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Effect of modified atmosphere packaging and 'Parka' treatments on fruit quality characteristics of sweet cherry fruits (*Prunus avium* L. '0900 Ziraat') during cold storage and shelf life

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ABSTRACT

The study was carried out to determine the effects of pre-harvest Parka and post-harvest MAP treatments on weight loss, decay ratio, color characteristics, firmness, soluble solids content (SSC) and titratable acidity-like quality parameters and vitamin C, total phenolics, total antioxidant capacity (according to FRAP and TEAC) and total monomeric anthocyanin-like bioactive compounds of '0900 Ziraat' sweet cherry cultivar throughout cold storage and shelf life. MAP treatments significantly retarded weight loss throughout cold storage. Decay ratios throughout cold storage and shelf life were also lower in Parka, MAP and Parka + MAP treatments. In general, higher L*, chroma and hue angle values were measured in MAP and Parka + MAP treatments. As compared to control treatment, higher flesh firmness values were observed in Parka and Parka + MAP treatments at the end of storage and in Parka, MAP and Parka + MAP treatments in the last shelf life analysis (21st day). In cold storage and shelf life analyses lower SSC values were obtained from Parka and Parka + MAP treatments. Vitamin C contents were better maintained with MAP and Parka + MAP treatments. Total phenolics were higher in Parka + MAP treatments in all analyses of cold storage, but higher in control treatment in all shelf life analyses. In 21st day storage and shelf life analyses, antioxidant capacity (according to FRAP) of all treatments was lower than the control treatment. In all analyses, generally higher total monomeric anthocyanin contents were obtained from control fruits. It was concluded that combining pre-harvest Parka treatments with post-harvest MAP treatments could be used as an efficient tool in maintaining flesh firmness of sweet cherry fruits significantly influencing consumer preferences.

1. Introduction

World sweet cherry production increases every year since it is a more profitable fruit compared to many others. Sweet cherry can be marketed easily. But the short harvest season and sensitive fruit texture limits fruit availability in market to a few weeks. Furthermore, it is not available to consumers in optimal conditions after transportation to long distances because of these reasons. Sweet cherry fruits are highly perishable due to rapid softening, high susceptibility to fungal infections and mechanical injuries such as bruises. Some factors drastically restrict their post-harvest storage potential and marketing possibilities (Akbulut et al., 2008; Sen et al., 2014). Fruit harvested and sent to retail stores should be in good quality. Product loss up to 12% can occur due to low quality fruits (Clayton et al., 2003). Therefore, special measures should be taken to minimize quality losses in sweet cherry, to prolong post-harvest life of the fruits and to reduce the damages to be encountered during the transport.

Both pre-harvest (Zhang and Whitting, 2011; Einhorn et al., 2013; Gimenez et al., 2014; Martinez-Espla et al., 2014; Valverde et al., 2015) and post-harvest (Petracek et al., 2002; Valero et al., 2011; Giacalone and Chiabrando, 2013; Valero et al., 2014) treatments may reduce quality losses in fruits throughout the storage period and thus prolong shelf life of fruits. While pre-harvest treatments improve fruit quality and have positive impacts throughout the storage, post-harvest treatments are generally performed to prevent fruits from potential losses during storage. Modified atmosphere packaging (MAP) is a post-harvest treatment used to prolong the storage period of fruits. MAP is to maintain an atmosphere over the product with low oxygen, high carbon

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dioxide and moisture content. These atmosphere conditions helps to reduce respiration rate and water loss, thus prolong storage life of the fruits (Guilbert et al., 1996). MAP treatments may provide significant advantages in storage of sweet cherry-like thinned-skinned and easily perishable fruits (Petracek et al., 2002).

Coating is another technique used to improve shelf life of fruits. Novel coating materials like *Aloe vera* gel, alginate, chitosan, acacia gum and bee wax have potential in enhancing the shelf life and maintaining the quality of fruits and vegetables (Valero et al., 2014). Coating creates a modified atmosphere around the fruit by providing a semipermeable barrier to water vapor and gases (Rojas-Argudo et al., 2005). In sweet cherry, pre-harvest RainGard and Parka (Meland et al., 2014), post-harvest chitosan (Romanazzi et al., 2003), *Aloe vera* (Martinez-Romero et al., 2006) and alginate (Diaz-Mula et al., 2012) treatments were performed to improve fruit quality and storage durations. There aren't any previous studies investigating the effects of pre-harvest Parka (stearic acid, cellulose and calcium based bio film provided by Cultiva) treatments in maintaining fruit quality parameters throughout cold storage periods.

