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The efficacy of the combined use of chlorine dioxide and passive modified atmosphere packaging on sweet cherry quality

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ABSTRACT

The efficacy of the combined use of passive modified atmosphere and aqueous chlorine dioxide at various concentrations of 4, 8, 12, 16, 20 and 25 mg/L on physical and chemical quality attributes of sweet cherry was evaluated during a five weeks storage period at 4 °C. The results showed that ClO_2 treatments at concentrations of 16 and 20 mg/L maintained pH, total soluble solid contents and firmness better than other samples at the end of the storage. Untreated samples and samples treated with 25 mg/L ClO_2, had higher weight loss and respiration rate than other treated fruit during storage. Steady-state equilibrium was achieved in the passive modified atmosphere packages of ClO_2 treated cherries between the second and the fifth weeks of storage. No significant differences were found between untreated and treated samples except for 25 mg ClO_2 treated fruit regarding electrolyte leakage. The L^* values of ClO_2 treated samples ascended with increasing concentrations of ClO_2 at each sampling day. ClO_2 treatments significantly affected the redness (a^*) values of fruit during storage. ClO_2 treatment at the concentration of 25 mg/L had a deleterious effect on cherry color and anthocyanins. The cherries treated with 16 and 20 mg/L ClO_2 tended to have higher scores than other treated and untreated samples in all sensory attributes. No mold growth was visually observed during the first two weeks of storage in treated cherries except 4 and 8 mg/L ClO_2 treated samples. In summary, our work has led us to conclude that combined use of passive modified atmosphere and ClO_2 treatments at a concentrations of 16 and 20 mg/L has potential to maintain the quality of sweet cherry.

1. Introduction

Sweet cherries are preferred by the consumers due to their sweet flavor, exquisite aroma and natural healthy compounds such as polyphenols and anthocyanins (Longobardi et al., 2013). Turkey is the largest producer of sweet cherry with 438.550 tons in 2011, however Turkey holds the third place for the exportation after USA and Chili according to the FAO statistical database (FAO, 2011). The most important reason for this situation is postharvest applications. Total losses in sweet cherries are related to their high respiration rate and great susceptibility to textural damage, color changes and fungal decay during postharvest life (Aday and Caner, 2010; Wang et al., 2014). In recent years, consumer demands for high quality and safe foods have increased, however their level of tolerance associated with low quality decreased. Therefore, promising preservation methods and effective chemical agents are necessary to improve storage quality, fulfill consumer demands, and reduce economic losses.

Chlorine is the most commonly used sanitizing chemical in the food industry. However, chlorine reacts with organic compounds and forms carcinogenic trihalomethanes and haloacetic acids which are harmful to humans and the environment (Keskinen et al., 2009). In addition, effectiveness of chlorine depends on pH and presence of organic matter. Compared to chlorine, chlorine dioxide has a lower oxidative potential but higher oxidation capacity which makes it act as an effective disinfectant. Unlike chlorine, chlorine dioxide does not oxidize organic matters to produce highly toxic hazardous molecules (Gómez-López et al., 2009). Moreover, the use of ClO_2, was approved by the Food and Drug Administration to sanitize fruit and vegetables. Concentration of residual ClO_2 should not exceed more than 3 mg/L in foods (FDA, 2014). In the European Union (EU), Regulation EC 853/2004 (EU, 2004a) allows a decontamination agent to be used as disinfectant for food of animal origin only if its use has been approved by the government of the European country. However, substances other than potable or clean water are not permitted to be used as decontamination agents for fresh produce according to EC 852/2004 (EU, 2004b). To the best of our knowledge, there is currently no regulation concerning the use of chlorine dioxide use

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in Russia that is the second largest export destination of Turkey after EU countries.

The application of ClO_2 technology in different produces such as tomato (Guo et al., 2014), 'Daw' longan (Saengnil et al., 2014), asparagus lettuce (Chen et al., 2010), plum (Chen and Zhu, 2011), fig (Karabulut et al., 2009) and strawberry (Aday et al., 2013; Aday and Caner, 2014) has been documented. Guo et al. (2014) reported that ClO_2 slowed down the ethylene production and total respiration in tomato. Saengnil et al. (2014) showed that ClO_2 reduced browning and preserved the total phenolic content of 'Daw' longan fruit. Chen et al. (2010) found that ClO_2 reduced the polyphenol oxidase (PPO) and peroxidase (POD) activity and inhibited the enzymatic browning of asparagus lettuce. Chen and Zhu (2011) observed that, combined treatment of ClO_2 and ultrasound was effective to maintain ascorbic acid and flavonoids in plum. Karabulut et al. (2009) reported that total microorganism and fungal population were inhibited by ClO_2 treatment in fig. Aday et al. (2013) showed that strawberries treated with ClO_2 had higher firmness and better color than untreated samples.

