Postharvest Biology and Technology 102 (2015) 32–41

Contents lists available at ScienceDirect

Postharvest Biology and Technology

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

The effect of different electrolyzed water treatments on the quality and sensory attributes of sweet cherry during passive atmosphere packaging storage

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ARTICLE INFO

Article history:
Received 4 October 2014
Received in revised form 29 January 2015
Accepted 23 February 2015
Available online 27 February 2015

Keywords:
Sweet cherry
Electrolyzed water
Storage
Quality

ABSTRACT

The present study was designed to determine the effectiveness of electrolyzed water (EW) prepared at six levels of free available chlorine concentrations (25, 50, 100, 200, 300, 400 mg/L), on postharvest quality attributes of sweet cherry. Cherries were analyzed for various quality parameters, such as gas concentration inside packages, pH, total soluble solid, water activity, weight loss, firmness, color, anthocyanin profile, sensory attributes, and decay rate during 30 d of storage at 4 °C. The oxygen (O_2) level reduced sharply during the first five days of storage inside the package of sweet cherries treated with 300 and 400 mg/L EW. However, steady-state gas concentration was formed in the packages of 25 and 50 mg/L EW between 10 and 20 d of storage. Weight losses were about 0.25% in 25, 50 and 100 mg/L EW treated samples while losses were in the range of 0.30–0.37% for other samples after 30 d of storage. The cherries treated with 25 and 50 mg/L EW had lower pH values, total soluble solid contents, and decay rate than control and other treated samples at each storage time. Color values of L^* increased with the increment of EW concentration at each sampling time. Cherries treated with 25, 50, and 100 mg/L EW showed higher a^* values than other treated and control samples. Cherries treated with 300 and 400 mg/L EW had the lowest cyanidin 3-rutinoside, cyanidin 3-glucoside, and pelargonidin 3-rutinoside content, whereas the highest amount belonged to the cherries treated with 25, 50, and 100 mg/L EW. Mold growth was the main factor in shortening the shelf life of sweet cherries. Electrolyzed water concentrations above 200 mg/L had a negative impact on sensory quality. The overall results indicated that electrolyzed water concentration below 200 mg/L combined with passive atmosphere packaging can be used to extend the shelf life of sweet cherry.

1. Introduction

Sweet cherry is one of the most appreciated fruits by consumers because of its taste and brilliant color. However, sweet cherry loses its quality quickly due to a high respiration rate, softening process, color changes, weight loss, and fungal spoilage (Aday and Caner, 2010; Martínez-Romero et al., 2006). Turkey is the largest sweet cherry producer in the world with 438.550 t. Turkey is also the world's third-largest cherry exporter, after Chile and USA, with a quantity of 46.477 t in 2011 (FAO, 2011). Among the cherry cultivars, '0900 Ziraat' is the major cultivar in terms of production and exportation in Turkey (Esturk et al., 2012). To boost export performance of this fruit, new postharvest technologies and sustainable chemical agents should be applied.

Chlorine is the most commonly used decontamination agent in food industry (Chaidez et al., 2012). However, the reactivity of the chlorine species present in one chlorine-based sanitizer could be different than other chlorine based sanitizers because of the reactive and complex nature of chlorine. Free chlorine, bound chlorine, total chlorine, chloride ion, and hypochlorous acid to hypochlorite ratio are the important factors that affect the reactivity of chlorine based sanitizers (Waters and Hung, 2013). In addition, the produce industry have raised concerns regarding the additional regulatory barriers, constraints, and safety

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http://dx.doi.org/10.1016/j.postharvbio.2015.02.009
0925-5214/

regulations for the use of chlorine in its present form (Keskinen et al., 2009). Therefore, new decontamination agents are gaining interest in the sector.

Electrolyzed water (EW) is an alternative to chlorine, and can be obtained by the electrolytically from dilute (15 g/L) NaCl solution by applying a voltage across an electrolytic cell. Chloride from salt water is converted into chlorine gas which immediately forms hypochlorite in solution (Boal, 2009). It received GRAS status in food plants since it meets the the requirements specified in 21CFR 173.315 (Chemicals for washing fruit and vegetables, criteria). Previous works showed that EW has a strong antimicrobial effect on alfalfa seed (Kim et al., 2003), lettuce (Park et al., 2001), egg (Park et al., 2005), seafood (Huang et al., 2006), mizuna baby leaves (Tomás-Callejas et al., 2011), carrot (Rahman et al., 2011), spinach (Gómez-López et al., 2013), broccoli, and strawberry (Hung et al., 2010b). The antimicrobial capacity of EW is related to pH, oxidation-reduction potential, free chlorine concentration, hypochlorite ion, and hypochlorous acid (Sharma and Demirci, 2003). In contrast to chlorine, EW is not harmful for human health and is easily converted back to ordinary water when in contact with water, or diluted by tap water (Tomás-Callejas et al., 2011). EW can be combined with other preservation methods such as passive modified atmosphere. Gas concentration inside food packages plays an extremely important role in reducing respiration rate, decreasing production of ethylene, inhibiting microorganism growth, and retarding senescence (Torrieri et al., 2010). Several studies demonstrated the effects of passive modified atmosphere on lettuce (Horev et al., 2012), endives (Charles et al., 2008), and mushroom (Ares et al., 2006).

