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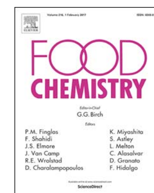

Enhanced functionality of pea-rice protein isolate blends through direct steam injection processing

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ABSTRACT

Direct steam injection (DSI) processing with pH adjustment was investigated to enhance the functionality of pea-rice protein isolate blends (PR). Protein slurries at concentration of 5% (w/w) of commercial pea and rice protein isolates in the ratio of 2:1 (w/w) across a range of steam temperatures (66–107 °C) and pH values (2 −1 1) were studied. After DSI treatment, the PR were freeze-dried to obtain the final dry protein powder. Based on protein solubility profiles, the optimal DSI processing conditions were 107 °C and pH 11. Available lysine was not reduced ($P > 0.05$) in the blend. Solubility (from 3 to 41%, at pH 7), emulsifying activity index (from 5.9 to 52.5 m^2/g), foam stability (from 68.2 to 82.8%), and oil holding capacity (from 1.8 to 4.9 g/g) values increased ($P < 0.05$) compared to the untreated PR. DSI can modify the functionality of PR without affecting the essential amino acid composition.

1. Introduction

Pea and rice are good sources of protein due to their nutritional value and availability (Boye, Zare, & Pletch, 2010). Market for pea protein is increasing rapidly and is expected to reach 34.8 million USD by 2020 due to growing consumer interest in plant protein ingredients, and relatively low cost of production of peas (Grand View Research., 2015). The production value of rice protein market was estimated at 34.3 million USD in 2015 and is also predicted to grow rapidly (Grand View Research, 2016). Protein isolates can be used to increase the nutritional value and functional properties of foods (Boye, Aksay, et al., 2010). Pea protein is considered a good source of essential amino acids with a high amount of lysine but low in methionine (Boye, Zare, et al., 2010). Rice protein, is rich in methionine and low in lysine, making it a complementary protein for pea. Combined in the proper proportions, pea and rice proteins ensure sufficient quantities of all essential amino acids needed in the human diet as recommended by United Nations (2011).

Protein extracted from dry peas and rice has great potential for use as a food ingredient (Boye, Aksay, et al., 2010; Cao, Wen, Li, & Gu, 2009). Pea protein possesses good foaming and emulsifying properties (Aluko, Mofolasayo, & Watts, 2009; Taherian et al., 2011), can form gels (Shand, Ya, Pietrasik, & Wanasundara, 2007) and bind water and oil (Osen, Toelstede, Wild, Eisner, & Schweiggert-Weisz, 2014). Rice protein is colorless and tasteless protein source, but its use in food formulations is limited due to it low solubility (Wang, Wang, Wang, & Chen, 2016). Commercially available pea and rice protein isolates have poorer functional properties than those reported above, primarily due to differences in the fractionation processes. Several authors (Aluko et al., 2009; Osen et al., 2014; Stone, Karalash, Tyler, Warkentin, & Nickerson, 2015) have related low protein solubility of isolates to more severe processing conditions such as high temperatures during spray-drying or alcohol decoloration in commercial settings.

DSI is a process that exposes the product to high temperatures for short periods of time (Lewis, Heppell, & Hastings, 2000). Use of this technology for improving functional properties of vegetable proteins, including soy, was previously proposed (Gomi, Hisa, & Soeda, 1978; Gomi, Hisa, & Soeda, 1980; Hawley, Frederiksen, & Hoer, 1972) Wang and Johnson (2001) used DSI to restore solubility properties of soy protein concentrate to approximately that of the native protein. Longer process times improved protein solubilities of soy concentrate and isolate, but the soy isolate had a darker color due to the creation of Maillard reaction products. The authors speculated that more than one biochemical mechanism contributed to the improvement of functional properties by steam injection.

In 2011, Ganjyal and others developed and patented a DSI processing method for preparing protein blends with enhanced functional and/or nutritional properties. Functionality evaluation revealed enhanced solubility, emulsification, foaming and gelling of protein treated by the DSI process. The authors speculated that the modification of electrostatic properties by adjusting pH combined with heat shock led

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to protein unfolding and the subsequent cooling period allowed for protein rearrangement. DSI was assumed to alter disulfide bonds (SS) and sulfhydryl groups (SH) to create cross-linked hybrid proteins from two or more protein sources, however there was a lack of analysis supporting this hypothesis. There is a need to better understand this process and investigate the potential mechanisms that help to enhance the functionality of the protein blends.

To exploit the potential applications of rice and pea proteins as a food ingredient, new methods to improve solubility without adversely affecting the nutritional value must be developed. Thus this study investigated high pressure DSI with pH adjustment to create modified pea:rice isolate (PR) blends with enhanced functional properties. The mechanism behind improvement of functional properties of commercial pea and rice protein isolate by DSI was investigated to help extend the use of these ingredients in wider food processing applications.

2. Materials and methods

2.1. Protein isolates

Pea protein isolate (Pisane B9), obtained from Cosucra (Warcoing, Belgium), and rice protein isolate (Oryzatein Silk80), obtained from Axiom Foods (Los Angeles, CA) were used for preparing pea-rice (PR) protein blends. All samples were stored in a dry place at room temperature (20–23 °C) in glass bottles sealed by plastic caps with liners to minimize changes in moisture content and oxidation.

2.2. Chemicals

Bovine albumin standard (BSA), Ellman's reagent, and 8-anilino-1-naphthalenesulfonic acid (ANS) were procured from Sigma-Aldrich (Saint Louis, MO, U.S.A). Coomassie Brilliant Blue was procured from Bio-Rad Laboratories (Hercules, CA, U.S.A). Acid Orange 12 was procured from Chem-Impex International Inc. (Wood Dale, IL, U.S.A). Dye propionic anhydride was procured from EMD Millipore Corporation (Billerica, MA, U.S.A). All chemicals were of reagent grade or better.

