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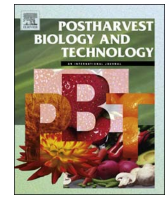

Research paper

Nanocoating with extract of tarbush to retard Fuji apples senescence

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ABSTRACT

This work aims to study the ability of a nanocoating based on candelilla wax and extract of tarbush (*Flourensia cernua*) as edible coating to retard Fuji apples senescence. The first part of the work consisted in obtaining the nanocoating solution with the suitable values of wettability on Fuji apple surface. The concentration of 0.8% of tween 80 was selected for use in the nanocoating. Subsequently, extract of tarbush was obtained and added in the improved nanocoating. The extract of tarbush significantly decreased the droplet size and increased the magnitude of the z-potential of the nanocoating. The optical profilometry results showed a closed surface and less rough on the nanocoating with extract. The effects of application of the nanocoating with extract of tarbush to Fuji apples were assessed by determining the physicochemical changes, water vapor transferred, morphological studies and microbiological stability of the Fuji apples treated during 56 d of storage. The minimum values of water vapor transferred and physicochemical changes was obtained in Fuji apples coated with nanocoating with extract of tarbush. The application of nanocoating with extract of tarbush on Fuji apples senescence delay of the fruits, wich resulted in a decrease in firmness loss, reducing the physicochemical changes and the microbial growth in fruit when compared to non-coated fruit.

1. Introduction

A natural alternative to extend shelf life of fruits during postharvest storage is typically the use of edible coatings, which are defined as a cover material that is applied to food to improve appearance, being an effective barrier to transmission of gases, solving problems of migration of moisture, oxygen, carbon dioxide and aromas (Fernández-Álvarez, 2000) prolonging life and quality of the fruit (Vernon et al., 1999).

Nanotechnology has a great potential to change the way that food products are preserved (Weiss et al., 2006). Applications of nanotechnology in food systems have focused mainly on functional products, packaging materials and microbial control (Weiss et al., 2006), so it is necessary to explore their functionality for preserving fruits (Zambrano-Zaragoza et al., 2014).

The use of a nanoemulsion as nanocoating is emerging as a potential tool (Salvia-Trujillo et al., 2015) for its application in fruits.

Nanocoatings are oil-in-water nanoemulsions that consist on lipid nano droplets (ranging from 10 to 100 nm diameter) dispersed in an aqueous solution with unique physicochemical and functional characteristics (Rao and McClements, 2011). Also, it has been recently pointed out that nanoemulsions may enhance the transport of active ingredients as antioxidants, flavors, bioactive compounds or antimicrobials through biological membranes, thus intensifying their bioavailability and effectiveness (Acosta, 2009; Donsí et al., 2011).

The regions of the north of Mexico, with its semiarid climate, have a great number and variety of wild plants grown under extreme climatic conditions, it is thought that some 25,000 species are registered and 30,000 are not described (Adame and Adame, 2000).

Candelilla (*Euphorbia antisyphilitica* Zucc.) is an endemic species of the semiarid regions of the borderline between Mexico and USA; from this plant is obtained a wax, which is a substance recognized as safe (GRAS) by the Food and Drug Administration (FDA) (Saucedo-Pompa et al., 2009).

Tarbush (*Fluorensia cernua* D.C.) is an abundant specie in arid and semiarid regions of Mexico, where the tea brewed from the leaves of this plant is used in traditional medicine to treat digestive disorders, rheumatism, venereal diseases, herpes, bronchitis, varicella and common cold (Ventura et al., 2009). It has been reported that extracts

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of tarbush have antioxidant (Abou-Gazar et al., 2004; De León-Zapata et al., 2013), anti-HIV (Gnabre et al., 1996), antifungal (De León-Zapata et al., 2013; Jasso-De Rodríguez et al., 2011; De León Zapata et al., 2016), antitumor (MacRae and Towers, 1984) and antidiabetic properties (Luo et al., 1998). The biological activity of the extract of tarbush is due to its bioactive compounds, mainly methyl orsellinate, ermanin, flourensadiol, dehydroflourensic acid, long chain hydrocarbons from tetracosane 4-olide to triacontano-4-olide, lactones (Jasso-De Rodríguez et al., 2007), saponins (Méndez et al., 2012), terpenes (Estell et al., 2013), catechins (Castillo et al., 2010; De León-Zapata et al., 2013; Méndez et al., 2012) and flavonoid glucosides (De León-Zapata et al., 2016). These compounds have the ability to form complexes with proteins and polysaccharides of microbial cells through polar interactions inhibiting the transport of ions and electrons (Scalbert and Williamson, 2000), breaking the membrane of the microorganism (Cowan, 1999; Urzua et al., 2006).

Particularly, the incorporation of extract of tarbush in emulsions with micro sized particles as edible coatings based on candelilla wax has been described as a good alternative to preserve fruit products such as peppers (Ochoa-Reyes et al., 2013), papaya, strawberry (Télles-Pichardo et al., 2013) and “Golden delicious” apple (De León-Zapata et al., 2015). However, this is the first scientific report about the incorporation of extract of tarbush in an emulsion with nano sized particles (nanocoating) as edible coating based on candelilla wax for application in whole Fuji apples.