In this study, Parka was used as coating material and effects of Parka and MAP combination on keeping quality of "0900 Ziraat" sweet cherry cultivar throughout cold storage and shelf life were investigated.

2. Materials and methods

2.1. Plant material and experimental design

The study was carried out in 2015 on fruits harvested from 5-year-old '0900 Ziraat' sweet cherry trees (*Prunus avium*) grafted on 'MaxMa 14′ (*P. mahaleb x P. avium*) rootstock in Suşehri, Sivas Province, Turkey (40° 10' 09.67"N latitude, 38° 06' 37.14"E longitude and 952 m altitude). The trees were planted at 3.5 × 4 m spacing and trained by Spanish Bush system. Standard cultural practices such as irrigation, fertilization, disease control were regularly applied during experimental period.

The study was laid out in a randomized complete-block design. A total of 18 trees with homogeneous fruit load were selected and they were separated into 3 blocks with 6 trees per block based on proximity in orchard and crop load. In each block, 1% biofilm (Parka, Cultiva, USA) was sprayed (one at straw color and another 7 days later) on three trees until run-off with a low pressure hand sprayer and three tree in each block was served as control treatment (sprayed only with water, pH = 6.50). The biofilm concentration (1%) was selected based on previous study (Meland et al., 2014) carried out under field conditions.

As 500 fruits from each tree, about 1500 fruit for each replication (block) were harvested randomly. The fruits were harvested at commercial maturity of color grade 4 according to the color scale developed by CTIFL (Centre Technique Interprofessionnel des Fruit et Legumes, Paris, France), in which 1-light pink and 7-dark mahogany. Fruits were placed 5 kg capacity plastic boxes. Then, fruits were immediately transported via a cooled truck to the postharvest laboratory of the Department of Horticulture at Ordu University where they were selected for uniform size, disease-free, with no mechanical damage and healthy greenish stems. Fruits were hydro-cooled and put into plastic boxes (fruit pulp temperature at 1–2 °C).

A total of 150 fruits from each replication were used to determine quality characteristics at harvest [19 June, 2015, (75 fruit for instant analysis; 75 fruits after 3 days at room temperature)]. For cold storage, treatments were designed as control (obtained from the trees that were not treated with Parka and storing without MAP treatment), MAP (storing fruits, which were obtained from the trees that were not treated with Parka, in MAP), Parka (storing fruits, which were obtained from the trees that were treated with Parka, without MAP treatment) and Parka + MAP (storing fruits, which were obtained from the trees that were treated with Parka, in MAP treatment). MAP bags (5 kg) for the sweet cherry were Xtend® (815-CH97/a, StePac, Tefen, Israel). The fruits were stored in plastic boxes (39 × 29 × 21 cm, Plastas, Turkey) each of which contains 225 fruits. For each repetition 3 boxes (675 fruits) were used.

Fruits were stored in the same storage together, at 0 ± 0.5° C and 90 ± 5% RH for 7, 14 and 21 days and analyzed at the end of each storage period (19 and 26 June, 3 July 2015). Analyses were also performed after three days at room temperature (23 °C and 90 ± 5% RH for 3 days) simulating a shelf-life period. In each analysis date, 3 plastic fruit box (1 plastic box for each replicate) were analyzed for each treatment. Of the fruits in each plastic box, half was used for cold storage analyses and the other half was used for shelf life analyses.

2.2. Weight loss and decay ratio

Fruit weights were determined using a digital scale (± 0.01 g) (Radvag PS 4500/C/1, Poland). Weight loss was determined by the difference between the initial and final weights of each replicate during cold storage and expressed as percent. The fruit decay was visually evaluated during the storage and shelf life. Sweet cherry fruits that showed any sign of surface mycelia development were considered as decayed with naked eye. Decay ratio was expressed as a percentage of infected sweet cherry fruits. Weight loss and decay ratio was replicated three times for each replication.