2.3. Preparation of protein blends

PR protein isolate blends were prepared by combining pea protein isolate and rice protein isolate in the ratio 2:1 w/w, to ensure sufficient quantities of methionine and lysine to meet the FAO (2011) recommendations. DSI process for preparing PR protein blends was conducted according to Ganjyal, Maningat, and Bassi (2011) (Fig. 1). Protein blends were combined with water (4 L, 5% w/w protein) and blended using a laboratory homogenizer (Model 17105 Omni-Mixer Homogenizer, Omni International, Waterbury, CT, U.S.A) while pH of the slurries was adjusted to acidic (pH 2 and 3) or alkaline (pH 9, 10, 11) conditions using either 1 M HCl or 1 M NaOH. Slurries were held for 1 h at room temperature (20–23 °C) before processing in the DSI system (EZ Heater H2010, Hydro - Thermal Corporation, Waukesha, WI, U.S.A) at temperatures of 66 °C, 80 °C, 93 °C, and 107 °C, with ± 3 °C variation during the process, and around 5 L/min flow rate. Slurries were cooled in a continuous-flow heat exchanger and then held at room temperature to cool down to approximately 23 °C. Following this the pH of the solution was readjusted to 7.0 with 1 M HCl or 1 M NaOH and then freeze dried (Unitop 600 L, The Virtis Company, Gardiner, NY, U.S.A) to target moisture contents below 7% (w.b.).

2.4. Experimental design

Fig. 1 provides the description of the experimental design and conditions used (pH, temperature). Additionally, 1 batch (1 L, 5% protein content w/w) at 2:1 PR ratio and pH 2, 3, 9, 10 was prepared without DSI processing to evaluate the influence of only pH adjustment on solubility. All batches were analyzed for protein content (n = 2) and protein solubility profiles were determined from pH 3–9 (n = 3).

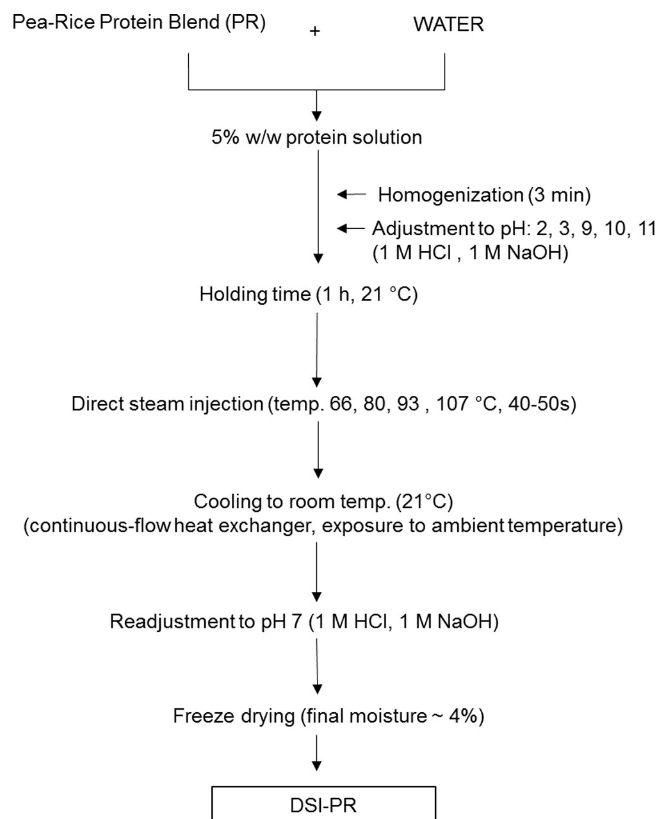

Fig. 1. Flow diagram for the direct stem injection procedure of pea:rice protein blends.

Three replicate batches of each of three treatments that resulted in the greatest solubility improvement were prepared and analyzed for biochemical and functional properties.

2.5. Chemical composition

Ash content (n = 3) was determined by dry ashing (AACCI 2000; 08-01.01a). Crude protein (n = 2) was determined using a nitrogen/protein analyzer (FP-528, Leco Corporation, St. Joseph, MI, U.S.A) (AACCI 2000; 46-30.01) with nitrogen conversion factor of 6.25.

2.5.1. Amino acid composition

Amino acid composition was determined at an external laboratory (AAA Service Laboratory, Damascus, OR, U.S.A). A Hitachi L8900 amino acid analyzer, Hitachi column (part# 855-4516), and Hitachi complex of buffers (Hitachi, Ltd, Tokyo, Japan) was used according to methods of Moore and Stein (1948). Proteins (n = 2) were hydrolyzed in 6 N HCl containing 2% phenol at 110 °C for 22 h (Roach and Gehrke, 1970) dried in a speed-vacuum system to 150 mTorr and re-suspended to a concentration of 10 mg material per mL of sample buffer, diluted 1:50 and 50 μL was injected onto the analyzer. Norleucine was included as an internal standard. Postcolumn derivatization with ninhydrin was used to visualize the peaks. Proline was detected at a wavelength of 440 nm, while the remaining amino acids were detected at 570 nm.

2.5.2. Available lysine content

Available lysine content was determined using propionic anhydride as the blocking agent (Aalaei, Rayner, Tareke, & Sjöholm, 2016). The concentration of available lysine was determined using a standard curve prepared from a stock solution of Acid Orange 12 dye at an absorbance of 475 nm. The standard curve ranged from 0.0048 to 0.0150 mg dye/mL buffer. The concentration of lysine was calculated from the difference in presence and absence of blocking agent.

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