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Impact of soybean protein isolate-chitosan edible coating on the softening of apricot fruit during storage

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ABSTRACT

A soybean protein isolate (SPI)-chitosan edible coating was used to prolong the shelf life of apricots stored at 2 °C. Apricots were coated with two different coating formulations (SPI and SPI combined with chitosan). The changes to several parameters including weight loss, firmness, titratable acidity, soluble solids content, pectin contents, and the nanostructural properties of pectin were investigated to evaluate the effectiveness of the coatings. The coatings, especially the SPI-chitosan coating, significantly decreased the weight loss of apricots. Meanwhile, this treatment prevented the decrease in firmness and benefited the textural properties of the tissue. The atomic force microscopy (AFM) results showed a greater F_q (the percent of pectin chains of particular width or length among all the chains observed by AFM) for the width and length of pectin molecules in the SPI-chitosan coated samples (width ≥ 61 nm; length ≥ 3 μm), which indicated that the SPI-chitosan coating could inhibit pectin degradation. The results showed that the SPI-chitosan coating is an effective method to preserve the quality of apricots.

1. Introduction

Prolonging the shelf life of fresh-cut fruit and vegetables using edible coatings has attracted great interest, especially using environmentally friendly and biodegradable materials. Several researchers have reported the application of edible coatings to preserve fruit and vegetables, such as Chinese cherry (Xin, Chen, Lai, & Yang, 2017), fresh-cut apple (Ghidelli, Mateos, Rojas-Argudo, & Pérez-Gago, 2014; Guerreiro, Gago, Faleiro, Miguel, & Antunes, 2017), grape berries (Oh et al., 2017) and eggplant (Singh et al., 2016).

Edible coatings, as biodegradable materials, can provide a semi-permeable barrier to gases and water vapour, reduce respiration, enzymatic browning, and water loss (Pérez-Gago, Serra, Alonso, Mateos, & del Río, 2005; Mannozzi et al., 2017). The basic ingredients of edible coatings are proteins, polysaccharides, and lipids. The coatings' protective function can be enhanced by the addition of ingredients such as antioxidants. Weinbreck, Tromp, and de Kruif (2004b) reported that protein-polysaccharide interactions play significant roles in controlling the structure, texture, and stability of coating and packaging materials. Chitosan has the advantage of biodegradability, biocompatibility, non-toxicity, and antimicrobial activity; therefore, interest in its application in edible coatings and films is increasing (Aider, 2010; Xin et al., 2017). However, chitosan films are highly permeable to water vapour. Many scientists have reported that chitosan combined with protein has a positive effect on the shelf life of fruit. The addition of quinoa protein and sunflower oil to chitosan resulted in low water vapour permeability and long shelf life of fresh blueberries (Abugoch et al., 2016). Simonaitiene reported that whey proteins-chitosan films with quince and cranberry juice inhibited the growth of *Penicillium expansum* on apples (Simonaitiene, Brink, Sipailiene, & Leskauskaite, 2015).

The shelf life of fruit and vegetables is closely related to their texture. The firmness of fruit tissue is determined by the composition and morphology of the cell wall materials, which include pectin, cellulose, and hemicelluloses. Thus, changes in polysaccharides including pectin structure induce changes in the texture of fruit and vegetables (Chen et al., 2018; Liu, Jiang, Yang, & Yang, 2017; Liu, Tan, Yang, & Wang, 2017; Yang, 2014; van Buggenhout, Sila, Duvetter, Van Loey, & Hendrickx, 2009). It is believed that tissue softening of fruit is determined by pectin modifications and solubilisation. Chen reported that fruit firmness is associated with pectin polymers of chelate-soluble pectin (CSP) (Chen et al., 2013). Lara found that increasing the CSP content and lowering the levels of the water-soluble fraction reduced

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Table 1
Effects of coating on the physicochemical properties of apricots during storage. *Different superscript uppercase letters in the same row and different superscript lowercase letters in the same column indicate a significant difference at $P < 0.05$; CK indicates the control group; SPI and SPI-chitosan indicate soybean protein isolate coating and soybean protein isolate-chitosan coating group, respectively. SSC: soluble solids content; TA: titratable acidity; d: day.