2.3. Color characteristics and firmness

Color characteristics (L*, chroma and hue angle) were measured at opposite sides of each fruit with a colorimeter (Konica-Minolta, model CR–400, Japan). Chromatic analyses were conducted in accordance with the CIE (Commission Internationale de l'Eclairage) system. Values of L^*, a^* and b^* were used to define a three-dimensional color space. The chroma value was calculated with Eq. (1), and the hue angle with Eq. (2). Color characteristics were determined for 20 fruits in each replication. Texture analyzer, TA-TX Plus (Stable Microsystems, Godalming, UK), fitted with a 2.0 mm penetrometer probe, a 50 N load cell, operating at a penetration speed of 10 mm s^{-1} and a penetration depth of 3 mm, was used to measure flesh firmness (N mm^{-1}). The maximum force needed for penetrating the fruit 3 mm deep was 5 N. Flesh firmness results were the average of 10 measurements in each replication.

$$C^* = (a^{*2} + b^{*2})^{1/2} \quad (1)$$

$$h^\circ = \tan^{-1} b^*/a^* \quad (2)$$

2.4. SSC, titratable acidity and vitamin C

For SSC, titratable acidity and vitamin C measurements, 90 fruits were selected from each replicate and fruits were divided into 3 groups each of with 30 fruits. Stones of each fruit were removed and fruit juices were extracted with an electrical fruit juice extractor (HR1855/70, Philips, Turkey). A digital refractometer (PAL-1, McCormick Fruit Tech., Yakima, Wash., USA) was used to determine SSC (%). For titratable acidity, 10 mL extract was diluted with 10 mL distilled water, and then titrating to pH 8.2 using 0.1 mol/L sodium hydroxide, expressed in malic acid equivalent (g malic acid 100 g^{-1}). For vitamin C content, sufficient amount of extract was taken and resultant volume was completed to 5 mL with the addition of 0.5% oxalic acid. Ascorbic acid test strip (Catalog no: 116981, Merck, Germany) was taken from reclose tube, dipped into the solution for 2 s and reflectometer set (Merck RQflex plus 10) was started. The test strip was then shaken off to remove excess liquid over it, waited for 8 s and reading was performed until the end of 15th second. The resultant value was expressed as mg 100 g^{-1}.

2.5. Total phenolics, total antioxidant capacity and total monomeric anthocyanin

For bioactive compounds, 90 fruits were selected from each replicate. Then stones of these fruits were removed, and the pulp was homogenized with a food blender. The homogenates were placed into 3 different tubes and stored at −20 °C for bioactive analyses. Samples were thawed at room temperature (≈21 °C) and homogenized in a food-grade blender. The resultant slurry was centrifuged (12.000*g*) at 4 °C for 30 min to separate the juice from the pulp. The freshly obtained juice was diluted with distilled water, divided into multiple sample aliquots and refrozen at −20 °C until used in phenolics, anthocyanin and antioxidant assay procedures.

2.6. Total phenolics (TP)

Total phenolics content was measured according to the procedure described by Singleton and Rossi (1965). Briefly, fruit pulp were extracted with a buffer containing acetone, water and acetic acid (70:29.5:0.5 v/v) for 2 h at dark. Samples were replicated four times. Extracts were combined with Folin-Ciocalteu's phenol reagent and water, and incubated at room for 8 min followed by the addition of 7% sodium carbonate. After 2 h, the absorbance at 750 nm was measured in an automated UV–vis spectrophotometer (Model T60U, PG Instruments). Gallic acid was used as the standard. The results were expressed as micrograms (μg) gallic acid equivalent (GAE) g^{-1} fresh weight (fw).

2.7. Ferric ions (Fe+3) reducing antioxidant power assay (FRAP)

Portions of 120 μL were taken from the samples, 0.2 M of phosphate buffer (PO_4^{-3}) (pH 6.6) was added to obtain a volume of 1.25 mL and then 1.25 mL of 1% potassium ferricyanide ($K_3Fe(CN)_6$) solution was added. After vortexing, they were incubated at 50 °C for 1 h. Afterwards, 1.25 mL of 10% TCA (trichloro acetic acid) and 0.25 mL of 0.1% $FeCl_3$ were added to the samples. The absorbances of the extract solution were read on an UV–vis spectrometer at 700 nm. The results were expressed as μmol Trolox equivalents (TE) per kilogram of fw (μmol TE g^{-1}fw) (Benzie and Strain, 1996).

