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Original Research Paper

Effect of micronization technology on physicochemical and antioxidant properties of dietary fiber from buckwheat hulls

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ABSTRACT

Buckwheat is at present considered a food component of high nutritional value. In order to study the effect of buckwheat hull dietary fiber (DF) particle size on its functional and antioxidant properties, buckwheat hull DF was ground by ultrafine grinding and its particle size was determined using laser diffraction method. The results showed that ultrafine grinding technology could efficiently pulverize the DF particles to submicron scale, particle size distribution was close to a Gaussian distribution, and soluble DF content increased. With particle size decrease, the water holding capacity (WHC), water retention capacity (WRC), swelling capacity, oil binding capacity (OBC) and nitrite ion absorption capacity were significantly ($p < 0.05$) increased. Micronized insoluble DF showed increased total phenolic content (TPC), 2,2′-azinobis(3-ethylbenzothiozoline-6-sulfonic acid) diammonium salt (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity and ferric reducing antioxidant power (FRAP). Positive correlations were detected between ABTS, DPPH, FRAP and TPC. A modification method was obtained to yield a kind of health beneficial DF with higher soluble DF content, WHC, WRC, swelling capacity, OBC, nitrite ion absorption capacity and antioxidant activity. This study could be useful for the application of buckwheat and related products in the food industry.

1. Introduction

Buckwheat is ubiquitous almost everywhere but grows mainly in the northern hemisphere. China ranks second in the production of buckwheat with about 10.2 million acres cultivating area and the buckwheat production fluctuates within the range of 0.6–0.95 million tons (Li and Zhang, 2001). Buckwheat has recently attracted attention as a novel material in functional food formulations because of its outstanding health properties. Buckwheat is rich in vitamin B_1 and B_2, it has balanced amino acid composition and is rich in lysine (Watanabe, 1998). In addition to being one of the important energy sources due to their starch content, these pseudocereals provide good quality protein, dietary fiber and lipids rich in unsaturated fats (Alvarez-Jubete et al., 2010).

Dietary fiber (DF) is frequently used in the development of functional foods (Puupponen-Pimia et al., 2002) and its importance in nutrition and health is well known (Anderson et al., 1990; Kritchevsky and Bonfield, 1995). In particular, DF has several physicochemical functions (such as water binding and alteration of viscosity) which in turn contribute to physiological attenuations such as cholesterol and fat binding, decrease in blood glucose levels, preventing constipation and facilitating good colonic health (Foschia et al., 2013). Nowadays, the average worldwide ingestion of DF is still considerably lower than the recommended daily intake levels. So, it is necessary to add DF to food products. DFs have been extensively studied for their ability to regulate transit time due to the increase of stool bulk, and other beneficial properties such as hydration properties like swelling, water-holding and water retention capacities (Robertson et al., 2000).

Micronization is the process of reducing the average diameter of a solid material's particles. For instance, mini-type airflow ultrafine grinding is a new technique, which is a useful tool for making superfine powder with good surface properties like disperse ability and solubility (Tkacova and Stevulova, 1998). Because the physicochemical properties of DF usually provide clues to their potential physiological effects, it is hence interesting to investigate the effect of micronization on functional activity of food fibers (Wu et al., 2009). Moreover, since the reduction of particle sizes might increase the particle surface area and cause the release of some antioxidant compounds (Rosa et al., 2013), it is valuable to find out the antioxidant properties of DF as affected by ultrafine grinding. Although the effect of ultrafine grinding on antioxidant properties of wheat bran DF (Zhu et al., 2010) and wine grape pomace DF (Zhu et al., 2014) have been published, the use of ultrafine grinding in DF processing remains rather limited, probably due to the toughness and polymer nature of DF and inadequate equipment support (Zhu et al., 2010).

The aim of this work was to evaluate the application of ultrafine grinding technology for producing buckwheat hull DF in the submicron range, and to evaluate the influences of

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micronizaiton on the physicochemical and antioxidant properties of insoluble DF from buckwheat hull.

2. Materials and methods

2.1. Materials and chemicals

Buckwheat hull (2012 crop year) was purchased from local supermarket in Qinhuangdao, China. Phosphate-buffered saline (PBS, pH 7.0), α-amylase, and protease were purchased from Beijing Aoboxing Biotechnology Co., Ltd. (Beijing, China). Gallic acid, 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2′-azinobis(3-ethyl-benzothiozoline-6-sulfonic acid) diammonium salt (ABTS), 2,4,6-tri (2-pyridyl)-s-triazine (TPTZ) were purchased from National Standard Samples Center (Beijing, China). All other reagents were of analytical grade.

