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Efficacy of pectin and insoluble fiber extracted from soy hulls as a functional non-meat ingredient

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ABSTRACT

The objectives of this study were to evaluate various chemical extraction methods of soy hulls for pectin and insoluble fiber and to determine the impacts of these fibers on physico-chemical and textural properties of meat emulsion systems. Crude soy hulls (CSH), lime treated soy hulls (LSH), acid and lime treated soy hulls (ALSH), and soy hull pectin (SHP) were extracted through various successive acid and lime treatments and incorporated in pork emulsion systems. Chemical extraction increased the redness, yellowness, acid detergent fiber (ADF) and ash content of soy hulls. Similar hydration properties were observed for CSH, LSH, and ALSH. In meat emulsions, LSH and ALSH influenced positive effects on reduction in cooking loss and increase in hardness without any adverse effect on springiness and cohesiveness ($P < 0.05$), and minimized color alteration. SHP resulted in a significant decrease in cooking loss and an increase in hardness. These positive effects of LSH and ALSH might be associated with the increase in ADF content and dispersibility based on observed microstructure images. Our results suggested that both pectin and insoluble fiber from soy hulls through acid and alkali hydrolysis could be used as novel functional non-meat ingredients.

1. Introduction

Soy hulls, which are the seed coat of soybean (approximately 8%), are one of the major by-products released during the initial cracking process for soybean oil production. Soy hull has a great potential to be used as a functional food ingredient due to its high content of dietary fiber including cellulose and pectin (59.9–72.2% insoluble fiber and 3.9–12.7% soluble fiber) (Cole et al., 1999; Monsoor, 2005). However, large amounts of soy hulls are currently either underutilized or discarded as an agricultural waste, causing considerable waste disposal costs and possible environmental issues (Alemdar & Sain, 2008; Crandall & McCain, 2000). Conversely, several soy by-products generated from soybean oil production, such as soy protein isolates, concentrates, grits, and textured, have been extensively used in processed foods as an emulsifier, extender, and binder (Jiang & Xiong, 2013; Lusas & Riaz, 1995). However, soy hulls have received very little industrial attention for practical use as a food ingredient.

In processed meat products, dietary fiber derived from several plant sources such as cereal, vegetable, and fruit has constantly attracted considerable attention due to its functional properties (e.g. water retention ability, oil absorption capacity, and gel forming ability, etc.) as well as various physiological benefits to human health (Mehta, Ahlawat, Sharma, & Dabur, 2013). In this respect, the effect of soy hulls on water-holding capacity (WHC) and texture of meat products was examined in few studies. However, Goldmon and Brown (1992) and Kumar, Biswas, Chatli, and Sahoo (2011) reported that 4% addition of soy hull flours had no impact on the cooking yield and texture of pork patties and chicken nuggets, respectively. In a subsequent study, Kumar, Biswas, Sahoo, Chatli, and Sivakumar (2013) indicated that 3–5% addition of soy hull flours slightly improved WHC and emulsion stability of chicken nuggets. Such marginal and/or no noticeable effects might be associated with the direct addition of soy hull flour without any pre-isolation and purification process.

Pectin, which is a functional food ingredient as a hydrocolloid gum, has been commercially obtained from apple pomace and citrus peel (Kliemann et al., 2009). Recently, soy hulls has been considered as a novel pectin source. In previous studies, hot acid method was used to extract pectin from soy hulls, which was based

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on the solubility of pectin in acidic condition (Kalapathy & Proctor, 2001; Monsoor, 2005). Acid and alkali hydrolysis has been applied to gain nanofiber from lignocellulosic wastes and increase insoluble fiber content (Alemdar & Sain, 2008; Kuan, Yuen, Bhat, & Liong, 2011). In addition, few studies have reported the improvement of the functionality of insoluble fiber contained in soy hulls by acid and alkali treatment (Alemdar & Sain, 2008; Yang, Xiao, & Wang, 2014). Taken together, it can be postulated that the successive chemical treatment, which implies acidic pectin extraction and continuous alkali treatments for residual insoluble fraction, will result in an effective recovery of both pectin and insoluble fiber from soy hulls, and improve the functionality of insoluble fiber through acid and alkali hydrolysis. Further, it could be also hypothesized that the inclusion of isolated soy hull pectin and insoluble soy hull fiber to the meat emulsion will result in positive impacts on improving functional properties of the emulsified meat product.

Therefore, the objectives of this study were to 1) evaluate the efficacy of successive acid and alkali treatments for pectin and insoluble fibrous fraction separation and 2) determine the impacts of these fibers on color, cooking loss, texture, and microstructure characteristics in meat emulsion systems.