Until now, most studies have focused on the use of EW in the field of microbial inactivation. However, no research has addressed the effects of EW combined with passive atmosphere on the main quality attributes in sweet cherry. Therefore, the aim of our work was to determine the effects of different EW concentrations on the storability and post-harvest quality attributes of sweet cherry (pH, total soluble solid, water activity, weight loss, firmness, color, anthocyanin profile, sensory attributes, and decay rate) during passive atmosphere storage.

2. Material and methods

2.1. Materials

Cherries (*Prunus avium* L. Cv. '0900Ziraat') grown in Lapseki, Canakkale, Turkey, were randomly harvested from multiple trees at commercial maturity stage (>26 mm, >9.5 g, bright red color). The fruits were transported to the food engineering laboratory under cold box conditions (around 4 °C) in less than 2 h. Cherries were selected based on weight (around 10 g), size (around 28 mm), color, and absence of any fruit deformity before treatments. The remaining fruit were split into seven equal batches for per replication (28 kg).

2.2. Preparation of electrolyzed water and treatment

EW was provided by MIOX (MIOX Corporation, New Mexico, USA) mixed oxidant brine pump system using 1% NaCl solution as an initial material in order to produce an electrochemically treated solution. After the electrolysis process of a brine solution inside the equipment, EW was collected from the mixture of cathode and anode solution in a receiving vessel (Clevenger et al., 2007). It is called 'MIOX' mixed oxidant solution. Then, stock solution of EW were diluted with distilled water to EW-25, EW-50, EW-100, EW-200, EW-300 and EW-400 (25, 50, 100, 200, 300, 400 mg/L free chlorine respectively). Solutions were stored for 4 h at 4 ± 1 °C to achieve a solution temperature of 4 °C. The amount of free chlorine was measured by the DPD (the *N*,*N*-diethyl-*p*-phenylenediamine) method using a DR/2800 spectrophotometer (HACH, Co., USA). According to the manufacturer, EW has a short storage life of 48 h, however, in our study; it was used within 2 h after generation.

Cherries were immersed in the EW solutions (4 °C) for 3 min at different concentrations (25, 50, 100, 200, 300 and 400 mg/L free chlorine respectively). Control cherries were immersed in distilled water at a temperature of 4 °C. After waiting for them to air dry (approximately 2 h), around 200 g of cherries were placed in the polypropylene trays (190 × 144 × 50 mm), and packaged with MAP25 (Apack Ltd., Sti., Istanbul, Turkey) machine by using 35 μ bi-oriented polypropylene film in air conditions (21% O_2, 0.03% CO_2 and 79% N_2) to achieve an equilibrium state with passive modified atmosphere. Samples were stored at 4 °C and 80–85% RH.

2.3. Measurements

2.3.1. Headspace gas composition

Gas composition inside the package (190 × 144 × 50 mm) of the treated and control cherries was measured with a calibrated mobile hand held Oxybaby (Hamburg, Germany) gas analyzer. Before a gas composition analysis, an adhesive silicon septum was bonded onto a surface of package film to avoid gas leakage during analysis. The needle of the gas analyzer was inserted through the septum into the package headspace (Aday et al., 2011). Three packages per treatment were used at each sampling point. After the headspace analysis, the cherries in the packages were used for other quality analysis.

2.3.2. Weight loss

Packages of treated and control cherries were coded, and the weights were recorded on day 0, 5, 10, 15, 20, and 25. Weight loss was calculated as loss of weight from the initial weight of the same packages (Almenar et al., 2007).

2.3.3. Total soluble solid and pH analysis

Ten pieces of fruit in the packages were halved and pits were removed. The fruit were then homogenized in a blender and the homogenate was filtered through the cheesecloth. Obtained juice was used to analyze total soluble solid content and pH values of cherries. Total soluble solid content was measured with a digital refractometer (Atago, Tokyo, Japan) and the pH value was determined by using a pH meter (Sartorius PP-50, Goettingen, Germany) (Kartal et al., 2012).

2.3.4. Water activity

Water activity of the sample was determined using Aqua Lab Series 4 TE (Decagon Devices, Pullman, USA) which measures the dew point of sample by means of an optical sensor. After removing the pits of ten cherries, half of the cherry (around 2 g), was put into the cup of the device, and placed in the sample cabinet (Alves et al., 2013).

2.3.5. Color

The surface color of the cherry was measured by using Minolta CR-400 colorimeter (Minolta, Osaka, Japan) with D65 illumination. Values were expressed using CIE color space coordinates L^*(lightness), a^* (red–green), and b^* (yellow–blue). Standard white plate was used to calibrate the device before analysis. The measurements were taken at two points around the equatorial region of ten cherries from each package (Bernalte et al., 2003).

2.3.6. Firmness

A firmness measurement was assessed based on a penetration test at a constant speed of 10 mm/s, and penetration distances of