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Use of modified atmosphere to extend shelf life of fresh-cut carambola (*Averrhoa carambola* L. cv. Fwang Tung)

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Abstract

Fresh-cut fruit products, including carambola (*Averrhoa carambola* L.), have limited marketability due to cut surface browning attributed to phenolic compound oxidation by enzymes, such as polyphenol oxidase (PPO). The objective of this study was to evaluate postharvest changes in carambola slices in three different packages. Carambola fruit (cv. Fwang Tung) were picked from the Estação Experimental de Citricultura de Bebedouro orchard at the mature-green stage. The fruit were washed, dipped in NaOCl solution (200 mg L^{-1} for 5 min), stored overnight at 10 °C, then manually sliced into pieces of approximately 1 cm. The slices were rinsed with NaOCl solution at 20 mg L^{-1}, drained for 3 min, and packaged in polyethylene terephthalate (PET) trays (Neoform® N94); polystyrene trays covered with PVC 0.017 mm (Vitafilm®, Goodyear); and vacuum sealed polyolefin bags (PLO, Cryovac® PD900). The packages were stored at 6.8 °C and 90% RH for 12 d, with samples taken every 4 d. PET trays and PVC film did not significantly modify the internal atmosphere and the high water permeability of PVC led to more rapid slice desiccation. PPO activity was lower when the slices were packaged in PLO vacuum sealed bags, which reduced degreening and led to better appearance maintenance for up to 12 d.

Keywords: Browning; Softening; Polyphenol oxidase (PPO); Polygalacturonase (PG); Minimally processed

1. Introduction

The Brazilian fresh-cut industry started at the beginning of 1980s and nowadays grows at a rate of 10% a year. According to some statistics this industry represented something around US$ 300 million in business in 1998 (Moretti and Sargent, 2002).

Carambola (*Avehrroa carambola* L.) is a fruit with great possibilities as a fresh-cut product. Oslund and Davenport (1983) and Wilson (1990) reported that carambola slices have great potential for use in salads and as garnishes for drinks or cocktails.

However, mechanical actions during processing cause tissue damage, affecting the fruit's physiological activity and consequently its quality (Watada et al., 1996). The acceleration in quality loss, especially in color and firmness, is related to endogenous enzymes and microorganisms (Yoo and Lee, 1999). The principal restraint of using fresh-cut carambola is its susceptibility to tissue browning due to polyphenol oxidase (PPO) mediated oxidation of phenolic compounds present in the tissue (Weller et al., 1995).

In order to control these modifications in fresh-cut carambola, a number of studies have been conducted (Matthews et al., 1989; Matthews and Myers, 1995; Weller et al., 1995, 1997) evaluating atmosphere modification by vacuum and LLDPE packages. According to Watada et al. (1996) the use of film wraps or edible coatings can modify the internal atmosphere, which has been shown to be beneficial in extending shelf-life. However, extensive modification of the atmosphere can cause injury to tissue, thus further study is needed to determine the recommended atmosphere. The objective of this study was to evaluate

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postharvest changes in carambola slices in three different packages.

2. Materials and methods

2.1. Plant material and treatments

'Fwang Tung' carambola fruit were harvested at the mature green (50% yellow) stage and transported to the Laboratório de Tecnologia dos Produtos Agrícolas of UNESP/FCAV, Jaboticabal Campus, Brazil. Following initial washing, the fruit were dipped in a sanitary wash of sodium hypochlorite (200 mg L^{-1}) for 5 min and stored overnight in a cold room at 10 °C. The fruit were transversely cut into slices approximately 1 cm thick. The slices were rinsed with sodium hypochlorite (20 mg L^{-1}), air-dried for 3 min, and then placed into three different packages: 0.058 mm polyolefin bags (PLO) (Cryovac® PD 900) sealed under a vacuum of 90 kPa (O_2 transmission rate (TR) of 5.43×10^{-5}, and CO_2 TR 5.08×10^{-4} g m^{-2} s^{-1} (NCPT); polystyrene trays overwrapped with 0.017 mm polyvinyl chloride film (PVC) (Vitafilm Goodyear®) (O_2 TR 1.05×10^{-4}, and CO_2 TR 1.21×10^{-3} g m^{-2} s^{-1} (NCPT), and 1 L polyethylene terephthalate (PET) trays provided with fitted covers (Neoform® N94). The TR of PET trays were not determined because the cover was not sealed, just fitted. The packages were stored at 6.8 °C for 12 d and samples were taken every 4 d. Three replicates were used per treatment withdrawal, with each package (weighing approximately 200 g) constituting a single replicate.

