LWT - Food Science and Technology 43 (2010) 903–909

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Potato peel-based biopolymer film development using high-pressure homogenization, irradiation, and ultrasound

Ho Jin Kang[a], Sea C. Min[b,*]

[a] *School of Food Science, University of Idaho, Agricultural Science Building, Moscow, ID 83844, USA*
[b] *Department of Food Science and Technology, Seoul Women's University, 126 Kongneung 2-dong, Nowon-gu, Seoul 139-774, Republic of Korea*

ARTICLE INFO

Article history:
Received 1 April 2009
Received in revised form
18 November 2009
Accepted 25 January 2010

Keywords:
Biopolymer film
Potato peel
High-pressure homogenization
Irradiation
Ultrasound

ABSTRACT

Edible films were developed from potato peel. High-pressure, gamma-ray, and ultrasound were applied to potato peel solutions to break down biopolymer particles in the solution small enough to allow for biopolymer film formation. Film properties, including moisture barrier and tensile properties, color, and microstructures, were investigated from the films formed with different concentrations of plasticizer (glycerol) and emulsifier (soy lecithin). High-pressure homogenization (HPH) produced the best films among the treatments at the conditions used in this research. Water vapor permeability (WVP) of films decreased by 32% with decrease in the concentrations of glycerol and soy lecithin by 40 and 75%, respectively. As the concentration of glycerol or soy lecithin increased, tensile strength of the films decreased up to 71%, but the elongation at break increased up to 161%, demonstrating lubricant effects of glycerol and soy lecithin. The lightness and yellowness of the films increased and the redness decreased with increase in the concentration of glycerol or soy lecithin. The concentrations of glycerol and soy lecithin were identified as important variables in producing biopolymer films from potato peel.

1. Introduction

Biopolymer materials have great applications commonly generated by replacing the roles of synthetic plastics, considering their renewable and biodegradable characteristics (Cutter, 2006). However, the commercial success of biopolymer food packaging is somewhat limited at present partially because of high cost of biopolymer materials and insufficient oxygen/moisture barrier, tensile and sensory properties of the materials (Sablani et al., 2009).

An estimated 4.5 million tons of potato-processing waste are produced each year in the U.S. Especially, potato processing is the second largest industry in Idaho, USA and produces about 160,000 tons of processing by-products every year (Sauter, Hinman, & Parkinson, 1985). Potato peel (PP) waste is produced as a by-product in the processing of potatoes for food products such as potato chips and French fry fillets (Rogols, Sirovatka, & Widmaier, 2003). The PP is costly to dispose of as waste, especially due to transportation. The waste provides only marginal economic value when used as animal feed. Thus, there remains a desire for new applications for PP (Rogols et al., 2003). Development of edible biopolymer film-coating food packages from PP, which are plant-based and biodegradable, may result in high-value commercial use of the by-product.

High-pressure homogenization (HPH) breaks down and deagglomerates biopolymer particles by shear, pressure involved simultaneously (Bouaouina, Desrumaux, Loisel, & Legrand, 2006; Hayes & Kelly, 2003; Sanchex, Pouliot, Gauthier, & Paquin, 1997). Irradiation can reduce sizes of biopolymers. Biopolymers can be broken down by free radicals formed from irradiation which can cause interruption in molecular bonding structuring the polymers (Woods & Pikaev, 1994). Irradiation has been applied to pectin, alginate, milk protein, gelatin, and chitosan to produce low molecular weight substances form the materials (Cho, Kim, & Rhim, 2003; Kang, Jo, Lee, Kwon, & Byun, 2005) and to form film-forming materials from caseinate and pectin (Brault, D'Aprano, & Lacroix, 1997; Kang et al., 2005). An ultrasound treatment (UST) involves formation, growth, and implosion of tiny gas bubbles or cavities in biopolymer solutions. Implosion of cavities results in micro-streaming and localized high shear that can be used for the separation of biopolymers (Zhang, Feng, Niu, & Eckhoff, 2005).

Reducing sizes of biopolymer aggregates/particles to improve uniformity in their distribution in the film matrix might be key elements in manufacturing the biopolymer films from PP. In this research, HPH, irradiation, and UST have been employed to reduce

---

* Corresponding author. Tel.: +82 2 970 5635; fax: +82 2 970 5977.
E-mail address: smin@swu.ac.kr (S.C. Min).

