Postharvest Biology and Technology 86 (2013) 45–52

Contents lists available at ScienceDirect

Postharvest Biology and Technology

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

Tomato shelf-life extension at room temperature by hyperbaric pressure treatment

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ARTICLE INFO

Article history:
Received 23 March 2013
Accepted 4 June 2013

Keywords:
Short-term storage
Shelf-life
Hyperbaric pressure
Bioactive compounds
Physiological stress

ABSTRACT

The effect of hyperbaric treatments on major hydrophilic and lipophilic antioxidants and antioxidant activity in tomato fruit, using ORAC and TEAC assays, was studied. Early breaker stage greenhouse grown tomatoes were subjected to different pressure and temperature conditions, including 0.1 (ambient atmospheric pressure, control), 0.3, 0.5, 0.7 and 0.9 MPa at 20 °C, and 0.1 MPa at 13 °C (cold treatment) for 4 days, followed by ripening at 20 °C for 5 and 10 days. Hyperbaric treatment significantly affected lycopene content by inhibiting, then enhancing its accumulation during treatment and ripening, respectively. In general, ascorbic acid and total phenolic contents increased as time progressed but generally were not affected by hyperbaric pressure treatment. All antioxidants were found in lower concentrations in tomatoes treated at 13 °C. The trend in antioxidant activity obtained from both ORAC and TEAC assays was generally similar. No significant effect of hyperbaric treatment on lipophilic antioxidant (LAA) and hydrophilic antioxidant (HAA) was observed compared with control tomatoes at 13 and 20 °C. However, the ORAC assay showed that hyperbaric treated tomatoes had significantly higher HAA than 13 °C treated tomatoes. Overall, hyperbaric treatment at 20 °C has potential to extend tomato shelf-life during short treatment durations without adverse impact on quality during ripening.

1. Introduction

Fruit and vegetables contain significant amounts of antioxidants that impart beneficial health effects beyond basic nutrition. These antioxidants are biologically active compounds that act against possible ill effects of free radical-induced damage in humans (Liu et al., 2000; Trichopoulou et al., 2003). According to epidemiological and clinical studies, it has been confirmed that a high antioxidant dietary intake results in lower incidence of chronic diseases such as cancer, cardiovascular disease, and cataract and immunity system dysfunctions (Halliwell and Gutteridge, 1999; Alothman et al., 2009). This growing awareness of the relationship between diet and health has led to an increased consumption of fresh fruit and vegetables.

As fruit and vegetables contain living tissues, they can potentially show sensory, microbial and nutritional quality changes after harvest and hence several postharvest techniques have been developed to maintain quality (Gonzalez-Aguilar et al., 2010). Chemical treatments are often used to prevent microbial growth and associated rots. However, there are growing health and environment concerns over current practices and consumers are demanding healthy foods with chemical-free treatments. As a consequence, physical treatments such as UV-C/UV-B irradiation, high temperature treatment, and high pressure are gaining interest from the fresh produce industry.

Postharvest physical treatments are used as a tool to extend shelf-life and help maintain quality, focusing primarily on disinfecting fresh produce and reducing decay during storage. Such treatments can also increase the concentration of some bioactive compounds such as antioxidants in the produce. For example, pomegranate fruit subjected to heat treatment (45 °C for 4 min) developed significantly higher amounts of ascorbate, phenolics, and overall total antioxidant capacity as compared with untreated fruit (Mirdehghan et al., 2006). Storage temperature at 20 °C increased anthocyanin contents in pink strawberry by 40% compared with cold storage at 10 °C (Miszczak et al., 1995). UV

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http://dx.doi.org/10.1016/j.postharvbio.2013.06.006

irradiation has been reported to increase antioxidant contents (e.g., ascorbic acid and total phenolics) of many fruits such as tomato (Jagadeesh et al., 2011), pear (Marais et al., 2001), and grape (Cantos et al., 2001). These changes in antioxidant contents may be attributed to the induction of pathways to produce these secondary metabolites (Gonzalez-Aguilar et al., 2010). Due to their biological activity, these secondary metabolites could present a commercial advantage in terms of production of healthier fruits and vegetables. Therefore physical treatments may be considered a complementary or an alternative strategy to other approaches such as breeding, crop management or genetic engineering activities (Cisneros-Zevallos, 2003).