Storage Time (d)	Weight Loss (%)			Firmness (N)			SSC (%)			TA (%)		
	CK	SPI	SPI-chitosan	CK	SPI	SPI-chitosan	CK	SPI	SPI-chitosan	CK	SPI	SPI-chitosan
0	$0.00 \pm 0.00^{a,A}$	$0.00 \pm 0.00^{a,A}$	$0.00 \pm 0.00^{a,A}$	$11.07 \pm 0.71^{a,A}$	$11.07 \pm 0.71^{a,A}$	$11.07 \pm 0.71^{a,A}$	$8.04 \pm 0.18^{a,A}$	$8.04 \pm 0.18^{a,A}$	$8.04 \pm 0.18^{a,A}$	$1.00 \pm 0.01^{a,A}$	$1.00 \pm 0.01^{a,A}$	$1.00 \pm 0.01^{a,A}$
7	$2.14 \pm 0.02^{b,C}$	$1.84 \pm 0.08^{b,B}$	$1.42 \pm 0.04^{b,A}$	$10.80 \pm 0.26^{a,B}$	$9.73 \pm 0.78^{b,A}$	$10.68 \pm 0.43^{ab,B}$	$8.32 \pm 0.57^{a,A}$	$8.44 \pm 0.27^{a,A}$	$8.60 \pm 0.35^{b,A}$	$0.99 \pm 0.01^{a,B}$	$1.01 \pm 0.02^{a,C}$	$0.93 \pm 0.00^{c,A}$
14	$7.13 \pm 0.55^{c,B}$	$6.14 \pm 0.14^{c,A}$	$5.73 \pm 0.37^{c,A}$	$5.94 \pm 0.29^{c,A}$	$9.21 \pm 0.84^{b,B}$	9.84 ± 0.67^{bcB}	$8.44 \pm 0.44^{a,AB}$	$8.12 \pm 0.34^{a,A}$	$8.80 \pm 0.30^{b,B}$	$0.79 \pm 0.00^{c,A}$	$0.86 \pm 0.02^{d,B}$	$0.86 \pm 0.03^{d,B}$
21	$9.44 \pm 0.27^{d,B}$	$8.46 \pm 0.60^{d,A}$	$8.32 \pm 0.45^{d,A}$	$7.27 \pm 0.43^{b,A}$	$8.06 \pm 1.05^{c,A}$	$9.58 \pm 0.91^{c,B}$	$9.36 \pm 0.46^{b,B}$	$9.06 \pm 0.25^{b,AB}$	$8.80 \pm 0.16^{b,A}$	$0.76 \pm 0.00^{d,A}$	$0.96 \pm 0.01^{b,B}$	$0.97 \pm 0.02^{b,B}$
28	$12.37 \pm 0.48^{e,A}$	$10.78 \pm 0.28^{e,A}$	$10.40 \pm 1.58^{e,A}$	$5.18 \pm 0.15^{d,A}$	$5.38 \pm 0.32^{d,A}$	$5.84 \pm 1.12^{d,A}$	$9.96 \pm 0.27^{c,A}$	$9.76 \pm 0.75^{c,A}$	$10.00 \pm 0.36^{c,A}$	$0.85 \pm 0.01^{b,B}$	$0.79 \pm 0.01^{f,A}$	$0.83 \pm 0.02^{d,B}$
35	$19.93 \pm 1.03^{f,C}$	$18.10 \pm 0.42^{f,B}$	$14.09 \pm 0.35^{f,A}$	$4.40 \pm 0.43^{e,A}$	$4.37 \pm 0.29^{e,A}$	$5.39 \pm 0.34^{d,B}$	$10.18 \pm 0.25^{c,A}$	$10.98 \pm 0.16^{d,B}$	$11.28 \pm 0.36^{d,B}$	$0.81 \pm 0.02^{c,A}$	$0.91 \pm 0.01^{c,B}$	$0.79 \pm 0.01^{e,A}$
42	$23.96 \pm 1.78^{g,B}$	$22.13 \pm 0.56^{g,B}$	$16.63 \pm 0.85^{g,A}$	$2.69 \pm 0.71^{f,A}$	$4.15 \pm 0.09^{e,B}$	$4.26 \pm 0.73^{e,B}$	$10.92 \pm 0.37^{d,A}$	$12.94 \pm 0.11^{e,B}$	$11.26 \pm 0.43^{d,A}$	$0.76 \pm 0.01^{d,A}$	$0.84 \pm 0.00^{e,B}$	$0.97 \pm 0.01^{b,C}$

the degree of fruit dissolution and improved its texture (Lara, Garcia, & Vendrell, 2004).