2.2. Quality evaluations

Weight loss assessment within each treatment was conducted by weighing the packages at each withdrawal. Visual appearance was determined based on the following subjective score: 5, excellent = absence of browning symptoms; 4, very good = small brown spots; 3, good = brown spots; 2, fair = brown spots and severe softening; 1, poor = slices completely brown and soft. Browning was quantified visually and softening by touching the slices. Color (CIE $L^*a^*b^*$) was determined using a Minolta chromameter (Model CR-200b, Minolta, Osaka, Japan). Two readings were taken on the cut surface of three slices randomly collected from each replicate and color was expressed as luminosity (L), hue angle (h°) and chromaticity (Chroma) similar to the method of Miller and McDonald (1998).

The slices were frozen and stored at −10 °C, before homogenization to determine the soluble solids content (SSC), total titratable acidity (TTA), pH (AOAC, 1997, Proc. 932-12, 942-15, 945-27, respectively), and SSC/TTA ratio. Ascorbic acid (AA) content was determined using the Tillman method (Strohecker and Henning, 1967). Total soluble sugar (SS) was determined using phenol-sulfuric assay (Dubois et al., 1956), and reducing sugar (RS) by dinitrosalicilic acid method (Miller, 1959). Total (TP) and soluble pectin (SP) were determined according to the method of McCready and McComb (1952).

2.3. Enzyme assays

Polyphenol oxidase (PPO) activity was determined by the method of Adnan et al. (1986), with slight modifications as follows: 40 g of carambola slices (without seeds) was weighed and homogenized in a blender (Kika Labortechnik T25 basic) for 30 s in 40 mL of potassium phosphate buffer at 0.2 M (pH 6.8), containing 1.5% polyvinyl polypyrrolidone (PVP) and 0.2 M KCl. The homogenate was filtered through cheesecloth, and centrifuged for 15 min at 26,000 × g, at 4 °C, discarding the pellet. PPO activity was determined by mixing 0.5 mL of enzymatic extract with 3.5 mL of 0.05 M catechol in potassium phosphate buffer 0.2 M (pH 7.2) and incubating in a water bath at 30 °C for 30 min. The reaction was terminated by adding 1 mL of 0.5 M of perchloric acid. Absorbance was measured at 410 nm at the beginning and end of the incubation time. Enzymatic activity was expressed in Enzymatic Activity Units (EAUs); where one EAU is defined as the activity that provides 0.001 absorbance changes per second under assay conditions (EAU s^{-1} kg^{-1}).

Polygalacturonase (PG) activity was determined according to the method of Ghazali and Leong (1987), with slight modifications as follows: 10 g of carambola slices (without seeds) was weighed and homogenized in a blender (Kika Labortechnik T25 basic) for 30 s in 20 mL of sodium acetate buffer at 0.1 M (pH 4.6), containing 1.0% polyvinyl polypyrrolidone (PVP) and 1.0 M NaCl. The homogenate was filtered through cheesecloth, and centrifuged for 30 min at 26,000 × g, at 4 °C, discarding the pellet. PG activity was determined by mixing 3.0 mL of enzymatic extract with 3.0 mL of polygalacturonic acid (Sigma Comp., P-3889) at 1.0% in sodium acetate buffer 0.1 M (pH 5.2), and incubating in a water bath at 35 °C for 180 min. The reaction was terminated by heating the tubes in a water bath at 100 °C for 5.0 min. Absorbance was measured at 540 nm at the beginning and end of the incubation time according to the method of Miller (1959) using galacturonic acid as standard. One PG unit is defined as the enzyme activity necessary to provide 1 μmol of reducing sugars (galacturonic acid) per kilogram of enzyme in one second, and is expressed as nmol s^{-1} kg^{-1}.

2.4. Package internal atmosphere analysis

The atmospheric composition (O_2 and CO_2) inside the package was measured by injecting 0.3 mL gas samples into a gas chromatograph (Finningan 9001, Finningan Corporation, San Jose, EUA) equipped with Porapack-N and molecular sieve (5A) columns, a thermal conductivity detector (150 °C) and a flame ionization detector (150 °C), using nitrogen as the carrier gas (5.74×10^{-4} g s^{-1}). The data were integrated using Borwin software (Borwin version 1.20, JMBS Developpements, Le Fontanil, France).