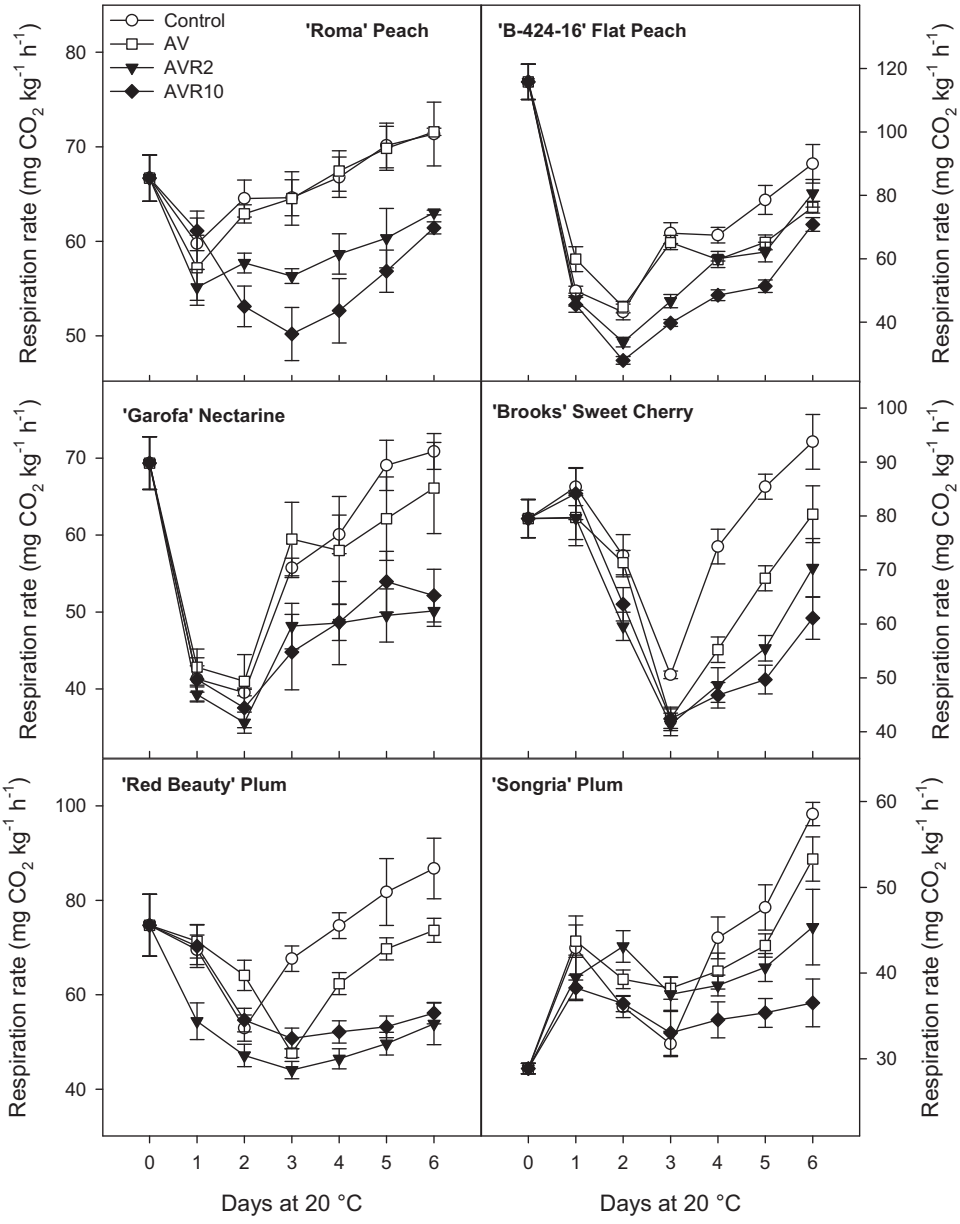

Fig. 2. Respiration rate (mg CO_2 kg^{-1} h^{-1}) of several *Prunus* species and cultivars during storage at 20 °C after treatments with *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Data are the mean ± SE. LSD values for 'Roma' and 'B-424-16' peaches, 'Garofa' nectarine, 'Brooks' sweet cherry, 'Red Beauty' and 'Songria' plums were 2.28, 3.32, 3.57, 3.45, 3.96 and 2.04, respectively.