2.8. Trolox equivalent antioxidant capacity (TEAC) assay

10 mmol/L ABTS (2.2-azino-bis- 3-ethylbenzothiazoline-6-sulfonic acid) was dissolved in acetate buffer and prepared with potassium per sulfate as described in Ozgen et al. (2006). The mixture was diluted using an acidic medium of 20 mM sodium acetate buffer (pH 4.5) to an absorbance of 0.700 ± 0.01 at 734 nm for longer stability. For the spectrophotometric assay, 2.90 mL of the $ABTS^+$ solution and 100 μL of fruit extract were mixed and incubated at room temperature and dark conditions for 10 min. The absorbance at 734 nm was then determined. The results were expressed in μmol trolox equivalent (TE) g^{-1}fw.

2.9. Total monomeric anthocyanin

Total anthocyanin levels were measured by the pH differential method described in Giusti et al. (1999). Sample extracts were combined in a 1:20 ratio (v:v) with potassium chloride and with sodium acetate buffers (pH 1.0 and 4.5, respectively) in separate vessels. After an equilibration period (15 min), the raw absorbance of each solution was measured at 533 and 700 nm. A corrected absorbance value was calculated as [(A520–A700) pH 1.0–(A520–A700) pH 4.5]. The anthocyanin content was calculated using the molar absorptivity (ϵ) and molecular weights (MW) of cyanidin 3-glucoside (ϵ = 26.900; MW = 449.2). Results were expressed as micrograms (μg) of cyanidin 3-glucoside equivalents (μg cy-3-glu g^{-1} fw).

Table 1
Effect of MAP and 'Parka' treatments on weight loss of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during storage at 0° C and 90% RH.

Treatments	Weight loss (%)		
	7 day	14 day	21 day
Control	2.79 a	4.54 a	6.05 a
Parka	2.55 a	4.36 a	5.97 a
MAP	1.13 b	1.23 b	1.03 b
Parka + MAP	1.35 b	1.57 b	1.73 b

n = 9 for the weight loss (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

2.10. Statistical analysis

The percentage values were transformed using the arcsin of the square root before analysis of variance (ANOVA). The normality of the data was confirmed by the Kolmogorov-Smirnov test and the homogeneity of variances by the Levene's test. Data for physical, mechanical and biochemical parameters were subjected to ANOVA by using SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) software. When the F test was significant, means were compared with Tukey's range test. The level of significance was set as 5%.

3. Results and discussion

Complying with the results of earlier studies (Fonseca et al., 2002; Kaynas et al., 2010; Guillen et al., 2013; Giacalone and Chiabrando, 2013), MAP treatments significantly retarded weight losses in this study. The lowest and the greatest weight losses at the end of cold storage (21st days) were respectively observed in MAP (1.03%) and control (6.05) treatments (Table 1). Coating preserves integrity of fruit peel, reduces gas exchange and water loss, and thus prolongs storage and shelf life of fruits and vegetables (Valero et al., 2014). It was reported in previous studies carried out with different fruits and vegetables; post-harvest coating treatments prevented water loss and thus reduced weight loss (Dang et al., 2008). In present study, Parka treatments did not have significant effects on weight loss according to the controls. Such a case may be resulted from differences in treatment time or low treatment doses. Thusly, Valero et al. (2014) indicated that 33% *Aloe vera* gel treatments did not have significant impacts on weight loss of sweet cherry and peaches as compared to 66% and 100% concentrations.

Sweet cherry rapidly decays after the harvest because of high respiration rates (Zhang and Whitting, 2011). While Parka treatments significantly reduced decay ratios on 7 and 14th day of cold storage as compared to the control treatment, Parka and control treatments had similar decay ratios on 21stday of storage. Such findings revealed that Parka treatments might be effective in reducing decay ratio in short-term storage and they may not be effective in long-term storage. In shelf life analyses, significant decreases were observed in decay ratios of MAP and Parka-treated fruits (Table 2). Reduced decay ratios were reported with *Aloe vera* gel coating in grapes (Asghari et al., 2013), sweet cherry (Martinez-Romero et al., 2006) and nectarines (Ahmed et al., 2009). MAP treatments were found to be more effective than Parka treatments in reducing decay ratios. Both Parka and Parka + MAP treated fruits had lower decay ratios than the control fruits throughout the storage. Current findings about MAP packaging comply with the results of Kaynas et al. (2010) in plums, Guillen et al. (2013) in peach and plum, Giacalone and Chiabrando (2013) indicating reduced oxygen level and ethylene production and consequently prolonged storage durations in various fruits with MAP treatments.