0023-6438/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.lwt.2010.01.025

sizes of biopolymers in the solution, which may result in formation of films with uniform matrices. Thus, the objectives of this research were to (1) develop biopolymer films from PP of potato process by-products using HPH, irradiation, and UST and (2) investigate effects of the concentrations of glycerol (plasticizer) and soy lecithin (emulsifier) on the water vapor permeability, water solubility, tensile properties, color, and morphology of PP-based films.

2. Materials and methods

2.1. Materials

Potatoes (Russet Norkotah) were purchased from Basin Gold Co. (Pasco, WA, USA). The PP contained polysaccharides, proteins, and lipids approximately at 70, 16, and 1 g/100 g PP, respectively (dry basis). The composition analysis was conducted by Korea Food Research Institute (Sungnam, Korea). Glycerol, used as a plasticizer to improve film flexibility, was purchased from Sigma-Aldrich Co. Ltd. (St. Louis, MO, USA). Soy lecithin (hydrophilic–lipophilic balance (HLB) value: 8) was purchased from Alfa Aesar Co. (Ward Hill, MA, USA). Soy lecithin was used as an emulsifier to provide uniform distribution of biopolymers and their aggregates in film-forming solutions and films.

2.2. Film preparation

Potatoes were hand-washed with tap water and peeled. The degree of flesh in the PP used in the study was little and was determined to make it similar to what a potato process waste practically had, observing one from Basic American Foods (Pocatello, ID, USA). The peel was air dried at 15 ± 4% relative humidity at 23 ± 2 °C for 3 days. About 1 kg was dried in one batch. The moisture content of the dried peel was 10 ± 4 g/100 g. The dried peel was ground by a multi mill and then sieved to prepare PP powder (<500 μm). Six or 10 g PP powder was mixed with 194 or 190 g water to prepare a PP solution at 3 or 5 g/100 g solution. The mixture was pre-homogenized with a high shear probe mixer (Ultra-Turrax, Model T25, IKA-Works, Inc., Wilmington, NC, USA) at 20,000 rpm for 5 min. The homogenate was treated by high-pressure homogenization (138 MPa), gamma irradiation (10–20 kGy), or ultrasound (400 W) to destruct biopolymers in the solution (more detail descriptions on each treatment follow below). The solution was maintained at 90 °C for 30 min in a water bath and then cooled on ice-water. Once cooled at 20 °C, glycerol was mixed into the solution at 30 or 50% (w/w) of PP powder (1.8 or 3 g glycerol with 6 g PP or 3 or 5 g glycerol with 10 g PP). After mixing, soy lecithin was incorporated at 0, 0.5, or 2% (w/w) of PP powder (0, 0.03 or 0.12 g soy lecithin with 6 g PP or 0, 0.05, or 0.2 g soy lecithin with 10 g PP). The ratios of PP:glycerol:soy lecithin are exhibited in Table 1. The mixture was homogenized using the high shear probe mixer at 20,000 rpm for 5 min and then degassed under vacuum. Films were cast by pipetting the degassed mixture onto Teflon plates (15.5 cm i.d.), resting on a leveled granite surface. The amount of the film-forming mixture pipetted was selected to produce a 0.1 mm-thick film. For example, the amount pipetted onto the plate to produce a film that had a PP:glycerol:soy lecithin ratio of 1:0.5:0.005 was 67 g. The film-forming mixtures were dried for 3 days at 23 ± 2 °C/35 ± 5% relative humidity (RH). Dried films were peeled intact from the casting surface and stored in a chamber (Tenney-10 model TTUFR-40240, Tenney Engineering, Inc., Union, NJ, USA) controlled at 23 ± 2 °C/52 ± 2% RH. A saturated salt solution of magnesium nitrate (Fisher Scientific, Fair Lawn, NJ, USA) was used to equilibrate films to an environment of 52 ± 2% RH.

2.3. Depolymerization processes

2.3.1. HPH

A 1 L PP solution was introduced into a high-pressure homogenizer (M-110S Microfluidizer® Materials Processor, Germany). The homogenizer with a H10Z (100 μm) interaction chamber was run at 138 MPa and 25–30 °C with 2, 5, and 10 passes. The temperature increase in the PP–water mixture during high-pressure homogenization was minimized by immersing the mixture-passing tubing in ice-water.

