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Hyperbaric pressure at room temperature increases post-harvest preservation of the tomato cultivar 'Débora'

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ABSTRACT

The aim of the present study was to evaluate the effect of the application of hyperbaric pressure at room temperature (23 ± 1 °C) for 2, 4 or 6 d, followed by 2 d under ambient conditions (23 °C, 50% relative humidity, 100 kPa), on the physical, chemical and metabolic characteristics of the tomato cultivar 'Débora'. The following pressures were tested: 100 (control), 200, 400, 600 and 800 kPa. Tomatoes subjected to 600 or 800 kPa for 6 d presented lower weight loss (up to 80%) and 1.2 times greater firmness than control tomatoes. Hyperbaric pressure did not decrease the tomato respiration rate. However, the initial tomato color was maintained with increasing applied pressure, and pressure decreased tomato lycopene synthesis by up to 57%. Normal tomato ripening was not negatively affected by the application of hyperbaric pressure. The present results show that application of hyperbaric pressure up to 800 kPa at 23 °C delays the ripening of the tomato cultivar 'Débora' and results in longer shelf life.

1. Introduction

The tomato (*Solanum lycopersicum* L.) is one of the most widely grown and consumed vegetables in the world and is therefore of great commercial importance (Beckles, 2012; Azabou et al., 2016). In addition, tomatoes synthesize a large variety of phytochemicals with high antioxidant power; many of these vitamins, carotenoids and phenolic compounds are associated with decreased risk of chronic diseases such as cardiovascular disease and cancer (Del Giudice et al., 2015; Stajčić et al., 2015). The tomato is a climacteric fruit that is usually harvested at the physiological maturation stage (green-ripe) to facilitate preservation and minimize losses during handling and transportation (Wang et al., 2008). At room temperature (23 °C), tomatoes ripen quickly, changing in color, firmness, taste and chemical composition and undergoing increased water loss, which significantly decreases their commercialization period (Javanmardi and Kubota, 2006).

The tomato cultivar 'Débora' presents oblong fruit that are reddish when ripe; these are generally consumed fresh due to their excellent organoleptic characteristics (Nascimento et al., 2013). However, the fruit of this cultivar has a short shelf life compared to other cultivars; its shelf life is less than one week when the fruit is stored at 24 °C.

A variety of technologies, the most common of which is refrigeration, are currently used to preserve fruit quality and prolong potential shelf life. Storage under refrigeration (at temperatures of 10–15 °C) effectively decreases the respiration rate of tomatoes, preserves the general quality of the fruit, and increases shelf life (Saltveit, 2003). However, refrigeration incurs high energy costs and cannot be implemented in regions without a supply of electrical energy (Raghavan et al., 2004).

Post-harvest hyperbaric treatment consists of subjecting fruit and vegetables to pressures between 100 kPa and 1000 kPa through a constant flow of compressed air (Goyette et al., 2011). Hyperbaric treatment acts instantaneously and uniformly on each item of produce, independently of its size, shape or composition, and is microbiologically safe. In addition, pressure treatment requires only 2–6% of the energy needed for refrigeration since pressurization does not need to be instantaneous and little energy is required to maintain pressure during storage (Vigneault et al., 2012).

Recent studies have shown that the use of hyperbaric pressure may slow metabolic processes in some vegetables, preserving their qualitative characteristics. Baba and Ikeda (2003), reported decreased CO_2 and C_2H_4 production in Japanese apricot (*Prunus mume* L.) fruit stored at

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5 °C and 500 kPa for 5 d; delayed ripening and decreased fresh weight loss were also noted. Tomatoes stored at 13 °C and 900 kPa for 5, 10 or 15 d presented a 22% decrease in respiration rate compared to controls stored at 13 °C and 100 kPa (Goyette et al., 2012b). In addition, the authors also observed delayed lycopene synthesis and maintenance of firmness compared to fruit maintained under ambient pressure. Liplap et al. (2013a), observed that tomatoes stored at 20 °C and 700–900 kPa for 4 d presented respiration rates similar to controls (20 °C and 100 kPa). However, the pressurized tomatoes remained greener and more turgid.

Although promising results of post-harvest hyperbaric treatment for the preservation of some fruit and vegetables have been reported, the number of studies in this area is still limited, and research in the field is still exploratory. No studies have been reported for specific regions, production conditions or varieties; thus, the application of pressure treatment as a post-harvest alternative has been limited. The aim of the present study was to evaluate the effect of hyperbaric pressure treatment at room temperature (23 °C) on the physical, chemical and metabolic characteristics of the tomato cultivar 'Débora'.

2. Material and methods

2.1. Plant material

Fruit of the tomato cultivar 'Débora' were used. The fruit originated from commercial farms in the region of Ribeirão Preto, state of São Paulo, Brazil (21°20′18″S and 47°43′58″W, 793 m altitude) and were harvested at the green-ripe stage according to the classification of López Camelo and Gómez (2004). The fruit were transported for 1 h to the Laboratory of Post-Harvest Technology on the Jaboticabal Campus of Universidade Estadual Paulista (São Paulo State University). The fruit were washed with potable water and neutral detergent, disinfected with 200 mg L^{-1} sodium dichloroisocyanurate (Sumaveg®, São Paulo, Brazil) for 5 min, dried at 23 °C on a paper-lined surface, and selected to guarantee homogeneity in size, shape, and color and to ensure the absence of damage and disease.