2.2. Preparation of insoluble dietary fiber (IDF) before ultrafine grinding

IDF was prepared from buckwheat hull using the procedure described by Park et al. (2009) with minor modifications. The buckwheat hull IDF before ultrafine grinding was obtained for the following step. Buckwheat hull (100 g, 40-mesh) was sonicated in pH 6.0 water (2000 mL) at 20 °C for 20 min. α-Amylase (1 g) was added and the mixture was incubated at 60 °C for 3.5 h. Protease (0.5 g) was added and the mixture was incubated at 55 °C for 3 h. Anhydrous ethanol (pre-heated to 60 °C) was added and the sample was allowed to precipitate at room temperature for 60 min. Finally, the residue was washed with cold water and dried at 50 °C overnight in a vacuum oven to yield buckwheat hull IDF.

2.3. Preparation of buckwheat hull before ultrafine grinding

Buckwheat hull was ground by a laboratory mill (FZ102, Tianjin Taisite Co. Ltd., Tianjin, China), and passed through a 40-mesh screen.

2.4. Preparation of buckwheat hull and IDF after ultrafine grinding

Buckwheat hull and IDF were micronized by mini-type airflow pulverization instrument (QLM-80K, Shangyu City Heli Powder Engineering Co., Ltd., Zhejiang, China). The working pressure was set at 70 MPa and the working frequency was set at 40 Hz. Buckwheat hull and IDF after ultrafine grinding were sealed in aluminum foil and kept in a desiccator for further study.

2.5. Chemical analysis of buckwheat hull DF before and after ultrafine grinding

Total dietary fiber (TDF), IDF and soluble dietary fiber (SDF) contents were determined as AOAC methods (AOAC, 2005; AOAC, 1996).

2.6. Particle size measurement of buckwheat hull DF

Laser diffraction particle size analyzer (LA-920, Horiba Limited, Japan) was employed for the determination of primary particle size distribution. The samples were suspended in ethanol directly in the measurement cell (small volume unit sample module) and the suspensions were analyzed when the obscuration was between 70% and 80%.

2.7. Water-holding capacity (WHC) of IDF

WHC is defined by the quantity of water that is bound to the fibers without the application of any external force (except for gravity and atmospheric pressure). Accurately weighed dried IDF (1.0 g) was loaded into a graduated test tube, around 30 mL of water was added and it was hydrated for 18 h. The supernatant was removed by passing through a sintered glass crucible (G4) under vacuum. The hydrated weight of IDF was recorded and it was dried at 105 °C for 2 h to obtain the residual dry weight (Raghavendra et al., 2004).

$$\text{WHC (g/g)} = (\text{Hydrated weight} - \text{Dry weight})/\text{Dry weight}$$

2.8. Water retention capacity (WRC) of IDF

WRC is defined as the quantity of water that remains bound to the hydrated fiber following the application of an external force. Accurately weighed dried IDF (1.0 g) was loaded into a graduated centrifuged tube, around 30 mL of water was added and it was hydrated for 18 h, followed by centrifugation at 3000*g* for 20 min and the supernatant solution was removed by passing through a sintered glass crucible (G4) under vacuum. The hydrated weight was recorded and then sample was dried at 105 °C for 2 h to obtain its dry weight (Raghavendra et al., 2004).

$$\text{WRC (g/g)} = (\text{Hydrated weight after centrifugation} - \text{Dry weight})/\text{Dry weight}$$

2.9. Swelling capacity of IDF

Swelling property is defined as the ratio of the volume occupied when the sample is immersed in excess of water after equilibration to the actual weight. Accurately weighed dried IDF (0.2 g) was placed in a graduated test tube, around 10 mL of water was added and it was hydrated for 18 h. After 18 h, the final volume attained by sample was measured (Raghavendra et al., 2004).

$$\text{Swelling capacity (mL/g)} = \text{Volume occupied by sample}/\text{Original sample weight}$$

2.10. Oil-binding capacity (OBC) of IDF

OBC is determined by the method of Sangnark and Noomhorm (2003) with slight modifications. A dried IDF (5.0 g) was mixed with peanut oil in a centrifugal tube and left for 1 h at room temperature (25 °C). The mixture was then centrifuged at 1500*g* for 10 min, the supernatant was decanted and the pellet was recovered by filtration through a nylon mesh. OBC was expressed as follows:

$$\text{OBC (g/g)} = (\text{Pellet weight} - \text{Original dry weight})/\text{Original dry weight}$$

2.11. Nitrite ion absorption capacity of IDF

Nitrite is a reactive ion and can react with secondary amines and amides under acid conditions to form *N*-nitroso compounds, many of which have been shown to be carcinogenic in animals (Lijinsky, 1984). Nitrite scavenging capacity may be a factor in the possible role for protecting against gastric cancer development (Moller et al., 1988). Dried IDF (1.0 g) was mixed with 100 mL 1 mol/L $NaNO_2$ solution in a 250-mL conical flask. The pH was adjusted to 2.0. The mixture was incubated at 37 °C for 75 min with continuous mild agitation. The residual concentration of nitrite ion was measured. Nitrite ion absorption capacity was