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Tea polyphenols incorporated into alginate-based edible coating for quality maintenance of Chinese winter jujube under ambient temperature

Lihua Zhang [a, b, *], Shunfeng Li [c], Yu Dong [a, b], Huanhuan Zhi [a, b], Wei Zong [a, b]

[a] School of Food and Bioengineering, Zhengzhou University of Light Industry, Zhengzhou 450002, PR China
[b] Collaborative Innovation Center for Food Production and Safety, Zhengzhou University of Light Industry, Zhengzhou 450002, PR China
[c] Institute of Agro-Products Processing, Henan Academy of Agricultural Sciences, Zhengzhou 450002, PR China

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ABSTRACT

The effects of different concentrations (1 g/L, 3 g/L and 5 g/L) of tea polyphenols incorporated into alginate-based (sodium alginate 1 g/L, glycerol 11.6 g/L and sunflower oil 0.25 g/L) edible coating on the respiration intensity, physicochemical properties, and activities of antioxidant enzymes of fresh winter jujube during 8 days storage under ambient temperature were evaluated. Coated jujube without tea polyphenols and uncoated jujube were stored under the same conditions and served as the controls. The alginate-based edible coating with 1 g/L tea polyphenols significantly reduced red indices, total chlorophylls content, respiration rate, electrolyte leakage and malonaldehyde content while maintaining the ascorbic acid content, total phenol content and the activities of antioxidant enzymes. However, the alginate-based edible coating incorporated with tea polyphenols, whichever their concentrations, had no significant effect on firmness. Alginate-based edible coating with 1 g/L tea polyphenols has a potential to maintain the quality of fresh jujube under ambient temperature.

1. Introduction

The winter jujube is deeply favored by consumers for its thin peel, juiciness and crispness, and high nutritional value (Gao et al., 2011; Hui et al., 2015; Li, Fan, Ding, & Ding, 2007; Siriamornpun, Weerapreeyakul, & Barusrux, 2015; Zhang, Jiang, Ye, Ye, & Ren, 2010). However, fresh winter jujube is subject to rapid loss of water, browning, alcoholic fermentation and decay during postharvest storage and transportation. In addition, it is also sensitive to carbon dioxide of the environment (Gao, Li, & Han, 2009; Wang, Zhao, Zhang, Li, & Wang, 2008). Therefore, many methods including nitric oxide fumigation (Sun, Liu, Zhu, Zhou, & Wang, 2007), 1-MCP treatment (Liang, Zhang, Wang, & Jiang, 2010; Zhong & Xia, 2007), controlled atmosphere storage (Wang et al., 2008), or coating edible film and irradiation (Zhang, Yu, Xiao, Wang, & Lei, 2014) were tested to improve the physiological quality and prolong the shelf life of fresh jujube.

Edible coatings are thin layers of edible material applied directly on the surface of foods, which may provide a selective barrier to moisture, carbon dioxide and oxygen, and control reactions that are detrimental to food quality (Ayranci, 2004; Azarakhsh, Osman, Ghazali, Tan, & Mohd Adzahan, 2014; Siripatrawan & Harte, 2010). Over the years, considerable studies have been conducted to develop and apply edible coating to preserve the qualities of fresh fruits and vegetables such as guavas, strawberry and mushroom (de Aquino, Blank, & Santana, 2015; Gol, Patel, & Rao, 2013; Guerreiro, Gago, Faleiro, Miguel, & Antunes, 2015; Jiang, 2013).

The incorporation of antioxidant agents in edible coatings may widen their functionality in protecting the quality (Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2008). Recently, natural antioxidants have gained considerable interest as alternatives to chemical preservatives. Tea polyphenols (TPs) are bioactive catechins that have been reported to maintain the good quality of yellow croaker (Li et al., 2012), pork meat patties (Feng, Jiang, Wang, & Li, 2012), red drum (Li, Li, Hu, & Li, 2013), while incorporated into coating film with chitosan or other filmogens. Few studies have been reported the effects of incorporation of TPs in edible coating for quality maintenance of fruit and vegetables (Wang & Zhao, 2000). Thus, the objective of this study was to evaluate the effects of

* Corresponding author. School of Food and Bioengineering, Zhengzhou University of Light Industry, Zhengzhou 450002, PR China. Tel.: +86 13603993251; fax: +86 371 86609631.
E-mail address: zhanglihua8@yahoo.com (L. Zhang).

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different concentrations of TPs incorporated into an alginate-based edible coating on the respiration rate, physicochemical properties, and the activities of antioxidant enzymes of jujube during ambient storage.

2. Materials and methods

2.1. Materials

Fresh winter jujubes (*Ziziphus jujube Mill.* cv. Dongzao) were harvested at commercial maturity (with no red color on the skin, at Sep.27, 2014) from a local orchard in Zhengzhou, Henan province, China. The fruits were selected for uniformity in shape, size and color without signs of mechanical damage and disease, and quickly transported to the laboratory.

Food grade sodium alginate (AL, Bright Moon Seaweed Group Co., Ltd, Qingdao, China) was used as a polysaccharide-based edible coating. Glycerol (Yangdong Chemical Industrial Co., Ltd, Guangdong, China) was applied as a plasticizer. Sunflower oil (Yihai Kerry Co., Ltd, Shanghai, China) was applied as an emulsifier and lipid source. Food grade tea polyphenols was purchased from Puremedie Biological Technology Co., Ltd (Hangzhou, China).

