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Effect of beeswax content on hydroxypropyl methylcellulose-based edible film properties and postharvest quality of coated plums (Cv. *Angeleno*)

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ABSTRACT

The effect of beeswax (BW) content of hydroxypropyl methylcellulose (HPMC)–BW edible coatings on stand-alone film properties and on postharvest quality of coated 'Angeleno' plums was studied. The coatings contained BW at 4 lipid content levels (0, 20, 40 and 60 g/100 g, dry basis). Coated and uncoated plums were stored 4 weeks at 1 °C and transferred to 20 °C for 1–3 weeks. Addition of BW to the HPMC film matrix reduced film mechanical resistance and oxygen barrier, and improved film moisture barrier. Film mechanical properties showed a good fit with an exponential and/or linear model that could provide a useful tool to predict mechanical properties with others HPMC–BW composition mixtures. Coatings with BW reduced plum weight loss compared to HPMC-based coatings with no BW. Plum weight loss decreased as BW content increased from 20 to 40 g/100 g, but above 40 g/100 g BW content, weight loss was not further reduced. Whereas, water vapor permeability of stand-alone films decreased significantly as BW content increased to 60 g/100 g. Coatings reduced plum softening and bleeding, with those with lower BW content being more effective, which could be related to the ability of coatings to create a modified atmosphere in the fruit. Flavor was not affected by coating application. Results indicate that HPMC–BW coatings with 20 g/100 g BW would provide the best compromise to extend shelf life of 'Angeleno' plums.

1. Introduction

Consumer interest in health, nutrition, and food safety combined with environmental concerns has renewed efforts in edible film and coating research. The main function of edible films and coatings is to offer a protective barrier to moisture, oxygen, flavor, aroma, etc., between the food and the environment. Additionally, edible films and coatings may act as carriers of food ingredients and help improving the handling characteristics of the food. Therefore, application of edible coatings to fruits is a simple technology that allows reduction in fruit moisture loss and permits regulation of respiration as a passive modified atmosphere packaging. In addition, coatings can also act as carriers for fungicides or growth regulators and improve fruit gloss (Banks, Dadzie, & Cleland, 1993; Cisneros-Zevallos & Krochta, 2002).

Edible films and coatings are made with food-grade ingredients, generally recognized as safe for human consumption. Materials used in edible films and coatings include proteins, polysaccharides, and lipids (Greener-Donhowe & Fennema, 1993). Among polymeric materials, cellulose is the most abundantly occurring natural polymer on earth with excellent film forming properties (Bravin, Peressini, & Sensidoni, 2004). However, native cellulose is insoluble in water due to the high level of intramolecular hydrogen bonding in the cellulose polymer. The usefulness of cellulose to form edible films and coatings can be extended by the use of different cellulose derivatives. Among them, hydroxypropyl methylcellulose (HPMC) yields films that are flexible, odorless, tasteless, water soluble, and resistant to oils and fats (Greener-Donhowe & Fennema, 1986), and present good oxygen and aroma barrier properties (Miller & Krochta, 1997). However, their hydrophilic nature makes them rather ineffective moisture barriers. Addition of lipids to the HPMC matrix, forming composite edible films, has improved film moisture barrier properties (Hagenmaier & Shaw, 1990; Kamper & Fennema, 1984).

Previous studies showed the potential of HPMC–Beeswax (BW) edible composite coatings to extend the self life of plums (Navarro-Tarazaga, Sothornvit & Pérez-Gago, 2008; Pérez-Gago, Rojas & Del Rio, 2003) and citrus (Navarro-Tarazaga, Del Río, Krochta & Pérez-Gago, 2008; Navarro-Tarazaga & Pérez-Gago, 2006; Navarro-

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Tarazaga, Pérez-Gago, Goodner & Plotto, 2007; Pérez-Gago, Rojas & Del Rio, 2002). However, the effectiveness of these coatings depends on fruit type and cultivar. In plums cv. 'Angeleno' the coatings did not reduce weight loss, but they had an important effect maintaining flesh firmness and reducing bleeding (Navarro-Tarazaga, Sothornvit et al., 2008).

The main interest in edible films and coatings has been based on their barrier properties, with most of those studies focused on improving film and coating moisture barrier. The study of the effect of coating composition on coating properties has been usually assessed by using stand-alone films as a model. In emulsion films, barrier and mechanical properties are highly dependent on lipid content, lipid particle size and viscoelasticity of the lipid (Debeaufort, Quezada-Gallo, & Voilley, 1998; Pérez-Gago & Krochta, 2001). However, coating performance should be also analyzed when formulations are applied on the fruit, because additional factors, such as skin morphology and physiology of the fruit commodity, are also important controlling mass transfer of coated fruit. Not many works studying simultaneously the effect of formulation composition on stand-alone film properties and postharvest quality of a coated fruit have been done. Therefore, the objective of this work was to study the effect of BW content of HPMC–BW coatings on postharvest quality of coated 'Angeleno' plums and to correlate the results with the barrier and mechanical properties of stand-alone films.

