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Shellac, gelatin and Persian gum as alternative coating for orange fruit

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ABSTRACT

Postharvest fruit coatings are an effective method to replace natural waxes lost during washing and handling. The coatings can reduce water loss and impart gloss to the fruit. Edible coatings, instead of synthetic waxes, are perceived to offer advantages with respect to human health concerns and environmental protection. In this research, edible coatings made from relatively inexpensive, easy to dissolve components that are suitable for increasing fruit gloss were studied on 'Valencia' oranges during storage. The coating materials included 5, 6 and 7% gelatin, 3.5, 4 and 4.5% Persian gum, 9, 10 and 11% shellac were compared to un-coated control, and fruit coated with a commercial wax. After coating, the fruit were stored for up to 60 days at 5 °C. Every 20 days fruit were removed from storage and evaluated. Scanning electron microscopy images of coated rind surfaces were also obtained. The results indicated that weight loss, fruit firmness, total soluble solids (TSS), titratable acidity (TA), pH, ascorbic acid content, total phenolic content (TPC), total antioxidant capacity (TAC) and respiration rate were affected by the coatings. Shellac coatings reduced weight and firmness loss. As the storage time was increased fruit TA and ascorbic acid content decreased, and pH, TPC and TAC increased. Glossiness was observed in all coatings, however, with increasing storage time, fruit coated by gelatin and Persian gum coatings, showed visible cracks. Shellac was the best coating as it dried quickly, forming a not sticky and odorless coating, and gave highest fruit gloss.

1. Introduction

Fruits and vegetables surfaces have natural cuticular waxes that protect harvested commodities against water loss (Sturm et al., 2003). This natural wax on citrus can be washed off or disturbed during cleaning fresh fruit before packing. Normal postharvest practice is to replace the natural barrier with various types of coatings (Bajwa and Anjum, 2007). Citrus fruit are coated with commercial synthetic waxes to reduce fruit weight loss and shrinkage, and to enhance the gloss to improve appearance (Petracek et al., 1998). However, many of the commercial coatings contain synthetic components such as oxidized polyethylene, ammonia or morpholine (Rhim and Shellhammer, 2005). Consumers are showing greater concern for human health and the environment. Natural biodegradable edible films and coatings are regarded as being more environmentally friendly and nonpolluting (Rhim and Shellhammer, 2005). Edible fruit films and coatings made with food-grade ingredients that are generally recognized as safe (GRAS) for human consumption are preferred. Edible films and coatings include polysaccharides, proteins, lipids, and resins. Their mechanical and functional properties are improved by adding plasticizers and emulsifiers (Rhim and Shellhammer, 2005). Films containing hydrocolloid components most polysaccharides have poor water vapor barrier properties though good barrier to gases. Lipid films have poor permeability to gases but they can be used as an adequate barrier to water vapor (Perez-Gago et al., 2002; Navarro-Tarazaga et al., 2008). So far, most evaluations of edible coatings for citrus fruit have focused on hydroxypropyl methylcellulose (HPMC), beeswax (BW) or their composites (Navarro-Tarazaga et al., 2008; Contreras-Oliva et al., 2011, 2012). It has been shown that coatings containing BW appear opaque (Arnon et al., 2014), while HPMC-BW coatings reduced weight loss rate in mandarins (Perez-Gago et al., 2002; Navarro-Tarazaga and Perez-Gago, 2006; Navarro-Tarazaga et al., 2008). However, these coatings do not improve fruit appearance (Contreras-Oliva et al., 2011). Arnon et al. (2014) evaluated the effect of various polysaccharide-based edible coatings, found that carboxymethyl cellulose (CMC) coatings maintained high structural integrity and provided a uniform matrix during storage but, imparted little gloss.

In our preliminary studies (2014–2016), we evaluated the efficacy

Abbreviations: GL, gelatin; PG, Persian gum; SH, shellac; HPMC, hydroxypropyl methylcellulose; BW, beeswax; CMC, carboxymethyl cellulose; TSS, total soluble solids; TA, titratable acidity; TPC, total phenolic content; TAC, total antioxidant capacity; SEM, scanning electron microscopy

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of various edible coatings, including wheat gluten, gelatin (GL), oleic acid, corn zein, gum Arabic, tragacanth gum, Persian gum (PG), shellac (SH), BW, carnauba and CMC. Tragacanth gum is a polysaccharide gum derived from several species of legumes in the genus Astragalus, while Persian gum is a polysaccharide from the wild almond tree. In the present study, we selected SH, PG and GL coatings that are relatively inexpensive, easy to dissolve and suitable for increasing fruit gloss were evaluated for their efficacy to help maintain postharvest quality of 'Valencia' orange during storage.

The main objective of this study was to develop a suitable edible coating to replace synthetic waxes and to compare the qualitative characteristic of fruit treated with edible films and commercial waxes during storage on Valencia oranges.

2. Materials and methods

2.1. Plant material and experimental design

'Valencia' oranges (*Citrus sinensis* (L.) Osbeck) were hand-harvested from a commercial citrus orchard in Darab, Fars, Iran (28°50′N, 54°30′E). The fruit (~400) were transported ~200 km in an air conditioned vehicle within 2 h of harvest to the postharvest lab at Shiraz University. Fruit were sorted on size, and visual quality and selected uniform fruit (180–210 g) were dipped in a solution of 0.2% dishwashing liquid, rinsed with water, and dried at room temperature (22 °C). The oranges were randomly divided into 11 groups of 36 fruit (three replicates of four fruit for each sampling time), and the following treatments applied: control (uncoated), commercial wax (CW), (Decco, Italy), 5, 6 and 7% gelatin (GL), 3.5, 4 and 4.5% Persian gum (PG), 9, 10 and 11% shellac (SH), (w/v). The fruit were dip by immersion into the coating solutions for 2–3 min, followed by draining the excess solution and drying at room temperature (22 °C, RH = 40%). After coating, fruit were stored for up to 60 days at 5 °C. Samples of 132 fruit were removed every 20 days from storage and held for 48 h at room temperature before quality evaluation.