The effect of AV on inhibiting and/or delaying the ethylene production and respiration rate has been previously reported in 'Flavela', 'Flanoba' and 'Artic Snow' nectarines (Ahmed et al., 2009; Navarro et al., 2011), 'Red Heaven' peach and 'Santa Rosa' plum (Guillén et al., 2013). This effect on ethylene production and respiration rate has been attributed to the fact that AV acts as an edible coating and decreases the gas permeability through the fruit surface, leading to modification of the internal atmosphere with enhanced CO_2 and diminution of O_2 concentration, in accord with results found with other coatings (Valero et al., 2013). In some non-climacteric fruit, such as table grape and sweet cherry, respiration rates were also reduced either during cold storage or after shelf-life periods at 20 °C (Valverde et al., 2005; Martínez-Romero et al., 2006; Castillo et al., 2010). Since AV gel is composed mainly of polysaccharides (Zapata et al., 2013), its barrier properties could be improved by the incorporation of lipids leading to the formation of a coating with higher barrier efficacy (Morillon et al., 2002), and thus higher modification of the internal atmosphere could be obtained and in turn higher ethylene inhibition. The rosehip oil used in this work contains oleic, linoleic, and linolenic acids as main fatty acids (Table 1) and thus the hydrophobic properties of the composite edible coating (AVR) would be greater than in AV alone. Similarly, edible coatings based on *A. arborescens* gel showed higher efficacy on reducing ethylene and respiration rate than AV in plum and peach (Guillén et al., 2013), which was attributed to the higher lipid composition of *A. arborescens* gel (Zapata et al., 2013). However, a direct effect of rosehip oil on inhibiting ethylene biosynthesis in some part of the pathway cannot be dismissed and deserves further research, since to our knowledge no available information exists on the effect of rosehip oil alone or in combination with edible coatings on postharvest fruit ripening.

Postharvest fruit quality attributes are influenced by several traits such as weight loss, colour, firmness, total soluble solids (TSS) and total acidity (TA) and their changes during storage.

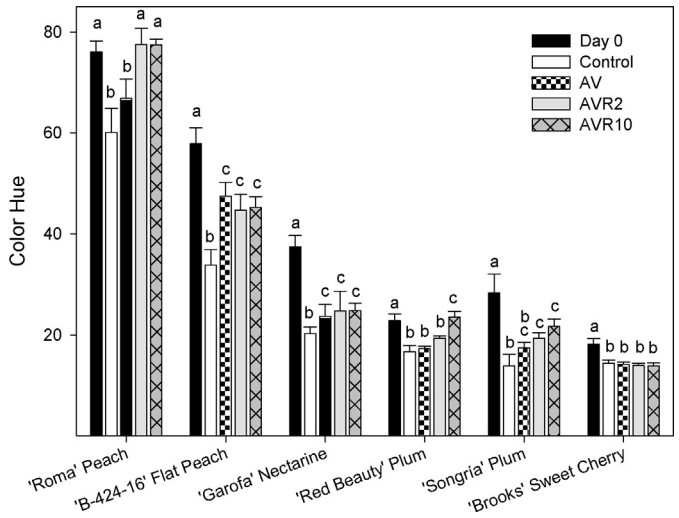

Fig. 3. Colour Hue of several *Prunus* species and cultivars at harvest (day 0) and after 6 days of storage at 20 °C affected by treatments with *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Data are the mean ± SE. Different letters show significant differences ($P < 0.05$) among treatments and storage time.

