Industrial Crops and Products 43 (2013) 159–164

Contents lists available at SciVerse ScienceDirect

Industrial Crops and Products

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

Thermoplastic films from peanut proteins extracted from peanut meal

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ARTICLE INFO

Article history:
Received 3 April 2012
Received in revised form 26 June 2012
Accepted 29 June 2012

Keywords:
Peanut
Proteins
Compression molding
Thermoplastics

ABSTRACT

Peanut proteins were extracted from peanut meal and compression molded into films with tensile properties better than those of solution cast and crosslinked peanut protein films. Peanut meal as coproduct of oil production is available in large quantiites and relatively low price. Currently, there are no major industrial use of peanut meal. Previously, films have been made from peanut proteins by the solution casting method and no reports are available on using the proteins in the meal to produce films. Compared to solution casting, compression molding is more convenient, provides better properties and is more environmentally friendly than solution casting. In this research, peanut proteins were extracted from peanut meal which contains about 45% proteins and compression molded to form films. The effect of protein extraction and compression molding conditions on the properties of the peanut protein films were studied. Peanut proteins have poor thermoplasticity and plasticizers are necessary to develop thermoplastic films. Protein extraction and compression conditions affected the tensile properties, especially elongation. Under conditions optimized in this research, the films developed had strength of 8.0 MPa, high elongation of 63% and modulus of 147 MPa under standard atmospheric conditions, higher than films developed from peanut and most other plant proteins. Peanut proteins show potential to be processable into thermoplastic products.

1. Introduction

Peanut meal is a byproduct generated during extraction of oil from peanuts. Currently, there are limited industrial applications of peanut meal and most of the available meals are used as feed ingredient for animals. Peanut meal contains about 45% proteins and could be a good source to develop protein films for various applications. Plant proteins such as soyproteins, wheat gluten and zein are commonly used for non-food industrial applications. Large availability, relatively low cost and unique properties are some of the reasons for the interests in using these proteins for non-food applications (Zhang and Mittal, 2010; Reddy and Yang, 2011; Yoshinoa et al., 2002). Plant proteins have been predominantly used to develop films but reports are also available on developing fibers, hydrogels, nano and micro particles from plant proteins for various applications (Chen et al., 2012; Reddy and Yang, 2011; Maltais et al., 2010). Films are primarily developed from plant proteins using the solvent casting method where the proteins are dissolved using appropriate solvents and the solvent is evaporated to form the films. Although films developed by compression molding are generally recognized to have superior properties than solvent cast films, plant proteins have poor thermo plasticity and therefore not ideally suited to form thermoplastic products (Mangavel et al., 2004; Guerrero et al., 2010). Chemical and/or physical modifications of proteins or adding plasticizers are some of the approaches that have been sucessfully used to improve the thermoplasticity and develop compression molded films from plant proteins. For instance, thermoplastic films have been developed from wheat and soyproteins using glycerol, sorbitol or other chemicals as plasticizers (Sun et al., 2007, 2008).

Other than soy, wheat and zein, relatively lesser known proteins such as sunflower proteins, pea and mung bean proteins have also been used to develop films (Orliac et al., 2003). Proteins from sunflower seeds have been used to develop films using compression and casting methods (Orliac et al., 2003). Pea proteins have been used to develop films by dissolving the proteins in alkaline solutions (Viroben et al., 2000; Choi and Han, 2001). Films were made from pea protein concentration with tensile strength ranging from 0.3 to 4.1 MPa and elongation ranging from 7.6 to 95% by varying the concentration of glycerol (Choi and Han, 2001). In another research, pea

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http://dx.doi.org/10.1016/j.indcrop.2012.06.051

protein isolate was made into films using an alkaline media with several polyols as plasticizers. Films with tensile strength from 0.5 to 3.0 MPa and elongation of 75 to 152% were obtained by changing the amount and type of plasticizers (Viroben et al., 2000). Red bean protein isolate was succinylated to three different degrees and used to develop films by solution casting (Tang et al., 2011). The tensile strength of the films was relatively low (1.8 MPa) but the films had high elongation (75–220%) that varied with changing glycerol concentration and the extent of succinylation (Tang et al., 2011).

Peanuts are one of the largest cereal crops grown in the world with 29 million metric tons produced every year (Zhang et al., 2011). A majority of the peanuts are crushed to produce oil and this process generates peanut meal as the coproduct (Zhang et al., 2011). Peanut meal roughly contains about 45% protein, 8–10% crude fiber, 2.5% fat and 5% ash and most of the meal is currently used as animal feed, a relatively low value application (Batal et al., 2005). In our previous researches, we have demonstrated that coproducts and byproducts generated during processing of cereal grains for food and fuel can be used for various industrial applications. Coproducts of ethanol production, distillers dried grains (DDG) were chemically modified and made into thermoplastic films (Hu et al., 2011a,b). Similarly, poultry feathers have also been made thermoplastic by etherification, esterification and grafting (Jin et al., 2011; Reddy et al., 2011). Such attempts add value to the byproduct/coproducts and benefit the farmers and processors economically and also provide an inexpensive, biodegradable and renewable source to develop various products.