2.2. Preparation of edible coating formulations

GL and PG powders were separately dissolved in distilled water with stirring at room temperature for 7–8 h to obtain homogenous dispersions of 5, 6 and 7% GL and 3.5, 4 and 4.5% PG (w/v). After complete hydration, glycerol (0.75 mL/g dry matter) was added as a plasticizer, followed by stirring for an additional 30 min. The PG solutions were centrifuged for 15 min at 4000*g* to remove undispersed impurities. The SH coatings were dissolved in ethanol (98%) with stirring at room temperature to obtain homogenous dispersions of 9, 10 and 11% (w/v).

2.3. Fruit quality studies

At each sampling time (20 days), fruit quality parameters were evaluated by measuring the weight loss, fruit firmness, total soluble solids (TSS), titratable acidity (TA), pH, ascorbic acid content, total phenolic content (TPC), total antioxidant capacity (TAC) and respiration rate. Fruit epidermal scanning electron microscopy (SEM) images of coated rind surfaces were captured.

Twelve oranges per treatment were used to measure the weight loss determined by weighing the fruit at the beginning and end of each storage period. The results were presented as the percentage loss of initial weight (Razzaq et al., 2014). Firmness of 3 oranges per replication was determined at the end of each storage time using an Instron Universal Testing Machine (STM-20, Iran). The instrument gave the 10% deformation after application of a compression load at a rate of 100 mm min^{-1} at the equatorial region of the fruit (Navarro-Tarazago et al., 2008).

TSS was measured by a hand-held refractometer (TI-RBX0032A, Singapore), TA (% as citric acid) was measured after titration of juice with a 0.1 N NaOH solution to pH 8.2 (Habibi and Ramezanina, 2017). pH was determined using a pH meter (Starter3000, OHAUS Corporation, USA); and TSS/TA ratio was calculated by dividing TSS to TA. Ascorbic acid content (mg 100 mL^{-1}) of the fruit juice was measured using the 2,6-dichlorophenol indophenol method (AOAC, 2000).

TPC was measured according to the Folin-Ciocalteau colorimetric method (Meyers et al., 2003). A mixture of 700 µL of fruit juice and 900 µL of 2% sodium carbonate were maintained for 3 min at room temperature, then 180 µL of 50% Folin reagent was added, and maintained for 30 min at room temperature. The mixture absorbance was read at 750 nm in a microplate spectrophotometer (Epoch Biotech, Germany). The concentration of total phenolic content was expressed as mg GAE L^{-1}. Gallic acid was used as the standard.

TAC of each extract was determined according to the method of Brand-Williams et al. (1995), 100 µL of fruit juice, 1 mL DPPH (0.1 mM) and 1 mL Tris-HCl buffer were mixed then held for 30 min at room temperature before absorbance was read by a Microplate Spectrophotometer (Model Epoch Biotech, Germany) at 517 nm. TAC was calculated using the following equation:

$$\text{Antioxidant activity}(\%) = \left(\frac{\text{A Control} - \text{A Sample}}{\text{A Control}}\right) \times 100$$

Respiration rate was measured using an infra-red CO_2 meter (Testo 535, Germany) after enclosing individual fruit in a sealed container for 20 min.

To prepare SEM images, one fruit from each treatment was randomly selected and processed within 24 h after the coating dried following application of the coating. Rind sections (1 × 1 cm) were dissected from equatorial area of the fruit, and stored at −80 °C. The sections were then transferred to freeze dryer (FD-5003-BT, Iran) for 3 h then mounted on a stub and coated with a thin layer of gold in order to make the sample surface electrically conducting (Desk Sputter Coater Dsr1 Nanostructural Coating). Imaging of the samples was done using a scanning electron microscope (Scanning Electron Microscope, TESCAN vega3, Czech). Digital SEM images were captured at 500× magnifications that showed the rind surface with natural wax and test.

2.4. Sensory evaluations

Fruit visual appearance was evaluated subjectively by 10 trained persons. Panelists were asked to evaluate gloss level and flavour (absence or presence of off-flavour). Fruit gloss was evaluated on a 0–10 scale in which 0 = no gloss and 10 = very glossy. The presence of off-flavour was evaluated using a ten-point intensity scale where 0 = high presence of off-flavour and 10 = absence of off-flavour. Sensory acceptance was evaluated according to a 1–10 point scale ranging at the end of storage period.

2.5. Statistical analysis

A split plot in time design was used to perform the analysis of the samples. Specific differences between the means were also determined by LSD (least significant difference) defined at $P = 0.01$. Data were analyzed using SAS (v. 9.1). GLM was used to determine storage duration and coating interactions, and Pearson correlation coefficients were calculated for all parameters to assess the nature and extent of relationship between them.

3. Results and discussion

3.1. Weight loss and firmness

Weight loss increased with longer storage times (Table 1). Both the CW and the SH coatings at all concentrations tested reduced weight loss rate. The lowest fruit weight loss was observed in fruit treated with CW