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Extension of green bell pepper shelf life using oilseed-derived lipid films from soapstock☆

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ABSTRACT

Edible films have been used for decades on fresh produce to create a semipermeable membrane on the surface to suppress respiration, control moisture loss, and more recently to provide a delivery mechanism for the inclusion of functional components. Scientists at the Southern Regional Research Center (SRRC) have previously demonstrated that a thin biodegradable film can be produced from soapstock, an underused byproduct from the vegetable oil industry. After physical and chemical treatments, a thin film was produced from various soapstocks (cottonseed and safflower). Different hydration ratios were tested since the initial soapstock solutions were rather viscous. To examine the potential use of an oilseed-derived lipid film for the extension of shelf life, different types of the oilseed-derived soapstocks were utilized to produce lipid films with different hydration ratios, and containing 0, 5, and 10% of paraffin wax for application on 'Camelot' bell peppers. Control bell peppers lost almost 25% weight per unit surface area (SA) in 78 h when stored under ambient conditions. Cottonseed film-coated peppers, hydrated at 1:4, lost only about 5% moisture per unit SA after 78 h and minimized weight loss by up to 79% compared to the control. However, since a 1:4 hydration ratio remained rather viscous, 1:8 was preferred and these cottonseed films reduced weight loss per unit SA by up to 48% during storage. Safflower-derived soapstock film resulted in the least effective water retention of the films and ratios tested, with roughly 21–25% reduction in weight loss per SA compared to controls. Safflower-derived soapstock was higher in unsaturated fatty acids, which are less efficient to control moisture migration because they are more polar than saturated lipid materials, as contained in cottonseed-derived materials. Addition of wax to the cottonseed-derived films decreased water loss slightly, similar to previous reports in the literature. An ANOVA supported the conclusion that the oilseed-derived lipid films significantly reduced moisture loss across the produce epidermis. To avoid potential allergenicity concerns in cottonseed soapstock, additional cleanup steps and tests with commonly used edible coating additives would be required before attaining food grade status.

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1. Introduction

Wax coatings have been used since the 1930s to protect and extend shelf life of various fruits and vegetables (Hardenburg, 1967; Kester and Fennema, 1986). Edible films and waxes have been used for decades on fresh produce to create a semipermeable membrane on the surface to suppress respiration, control moisture loss, add gloss, and more recently, to provide a delivery mechanism for additional functional components (Hardenburg, 1967; Kester and Fennema, 1986; Min and Krochta, 2005). Wax coating applications to fruits and vegetables such as apples, cucumbers, citrus, rutabagas and tomatoes were common, and are still commonly practiced (Hitz and Hout, 1939; Jones and Richey, 1939; Paredes-López et al., 1974; Hagenmaier and Baker, 1994; Kays, 1997). Alternatives to wax have been explored with edible films (Kester and Fennema, 1986).

Moderate water barrier properties have been reported in mechanically abused brownies using films containing lipids and hydrocolloids (Greener and Fennema, 1989). An edible film, composed of straight-chained fatty acids made of carbons between 12 (lauric) and 18 (stearic), had a good characteristic to be used as a shelf life extender, even applicable to cereal products (Hagenmaier and Shaw, 1990). Utilization of protein-based lipid films has been reported for extending shelf life of vegetables such as carrots,

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cucumber and bell peppers (Gauoth et al., 1991; Avena-Bustillos et al., 1994).

In processing oil-bearing materials, free fatty acids (FFAs) are extracted with the main components of edible oil, triacylglycerols. These FFAs are fractioned and separated from the edible oil by titration with caustics, producing a byproduct, soapstock. In the past decades, soapstock has been recovered as raw materials for producing low grade industrial soaps. After vegetable oil production, typical oilseed (soy, cottonseed and safflower) byproducts like cake and/or soapstock may be used in animal feeds. Because of low economical return, most soapstock is rarely recovered today, but added back to animal feed without much economic compensation (Matthäus and Zubr, 2000). Most commercial seed oils and resulting cakes are unlike certain seeds possessing high quantities of antioxidants that warrant commercial extraction of key phytonutrients (Peschel et al., 2007). Alternative byproducts such as lipid film constituents (Kuk and Ballew, 1999) or biodiesel production (Haas et al., 2001, 2006; Dumont and Narine, 2007) have been explored, and may therefore be warranted.

In general soapstock is mostly made of FFA with minor components including glycerol, acylglycerides, sterols, phospholipids, phenolics and their degenerated compounds (Dowd, 1996, 1998; Kuk and Ballew, 1999). With application of a few physical/chemical treatments to these oilseed lipids, a bilayer film of oilseed lipids can be produced by hydrating the materials produced from oilseed soapstock (Kuk and Ballew, 1999). Because of the unique chemical compositions, most soapstocks have a property necessary for structural facilitation known as "mesomorphism" (Small, 1986). Lipid films developed from various oilseeds were postulated to have potential postharvest application as a shelf life extender for produce. Freshly harvested bell peppers were therefore tested to evaluate the potential of preliminary oilseed-derived lipid films from soapstock as shelf life extenders. Retention of fresh weight in bell peppers with and without various oilseed-derived film coatings is reported.

