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Postharvest quality of peeled prickly pear fruit treated with acetic acid and chitosan

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ABSTRACT

White (*Opuntia albicarpa*) and red (*Opuntia ficus-indica*) prickly pears were peeled and submerged in chitosan solutions containing different concentrations of acetic acid (1.0 or 2.5%) to obtain ready-to-eat prickly pear products. Some physicochemical (pH, total soluble solids, color, weight loss, and firmness), antioxidant (phenolic compounds and antioxidant activity), microbiological (aerobic mesophile bacteria and yeasts plus molds), and sensory (color, firmness, aroma, flavor, and overall acceptance) characteristics were assessed during 16 d of storage at 4 ± 1 °C and 85 ± 5% of relative humidity. Chitosan coating containing 1.0% of acetic acid delayed weight loss, maintained firmness and color of white prickly pear during the storage time. Most of the sensory values for white prickly pear coated with chitosan containing 1.0 and 2.5% of acetic acid were higher than those obtained for uncoated fruit. Red prickly pear coated with chitosan with 2.5% acetic acid did not maintain its sensory quality throughout 16 d of storage. Chitosan coating with 1 and 2.5% acetic acid did not affect phenolics content and antioxidant activity in white prickly pears; however, an increase of these compounds was observed in red prickly pears. Microbe populations were unchanged in white prickly pears (<10 CFU g^{-1}) and slightly increased in red prickly pears (10–500 CFU g^{-1}) coated with chitosan during the entire storage time.

1. Introduction

Recently, demand for minimally processed fruits and vegetables has increased. Ready-to-eat commodities might have similar nutrition and sensory properties as whole fresh products (Artés et al., 2007; Gil et al., 2006). The consumption of fresh fruits and vegetables has been associated with enhanced human health because of their bioactive compounds. Minimally processed fresh-cut fruit and vegetables is a division of the food processing industry with potential to grow due to the convenience, healthiness, attractive appearance, and flavor (Artés et al., 2007; Chafer et al., 2008) of products. Therefore, the availability of the ready-to-eat products has increased in markets and supermarkets.

Methods for preparing ready-to-eat products include washing, peeling, cutting or shredding, disinfecting, draining, drying, packaging, and storage under refrigerated conditions (Baldwin et al., 1995; Aguayo et al., 2004). However, some of these treatments may stress the fruit and vegetable tissues. As a result of the mechanical injuries, an increased respiration rate may occur, followed by decay, dehydration, enzymatic browning, discoloration, ethylene production, softening, loss of vitamins and phenolic compounds, microbiological growth, and changes in sensory quality (Gontard et al., 1996; Rojas-Graü et al., 2009). Also, the ethylene production of the ready-to-eat commodities may stimulate the biosynthesis of enzymes such as phenyl-alanine-ammonia-lyase (PAL), associated with senescence (Martinez et al., 2005) of fruits and vegetables.

The main problem to face of the minimally processed fruits and vegetables is their short shelf life (Wang et al., 2007). Therefore, the application of some superficial protection on these products, like edible coatings, is necessary to delay deterioration and maintain quality characteristics. Some edible coatings possess antimicrobial characteristics (Petersen et al., 1999; Ali et al., 2011).

Chitosan is the deacetylated form of chitin. It is a natural compound similar to cellulose. Chitosan is prepared from crustaceous shells and has been widely used for coating of fruits and vegetables due to its capacity of inhibit growing of many spoiling and pathogenic microorganisms (Bautista et al., 2006; Romanazzi et al., 2005). Chitosan coatings can form a semi-permeable barrier that may control gas and moisture exchange (Ali et al., 2011). Many researchers have conducted experiments on the application of chitosan on fresh-cut fruits and vegetables. For example, González-Aguilar et al. (2009) applied chitosan coatings on fresh-cut papaya. They found that chitosan may reduce the natural deteriorative

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processes, increasing the shelf life of fresh-cut papaya. Chien et al. (2007), similarly, reported that chitosan coatings increased the shelf life of slices of mango fruit.

Prickly pear or cactus pear is the fruit of the *Opuntia* spp., native of Mexico. The fruit is appreciated for its flavor and juiciness. It is an oval shaped fruit that contains many seeds, a thick skin, and many prickles on the surface (Piga et al., 2000; Ochoa and Guerrero, 2012). Some researchers have demonstrated that the red prickly pear pulp has antioxidant compounds, such as ascorbic acid, phenolics, and betalains (Tesoriere et al., 2005; Ochoa and Guerrero, 2012). However, the main problem with commercial marketing of prickly pears is their perishability because of the low acid and high sugar contents (Piga et al., 2000). The aim of this study was to evaluate the effect of chitosan coatings on the physicochemical, antioxidant, microbiological, and sensorial characteristics of peeled white and red prickly pears.

2. Materials and methods

2.1. Prickly pears

White (*Opuntia albicarpa*) (WPP) and red (*Opuntia ficus-indica*) (RPP) prickly pears were obtained from San Sebastian Villanueva, Puebla, Mexico. Prickly pears free from physical and microbiological injuries were selected. Fruit were washed, manually peeled, disinfected in a 150 $\mu L\,L^{-1}$ hypochlorite sodium solution for 1 min. Excess of water was removed with absorbent paper.