Parka treatments did not result in significant changes in L* values in all measurement periods except for harvest time and 7thday of storage.

Table 2
Effect of MAP and 'Parka' treatments on decay ratio of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Decay ratio			
	Harvest	7 day	14 day	21 day
Control		1.0 a	3.2 a	5.4 a
Parka		0.5 b	2.1 b	4.8 a
MAP		0.2 c	1.0 c	2.2 b
Parka + MAP		0.2 c	1.1 c	1.4 b

Treatments	Decay ratio			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	nd.	2.6 a	6.2 a	10.4 a
Parka	nd.	1.5 b	3.8 b	6.6 b
MAP		0.6 c	2.1 c	3.4 c
Parka + MAP		0.5 c	1.6 c	1.8 d

nd: not determined. n = 9 for the decay ratio (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 3
Effect of MAP and 'Parka' treatments on L* values of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	L*			
	Harvest	7 day	14 day	21 day
Control	40.37 a	37.07 a	33.59 b	32.84 b
Parka	38.57 b	35.24 b	34.07 b	33.58 b
MAP		36.86 a	35.95 a	35.82 a
Parka + MAP		37.52 a	36.12 a	33.87 b

Treatments	L*			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	37.04 a	33.26 b	32.69 b	31.22 b
Parka	34.35 b	32.97 b	32.73 b	31.78 b
MAP		33.93 b	33.08 b	32.10 b
Parka + MAP		36.14 a	34.98 a	34.02 a

n = 120 for the L* (three replications x twenty fruits x two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 4
Effect of MAP and 'Parka' treatments on chroma values of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Chroma			
	Harvest	7 day	14 day	21 day
Control	43.54 a	42.43 b	38.91 b	34.66 b
Parka	43.67 a	39.71 c	37.80 b	34.20 b
MAP		45.69 a	42.88 a	41.09 a
Parka + MAP		42.09 b	41.20 a	40.46 a

Treatments	Chroma			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	40.99 a	35.13 b	33.66 b	29.93 b
Parka	38.87 b	35.96 b	32.21 b	30.73 b
MAP		38.20 a	36.40 a	35.92 a
Parka + MAP		39.77 a	39.48 a	36.61 a

n = 120 for the chroma (three replications x twenty fruits x two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 5
Effect of MAP and 'Parka' treatments on hue angle values of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Hue angle			
	Harvest	7 day	14 day	21 day
Control	28.47 a	24.39 b	23.54 b	20.17 b
Parka	27.60 a	23.04 b	22.83 b	20.24 b
MAP		26.88 a	25.40 a	24.21 a
Parka + MAP		26.73 a	24.65 a	24.56 a

Treatments	Hue angle			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	24.18 a	21.84 b	19.18 b	14.47 b
Parka	23.36 a	21.61 b	17.28 b	15.10 b
MAP		24.15 a	22.35 a	19.54 a
Parka + MAP		26.52 a	23.12 a	18.12 a

n = 120 for the hue angle (three replications x twenty fruits x two different measurements for each fruit). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

L* values of MAP-treated fruits were higher than the control fruits on 14 and 21stday of storage. In shelf life measurement, Parka + MAP treatments yielded higher L* values than the other treatments (Table 3). Except for the 7th day of storage, Parka treatments did not result in significant changes in chroma values. On the other hand, MAP and Parka + MAP treatments resulted in significant increases in chroma value in cold storage and shelf life measurements (Table 4). MAP and Parka + MAP treated fruits had also higher hue angle values than the control fruits in both storage and shelf life measurements (Table 5).

It was reported in earlier studies that *Aloe vera* retarded color development in mango fruits (Carrillo-Lopez et al., 2000) and alginate retarded color development in sweet cherry fruits (Chiabrando and Giacalone, 2015). In present study, pre-harvest Parka treatments did not result in significant changes in color development. Considering color values, it was observed that MAP treatments retarded color development during the storage and shelf life. It was also reported in previous studies that MAP treatments retarded color development (Cantín et al., 2008; Diaz-Mula et al., 2012; Giacalone and Chiabrando, 2013). Similarly, Artes-Hernandez et al. (2006) reported that MAP treatments retarded the formation of carotenoids and anthocyanin-like color pigments.