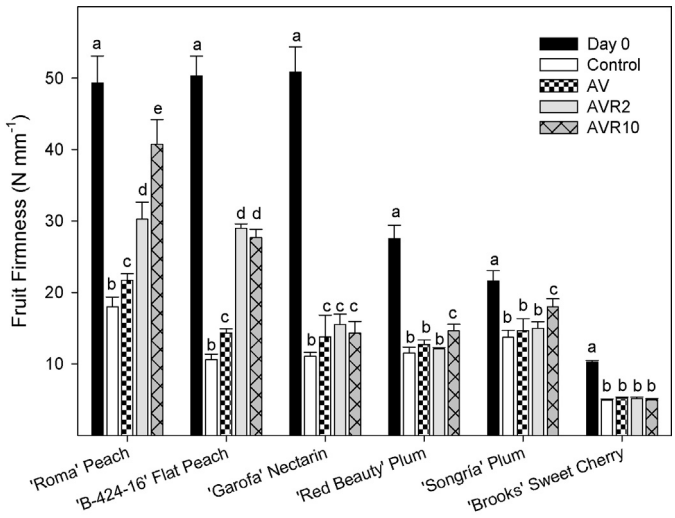

Fig. 4. Fruit firmness (N mm^{-1}) of several *Prunus* species and cultivars at harvest (day 0) and after 6 days of storage at 20 °C affected by treatments with *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Data are the mean ± SE. Different letters show significant differences ($P < 0.05$) among treatments and storage time.

Physiological weight loss of control fruit increased after 6 days of storage at 20 °C reaching values of 3–7% depending on fruit species and cultivar, which were reduced (on average 1–2%) by the use of edible coatings (data not shown). The effect of edible coatings based on AV on reducing weight loss has been reported for a wide range of fruit such as table grape, sweet cherry, peach, plum, nectarine (Guillén et al., 2013 and references therein), fig (Marpudi et al., 2013), apple (Ergun and Satici, 2012), and strawberry (Singh et al., 2011).

As expected, in control fruit, ripening parameters such as colour, fruit firmness and TSS/TA ratio showed significant changes from the initial levels to the final values after 6 days at 20 °C. Colour Hue significantly diminished in all control fruit species and cultivars, which was related to darkening of the fruit surface, while the use of AV, alone or in combination with rosehip oil (at 10 or 2%) led to generally lesser changes (Fig. 3). The most prominent effect was observed for 'Roma' peach, for which any significant colour changes were detected in those fruit treated with AVR, either at 10 (AVR10) or 2% (AVR2) and in the two plum cultivars, in which the Hue angle was significantly higher in AVR10 coated fruit than in AV coated ones, while in 'Brooks' sweet cherry, treatments did not affect colour changes. Similarly, fruit firmness significantly decreased in control fruit for all species (Fig. 4), and the application of AV or AVR led to lower softening in the two peach cultivars and nectarine, while no significant effect was observed in plums and sweet cherry. Interestingly, in both peach cultivars, the addition of rosehip oil to AV led to fruit with higher firmness levels than AV alone at the end of the experiment, as well as AVR10 treatment on 'Songria' plum. Finally, the ratio between TSS and TA or ripening index significantly increased in control fruit from the values at day 0 (Fig. 5), the increase being lower by the action of the treatments. Again, the greatest effect of the addition of rosehip oil to AV on delaying the increase in ripening index was observed for 'Roma' peach and 'B-424-16' flat type.

Previous reports have demonstrated that AV as an edible coating was a good postharvest tool to retard postharvest ripening of both climacteric and non-climacteric fruit such as table grape, sweet cherry, nectarine, peach, plum, papaya, tomato (Valverde et al., 2005; Martínez-Romero et al., 2006; Serrano et al., 2006; Ahmed et al., 2009; Navarro et al., 2011; Marpudi et al., 2011; Chauhan et al., 2013; Guillén et al., 2013) as well was fresh-cut kiwifruit (Benítez et al., 2013) and apple (Chauhan et al., 2011). As in these reports, AV was effective on delaying the changes of the parameters related to ripening such as colour darkening, softening and ripening index increase in a wide range of stonefruit such as peach, flat peach, nectarine, plums and sweet cherry. Moreover, rosehip oil (at 10 or 2%) combined with AV generally improved the efficacy of AV as edible coating on retarding the above parameters related to the postharvest ripening process. In fact, the reduction in colour Hue and firmness as well as the increase in ripening index were lower in fruit coated with AVR10 than in AV coated fruit, leading to higher maintenance of fruit quality and extension of their shelf-life. It is interesting to highlight that the greatest delay on the postharvest ripening process was observed for 'Roma' peach, which had the highest ethylene production rate (≅30 nL g^{-1} h^{-1}) in comparison with the other stonefruit, and in which the highest ethylene inhibition was obtained by the addition of rosehip oil to AV gel.