2. Materials and methods

2.1. Preparation of soy hulls

Whole soybeans were donated from Clarkson Grain Company INC. (Cerro Gerdo, IL, USA) and delivered to Food Protein R&D Center (College Station, TX, USA). The whole soy grain was stored in a refrigerator until placed in a sealed container. The soybeans were cleaned, and then, selected with SWECO 10-mesh vibrating screen (Florence, KY, USA). Soybeans were cracked into 2–5 pieces by using a corrugated roller mill (model 10 × 12 SGL, Ferrell-Ross, Oklahoma City, OK, USA), and the hulls were separated from the meats (cotyledons) by aspirating with a multi-aspirator (Kice, Wichita, KS, USA). Approximately, 7.04% soy hulls were generated from whole soybean grain. The soybean hulls were selected with SWECO vibrating screen (14-mesh). The selected soybean hulls were ground by hammer mill (Fitzpatrick, The Standard FitzMill® Comminutor, Elmhurst, IL, USA) and all flours were passed through a 20-mesh sieve (Seedburo Equipment Company, Chicago, IL, USA) for further preparation. Moisture content of the prepared crude soy hulls (CSH) was determined using oven air-drying method (AOAC, 2000), which was 9.48%.

2.2. Chemicals

Calcium hydroxide (lime, >96%), 2-propanol (>99.5%), hydrogen chloride (HCl), and sodium hydroxide (NaOH) were purchased from Fisher Scientific.

2.3. Preparation of chemically treated soy hulls (CTSH) and soy hull pectin (SHP)

CTSH and SHP were prepared with modification of the methods described by Alemdar and Sain (2008) and Monsoor (2005). Each dried treatment was ground with a food blender after dehydration (Blender 700S, Waring Commercial, Torrington, CT, USA) and passed through a nylon sieve. The collected samples were individually vacuum-packaged in polyethylene bags and stored in a −20 °C freezer until analysis and/or use.

2.3.1. Lime treated soy hulls (LSH)

CSH was mixed with water (1:10 ratio) and stirred with lime (0.2 g lime/g dry hulls) at 90 °C for 1 h. The lime treated slurries were centrifuged (Sorvall RC-5C Plus Centrifuge and SLA-1500 rotor, Kendro Laboratory Products, Asheville, NC, USA) to separate the supernatant from the wet cake at 4500 rpm for 20 min. After centrifugation, the residue was washed with deionized water to adjust pH (6.2–6.8), and then dehydrated in a 55 °C air dryer for 48 h.

2.3.2. Acid and lime treated soy hulls (ALSH) and soy hull pectin (SHP)

CSH were mixed with 0.1 N HCl solutions (1:10 ratio) and stirred at 90 °C for 1 h. The acid treated slurries were allowed to cool to room temperature, and centrifuged at 4500 rpm for 20 min. The supernatants were collected, and dispersed in equal volume of 2-propanol for 30 min. SHP was precipitated by adjusting the pH 3.5 with 0.1 N HCl and allowed to stand for 6 h. The precipitate was collected, centrifuged (4500 rpm for 20 min), dispersed in 2-propanol, stirred for 1 h, and centrifuged. The precipitate was washed with 70% 2-propanol, centrifuged, and dehydrated in a 55 °C air dryer for 72 h. At the above first centrifugation step, the wet cakes were washed with deionized water after collecting supernatant. After centrifugation (4500 rpm for 20 min), the wet cake was treated equally by following the procedure for LSH.

2.4. Preparation of soy hulls and soy hull pectin suspensions

Final pH values of LSH, ALSH, and SHP were 10.16 ± 0.04, 9.40 ± 0.03, and 3.10 ± 0.01, respectively, which were considerably different as compared to that of CSH (6.46 ± 0.02) despite several washing step. Thus, the pH values of LSH, ALSH, and SHP were adjusted to eliminate any pH confounding effect on meat emulsion. Three gram of soy hulls and pectin were mixed with 18 ml of deionized distilled water, which was proper ratios (1:6) to sufficiently stir the particles in water phase, and gently stirred for several times for 1 h. The pH values were adjusted with 6 N HCl (for LSH and ALSH) or 2 N NaOH (for SHP) to 6.45–6.55 by measuring an electronic pH meter (Sartorius Basic Meter PB-11, Sartorius AG, Germany). CSH suspension was prepared without the pH adjustment.

2.5. Meat emulsion manufacturing

Fresh pork bottom round muscle (*M. biceps femoris*) and pork back fat were obtained at Purdue University meat laboratory at 48 h postmortem, vacuum packaged, and stored at −18 °C for maximum 1 month. Frozen pork round muscle and fat were thawed in a 2 °C cooling room for 24 h. After thawing, all subcutaneous and intramuscular fat and visible connective tissue were removed. Lean materials were initially ground through a 3/8 inch plate and reground 1/4 inch plate using a meat grinder (M-12-FS, Torrey, Monterrey, NL, Mexico). The pork back fat was also ground through 3/8 inch and 1/4 inch plates. Control was formulated with 60% pork ham, 20% back fat, 2% ice, and 18% cold water, and four treatments 57% pork ham, 20% back fat, 2% ice, and 21% each soy hull suspension were prepared. Based on total weight, 3% pork ham portion was replaced with 3% each soy hull, respectively. Other non-meat ingredients, such as 1.5% sodium chloride and 0.3% sodium tripolyphosphate, 0.012% sodium nitrite, and 0.05% L-ascorbic acid, were equally added. All treatments were individually emulsified using a food blender in a cooling room, and the final temperature of meat emulsions was maintained below 10 °C during manufacturing. Total three independent batches per treatment were prepared.

2.6. Analysis of CTSH and SHP

The pH value of soy hulls and pectin (3 g) mixed with 27 ml