Modified atmosphere packaging (MAP) is another technology used to extend shelf life of fruit and vegetables. In passive MAP, desired gas concentration inside the package of fruit and vegetables can be established with the interaction between gas permeability of polymer film and produce respiration rate (Costa et al., 2011). Passive MAP maintains the quality of food by slowing down the respiration rate and ethylene production, decreasing enzymatic activity, and decay (Sandhya, 2010). The studies related to the passive modified atmosphere packaging were carried out on several fruit and vegetables including, grape (Costa et al., 2011), endives (Charles et al., 2008), lettuce (Horev et al., 2012), strawberry (Aday et al., 2013; Aday and Caner, 2014) and honey pomelo (Li et al., 2012).

Many researcher have addressed the antimicrobial efficacy of ClO_2 against microorganisms. However, these studies failed to take into account of the effects of ClO_2 on anthocyanin compounds such as cyanidin 3-glucoside, cyanidin 3-rutinoside, pelargonidin 3-rutinoside. In addition, to the best of our knowledge, no studies have been conducted on the combined effect of ClO_2 and passive modified atmosphere packaging on sweet cherry quality. Therefore, the goal of this study was to determine the best ClO_2 concentration to extend shelf life of sweet cherry during refrigerated storage.

2. Material and methods

2.1. Material

Samples of 'Van' sweet cherry variety were harvested at a ripe maturity stage from a local farm located in Lapseki, Canakkale, Turkey. The fruit were transported to the Food Engineering Laboratory within 1 h and immediately processed. Prior to treatments, sweet cherries with signs of decay and presence of physical damage were discarded. Then fruit were divided randomly into seven groups.

2.2. Chlorine dioxide treatment

Chlorine dioxide was prepared by using a chlorine dioxide generator (ALLDOS, Oxiperm D164-005, Alldos Eichler GmbH, Grundfos company, Pfinztal, Germany), as described previously (Aday et al., 2013). Then gaseous chlorine dioxide was dissolved in water and concentrated stock solution was prepared. Stock solution was then diluted to 4, 8, 12, 16, 20 and 25 mg/L concentrations. Obtained concentrations were checked by the *N*, *N*-diethyl-*p*-phenylenediamine method using a DR/2800 spectrophotometer (HACH Company, Loveland, CO).

Fruit were not washed in demineralized water prior to ClO_2 application to mimic current practices in the fresh fruit industry where typically a single-stage washing process with sanitizing agents is applied. Therefore, approximately 200 g sweet cherries were dipped in glass beakers containing 1 L aqueous solutions of 4, 8, 12, 16, 20 and 25 mg/L ClO_2 for 3 min under dark conditions to prevent decomposition of ClO_2 by sunlight. Solutions were refreshed after each dipping process. Untreated cherries were treated with distilled water. After the treatments fruit were taken out and air-dried (approximately 2 h). Then around 200 g sweet cherries were put into polypropylene trays ($190 \times 144 \times 50$ mm) and sealed by using 35 μ bi-oriented polypropylene film as lidding film and a MAP25 machine (Apack Ltd., Sti., Istanbul, Turkey) under air conditions (21% O_2, 0.03% CO_2 and 79% N_2) to achieve desired steady-state equilibrium by passive modified atmosphere. Samples were stored at 4 °C for five weeks.

2.3. Methods

2.3.1. Headspace gas composition

The gas atmosphere (% O_2 and% CO_2) changes in the headspace of package were measured using Oxybaby (Hamburg, Germany) gas analyzer. Needle of instrument was inserted through adhesive silicon septum which was attached onto a surface of the package film. Each package was used only for one measurement. Three packages were used on each sampling day for per treatment.

2.3.2. Total soluble solid content and pH

Sweet cherries (twelve fruit) were homogenized using a blender and then homogenates were filtered by using cheesecloth. Obtained juice was used to determine total soluble solid content with Atago digital refractometer (Tokyo, Japan) and pH with a Sartorius PP-50 pH meter (Goettingen, Germany).

2.3.3. Water activity

Water activity was measured using an Aqua Lab Series 4 TE (Decagon Devices, Pullman, USA). Before water activity analysis, the instrument was calibrated with independent salt standards. Briefly, half of the cherry was placed in the sample cabinet of the device and dew point of cherry was determined by an optical sensor. Twelve cherries for per treatment were used to determine the water activity.

2.3.4. Weight loss

Weight of the coded packages were recorded on weekly. Percent weight loss was calculated by measuring the weight of the packages at the beginning of storage and after every week during the storage (Nunes et al., 2013).

2.3.5. Firmness

Texture Analyzer (Stable Micro Systems, Surrey, England) with a diameter of 3 mm probe was used to determine the firmness (N) of twelve cherries for each package. The test conditions were: test speed, 10 mm/s and penetration distance, 7 mm (Aday and Caner, 2010).

2.3.6. Electrolyte leakage

Approximately five grams of cherry was placed in 90 mL deionized water and incubated at 25 °C. Then electrical conductivity of this solution was recorded at 1 min and 60 min. Total electrolytes were measured on the same solution after autoclaved for 25 min at 121 °C. The percentage electrolyte leakage of samples was determined by the following equation, $E = (C_{60} - C_1)/C_T \times 100$ (Fan and Sokorai, 2005).