2.2. Preparation of the coating solution and fruit treatment

An optimized alginate-based edible coating formulation was prepared by dissolving sodium alginate (AL, 10 g/L) powder in distilled water while stirring at 70 °C until the mixture became clear. Glycerol (11.6 g/L) was then added, then 0.25 g/L of sunflower oil. Different concentrations (1 g/L, 3 g/L and 5 g/L) of TPs were then incorporated into the alginate-based edible coating solution. The overall volume for each formulation was 1000 mL and this included sodium alginate, glycerol, sunflower oil, TPs with the remainder distilled water. All formulations were mixed in a multifunctional food processor (KYH-777, Guangdong Foshan Lechuang Network Technology, Co., Ltd, Foshan, China) for 15 min to form emulsions and then degassed under vacuum.

The jujube fruits were washed clean with tap water and air-dried for 2 h at room temperature. Then the fruits were randomly categorized into five groups. The treatments were: Control (fruit not coated); AL (jujube fruit coated with AL (10 g/L)); 1 g/L TPs (AL 10 g/L + TPs 1 g/L); 3 /L TPs (AL 10 g/L + TPs 3 g/L) and 5 g/L TPs (AL 10 g/L + TPs 5 g/L).

The jujube fruits were dipped into the coating solutions for 3 min and excess coating materials were allowed to drip off. The samples were then air-dried at ambient temperature (20 °C ± 1 °C) for 1 h, and then fruits were placed in plastic trays (29.0 cm × 20.0 cm × 7.0 cm, 20 fruits per tray, 3 trays per treatment), and stored under ambient temperature with 30% of relative humidity. The related parameters of the jujubes were determined periodically. Three trays of each treatment were randomly taken out every two days and evaluated. Half of the jujubes was used immediately for measurements of red indices, flesh firmness, respiration intensity and electrolyte leakage. The other half was immediately pitted and cut into small pieces, then liquid nitrogen frozen and smashed (MJ-25BM05B, Midea Guangdong, China) into jujube powder to measure the ascorbic acid content, malonaldehyde content, total phenol content, total chlorophylls content, activities of superoxide dismutase, peroxidase and catalase.

2.3. Determination of red indices and total chlorophylls content

Red indices were assayed as described by Yu et al. (2012). Jujube samples were classified visually in five ranks of red as follows: 1, no red; 2, red surface less than 1/4; 3, red surface between 1/4 and 1/2; 4, red surface between 1/2 and 3/4; and 5, red surface more than 3/4. The red indices for the treatment unit were calculated as follows: red indices = [(Σrank × quantity)/(5 × 20)] × 100%.

Total chlorophylls were extracted by grinding 5 g of jujube powder in 10 mL of 0.8 L/L cold acetone with a mortar and pestle at 4 °C, sodium carbonate (0.3 g) was added to prevent the degradation of chlorophylls to pheophytin. The residue was then washed with 0.8 L/L cold acetone until the residue was colorless, and the final volume was diluted to 25 mL with 0.8 L/L cold acetone. The mixture was extracted for 30 min at 4 °C, then centrifuged at 9279 ×*g* for 10 min at 4 °C and the supernatant was used for determination. The total chlorophylls content was determined by measuring the absorbance at 663 and 645 nm simultaneously and calculated according to Arnon (Arnon, 1949). The content was expressed in μg/g fresh weight.

2.4. Determination of respiration intensity

The respiration intensity of jujube fruit was measured by the concentration of carbon dioxide (CO_2). Jujubes (approx. 100 g) were placed in a 1 L glass container under ambient temperature for 2 h. Samples of 10 mL of headspace gas were taken from each glass jar and monitored using an CO_2 analyzer (CYES-II, Shanghai Jiading instrument company, China). The respiration intensity was expressed as mg CO_2/(kg· h).

2.5. Determination of flesh firmness

Whole fruit firmness (without removal of the peel) was conducted using a hand-held fruit firmness tester (GY-1, Tuopu instrument Ltd. Company, Hangzhou, China). Five fruits for each treatment were randomly selected and firmness was measured on the equatorial zone on two sides of each fruit. Puncture tests involved the use of a 3.5 mm cylinder probe, the penetration depth was 10 mm and results were expressed in × 10^5 Pa.

2.6. Determination of ascorbic acid content

The ascorbic acid content was measured by the 2,6-dichloroindophenol titration method (GB 6195-86). The ascorbic acid concentration was calculated according to the titration volume of 2,6-dichloroindophenol, and was expressed as mg/100 g fresh weight.

2.7. Determination of electrolyte leakage and malonaldehyde content

Electrolyte leakage was determined as described by Zhang et al. (2014) with slight modification. Jujube fruits were sliced into small discs (0.05 cm thick) and washed three times with de-ionized water to remove surface-adhering electrolytes. After drying with filter paper, 10 discs were placed in beakers containing 40 mL de-ionized water. The water was stirred slowly, and conductivity was measured as C_1 with a Conductivity Meter (DDS-307A, Shanghai REX Instrument Factory, Shanghai, China). The water was boiled for 10 min and cooled quickly. Afterward, the water was made up to 40 mL with de-ionized water and the conductivity was measured as C_2. Electrolyte leakage was calculated through the formula, electrolyte leakage (%) = $C_1/C_2 \times 100$.

The malonaldehyde content was measured according to the method of Liu and Wang (2012). Frozen jujube powder (2.0 g) was homogenized with 10 mL of trichloroacetic acid (100 g/L) and centrifuged at 9279 ×*g* for 20 min at 4 °C. 2 mL of supernatant was mixed with 2 mL of 6.7 g/L 2-thiobarbituric acid, heated at 100 °C for 20 min, then immediately cooled. The absorbance was read at