2. Materials and methods

2.1. Chemical properties of lipid/wax film

Soapstock samples of cottonseed and safflower seed oils were obtained from industrial plants. The capillary gas chromatography (GC) composition analyses of the soapstocks after trimethylsilyl derivatization (TMS) were previously reported (Kuk and Ballew, 1999), according to GC analyses presented elsewhere (Dowd, 1996). Typical ranges of these analyses are summarized in Table 1. The typical properties (volatiles, neutral oil and fatty acids) were determined by the AOCS (American Oil Chemists Society) official and recommended methods. The elemental analysis (phosphorus and nitrogen) of the soapstock material was done by ASTM D5373/E258. The chemical composition analysis was done by a high temperature capillary GC (Hewlett-Packard 5890, Avondale, PA) with a TMS technique using the AOCS method Cd.11b-91. A thin layer chromatography method with a flame ionization detector was used to determine phospholipids in the film material (St.Anjelo and James, 1993). The Iatroscan TH-10 TLCEFID Analyzer was interfaced with a Hewlett-Packard (Palo Alto, CA) 3390 Integrator. The FID was operated with a hydrogen gas flow of 160 mL/min. Air was supplied via an electrical air pump. The air flow was 2 L/min. Separations were performed on silica-coated Chromarods S-III (Iatron Labs., Inc.). Until initial use, the rods were stored in 60% sulfuric acid. Rods were thoroughly washed with distilled water immediately prior to use and scanned twice to burn off impurities that may have remained. After spotting rods with extracts from experimental samples and scanning with the Iatroscan TLC/FID Analyzer, they were routinely burned again and then stored in a 100% humidity chamber until the next analysis (St.Anjelo and James, 1993). As a supplementary analysis, the amount of FFA in crude oil samples was determined by AOCS method G 5a-40 (Firestone, 1993).

Table 1
Chemical and elemental composition of cottonseed and safflower soapstocks.

Chemical classes (% dry basis)	Soapstocks	
	Cottonseed	Safflower
Total fatty acids	50–55	50–63
Neutral oils	15–22	11–15
Saturated fatty acids[a]	21	12
Unsaturated fatty acids	41	50
Phosphorus	0.5–0.6	0.9–1.1
Nitrogen	0.5–0.7	0.7–1.0
Sucrose	Trace	1.9
Oligosaccharides[b]	0.8	1.2
Sterols[c]	2.9	2
Monoglycerides	1.8	1.3
Diglycerides	2.6	1.5
Triglycerides	11.5	10.5

[a] Saturated fatty acids included myristic, palmitic, stearic, arachidic acids. Unsaturated fatty acids included palmitoleic, oleic, and linoleic acids. Official AOCS methods were used per Section 2 and Firestone (1993).
[b] Oligosaccharides included raffinose and stachyose.
[c] Sterol mixture included β-sitosterol, campesterol and stigmasterol.

2.2. Soapstock treatments for lipid films

Soapstocks were used to prepare the oilseed-derived lipid films via the following physical treatments: 1. Freeze drying (overnight at −40 °C; 40 mm Hg), 2. particle size reduction (passable through 35 US sieve), 3. pH reduction (neutralization) and hydration, and 4. casting and drying. The film preparation steps were essentially the same as previously reported (Kuk and Ballew, 1999) with exception of the neutralization step. In general the industrial soapstock samples had pH values between 9 and 11. The soapstock samples were neutralized to a pH between 6.5 and 7.5 using diluted 5% sulfuric acid (J.T. Baker, Phillipsburg, NJ). These soapstock materials were then hydrated (soapstock:de-ionized water ratios of 1:4 and 1:8), and some were amended with 0, 5 and 10 wt.% paraffin wax (Sigma–Aldrich, Milwaukee, IL) with a melting point of 65 °C.

2.3. Produce

'Camelot' green bell peppers (161.5 g average) were collected in the middle of yearly harvest from a Louisiana farm, washed with deionized water, air dried, and inspected on the same day of collection to assure that samples were free from skin damage and fungal infestation. The dimensional specifics (length and radius), weight and volume were recorded. The surface area of the bell pepper samples was computed using a cylinder with hemisphere as the model.

The bell pepper samples were divided into several groups which were used to apply tested films including control, cottonseed at 1:4 and 1:8 hydration ratio, cottonseed film at 1:8 with 5% paraffin wax, safflower at 1:8 hydration, and safflower film hydrated to 1:8 receiving 10% paraffin wax. A single coat of the soapstock-derived film was uniformly applied to the samples using a fine paint brush initially, then sprayed on with a pressurized sprayer. The same coat was applied to a thin glass plate to examine and assure the uniformity of the film. Film thickness was measured using a micrometer. Microscopic examinations were conducted when necessary.

To purposely accelerate weight loss and rapidly assess film coating effects, control and the coated samples were stored in open air for up to 10 days in a laboratory at 21–24 °C with 60–75% relative humidity. Elevated storage temperatures were chosen to hasten moisture loss, and also mimic short-term local farmer's market conditions. An analysis was also performed after allowing