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Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes

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ABSTRACT

The effects of active modified atmosphere packaging (MAP) on the postharvest quality of cherry tomatoes stored at cold temperature (5 °C) and in bi-oriented polypropylene/low density polyethylene BOPP/LDPE bags were investigated. The atmosphere composition used in the packaging was 5% O_2 + 5% CO_2 (MAP), and synthetic air (control). The variables measured were weight loss, firmness, sugar, organic acids, color, lycopene, respiration rate, and ethylene biosynthesis over 25 days. The results showed that active MAP could extend the shelf life of cherry tomatoes to 25 days and the gas concentration could influence the postharvest quality of cherry tomatoes. MAP treatment decreased the respiration rate and ethylene production rate while reducing weight loss, lycopene biosynthesis, and the formation of red color. Through the use of MAP it was possible to maintain firmness and delay changes in sugar and organic acid contents. The combination of active MAP and low temperature treatments was effective with regard to delaying maturity during the storage period, and preserving the quality of cherry tomatoes.

1. Introduction

The increasing growth in the consumption of fresh fruits and vegetables over the last century has driven commercial demand for improving the storage and transit conditions to manage postharvest disease proliferation while also maintaining the quality (i.e., flavor, color, nutritional aspects, firmness, shelf life, and processing attributes) of fresh produce during their shelf life (Tzortzakis et al., 2007).

Tomatoes are important worldwide, both for the fresh and the processing markets. This vegetable is available all year and is rich in compounds including vitamin C, flavonoids, and carotenoids, which are believed to be beneficial to human health (Wold et al., 2004). Tomatoes have been ranked as the number one source of lycopene (71.6%), as well as an important source of vitamin C (12.0%), pro-vitamin A carotenoids (14.6%), beta-carotene (17.2%), and vitamin E (6.0%) (Raffo et al., 2006). However, this vegetable has a relatively short postharvest life and during fruit ripening many quality-affecting processes take place (Hoeberichts et al., 2002).

Tomatoes characteristically follow a climacteric ripening pattern, which is controlled by ethylene (Carrari and Fernie, 2006), and involves a wide range of physical, chemical, biochemical, and physiological changes. Thus, most tomato postharvest storage technologies are focused on controlling respiration and the action of ethylene in order to delay these changes (Martínez-Romero et al., 2007; Serrano et al., 2008). Tomatoes and derived products are major sources of lycopene and significantly contribute to carotenoid intake by humans. However, processing and storage conditions of tomato products may cause lycopene degradation as reviewed by Nguyen and Schwartz (1999).

An important strategy to control some of these transformations and degradations is the use of modified atmospheres (Lin and Zhao, 2007). Modified atmosphere packaging (MAP) storage and controlled atmosphere (CA) storage are used to increase the shelf life of fruits and vegetables. MAP is the alteration of the gaseous environment produced as a result of respiration (passive MAP) or by the addition and removal of gases from food packages (active MAP) to manipulate the levels of O_2 and CO_2. Depleted O_2 and/or enriched CO_2 levels can reduce respiration, delay ripening, decrease ethylene production, retard textural softening, and slow

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down compositional changes associated with ripening, thereby resulting in an extension of shelf life (Daş et al., 2006).

Generally, 3–8% CO_2 and 2–5% O_2 are recommended for fruits and vegetables for MAP storage (Farber, 1991). According to Sandhya (2010), the ideal concentrations of O_2 and CO_2 for storing tomatoes are 3–5% and 0%, respectively. Storage of pink 'Buffalo' tomatoes (*Solanum lycopersicum*) in 4% O_2 + 2% CO_2 at 12 °C contributed to extending their shelf life (Nunes et al., 1996). In contrast, Ratanachinakorn et al. (1997) found that pink 'Bermuda' tomatoes were not harmed by exposure to 0.5% O_2 for 1 day or 80% CO_2 for 2 days at 22 °C. Akbudak et al. (2012) studied the effect of a bioactivator derived from *Erwinia amylovora*, called harpin (H), and passive modified atmosphere packaging on cherry tomato quality. The authors found that these treatments were effective in retaining fruit quality. However, there has been limited information available on the use of active modified atmosphere for controlling respiration rate and delaying ripening processes, including its influence on texture, color, lycopene, sugars, and organic acids, during storage of cherry tomatoes (*S. lycopersicum* L. var. *cerasiforme* cv. Josefina). Therefore, the aim of this study was to determine whether the gas composition of 5% O_2 + 5% CO_2 + balance N_2 has the potential to be used as a modified atmosphere for delaying ripening of cherry tomatoes during storage in multilayer plastic bags (low density polyethylene [LDPE] and bi-oriented polypropylene [BOPP]) while maintaining their physical–chemical and antioxidant properties.