Hyperbaric treatment is a physical postharvest preservation technique in which fresh produce are subjected to an elevated pressure environment ranging from 0.1 to 1.0 MPa (Goyette et al., 2012). Recently, a few studies have shown that hyperbaric treatment provides beneficial effects on extending the shelf-life of some fruits and vegetables. For example, Baba and Ikeda (2003) showed that shelf life of mume fruit subjected to 0.5 MPa for 5 days was prolonged through suppression of respiratory CO_2 and ethylene production. It was also reported that pressure treatment could maintain a commercially acceptable color quality, reduce weight loss, and protect against chilling injuries. Romanazzi et al. (2008) studied the effect of short hyperbaric treatments on postharvest decay of sweet cherries and table grapes and found that the incidence of brown rot, gray and blue mold, and total rot was greatly reduced after storage at 20 °C. Similar positive results were reported by Goyette et al. (2012) who investigated the effects of hyperbaric treatments on tomato fruit. They found that elevated pressure (from 0.3 to 0.9 MPa) during storage at 13 °C could reduce respiration rate and maintain freshness and quality attributes of tomato fruit. Moreover, Goyette (2010) showed that lycopene content was enhanced by hyperbaric treatment at the end of ripening period. The above findings imply that hyperbaric treatment may not only extend shelf-life and preserve produce quality but also induce a secondary metabolic response during the treatment, thus possibly inducing disease resistance and enhancing synthesis of certain antioxidants in the produce. However, to date, very limited studies of hyperbaric treatment on bioactive compounds have been reported. Therefore, the present study was carried out to investigate the effect of hyperbaric treatment on major antioxidants (i.e., lycopene, ascorbic acid and total phenolic compounds) and antioxidant capacity of tomato during postharvest treatment and ripening periods.

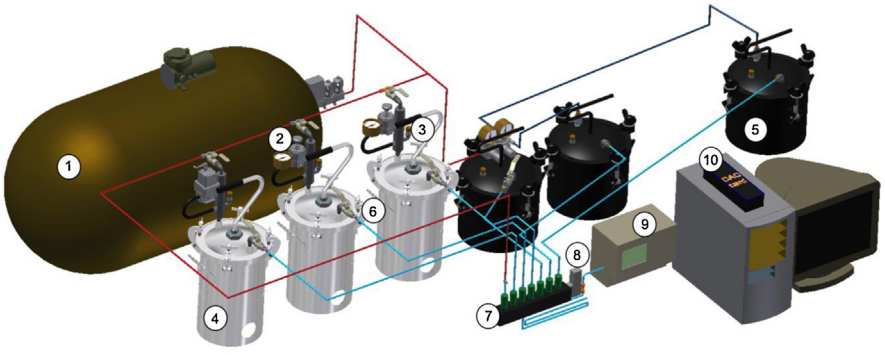
2. Materials and methods

2.1. Raw material and treatment

Tomato fruit (*Lycopersicon esculentum* Mill. cv. DRK 453) were harvested at early breaker stage at a commercial greenhouse (Saint Damase, QC, Canada) and transported within 2 h to the laboratory. The average fruit weight was 196 ± 5 g. All tomatoes were sanitized in 100 μL L^{-1} sodium hypochlorite solution for 5 min, then rinsed with potable tap water for another 5 min, and finally dried with a soft cloth. Color was measured on arrival to ascertain the uniformity of tomatoes harvested at different dates (replications) using a Minolta Chromameter (Model CR-400, Osaka, Japan) and expressed as hue angle (H°), chroma (C) and lightness (L).

2.2. Hyperbaric system

Fig. 1 shows the schematic of the dynamic hyperbaric respirometer (flow-through) system used during the tests. It consisted of a compressed air tank, three low pressure vessels, three high pressure vessels, and an infrared gas analyzer. The low pressure steel vessels were made from a paint apparatus (PRO-TEK, Mirabel, Quebec, Canada), 220 mm in height and 265 mm inside diameter; whereas the high pressure vessels were made from a stainless steel container (Graco™, Minneapolis, MN, USA), 225 mm in height and 235 mm inside diameter. The two different volumes of the vessels were equalized by adding adequate number of snooker balls (52.61 mm diameter) to the low pressure vessels. The net volume of each vessel was 10.75 L. A 12.7 mm flat rubber ring was used to ensure air tightness between the cover and the chamber. Each vessel was equipped with a pressure regulator and a flow control needle valve to individually regulate the pressure and air flow rate, respectively. A safety relief valve was used to prevent pressure overload. Two compression fittings were fastened to the vessel to quick connect the airflow inlet and outlet using plastic tubes of 3.2 mm inner diameter. The air inlet of the vessel was connected to a compressed air tank equipped with a regulating manometer. A channel selector (a manifold equipped with controlled valves) was installed to connect the air outlet of the selected vessel to a CO_2 infrared gas analyzer (Guardian® Plus, Kirkton Capus, Livingston, England) and the electronic air flow meter (Bronkhorst™, Ruurlo, Netherlands). The air flow meter, controlled valves at manifold and CO_2 gas analyzer were all connected to a data acquisition and



No.	Description	No.	Description
1	Compressed air tank	6	Flow control valve
2	Pressure regulator	7	Manifold
3	Safety valve	8	Air flow meter
4	High pressure vessel	9	CO_2 sensor
5	Low pressure vessel	10	Data acquisition card

Fig. 1. Hyperbaric system for evaluation of the effect of different pressure levels on tomato.