Soybean protein materials are suitable for edible coatings because of their low permeability to oxygen and carbon dioxide, and reasonable cost (Kang, Kim, You, Lacroix, & Han, 2013). Soybean protein materials together with other materials have been used to extend the shelf life of fresh-cut eggplants and walnut kernels (Ghidelli et al., 2014; Kang et al., 2013). However, to the best of our knowledge, there has been little research focused on the effect of soy protein isolate (SPI) with chitosan coating on fruit. The aim of the current study was to investigate the physicochemical properties of apricots coated with an SPI-chitosan coating during storage. The softening mechanism of fruit was also studied from the aspect of the nanostructure of water-soluble and chelate-soluble pectin. The results will help to extend the use of SPI-chitosan coatings in postharvest fruit and vegetables.

2. Materials and methods

2.1. Materials

Apricot fruit (*Prunus armeniaca* L. 'Kaite') were harvested about one week before commercial maturity (their colour turned to light yellow) and were purchased from Zhengzhou, Henan, China. The fruit were transported to the laboratory within 2 h after harvest, and selected based on uniform colour, size, and absence of visible physical injury as the experiment materials. Food grade SPI (protein content 86.65%) was purchased from Shandong Wonderful Industrial Group Co. Ltd. (Dongying, Shandong, China). Food grade chitosan (viscosity < 100 mPa s and degree of deacetylation > 90%) was purchased from Zhejiang Aoxing Biotechnology Co. Ltd. (Hangzhou, Zhejiang, China). D-galacturonic acid (> 97.0%) was purchased from Sigma-Aldrich Co. Ltd. (St. Louis, MI, USA). All other reagents were of analytical grade.

2.2. Fruit coating

Fruit coating solutions were prepared according to previous reported methods with slight modifications (Huang, Sun, Xiao, & Yang, 2012; Xin et al., 2017). SPI (50 g) was dispersed in 1000 mL of distilled water, homogenised using ultrasound (power 80 W, time 5 min, and temperature 40 °C) (KQ-400E, Kunshan Shumei Ultrasonic Instrument Co. Ltd., Kunshan, Jiangsu, China), and used as the SPI coating solution (50 g SPI/1000 mL of water).

SPI solution (500 mL) was prepared by dispersing 50 g SPI in 500 mL distilled water, homogenised by ultrasound as the above. Chitosan solution (500 mL) was prepared by dissolving 1 g chitosan in 400 mL distilled water to which 32.5 mL glacial acetic acid was added. The solution was homogenised using ultrasound (power 80 W, time 5 min, and temperature 40 °C), adjusted to pH 5.6 with 0.1 M NaOH, and made up to 500 mL. The mixture of the SPI solution (500 mL) and chitosan solution (500 mL) formed the SPI-chitosan coating solution (50 g SPI/1000 mL of solution).

Two groups of 100 apricots were dipped into the SPI and SPI-chitosan coating solution, respectively, for 3 min, dried naturally, and defined as the SPI coated group and SPI-chitosan coated group. Another 100 apricots were dipped into distilled water for 3 min and defined as the control group (CK group). Fruit, harvested and delivered to the laboratory without any coating treatment, were defined as fresh fruit. Every 7 days, 10 fruit from each group were randomly selected from storage (temperature, 2 ± 1 °C; humidity, 75%) and analysed.

2.3. Firmness and weight loss determination

The firmness of the apricots was evaluated using a TA-XT2i texture analyser (Stable Micro System Ltd., Godalming, Surrey, UK). Based on a preliminary experiment (Liu et al., 2017), the operating settings were: