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Effects of high pressure on the physicochemical and functional properties of peanut protein isolates

Xuan-Hui He, Hong-Zhi Liu, Li Liu, Guan-Li Zhao, Qiang Wang*, Qiong-Ling Chen

Institute of Agro-Products Processing Science and Technology, Chinese Academy of Agricultural Sciences/Key Laboratory of Agro-Products Processing, Ministry of Agriculture, P.O. Box 5109, Beijing 100193, People's Republic of China

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ABSTRACT

This study aimed to investigate the effects of high pressure (HP) on the physicochemical and functional properties of peanut protein isolates (PPI). The properties studied were surface hydrophobicity (H_0), contents of sulfhydryl group (SH) and disulfide bond (S–S), sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) characteristics, differential scanning calorimetric(DSC) characteristics, protein water-holding capacity (WHC), oil-binding capacity (OBC), and heat-induced gelling property. HP treatment from 50 MPa to 200 MPa for 5 min gradually increased the WHC and OBC, and significantly increased the H_0 ($p < 0.05$). The hardness of the heat-induced gelling increased by 50% after HP treatment at 100 MPa, but gradually decreased with further increased pressure. HP treatment at 50–200 MPa significantly increased the S–S content ($p < 0.05$) but decreased the SH content. The content of conarrachin II significantly changed with HP treatment in SDS-PAGE. These results suggest that HP treatment can be used to modify the properties of PPI at the appropriate pressure within a short time.

1. Introduction

Peanut is one of the main oil crops in China. Its planting area is the world's second, reaching about 4.55 million hm. in 2010. Its yield is also the world's highest, reaching 15.7 million tons and accounting for about 42% of the total yield worldwide, according to the statistical data of the Food and Agriculture Organization (http://faostat.fao.org). Peanut has become one of the few agricultural exports with international competitiveness in China. About 50–60% of peanuts grown in China are used to produce edible oil. The remaining meal, also called as defatted flour, is a protein-rich, inexpensive, and underutilized byproduct of peanut which contains approximately 50% high quality protein. Therefore, research on defatted peanut flour especially peanut protein is important to improve the added value of peanut (Wang, 2012, p. 26).

Peanut protein has high nutritional values, close to animal proteins, and contains no cholesterol (Zhou, Zhou, & Jiang, 2012, p. 7). Peanut protein not only contains many essential amino acids that are easily uptaken by the human body, but also possesses an attractive aroma and white color, which make it superior to soybean protein. Therefore, it is widely used in the food industry as a kind of plant protein resources. To optimize the application of peanut protein in food processing, many physical and chemical modifications have been applied to peanut protein. Food treated with high pressure (HP) is a brand-new high technology with bright prospects. High pressure (HP), also can be called the ultra high-pressure (UHP), and belong to the non-thermal processing techniques, using the fluid medium transmission pressure, can make the water, also can be oil, so they called high hydrostatic pressure (HHP). The mechanism of action is instantaneous and evenly throughout all parts of the material, neither depend on its size, shape, and composition of materials, also do not depend on the size, shape and composition of the package. In recent years, it has been widely used in the property modification of food proteins (Apichartsrangkoon, 2003; Ibanoglu & Karatas, 2001; Messens, Van Camp, & Huyghebaert, 1997; Molina, Defaye, & Ledward, 2002; Molina, Papadopoulou, & Ledward, 2001; Puppo et al., 2004, 2005; Torrezan, Tham, Bell, Frazier, & Cristianini, 2007; Wang et al., 2008; Zhang, Li, Tatsumi, & Kotwal, 2003). Treatment with HP reported changes the functional properties, such as protein emulsifying activities, solubility, and foaming, and the components of soybean protein, whey protein and lactalbumin (He, Liu, Liu, Hu, & Wang, 2013).

Recent studies have shown that HP treatment can change not only the functional characteristics of food proteins, but also their physical and chemical properties as well as molecular conformation (Kiffer & Schurer, 2007; Puppo et al., 2004; Zhang et al., 2003). However, only a few studies have investigated the modification of

* Corresponding author. Tel.: +86 (0)1062816452.
E-mail address: qwqw403@126.com (Q. Wang).

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peanut protein by the HP technology (Zong & Chen, 2007, 2008). In these studies, mainly for its solubility and emulsifiability, didn't research gelling property, water-holding capacity and oil holding capacity, and the pressure used was high. In the meat products production, such as ham sausage production, mostly added a certain amount of plant protein, such as soybean protein, so as to improve the quality of products at the same time can save the cost, and in the application, it mainly used gelling property, water-holding capacity and oil holding capacity of protein etc. Therefore, this study main aimed to investigate the influences of HP (in the lower pressure range) on prior to freeze-drying on some physico-chemical and gelling property, water-holding capacity and oil holding capacity of peanut protein isolates (PPI) to optimize their application in the food industry.

2. Materials and methods

2.1. Preparation of peanut protein isolate

Defatted peanut flour was obtained from Gaotang Lanshan Co., Ltd. (Shandong province, China, and the content of protein was 45.90 ± 0.13%). PPI was prepared at room temperature as follows. Briefly, the defatted peanut flour was mixed with 10-fold (w/v) deionized water with 1 N sodium hydroxide (Sinopharm Chemical Reagent Co., Ltd., Beijing, China) at pH 9.0. The proteins were then extracted with stirring with 150 rpm for 2 h at room temperature and centrifuged at 3500 *g* for 10 min. The supernatant was adjusted to pH 4.5 with 2 N hydrochloric acid (HCl, Beijing Chemical Factory, China), centrifuged at 3500 *g* for 10 min, and discarded. The precipitants were then thoroughly stirred with deionized water and freeze dried until further use. For HP treatment, the protein concentration was adjusted to 43.23 g/L (concentration obtained through preliminary experiments, in preliminary experiments, changes in the hardness of the heat-induced gelling of various protein concentration (4.323, 8.65, 43.23, 86.46, 129.69, 172.92 g/L) treated with high pressure have been studied, and results shown the hardness of the heat-induced gelling of 4.323, 8.65, 86.46, 129.69, 172.92 g/L protein (99.43–128.13 g) were smaller than that of 43.23 g/L. So 43.23 g/L protein concentration was studied in this paper), and the content of protein was 86.46 ± 0.09%, which was determined by micro-Kjeldahl method using a nitrogen conversion factor of 5.46, the contents of ash, moisture, crude fat and total carbohydrate were 3.35 ± 0.25%, 4.12 ± 0.13%, 0.60 ± 0.08% and 5.47 ± 0.10%, respectively, which were determined using AOAC methods (AOAC, 1990, 1996), and the control samples (un-treated) were prepared by freeze-drying the PPI without HP treatment.

2.2. High pressure processing

HP treatment was carried out in a 0.6 L reactor unit (HPP.L2-600/2 ultra HP systems, Huatai Sen Miao Biological Engineering Technology Co., Ltd., Tianjin, China) equipped with temperature and pressure regulators. Water was used as the pressure transmitting medium in the vessel. Prior to pressure processing, 5% (w/v) (concentration obtained through preliminary experiments, in preliminary experiments, changes in the hardness of the heat-induced gelling of various protein concentration (0.5%, 1%, 5%, 10%, 15%, 20% w/v) treated with high pressure have been studied, and results shown the hardness of the heat-induced gelling of 0.5%, 1%, 10%, 15%, 20% w/v protein (99.43–128.13 g) were smaller than that of 5% w/v. So 5% w/v protein concentration was studied in this paper) of PPI solutions with a suitable volume were vacuum-conditioned in a polyethylene bag. The PPI solutions were then subjected to HP treatment at 50, 80, 100, 150, and 200 MPa for 5 min (pressure fluctuation range ± 10 MPa), and its temperature was kept at 25 ± 2 °C during processing. After HP treatment, the PPI solutions were freeze-dried.

2.3. Preparation of peanut protein isolate gels

The preparation of PPI gels followed the method by Wu, Wang, Ma, and Ren (2009), with some modifications. About 14% (w/v) of PPI solutions for untreated and HP-treated samples (50–200 MPa) were heated for 1 h at 95 °C and cooled immediately in a cold water bath. The heated samples were stored at 4 °C for 24 h until test.

2.4. Gelling property

To evaluate the texture of PPI gels, a uniaxial compression test was performed with a TA-TX2i texture analyzer (Stable Micro System Ltd., Godalming, England) according to the procedure of Guo et al. (2005) and Pinterits and Arntfield (2008) with some modifications. A spherical plunger (12 mm) was utilized. The samples were compressed to 50% at a rate of 0.1 mm/s. The trigger point was 100 g. The resulting data were interpreted using Texture Expert Version 1.22 analysis software (Stable Micro System Ltd., Godalming, England). The program produced a force–displacement curve. Two parameters, the springiness and hardness of the material, were determined.

2.5. Water-holding capacity and oil-binding capacity

WHC of samples was determined as described by Beuchat (1977). The sample (1.000 g) was placed in a centrifugal tube, weighed, added with 10 mL of distilled water, and mixed using a Fisher Gene II vortex at the highest speed for 5 min. After the mixture was thoroughly wetted, the samples were allowed to stand at room temperature for 30 min and centrifuged at 3000 *g* for 20 min. The supernatant was decanted and the centrifuge tube containing the sediment was weighed. The WHC (gram of water per gram of protein) was calculated as: $WHC = (W_2 - W_1)/W_0$, where W_0 is the weight of the dry protein (g), W_1 is the weight of the tube plus protein samples (g), and W_2 is the weight of the centrifuge tube with the sediment (g).

The OBC was determined following the method of Chakraborty (1986). The sample (1.000 g) was placed in a centrifugal tube, weighed, added with soybean salad oil (obtained from a commercial supermarket in Beijing, Beihai COFCO Grain and oil industry (Tianjin) Co. Ltd., China) of 5 mL, and mixed for 5 min using a vortex mixer. The samples were allowed to stand for 30 min. The protein–oil mixtures were then centrifuged at 3000 *g* (Feige Centrifuge 4500 R) for 20 min. The supernatant of salad oil was decanted and the centrifuge tube containing the sediment was weighed. The OBC (gram of oil per gram of protein) was calculated as: $OBC = (W_2 - W_1)/W_0$, where the symbols have the same meaning as those in the WHC formula.

2.6. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE)

SDS-PAGE was performed following the method of Wang and Zou (2004, pp. 100–120) as well as Laemmli (1970). For sample preparation, the protein samples (0.1000 g) were dissolved in 20 mL of phosphate-buffered saline (PBS; 0.01 M, pH 7.2), mixed for 10 min using a vortex mixer, and centrifuged at 10 000 *g* for 10 min. Up to 10 μL of supernatant were then added with 10 μL of sample buffer (0.08 M Tris–HCl buffer, pH 6.8), 1% (w/v) SDS, 2% (v/v) 2-β-mercaptoethanol, 5% (v/v) glycerol, and 0.025% (w/v) bromophenol blue and mixed well. The samples were then heated in a boiling water bath for 5 min and cooled down before 8 μL of samples were