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Influence of ozonated water sanitation on postharvest quality of conventionally and organically cultivated mangoes after postharvest storage

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ABSTRACT

We investigated the alterations on bioactive compounds after treatments with ozonated water during the storage of organically and conventionally cultivated mangoes, cv. Palmer. Mangoes were stored in a cold chamber (14 ± 2 °C) for 15 d and evaluated after the harvest and sanitization treatments (chlorine and ozonated water—10 and 20 min) at 7 and 15 d. To simulate the market, after 7 d, mangoes were removed from cold storage and kept at room temperature (27 ± 2 °C) to!——!> be analyzed following 4 (7 + 4) and 8 (7 + 8) d at room temperature. The conventionally mango showed higher firmness, regardless of the sanitization system used. Ozonated water did not alter the levels of β-carotene, ascorbic acid, dehydroascorbic acid and phenol in organically or conventionally cultivated mangoes during storage, but when the mangoes, cv. Palmer were transferred to room temperature, the β-carotene level increased. Organically cultivated mangoes showed higher levels of antioxidant activity. Ozonated water can be used as an alternative to chlorine sanitizer without causing damage to mango, cv. Palmer fruit or inducing a decrease in the various compounds and the treatment using ozonated water was efficient for maintaining fruit without microorganisms, preventing the reduction of quality and avoiding the generation of organic waste.

1. Introduction

Fruits are a rich source of antioxidant compounds such as vitamins (ascorbic acid, dehydroascorbic acid and β-carotene), vitamins precursors and polyphenols, and a high dietary intake of these compounds is associated with reduced disease (Kris-etherton et al., 2002). Mango (*Mangifera indica* L.) is consumed worldwide, have increasing production rates and are of particular interest due to their nutritional value and remarkable taste. However, postharvest losses may occur due to several factors, but mostly because the postharvest life of mango usually does not exceed a few weeks and is limited by physiological deterioration of the fruit related to over-ripening, and by pathogen development leading to decay (González-Aguilar et al., 2001). For this reason, effective technologies are needed to ensure longer shelf-life and fruit quality, such as crop system management and methods of sanitization.

Organic crop cultivation has been reported to influence bioactive content. Some studies have shown that fruits and vegetables that are growing organically have a higher content of antioxidants (vitamin C, phenolic compounds, minerals, poly-amines, among others) (Lima and Vianello, 2011; Hallmann and Rembial kowska, 2012). Nowadays, the demand for organic food is due to absence of agrochemicals residues that cause damage to health.

Ozone is a powerful oxidant that has been accepted as a food sanitizer, mainly in organic farming because it safely and spontaneously decomposes without forming hazardous residues (Ölmez and Kretzschmar, 2009). To sanitize vegetable foods, some products including chlorine gas, sodium or calcium hypochlorite

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and organic chlorine should be avoided because they form carcinogenic chlorinated compounds such as trihalomethanes that cause serious problems to human health and the environment (Yeoh et al., 2014). In this context, ozonated water has emerged as a safe form of sanitization in various plant products such as broccoli (Lima et al., 2014), honey pineapple, banana, and guava (Alothman et al., 2010), papaya (Yeoh et al., 2014).

Some studies have shown that the exposure of some fruits and vegetables to ozone increases the content of total phenols (González-Aguilar et al., 2007; Alothman et al., 2010; Yeoh et al., 2014) and other molecules with antioxidant activity (Lima et al., 2014). Ozone causes an oxidative action and in the plant may be harmful because of the production of free radicals. However, when sanitized with ozone, plant foods tend to have higher levels of antioxidant compounds as a way to protect the cell against damage promoted by reactive oxygen species (ROS) generated after sanitization (Minas et al., 2012).

2. Materials and methods

2.1. Fruit

Mango (*Mangifera indica* L., cv Palmer) fruit under conventional and organic cultivation were obtained from commercial orchards. Fruit produced in an organic system were harvested in Borborema city, São Paulo state (latitude 21° 37′ 11″ S, longitude 49° 04′ 25″ W, 429 m altitude) and those produced in the conventional system were harvested in Taquaritinga city, São Paulo state (latitude 21° 24′ 23″ S, longitude 48° 30′ 20″ W, 579 m altitude).

The soil at both sites was subject to routine chemical analysis (Embrapa, 1997). The analysis results presented the following characteristics (organic farm): pH ($CaCl_2$ 0.01 mol L^{-1}) 5.5; 11.0 kg m^{-3} of organic material (OM); 35.0 g m^{-3} phosphorus (P); 0.47 g kg^{-1} H + Al; 0.09 g kg^{-1} potassium (K); 0.54 g kg^{-1} calcium (Ca); 0.07 g kg^{-1} magnesium (Mg); 1.41 g kg^{-1} sum of bases (SB); 1.88 g kg^{-1} cation exchange capacity (CEC); base saturation (V) of 74.0%. The micronutrient levels found were 25.0 g m^{-3} sulfur (S); 0.3 g m^{-3} boron (B); 3.8 g m^{-3} copper (Cu); 18 g m^{-3} iron (Fe); 3.4 g m^{-3} manganese (Mn) and 2.7 g m^{-3} zinc (Zn).