2. Materials and methods

2.1. Materials

HPMC (Methocel E15) was supplied by Dow Chemical Co. (Midland, MI, U.S.A.). Refined BW (grade 1) was obtained by Brillocera, S.A (Valencia, Spain). Stearic acid and glycerol were purchased from Panreac Química, S.A. (Barcelona, Spain).

2.2. Emulsion film and coating formulation

HPMC at 5 g/100 g (w/w) was prepared by initial dispersion of the cellulose in hot water at 90 ± 2 °C and later hydration at 20 °C. Next, BW was added at 0, 20, 40 and 60 g/100 g (dry basis, db). Glycerol was added as plasticizer at a HPMC:glycerol ratio of 2:1 (w/w) and stearic acid was added as emulsifier at a BW:stearic acid ratio of 5:1 (w/w). These ratios were kept constant for all formulations. Water was added to bring the mixtures to a final solid content of 7 g/100 g for stand-alone films and 4 g/100 g for coating formulations. Mixtures with all the ingredients were heated at 90 ± 2 °C to melt the BW and emulsions were formed by homogenization with a high-shear probe mixer UltraTurrax® (Mod. T25 basic; IKA-Werke GmbH & Co. KG, Staufen, Germany) for 1 min at 13,000 rpm followed by 3 min at 22,000 rpm. After cooling the emulsions in an ice bath to less than 20 ± 2 °C, they were continuously stirred for approximately 45 min to ensure complete hydration of the HPMC. Composition of emulsion films is shown in Table 1.

2.3. Film preparation

The film forming solutions were degassed and applied onto a 15 cm internal diameter smooth high-density polyethylene casting plate at 30 g of total solids per plate to minimize thickness variations between formulations. The plates were placed on a leveled surface and dried at room conditions until films could be removed from the casting surface. Three replications were prepared for each formulation.

2.4. Film tensile properties

Film mechanical properties were measured according to the American Society of Testing and Materials Standard Method (ASTM) DS882-97 (ASTM, 1997). Films were conditioned 24 h at 23 ± 2 °C and 50 ± 1% relative humidity (RH), cut into 50 mm × 8 mm rectangular strips, and tested for tension analysis using an Instron Universal Machine (Model 3343; Instron Corp., Canton, MA, USA). Load cell and cross head speed were 0.3 kN and 5 mm/min, respectively. Testing conditions were held constant at 23 ± 2 °C and 50 ± 1% RH throughout the analysis. Young's modulus (YM), maximum tensile stress (TS) and elongation at break (%E) were calculated from the plot of stress versus strain, considering a rectangular cross-sectional area and using the average film thickness, measured at 9 random positions. Fifteen specimens from each replicate of each formulation were analyzed.

2.5. Film water vapor permeability

A modification of the ASTM E96-80 (ASTM, 1980) gravimetric method for measuring water vapor permeability (WVP) was used (McHugh, Avena-Bustillos, & Krochta, 1993). Upon drying, films were chosen on the basis of lack of physical defects such as cracks, bubbles, or pinholes. Two specimens from each replicate of each formulation were cut and mounted on polymethacrylate test cups containing 6 mL of distilled water. The specimens were analyzed with the film surface that had been exposed to air during drying facing either the low RH environment ('facing up') or the high RH environment ('facing down'), allowing detection of any phase separation within the film. The cups were placed in a pre-equilibrated desiccator cabinet fitted with a variable speed-fan. The environment within the cabinet was held constant at 23 ± 2 °C and 40 ± 1% RH using anhydrous potassium carbonate. Weights taken periodically until steady state was achieved and the average film thickness measured at six random positions were used to calculate the resulting WVP. Three replicates of each film were evaluated.

2.6. Film oxygen permeability

Oxygen permeability (OP) of stand-alone films was measured at 23 °C and 50 ± 1% RH using a Systech Oxygen Analyzer (Mod. 8001; Systech Instruments; Oxfordshire, UK) according to the ASTM D3985-95 standard method (ASTM, 1995). Films were placed on a stainless steel mask with an open testing area of 5 cm^2. Masked films were placed into a test cell and exposed to 98 kPa N_2 + 2 kPa H_2 flow on one side and pure O_2 flow on the other side. OP was calculated by dividing the oxygen transmission rate by the difference in oxygen partial pressure between both sides of the film (1 atm) and multiplying by the average film thickness, measured at 4 random positions. Three replicates of each film were evaluated.

Table 1
Emulsion film and coating composition (g/100 g, dry basis).

Formulation[a]	HPMC	BW	G	SA
0 BW	66.7	0	33.3	0
20 BW	50.7	20	25.3	4
40 BW	34.7	40	17.3	8
60 BW	18.7	60	9.3	12

HPMC = hydroxypropyl methylcellulose; BW = beeswax; G = glycerol; SA = stearic acid.
Solid contents were 7 and 4 g/100 g for stand-alone films and coating formulations applied to plums, respectively.
[a] Formulation name represents BW content (g/100 g, dry basis).