The effectiveness of edible coatings for protection of fruits depends primarily on controlling the wettability of the coating solutions, which affects the coating thickness (Park, 1999).

Therefore, the aim of this work was to study the ability of the nanocoating with extract of tarbush to retard Fuji apples senescence.

This study was divided into two parts: in the first part was improved the wettability of the nanocoating on the Fuji apple surface; and, in the second one, the nanocoating with extract of tarbush was applied to the Fuji apples and the changes of the fruit were followed during postharvest storage.

2. Materials and methods

2.1. Materials

Glycerol, arabic gum, polysorbate 80 (Tween® 80) and jojoba oil of food-grade were supplied by Panreac (Madrid, Spain). Candelilla wax of food-grade was supplied by Bioingenio Liftech S.A. de C.V. (Saltillo, México). Reagents and culture medium for microbiology analysis were obtained from Panreac (Madrid, Spain). All solutions were prepared using ultra pure water obtained from a Milli-Q filtration system (Millipore Corp., Massachusetts, USA).

2.2. Fruit source

Fuji apples (*Malus domestica* Borkh) were obtained in the month of October (2014) in the region of Pontevedra, Galicia, Spain. The apples were selected based on physiological maturity, color, size and uniformity of shape. The selected fruit were kept at 5 ± 2 °C for 24 h prior to use.

2.3. Tarbush material

Leaves of tarbush *F. cernua* were collected during March and April (2014) in areas nearby to Saltillo, Coahuila, Mexico. Plant material was dehydrated at room temperature for 8-10 d using a conventional oven (Labnet, International, Inc.) at 60 ± 1 °C for 2 d. The leaves were stored in amber bottles or dark plastic bags at room temperature (25 ± 1 °C) until the obtaining of the extract.

2.4. Preparation of nanocoating solutions

Nanocoatings were prepared using the hot high shear stirring method (Solans et al., 2005). Gum arabic (3% w/v) was homogenized using a high shear stirrer Ultra-Turrax T25 Digital, IKA®, (Staufen, Germany with a S25N-25G, IKA disperser element) in distilled water at 800 rpm for 1 min and then heated to 85 ± 2 °C. Candelilla wax (1% w/v), jojoba oil (0.15%), glycerol (0.4%) and tween 80 were added. Nanocoating solution at several concentrations of tween 80 (0, 0.2, 0.4, 0.6, 0.8, 1 and 1.2%) were made in order to evaluate the effect of tween 80 on the wettability of the nanocoating to improve its compatibility with the surface of the fruit. For the emulsification of components a high shear stirrer at 10,000 rpm for 5 min was used.

2.5. Wettability

The wettability of nanocoating was studied by determining the values of the spreading coefficient (W_s) the works of adhesion (W_a) and cohesion (W_c).

The wetting behavior of the coating solution will depend mainly on the balance between the adhesive forces and cohesive forces. The surface tension of the nanocoating solution was measured by the pendant drop method using the Laplace-Young approximation (Song and Springer, 1996).

The contact angle (θ) of a liquid drop on a solid surface is defined by the mechanical equilibrium of the drop under the action of three interfacial tensions: solid-vapor (γ_{SV}), solid-liquid (γ_{SL}), and liquid-vapor (γ_{LV}). The equilibrium spreading coefficient (W_s) is defined by Eq. (1) (Rulon and Robert, 1993) and can only be negative or zero.

$$W_S = W_a - W_c = \gamma_{SV} - \gamma_{LV} - \gamma_{SL} \quad (1)$$

where W_a and W_c are the works of adhesion and cohesion, defined by Eqs. (2) and (3), respectively.

$$W_a = \gamma_{LV} + \gamma_{SV} - \gamma_{SL} \quad (2)$$

$$W_c = 2 \cdot \gamma_{LV} \quad (3)$$

Contact angle was determined with a face contact angle meter (OCA 20, Dataphysics, Germany). Samples of the nanocoating solution where taken with a 500 µL syringe (Hamilton, Switzerland) in order to determine the drop shape, using computer-aided image processing. The contact angle at the apple surface was measured by the sessile drop method (Newman and Kwok, 1999), in which a droplet of the tested liquid was placed on a horizontal surface and observed with a face contact angle meter. To avoid changes on the apple surface, measurements were made in less than 30 s. Ten replicates of both the contact angle at the apple surface and of the surface tension measurements were performed at room temperature (25 ± 2 °C).

2.6. Preparation of nanocoating with extract of tarbush

2.6.1. Obtaining of extract of tarbush

The extract of tarbush were obtained by infusion method and heating reported by De León-Zapata et al. (2016). It was used one sample of 10 g of leaves of tarbush and placed in an amber flask and then 100 mL of deionized water were added. The mixture was manually stirred and heated for 2 h at 60 ± 1 °C. The extract was filtered with a Wathman Num. 1 paper, transferred to a glass Petri plates and then placed in a conventional oven (Labnet, International, Inc.) during 36 h at 60 ± 1 °C. The extract of tarbush were stored in containers covered with aluminum or amber bottles at 5 ± 2 °C.

2.6.2. Preparation of nanocoating

Nanocoating was prepared using the hot high shear stirring method (Solans et al., 2005). Briefly, gum Arabic (3% w/v) was homogenized using a high shear stirrer Ultra-Turrax T25 Digital, IKA®, (Staufen,