2. Material and methods

2.1. Plant material and storage conditions

Cherry tomatoes (*S. lycopersicum* L. var. *cerasiforme* cv. Josefina; syn.: *Lycopersicon esculentum* Mill.) used in the experiments were commercially grown and collected in Florianópolis city (Santa Catarina State, southern Brazil) and stored for up to 24 h at 5 °C until use. The fruit were free from previous postharvest treatments. Before each experiment, cherry tomatoes were selected according size (diameter 20–30 mm), red color (more than 80 percent of the surface showed red color), on total soluble solids (which averaged 5.5%), and physical integrity. Samples were washed in running water and sanitized in a 0.5 mg kg^{-1} ozonized solution for 1 min, then allowed to air-dry at room temperature. One hundred grams of cherry tomatoes (approximately ten fruit) were place into multilayer plastic bags (low density polyethylene [LDPE] and bi-oriented polypropylene [BOPP]); 175-mm wide × 240-mm long, 75 μm thickness. The permeability of O_2 7.64×10^{-10} mol μm m^{-2} s^{-1} Pa^{-1} and of CO_2 2.09×10^{-9} mol μm m^{-2} s^{-1} Pa^{-1} Lamine Cia Package, SP, Brazil). The packages containing the fruit were divided into two batches, the first batch was filled with a gas composition of 5% O_2 + 5% CO_2 + 90% N_2 and the second one was filled with synthetic air (O_2–21%; CO_2–0.03%; N_2–78%). The gas composition in the multilayer plastic bags was achieved by injecting the gases using a vacuum sealer (200B, Selovac, São Paulo, Brazil) apparatus with injection pressure and time of 1.10×10^2 kPa and 12 s, respectively. Cherry tomatoes inside the bags were stored in temperature-controlled chambers (model ECB-EX, Expectron Tecnologia Industrial Ltda, São José, SC, Brazil) at 5 °C for 25 days. The samples were assessed at 6, 12, 20, and 25 days. During the storage period, the relative humidity (RH) of the atmosphere ranged from 80 to 85% and was controlled by a humidity system. For each day of analysis, three packages were used. All experiments and analyses were carried out in triplicate. Previous studies using temperatures of 5 °C, 10 °C, and 15 °C showed that 5 °C is the most suitable for storing tomatoes in multilayer plastic bags (low density polyethylene [LDPE] and bi-oriented polypropylene [BOPP]) under modified atmosphere.

2.2. Weight loss

Tomato samples were weighed non-destructively on days 0, 6, 12, 20 and 25 days. The difference between initial and final fruit weight was considered as total weight loss during each storage interval and calculated as percentages on a fresh-weight basis by the standard AOAC (2005) method.

2.3. Firmness

Compression force was determined using a digital texture analyzer TAXT2i (Stable Micro System, Surrey, UK) with a 50 N load cell. The experiment was conducted with a 45 mm diameter cylindrical probe and test, pre-test, and post-test speeds were 1 mm/s, 2 mm/s, and 5 mm/s, respectively. The strain used was 10% of tomato compression. Fifteen fruit for each treatment were randomly selected, and the results were expressed in N.

2.4. Organic acids

The analysis of organic acids in fruit samples was performed by high performance liquid chromatography (HPLC) in a liquid chromatograph (Series 200, PerkinElmer, UK) equipped with a vacuum degasser, binary pump, manual injector (100 μL microsyringe), loop of 20 μL and UV–vis detector, wavelength range of 250 nm for ascorbic acid and 210 nm for other acids adapted from Mikulic-Petkovsek et al. (2012). The chromatographic separation used a reversed-phase C18 column (ODS-II, 4.6 × 250 mm ID, 3 μm). The mobile phase used for separation of acidic aqueous solution was 0.01 M KH_2PO_4 at a flow rate of 1.2×10^{-2} mL s^{-1}, pH adjusted to 2.6 with phosphoric acid, and run time of 15 min. The quantification of organic acids was carried out by external standard curve with 6 points for each organic acid (citric, malic, ascorbic, tartaric acid). All samples and the mobile phase were filtered on regenerated cellulose membrane with a diameter of 47 mm and a pore size of 0.45 μm. The same chromatographic conditions were kept for standards and samples. The fruit samples were pressed and the juice obtained was diluted with the mobile phase (1/9) previously filtered through regenerated cellulose membrane. The juice was filtered through filter paper and Minisart (CR 4, Sartorius). The identification of organic acids in fruit samples was performed by comparison of its retention time with the respective standard. The analyses were performed in duplicate.

2.5. Sugar extractions

Analysis of sugars in the fruit samples was performed by high performance liquid chromatography (HPLC) on a liquid chromatography (Series 200, PerkinElmer, UK) equipped with a vacuum degasser, binary pump, manual injector (100 μL microsyringe), loop of 20 μL, refractive index detector, column temperature of 50 °C, and oven temperature of 65 °C. The chromatographic separation used the column Lichrospher 100 NH_2 5 μm (250 × 4 mm). The mobile phase used for separation of the sugars was an aqueous solution of 75% (v/v) acetonitrile at a flow rate of 1.3×10^{-2} mL s^{-1} with a run time of 15 min according to Macrae (1998). The quantification of sugar was performed using an external standard curve with 6 points for each pattern (sucrose, glucose, fructose). The same chromatographic conditions were kept for standards and samples. The samples were pressed fruit juice and 1 g obtained was homogenized in aqueous 75% acetonitrile and transferred to a flask supplementing the volume to 50 mL. The solution was subjected to an ultrasonic bath for 10 min and filtered on filter paper and Minisart (CR 4, Sartorius) for injection into the chromatograph. The identification of the sugars in the fruit samples was performed by comparison of their