Flesh firmness of Parka-treated fruits was higher than the control fruits at harvest and on 21stday of storage. Likewise, flesh firmness of MAP and Parka + MAP treated fruits were significantly higher than the control fruits in almost all measurement periods. In shelf life measurements, flesh firmness of Parka, MAP and Parka + MAP treated fruits were significantly higher than the control fruits (Table 6). Flesh firmness is the most important quality factor influencing consumer preference of sweet cherry. Complying with the results of earlier coating studies (Martinez-Romero et al., 2006; Zapata et al., 2008; Guillen et al., 2013), the results presented here indicated that pre-harvest Parka application may slow down fruit fresh softening. In the same way, the results showed that MAP may be effective in maintaining flesh firmness after harvest, compared to storage without MAP (control). Current findings comply with the results of earlier studies (Kaynas et al., 2010; Giacalone and Chiabrando, 2013; Guillen et al., 2013).

Besides studies that show MAP slows down SSC increase (in kiwifruit and sweet cherry) by slowing down ripening (Zhang et al., 2003; Diaz-Mula et al., 2012), there are studies that state MAP treatment does not cause much change in the SSC value of sweet cherry (Tian et al., 2002, 2004). Kappel et al. (2002) indicate that changes in SSC value vary depending on sweet cherry varieties. SSC of MAP-treated fruits of the present study was not different from the control

Table 6
Effect of MAP and 'Parka' treatments on firmness of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Firmness (N)			
	Harvest	7 day	14 day	21 day
Control	5.90 b	5.15 b	4.44 b	3.66 c
Parka	6.78 a	5.29 b	4.32 b	4.11 b
MAP		5.68 a	4.84 a	3.71 c
Parka + MAP		5.76 a	4.97 a	4.49 a

Treatments	Firmness (N)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	5.46 b	4.79 b	4.10 b	3.39 c
Parka	6.26 a	5.29 a	4.62 a	3.80 b
MAP		5.35 a	4.67 a	4.33 a
Parka + MAP		5.45 a	4.76 a	4.47 a

n = 30 for the firmness (three replications x ten fruits for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 7
Effect of MAP and 'Parka' treatments on SSC of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	SSC (%)			
	Harvest	7 day	14 day	21 day
Control	13.6 a	14.1 a	15.5 a	16.5 a
Parka	11.6 b	12.5 b	12.8 c	13.8 b
MAP		14.8 a	15.9 a	16.0 a
Parka + MAP		13.0 b	13.5 b	13.6 b

Treatments	SSC (%)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	13.2 a	13.6 ab	14.6 a	15.1 a
Parka	11.1 b	12.4 c	12.7 b	13.2 b
MAP		14.3 a	14.7 a	15.4 a
Parka + MAP		12.7 c	13.0 b	13.0 b

n = 9 for the SSC (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

fruits. Both in cold storage and in shelf life analyses, lower SSC values were measured from Parka and Parka + MAP treated fruits (Table 7). Conflicting results were reported about the effects of coating materials on SSC values of the fruits (Valero et al., 2014; Chiabrando and Giacalone, 2015; Naserzaeim et al., 2015).

In terms of titratable acidity of the fruits right after harvest and of the fruits stored in room temperature for three days after harvest, there were no significant differences found between Parka-treated and control groups. Based on the measurements made on the fruits right after taken out of storage on the 7th day of storing and after kept for three days in room temperature, compared to control group, Parka-treated fruits were found to have higher acidity. On the other measurement dates, however, compared to control, it was determined that Parka treatment did not cause much change in terms of acidity. Acidity levels of MAP-treated fruits were similar to those of control on all measurement dates. Acidity levels of Parka + MAP-treated fruits were higher than those of control on all measurement dates (Table 8). Gonçalves et al. (2004) reported that as SSC rate of sweet cherry increases titratable acidity rate decreases. Our findings share similarity with the researchers' findings.