2.2. Hyperbaric system

The experiments were conducted using a hyperbaric pressure system as described by Goyette et al. (2011) and Liplap et al. (2014), (Fig. 1). The system consists of 6 steel vessels connected in an open circuit through which a constant flow of compressed air circulates to maintain constant concentrations of oxygen (21%) and nitrogen (78%). Carbon dioxide is adsorbed prior to inflow by passing the air through a chamber containing calcium oxide. The vessels had an interior volume of 10.75 L (approximate capacity 20 tomatoes) and were closed with a bolted steel lid. Each lid was equipped with a pressure regulator at the entrance point and a needle valve at the exit point of each vessel to regulate the air pressure and airflow, respectively, in each vessel. A safety relief valve was also installed on the lid to prevent pressure overload. The inlet of the vessel was connected to a 250-L compressed air cylinder (Schulz, model MSV 20 MAX, Joinville, Santa Catarina state, Brazil) for compressed air supply. Air flow was measured using a flow meter with a measuring range of 5–2000 mL min^{-1} ± 12 mL min^{-1} (Bronkhorst™, Ruurlo, Netherlands). CO_2 concentration was measured using an infrared gas analyzer (Guardian® Plus, Kirkton Campus, Livingston, England). The flow meter, control valve and CO_2 gas analyzer were connected to a data acquisition and control card (Personnel DAQ 3000, Cleveland, OH, USA) and a laptop computer. Pressure, air flow rate and CO_2 level were recorded using DasyLab® software (Measurement Computing Corporation, Norton, MA, USA). The respiration rate in real time was calculated using the following equation:

$$RR = \frac{\Delta CO_2 \times Q}{w}$$

in which ΔCO_2 is the difference between the CO_2 concentration at the vessel entrance and the CO_2 concentration at the vessel exit, Q is the air flow rate, and w is the produce weight.

2.3. Treatment application

Sixty tomatoes (average weight 130 g) were selected based on the parameters described in Section 2.1. Ten tomatoes were used to determine the initial fruit quality and to confirm fruit homogeneity (Table 1); the remaining fifty tomatoes were divided into 5 groups of 10 each. Each group of tomatoes was placed in a sealed vessel and subjected to one of the following pressures: 100 (control), 200, 400, 600 or 800 kPa. The relative humidity (RH) inside the vessels was maintained at 95 ± 2.5% and was monitored every 30 min using a data logger (HOBO Prov2 U-23-001).

The tomatoes remained under hyperbaric pressure (HP) for 2, 4 or 6 d at 23 ± 1 °C. At the end of each period, the vessels were automatically depressurized for 2 h, 5 tomatoes (experimental unit) were removed from each vessel and immediately evaluated, and the

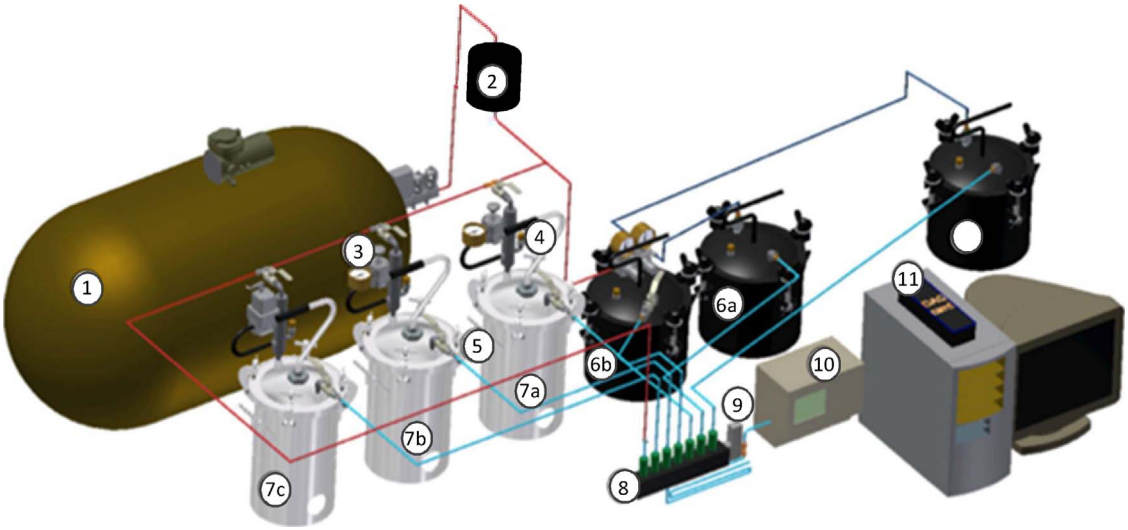

Fig. 1. Schematic of the main devices assembled in the hyperbaric system used for measuring the effect of hyperbaric pressure on tomato cv. Débora: 1. Compressed air reservoir; 2. CO_2-scrubber; 3. Pressure regulator; 4. Safety valve; 5. Flow control valve; 6a. Ambient pressure vessel (100 kPa); 6b. 200 kPa vessel; 7a–c. 400 kPa, 600 kPa, and 800 kPa vessel, respectively; 8. Valve-manifold assembly; 9. Airflow meter; 10. Infrared gas analyzer; 11. Data acquisition board and computer.