2.3.2. Gamma irradiation

Irradiation on a 500 mL PP solution was done at the United States Department of Agriculture (USDA) irradiation facility (Food Safety Intervention Technologies Research, ERRC, Wyndmoor, PA, USA). A Lockheed Georgia Company (Marietta, GA, USA) self-contained ^{137}Cs radiation source was used for all exposures. The dose rate (0.095 kGy/min) was verified according to methodology outlined by ASTM E 2116-00 using dosimeters obtained from the National Institute of Standards and Technology. The temperature during irradiation was maintained at 4.0 ± 1.0 °C by the gas phase of a liquid nitrogen source that was introduced directly into the top of the sample chamber. The absorbed dose was verified by use of 5 mm alanine pellet dosimeters that were attached to the sides of the sample bags, which were then measured using a Brucker EMS 104 EPR Analyzer (Billerica, MA, USA). Radiation doses of 10 and 20 kGy were used in this study.

Table 1
Effects of film composition on water vapor permeability (WVP) and film water solubility (FWS) of the potato peel films prepared using high-pressure homogenization.

Film name	Potato peel (g/100 g film-forming solution)	Ratio			WVP (g mm/kPa h m^2)[a,b]	FWS (%)	Tensile properties		
		Potato peel	Glycerol	Soy lecithin			TS (MPa)	EM (MPa)	%E (%)
3-0.3-0	3	1	0.3	0	[a, b]2.99 ± 0.54^{B}	41.22 ± 7.23^{ABC}	9.48 ± 1.24^{A}	366.37 ± 9.24^{AB}	5.33 ± 2.05^{F}
3-0.3-0.005		1	0.3	0.005	3.81 ± 0.72^{AB}	37.30 ± 4.03^{BCD}	5.94 ± 0.66^{BC}	188.22 ± 2.67^{CD}	8.70 ± 2.84^{DEF}
3-0.3-0.02		1	0.3	0.02	3.99 ± 0.61^{AB}	37.44 ± 0.91^{BCD}	6.55 ± 3.30^{B}	179.00 ± 1.47^{CD}	11.20 ± 3.64^{CD}
3-0.5-0		1	0.5	0	4.04 ± 0.42^{AB}	43.38 ± 1.51^{A}	3.99 ± 0.80^{CDE}	85.44 ± 3.29^{D}	14.35 ± 3.57^{BC}
3-0.5-0.005		1	0.5	0.005	3.88 ± 0.37^{AB}	42.29 ± 1.16^{AB}	4.17 ± 1.97^{CDE}	75.91 ± 5.97^{D}	17.20 ± 1.38^{AB}
3-0.5-0.02		1	0.5	0.02	3.94 ± 0.44^{AB}	41.38 ± 2.19^{ABC}	3.67 ± 1.31^{DE}	66.15 ± 5.16^{D}	15.94 ± 1.04^{B}
5-0.3-0	5	1	0.3	0	3.17 ± 0.93^{AB}	33.81 ± 0.64^{DE}	9.92 ± 2.65^{A}	471.50 ± 3.41^{A}	7.54 ± 4.31^{EF}
5-0.3-0.005		1	0.3	0.005	3.63 ± 0.60^{AB}	31.29 ± 1.34^{E}	8.87 ± 2.66^{A}	378.07 ± 2.03^{AB}	6.76 ± 3.20^{EF}
5-0.3-0.02		1	0.3	0.02	4.12 ± 1.10^{AB}	40.19 ± 2.10^{ABC}	7.36 ± 1.18^{B}	308.28 ± 1.11^{BC}	9.28 ± 2.35^{DE}
5-0.5-0		1	0.5	0	4.05 ± 0.97^{AB}	36.50 ± 3.51^{CDE}	5.36 ± 1.23^{BCD}	107.44 ± 6.00^{D}	19.69 ± 3.13^{A}
5-0.5-0.005		1	0.5	0.005	4.60 ± 2.43^{AB}	37.07 ± 1.07^{BCD}	2.54 ± 0.43^{E}	33.10 ± 1.66^{D}	16.90 ± 3.11^{AB}
5-0.5-0.02		1	0.5	0.02	5.30 ± 2.13^{A}	41.67 ± 2.58^{ABC}	2.53 ± 0.32^{E}	39.42 ± 1.56^{D}	19.85 ± 2.30^{A}

[a] Values are mean ± standard deviation ($n = 6$, 6, and 8 for WVP, FWS, and tensile properties, respectively).

[b] Different letters within the same column differ significantly ($P < 0.05$).