At the farm with the conventional system, the following soil characteristics were found: pH ($CaCl_2$ 0.01 mol L^{-1}) 5.4; 12.0 kg m^{-3} OM; 78.0 g m^{-3} P; 0.74 g kg^{-1} H + Al; 0,05 g kg^{-1} K; 1.05 g kg^{-1} Ca; 0.23 g kg^{-1} Mg; 1.13 g kg^{-1} SB; 1.84 g kg^{-1} CEC; V of 60.7%. For the micronutrients, the levels found were: 0.68 g m^{-3} B; 19.1 g m^{-3} Cu; 20 g m^{-3} Fe; 23.7 g m^{-3} Mn and 3.5 g m^{-3} Zn.

2.2. Sampling and preparation of the samples

To ensure a fair comparison, organic and conventional mangoes at the same physiological age and with maturity index 2 (hard consistency, green peel color and light cream pulp) were used. After harvest, 120 fruit from each cultivation system were selected and submitted to 3 different sanitization methods. The fruit was either soaked for 10 min in distilled water containing Tween-20 (control), or soaked for 5 min in tap water containing 1% of sodium hypochlorite (400 μL L^{-1}), or soaked in ozonated water using an ozonizer (Degradatox/OZ Engineering, Industries LTD Equipment Ozone-generator, Porto Alegre, Brazil) that could generate approximately 1 mg L^{-1} s^{-1} in a 180 L tank. The ozonated mangoes were divided into two groups based on the time of immersion (10 or 20 min). Mangoes were air-dried at room temperature for 60 min.

The fruit were stored in a cold room at 14 ± 2 °C and with 90 ± 2% air humidity. Assays were conducted at day 0 (immediately after sanitization) and after 7 and 15 d of storage. To simulate market conditions, after 7 d in cold storage, the fruit were brought to room temperature and analyzed on day 4 (7 + 4) and 8 (7 + 8) after storage at room temperature (27 ± 2 °C and 65 ± 5% air humidity). Fruit stored for 15 d in the cold room were at the limit of market conditions and were therefore not submitted to holding at room temperature.

To measure the ascorbic acid, total phenolics, total flavonoids, β-carotene, DPPH and FRAP radical scavenging activity, the pulp was immediately was powdered by an analytical mill (IKA, A11) with liquid nitrogen and stored at −80 °C.

2.3. Firmness, pH, titratable acidity and total soluble solids

The firmness (F) of the fruit pulp was determined using a manual digital penetrometer with an 8 mm probe (model 53205, Turoni, Italy) on the equatorial region of two fruit. The pH was measured in pulp mango juice (Ultra-Turrax for 5 min at 7500 rpm), using a pH meter (model HI 4221, Hanna Instruments Brazil). The titratable acidity (TA) of the fruit pulp was determined by the AOAC 942.15 method (1997) using 0.1 mol L^{-1} NaOH and two to three drops of 0.1% (w/v) phenolphthalein as an indicator, and the results were expressed as% malic acid. The total soluble solid (TSS) in the filtered mango pulp juice was determined using a digital refractometer (Atago RX5000, Atago Co. Ltd., Itabashi-Ku, Tokyo, Japan), and the results were expressed in%.

2.4. Ascorbic acid and dehydroascorbic acid

The levels of ascorbic acid (AA) and dehydroascorbic acid (DHAA) were measured as described by Pertuzatti et al. (2015), with minor modifications. Fifty milligrams of mango pulp were placed in a 15 × 120 mm test tube and overlaid with 5 mL of cold extraction solution. This solution consisted of 10 g of metaphosphoric acid (4.5% in ultrapure water) and 40 mL of glacial acetic acid. The tubes were vortexed for 2 min and incubated for 30 min in an ultrasonic bath at 5 °C. The test tubes were then centrifuged at 4500*g* (Hettich Zentrifugen, Mikro220R) for 15 min and supernatant transferred to amber flasks. The residue was twice subjected to similar procedures of extraction, and the supernatants obtained from three separate extractions were combined to reach a final volume of 15 mL. After that, the sample was transferred to a 1.5 mL vial, and 20 μL of the sample were injected into a UHPLC system (Ultimate 3000, Dionex-Thermo Scientific, USA) equipped with a diode array detector with an Ace 5 C18 (Advanced Chromatography Technologies, UK) column (5 μm, 250 × 4.6 mm). The mobile phase used was 2% acetic acid in an isocratic flow of 0.5 mL min^{-1}. The column temperature was set to 25 °C, and the detection wavelength was 248 nm for the ascorbic acid and 240 nm for the dehydroascorbic acid. The results were expressed in mg kg^{-1} of sample.

2.5. Total polyphenolic (TP)

The total polyphenolic content was analyzed using a spectrophotometric method, with Folin-Ciocalteu used as the reagent (Singleton and Rossi, 1965). Pulp (0.1 g) was extracted with 10 mL of a mixture of methanol:water (80:20; v/v), kept in an ultrasonic bath for 30 min and centrifuged at 6000*g* (Hettich Zentrifugen, Mikro220R) for 10 min at 4 °C. The supernatant was collected, the precipitate was re-extracted and the supernatants were combined. The methanolic extract 0.5 mL was added to 0.5 mL Folin-Ciocalteu reagent in test tubes, and it was vortexed for 1.5 min. The reaction mixture was added to 1 mL of saturated sodium carbonate solution (25%, w/v). The reaction mixture was incubated in the dark for 1 h at room temperature, and the absorbance was read at 760 nm. The TP content was expressed as% of gallic acid equivalent per mass of