2.2. Chitosan solution

Chitosan solution was prepared by placing 0.6 mL of olive oil (plasticizer) and 1.0 or 2.5 mL of glacial acetic acid (solvent) into a 100 mL volumetric flask and made up to volume with distilled water. The solution was poured into a beaker, warmed (80 °C), and blended, using an Ultraturrax T18 basic homogenizer (IKA Works, Inc., Wilmington, NC, USA), for 10 min at 233–300 s^{-1}. One gram of chitosan (Sigma–Aldrich, St. Louis, MO, USA), medium molecular weight and 85% deacetylated, was added slowly while stirring until completely dispersed.

2.3. Fruit coating and storage

Peeled white and red prickly pears were randomly sorted and divided in three batches. Three different treatments were performed: control (no coating) and chitosan coatings containing 1.0 or 2.5% of acetic acid. Prickly pears were immersed twice in the chitosan solution for 1 min. The superficial moisture was removed at 25 °C by placing fruit in a food dehydrator (Excalibur, Sacramento, CA, USA) for 10 min. Prickly pears were then placed into clear plastic (polyethylene) boxes (0.15 m × 0.15 m × 0.10 m) and stored at 4 ± 1 °C (relative humidity of 85 ± 5%). Physicochemical analysis was performed every 4 d for 16 d. The experiment was performed three times.

2.4. Weight loss

Prickly pears were weighed during the storage time. The weight loss was calculated as follows:

$$W_l = \left(\frac{W_i - W_f}{W_i}\right) \times 100 \quad (1)$$

where W_l is the weight loss (%), W_i (g) and W_f (g) are the initial and final weights, respectively.

2.5. Physicochemical characteristics

Fruit was blended using a domestic food processor (Black and Dekker, Towson, MD, USA) for 30 s. pH and total soluble solids were determined using a pH-meter (Orion 420 A, MA, USA) and a digital refractometer (ATAGO, Tokyo, Japan), respectively, in the fruit pulp.

2.6. Color

Three prickly pears of each treatment were used to evaluate the *L* (luminosity, white-black), *a* (green-red), and *b* (yellow-blue) color parameters, in the Hunter scale, using a Gardner colorimeter (Colorgard® System05, Geretsried, Germany) in the reflectance mode. The total color change (ΔE) was calculated using the next equation:

$$\Delta E = \sqrt{(L - L_0)^2 + (a - a_0)^2 + (b - b_0)^2} \quad (2)$$

where L_o, a_o, and b_o are the initial color parameters and *L*, *a*, and *b* are the color parameters at each storage period.

2.7. Firmness

A compression test was performed on peeled prickly pear halves using a TA-XT2 texture analyzer (Stable Micro Systems, Haslemere, England). The prickly pear halves were compressed 5 mm in depth, using a plate of 3.8 cm in diameter, at a speed of 1 mm s^{-1}.

2.8. Juice extractions

Fruit was blended using a domestic food processor (Black and Dekker) for 30 s. The homogenized prickly pears pulp was centrifuged at 2860 × *g* for 20 min at room temperature to obtain juice.

2.9. Phenolic compounds

Phenolic compounds of prickly pear juice were analyzed using the method of Gao et al. (2000) with modifications. Two milliliters of distilled water were placed in an amber glass tube. Then, 200 μL of the Folin and Ciocalteu' phenol reagent (Sigma–Aldrich, Toluca, Mexico) and 100 μL of prickly pear juice were added. This mixture was thoroughly homogenized and incubated for 3 min at room temperature (25 °C). Afterward, 1 mL of a 20% (w/v) Na_2CO_3 solution was added and thoroughly mixed. This blend was incubated for 1 h at room temperature in a dark environment. The absorbance was measured at 765 nm using a UV–vis spectrophotometer model 2800H (UNICO, Dayton, NJ, USA). The phenolic compound content was calculated using a standard curve of Gallic acid (GA):

$$\text{GA} = \left(\frac{A - b}{m}\right) \times 1000 \quad (3)$$

where *A* is the absorbance of the sample, *b* is the intercept (abs) and *m* is the slope (mg^{-1}). The standard curve was $A = 4.108 \times x$ (mg) − 0.010 ($R^2 = 0.989$). The results were reported as GA equivalents (mg L^{-1}).

2.10. Antioxidant activity

The antioxidant activity was analyzed according to the Kuskoski et al. (2004) methodology. The $ABTS^+$ radical was prepared placing 5 mL of distilled water, 3.3 mg of potassium persulfate (Sigma–Aldrich, Steinheim, Germany), and 19.4 mg of the ABTS (2, 2′ Azino-bis (2-ethylbenzothiazoline-6-sulfonic acid) diammonium salt) (Sigma–Aldrich, Steinheim, Germany) reagent in an amber glass flask. Reagents were thoroughly mixed and let stand for 16 h in a dark environment. Afterward, absolute ethanol was