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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}.