Tian et al. (2004) reported rapid decreases in vitamin C content of sweet cherry fruits throughout the storage. A similar case was also

Table 8
Effect of MAP and 'Parka' treatments on titratable acidity of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Titratable acidity (g malic acid 100 g^{-1})			
	Harvest	7 day	14 day	21 day
Control	1.49 a	1.34 b	1.30 b	1.12 b
Parka	1.51 a	1.45 a	1.22 b	1.17 b
MAP		1.33 b	1.24 b	1.16 b
Parka + MAP		1.47 a	1.44 a	1.29 a

Treatments	Titratable acidity (g malic acid 100 g^{-1})			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	1.42 a	1.17 b	1.10 b	1.05 b
Parka	1.48 a	1.39 a	1.21 b	1.06 b
MAP		1.24 b	1.19 b	1.13 b
Parka + MAP		1.43 a	1.40 a	1.28 a

n = 9 for the titratable acidity (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 9
Effect of MAP and 'Parka' treatments on vitamin C of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Vitamin C (mg 100 g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	17.37 a	9.15 b	7.63 b	6.63 b
Parka	14.33 b	8.45 b	8.03 b	6.57 b
MAP		12.75 a	12.23 a	12.03 a
Parka + MAP		12.55 a	11.83 a	10.57 a

Treatments	Vitamin C (mg 100 g^{-1} fw)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	12.80 a	8.95 b	7.17 b	6.27 b
Parka	10.60 b	7.90 b	7.87 b	6.19 b
MAP		11.53 a	11.43 a	11.30 a
Parka + MAP		11.85 a	10.94 a	10.31 a

n = 9 for the vitamin C (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

observed in this study. Vitamin C content of control fruits was 61.99% lower at the end of storage period. In both cold storage and shelf life measurements, vitamin C content of MAP-treated fruits was higher than the control and Parka-treated fruits (Table 9). Mohammadi and Hanafi (2014) reported significantly restarted losses in vitamin C content of strawberry fruits with MAP treatments and Sharmin et al. (2015) reported the same case in papaya fruits with *Aloe vera* treatments. In harvest, it was observed that Parka treatment caused a decrease in the vitamin C content. This might be a result of that Parka-treated fruits were less exposed to sunlight. Harris (1975) reported that outside fruit exposed to maximum sunlight contained higher amount of vitamin C than inside and shaded fruit on the same plant.

Parka treatments had similar total phenolics with the control treatment in all measurement periods except for 14thday of storage. MAP treatment caused an increase in the total phenolics content on 7th and 14th days of storage, while it caused a decrease in the total phenolics content on 21st day of storage. Compared to the control, it was determined that Parka + MAP treatment caused an increase in the total phenolics content on 7th and 14th days of storage and it did not cause much change in the phenolics content on the 21st day. Except for shelf life measurements at harvest, Parka, MAP and Parka + MAP

Table 10
Effect of MAP and 'Parka' treatments on total phenolics of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Total phenolics (μg GAE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	573.2 a	589.7 b	622.9 b	725.8 a
Parka	581.3 a	594.5 b	655.9 a	728.4 a
MAP		630.0 a	663.3 a	679.7 b
Parka + MAP		635.0 a	662.7 a	749.6 a

Treatments	Total phenolics (μg GAE g^{-1} fw)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	707.8 a	875.9 a	943.1 a	1192.7 a
Parka	658.0 a	671.8 c	688.2 d	875.1 b
MAP		809.9 b	882.5 b	891.5 b
Parka + MAP		689.3 c	780.3 c	781.1 c

n = 9 for the total phenolics (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 12
Effect of MAP and 'Parka' treatments on antioxidant activity (according to TEAC) of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	TEAC (μmol TE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	2.94 a	3.72 a	4.15 a	4.87 a
Parka	2.81 a	2.83 b	4.21 a	5.29 a
MAP		2.67 b	4.26 a	5.07 a
Parka + MAP		2.94 b	3.66 b	3.78 b

Treatments	TEAC (μmol TE g^{-1} fw)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	3.81 a	4.15 a	5.05 a	6.77 a
Parka	3.38 b	3.74 b	3.76 b	4.81 b
MAP		4.20 a	5.09 a	6.24 a
Parka + MAP		3.82 b	4.02 b	5.05 b

n = 9 for the antioxidant activity according to TEAC (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

treatments had lower total phenolics than the control treatments (Table 10). The reason for this might be the positive effect of MAP and Parka treatments on hindering oxidative stress conditions. In other words, MAP and Parka-treated fruits might have been exposed to less stress during their shelf life.