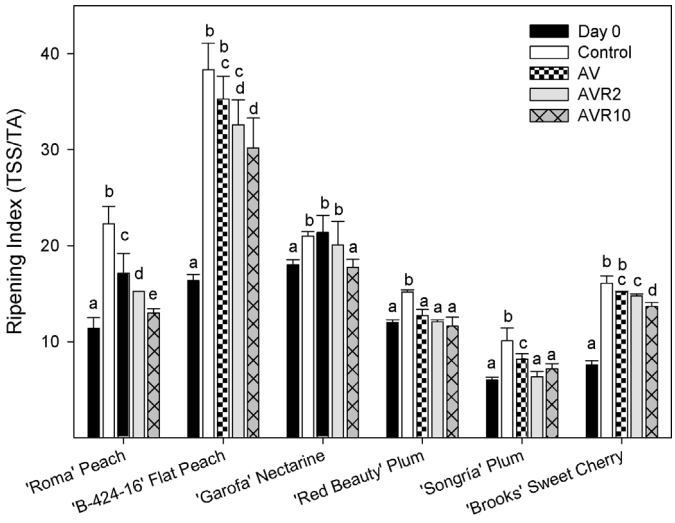

Fig. 5. Ripening index expressed as the ratio between total soluble solids (TSS) and total acidity (TA) of several *Prunus* species and cultivars at harvest (day 0) and after 6 days of storage at 20 °C affected by treatments with *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Data are the mean ± SE. Different letters show significant differences ($P < 0.05$) among treatments and storage time.

Table 2
Results of sensory evaluation (visual aspect) of the *Prunus* species and cultivars affected by treatments: *Aloe vera* gel (AV), *Aloe vera* + rosehip oil at 2% (AVR2), *Aloe vera* gel + rosehip oil at 10% (AVR10) or distilled water (control). Description of the scores (1–5) shown in "Materials and Methods" section.

	Control	AV	AVR10	AVR2
'Roma' Peach	2.1 ± 0.4a	3.5 ± 0.22b	3.7 ± 0.34b	4.5 ± 0.33c
'B-424-16' flat peach	2.5 ± 0.32a	3.3 ± 0.52b	3.4 ± 0.36b	3.7 ± 0.13b
'Garofa' nectarine	2.3 ± 0.16a	3.1 ± 0.12b	3.3 ± 0.21b	3.8 ± 0.06c
'Red Beauty' plum	2.1 ± 0.15a	3.5 ± 0.16b	3.4 ± 0.21b	4.6 ± 0.32c
'Songria' plum	2.1 ± 0.14a	2.8 ± 0.22b	3.2 ± 0.18b	3.6 ± 0.11c
'Brooks' sweet cherry	1.9 ± 0.06a	2.6 ± 0.11b	2.8 ± 0.15b	3.1 ± 0.12b

For each stonefruit, different letters after mean ± SE are significantly different ($P < 0.05$) among treatments.

Results from the sensory analysis revealed that the lowest scores were given to control fruit (Table 2) in terms of external visual aspect. Those fruit treated with AV received significantly higher scores than the control, while the highest scores were reported for those fruit treated with AVR, especially at the concentration of 2% (AVR2) of 'Roma' peach, 'Red Beauty' and 'Songria' plums, and 'Garofa' nectarine. Panellists detected an excess of gloss and oiliness on the fruit surface in those fruit treated with AVR10, which was considered a negative aspect and not related with fruit characteristics. This effect was not observed on those fruit treated with AV and AV2.

4. Conclusions

We demonstrate in this paper for the first time that rosehip oil added to AV inhibited ethylene production to a greater extent than AV alone, and delayed the changes in fruit quality parameters related to ripening. Taking into account results of sensory analysis in terms of visual acceptance, it is advisable to use rosehip oil at a concentration of 2%. More studies are needed at two levels: first, the possible effect of rosehip oil on inhibiting any step of the ethylene biosynthesis pathway, and second, its effect during prolonged periods of cold storage.

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