There are no reports on utilizing peanut meal for industrial applications. However, peanut proteins extracted from the peanut seed or peanut flour have been used to develop films. The physical and mechanical properties of peanut protein films formed by casting were studied (Liu et al., 2004). Peanut protein isolate was extracted from peanut flour and the proteins were treated in alkaline solution at 90 °C and the solution containing glycerin as plasticizer was cast and later dried to form the films (Liu et al., 2004). The effect of heating, UV and ultrasound on the properties of the films was studied. It was found that tensile strength of the films varied from 0.28 to 1.3 MPa and elongation ranged from 40 to 160% depending on the type of modification used (Liu et al., 2004). The effect of drying temperature (70–90 °C) and pH (6.0–9.0) of film forming solution on the properties of the peanut protein films was investigated (Jangchud and Chinnan, 1999a). It was concluded that pH and drying temperature affected the physico-chemical properties of the films. Tensile strength of the films did not change but elongation increased with increasing pH (Jangchud and Chinnan, 1999a). The effect of the type and amount of plasticizer on the properties of peanut protein films formed by solution casting have also been investigated (Jangchud and Chinnan, 1999b). Surprisingly, relatively high tensile strength ranging from 4.1 to 5.14 MPa were obtained even after using high amounts of glycerol (0.67–1.67 g/g of protein) (Jangchud and Chinnan, 1999a). Recently, we have developed solution cast films from peanut proteins and crosslinked the films using citric acid (Yang and Reddy, 2012). It was found that crosslinking was necessary to improve the wet strength of the films (Yang and Reddy, 2012).

Peanut protein films reported so far have been developed using the casting method and there are no reports on developing compression molded peanut protein films. Compression molding is more convenient, environmentally friendly and provides better film properties than solution casting. In addition, utilizing the proteins in peanut meal could be more economical than using the proteins from peanut concentrate or peanut flour. Utilizing peanut meal for thermoplastics would add substantial value and increase the value of peanut crops. In this research, peanut proteins were extracted from peanut meal and the proteins were compression molded into films. Properties of the peanut protein films were studied at different extraction and compression molding conditions.

2. Experimental

2.1. Protein extraction

Peanut meal was supplied by Golden Peanut Company (Alpharetta, GA). Proteins were extracted from the meal using alkaline solutions. Peanut meal was treated with 0.25–1% (w/w) of reagent grade sodium hydroxide (Aqua Solutions, Deer Park, TX) solution at 30 °C for 1 h with a meal to solution ratio of 1:10. After treatment, the solution was centrifuged and the proteins in the supernatant were precipitated by adding acetic acid. The precipitated proteins were centrifuged, washed in water and dried. Yield of the proteins from the meal ranged between 17 and 24% depending on the extraction conditions used.

2.2. SDS–PAGE

An SDS–PAGE of the peanut proteins obtained using various concentrations of alkali was performed to understand the effect of alkali concentration on the molecular weights. Protein samples (1 mg) were dissolved in 100 μl of 2× LDS buffer containing β-mercaptoethanol as the reducing agent. The samples were heated at 70 °C for 10 min to ensure complete dissolution of the proteins. Dissolved samples (10 μl) were loaded into the pre-cast gel (NuPAGE 4–12% Bis–Tris Gel) along with the molecular weight standards and electrophoresed in NuPage 1× MES running buffer. The electrophoresis was completed in about 40 min. The gel was stained with Coomassie blue for the molecular weight bands to be visualized. Images of the gel were collected for analysis.

2.3. Compression molding films

Peanut proteins were mixed with the desired ratio of glycerol and the mixture was compression molded in a hot press (Carver, Inc., Wabash, IN). To ensure homogenous mixing of the plasticizer, a known quanitity of glycerol was mixed with water and the solution was added and thoroughly mixed with the peanut proteins. Water was removed from the proteins by drying in a oven at 50 °C until a constant weight was obtained. The proteins were evenly spread on aluminum sheets and placed in a Carver press (Carver, Inc., Wabash, IN) and compression molded at 40,000 psi. The compression time was varied from 2 to 8 min and temperature was varied from 150 to 175 °C. Compression temperatures below 150 °C did not melt the proteins and temperature above 175 °C made the films too thin and discontinous. After compression, the press was cooled by running cold water and the samples were collected for further analysis.

2.4. Tensile tests

Films were conditioned at 21 °C and 65% relative humidity for at least 24 h before tensile testing. Tensile properties were determined in terms of breaking strength, breaking elongation and modulus on a MTS (Qtest 10) tensile tester accorrding to ASTM standard D882 using a gauge length of 2 inches and crosshead speed of 5 mm/min. At least 8 samples selected from two to three seperately compression molded films were tested for each condition. Data obtained were analyzed using Student's *t*-test with a significance level of $p = 0.05$ using SAS.

2.5. Morphology

A variable pressure scanning electron microscope (VP-SEM) was used to observe the cross-sectional morphology of the films.