In both FRAP tests conducted right after harvest and after three-day shelf life, compared to control, Parka-treated fruits were found to have less antioxidant capacity. Parka and Parka + MAP treatments had lower antioxidant capacity than the control treatment on 7th day, Parka + MAP treatments on 14th day and MAP and Parka + MAP treatments on 21st day of the storage. In shelf life measurements on the other hand, MAP and Parka + MAP treatments had lower antioxidant capacity than the control treatment on 7 and 14th days, Parka, MAP and Parka + MAP treatments on 21st day (Table 11). According to TEAC test, Parka, MAP and Parka + MAP treatments had lower antioxidant capacity than the control treatment on 7thday and Parka + MAP treatments on 14 and 21st day of cold storage. Parka and Parka + MAP treatments had lower antioxidant capacity than the control treatment (Table 12).

An increase was observed in anthocyanin content from the beginning till the end of cold storage. Anthocyanin content of Parka-treated fruits was lower at harvest period measurements. While anthocyanin content of all treatments was lower than the control treatment on 7thday of cold storage, only the MAP and Parka + MAP treatments had significantly lower anthocyanin content than the control treatment on 14 and 21stday of cold storage. In shelf life measurements on the other hand, anthocyanin content of Parka and Parka + MAP treatments were lower than the control and MAP treated fruit at all analysis times on 7thday and all treatments (especially the Parka-treated fruits) had lower values than the control treatment in other measurement periods (Table 13).

Varied with measurement dates in general, decreases were observed in total phenolics, total monomeric anthocyanin content and thus in antioxidant capacity of Parka and MAP treatments. Chiabrando and Giacalone (2015) carried out a study with two different sweet cherry cultivars and reported that 3% alginate treatments decreased total phenolics and total anthocyanin contents throughout the storage. Similarly, Guan and Dou (2010) reported lower antioxidant capacity for MAP-treated Friar cv. plums. Artes-Hernandez et al. (2006) reported retarded carotenoid and anthocyanin formation with MAP treatments.

As to conclude, it was observed that pre-harvest Parka treatments could reduce decay rate throughout the cold storage, but they were not

Table 11
Effect of MAP and 'Parka' treatments on antioxidant activity (according to FRAP) of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	FRAP (μmol TE g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	2.97 a	3.57 a	3.61 a	4.22 a
Parka	2.16 b	2.32 b	3.40 a	3.88 b
MAP		3.21 a	3.30 a	3.81 b
Parka + MAP		2.43 b	2.57 b	2.91 c

Treatments	FRAP (μmol TE g^{-1} fw)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	3.88 a	5.15 a	5.89 a	7.15 a
Parka	2.92 b	5.12 a	5.60 a	6.42 b
MAP		3.29 b	3.43 b	4.07 c
Parka + MAP		3.50 b	3.83 b	3.99 c

n = 9 for the antioxidant activity according to FRAP (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

Table 13
Effect of MAP and 'Parka' treatments on total monomeric anthocyanin of sweet cherry fruits (*Prunus avium* L. cv. '0900 Ziraat') during cold storage and shelf life.

Treatments	Total monomeric anthocyanin (μg cy-3-glu g^{-1} fw)			
	Harvest	7 day	14 day	21 day
Control	16.0 a	32.8 a	33.7 a	54.9 a
Parka	13.8 b	18.1 b	44.9 a	54.8 a
MAP		16.4 b	16.6 b	20.3 b
Parka + MAP		14.3 b	15.8 b	17.7 b

Treatments	Total monomeric anthocyanin (μg cy-3-glu g^{-1} fw)			
	Harvest + 3	7 + 3 day	14 + 3 day	21 + 3 day
Control	26.9 a	55.2 a	76.9 a	122.9 a
Parka	17.2 b	24.8 c	55.5 c	56.6 c
MAP		55.3 a	69.6 b	91.3 b
Parka + MAP		32.7 b	58.7 c	59.1 c

n = 9 for the total monomeric anthocyanin (three replications x three different measurements for each replication). Means in columns with the same letter do not differ according to Tukey's test at $P < 0.05$.

as much effective as MAP treatments. However, Parka treatments together with MAP retarded the losses in flesh firmness especially throughout the shelf life of the fruits.

Conflicts of interest

The authors declare no conflict of interest.

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