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Particle size of insoluble dietary fiber from rice bran affects its phenolic profile, bioaccessibility and functional properties

Guanghe Zhao [a, b], Ruifen Zhang [a, b, **], Lihong Dong [b], Fei Huang [b], Xiaojun Tang [b], Zhencheng Wei [b], Mingwei Zhang [b, *]

[a] College of Food Science & Technology, Huazhong Agricultural University, Wuhan 430070, China
[b] Sericultural & Agri-Food Research Institute, Guangdong Academy of Agricultural Sciences/Key Laboratory of Functional Foods, Ministry of Agriculture/ Guangdong Key Laboratory of Agricultural Products Processing, Guangzhou 510610, China

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ABSTRACT

Despite its various health benefits, rice bran insoluble dietary fiber (IDF) is not favored by people because of its rough texture and bad flavor. Therefore, many efforts have been made to modify IDF, including reducing its particle size. In the present study, the effects of superfine processing on the functional properties of rice bran IDF and its phenolic profiles and bioaccessibility were investigated. Superfine rice bran IDF powder exhibited a higher water holding capacity, swelling capacity and nitrite ion adsorption capacity, and a lower oil holding capacity than the other IDF powders. Moreover, the superfine rice bran IDF powder exhibited a higher extractability in both free and bound phenolics, higher phenolic bioaccessibility and antioxidant properties than its coarse counterpart. The extractable phenolic profile in superfine rice bran IDF was also different from those of other IDFs. These results suggest that superfine grinding can improve the functional properties of rice bran IDF and may benefit its application in functional foods.

1. Introduction

Epidemiological surveys and experimental evidence from human and animal trials have revealed that dietary fiber (DF) has various health benefits, including an attenuation of blood cholesterol and/or glucose, a laxative effect and a reduced risk of colon cancer, heart disease and obesity (Afify, Romeilah, Osfor, & Elbahnasawy, 2013; Brockman, Chen, & Gallaher, 2014; Huang, Sheu, Lee, & Chau, 2007; Pérez-Jiménez et al., 2008; Smith & Tucker, 2011). Therefore, many food byproducts, such as citrus pomace (Tao et al., 2014) and carrot pomace (Ma et al., 2016), have been investigated as good sources of DF. Rice is a staple food for more than half of the global population. The annual production of paddy rice worldwide in 2013 was 740.9 million metric tons (FAOSTAT, 2015). Rice bran constitutes approximately 10% of the weight of brown rice. Because the bulk of the rice is consumed as milled rice, approximately 74 million metric tons of rice bran are produced, annually, most of which is underutilized as animal feed or directly discarded. The content of the total dietary fiber (TDF) in rice bran is approximately 20–30%, but nearly 90% of that content consists of insoluble dietary fiber (IDF). Rice bran IDF has been shown to possess certain *in vitro* hypoglycemic and hypolipidemic properties, such as altering the conformation and inhibiting the activity of porcine pancreatic lipase, binding glucose and retarding α-amylase action (Qi et al., 2015, 2016). Rice bran IDF has been proved to have a hypocholesterolemic effect in rats (Topping et al., 1990) and certain beneficial effects in mildly hypercholesterolemic men (Kestin, Moss, Cliftonm, & Nestel, 1990). Furthermore, rice bran IDF was demonstrated to decrease both fasting and postprandial glucose levels in diabetic patients (Silva, de Oliveira, de Souza, & Silva, 2005).

Despite its various health benefits, rice bran IDF, similar to IDFs from other sources, is not favored by people due to its rough texture and bad flavor. Therefore, many efforts have been made to modify IDFs, including reducing their particle size. Reducing the particle size of IDF may result in certain changes in its structure, porosity, surface area, and functional properties, etc. (Liu, Wang, Liu, & Pan,

* Corresponding author.
** Corresponding author. Sericultural & Agri-Food Research Institute, Guangdong Academy of Agricultural Sciences/Key Laboratory of Functional Foods, Ministry of Agriculture/ Guangdong Key Laboratory of Agricultural Products Processing, Guangzhou 510610, China.
E-mail address: zhangfood@tom.com (M. Zhang).

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2016; Wu, Chien, Lee, & Chau, 2007). Grinding, particularly superfine grinding, can lead to a redistribution of the fiber components from insoluble to soluble fractions (Liu et al., 2016; Zhu, Du, & Xu, 2015). Meanwhile, superfine IDF powders usually exhibit better hydration properties and a higher adsorption capacity (Ma et al., 2016; Zhu et al., 2015). Furthermore, superfine IDF powders from Qingke bran and citrus pomace have more detectable free phenolics and thus show a higher antioxidant capacity than their coarse counterparts (Tao et al., 2014; Zhu et al., 2015). Additionally, superfine processing results in different detectable phenolic profile in IDF (Tao et al., 2014) and a higher phenolic bioaccessibility (Hemery et al., 2010). However, other studies demonstrate that superfine grinding does not significantly improve the water holding capacity (WHC) of carrot IDF (Chau, Wang, & Wen, 2007) and markedly decreases the WHC and swelling capacity (SC) of wheat bran DF (Zhu, Huang, Peng, Qian, & Zhou, 2010) and citrus pomace IDF (Ye, Tao, Liu, Zou, & Zhao, 2015). The changes in the functional properties of IDFs caused by superfine grinding are inconsistent due to their different sources. Even though it is a good resource of IDF, limited data regarding the effects of particle size on rice bran IDF are available. Therefore, the differences in the phenolic profiles, bioaccessibility and functional properties of rice bran IDF with different particle sizes were evaluated in this study. The information offered by this study may provide useful insight into the potential applications of rice bran IDF in the food industry.

2. Materials and methods

2.1. Chemicals and reagents

Analytical grade methanol (MeOH), ethyl acetate, hydrochloric acid (HCl), sodium carbonate (Na_2CO_3), sodium hydroxide (NaOH), potassium phosphate monobasic (KH_2PO_4),and potassium phosphate dibasic (K_2HPO_4) were purchased from Mallinckrodt Chemicals (Phillipsburg, NJ, USA). *p*-Hydroxybenzonic acid, vanillic acid, syringic acid, vanilline, *p*-coumaric acid, gallic acid ferulic acid, isoquercitrin and quercetin were purchased from Sigma. Folin–Ciocalteu reagent (FC), 6-hydroxy-2, 5, 7, 8-tetramethylchroman-2-carboxylic acid (Trolox), acetonitrile (chromatographic grade), pepsin (from porcine stomachmucosa), pancreatin (from porcine pancreas), and bile extract (from porcine) were purchased from Sigma-Aldrich. Caffeic acid methyl ester, ferulic acid methyl ester and 2, 2′-azobis (2-amidinopropane) dihydrochloride (ABAP) were purchased from Tokyo Chemical Industry Co., LTD. (Tokyo, Japan) Ark Pharm Inc.(Chicago, USA) and Wako Chemicals (Richmond, VA, USA), respectively. Heat-stable α-amylase (Termamyl SC, 120 KNU/g), protease (Alcalase 2.4 L, 2.4AU/g), and amyloglucosidase (AMG 300 L, 300AGU/g) were purchased from Novozymes (China) Biotechnology Co. Ltd.

2.2. Preparation of the rice bran IDF

Rice bran was freshly prepared by polishing brown rice using a rice milling machine. After the removal of the oil, freshly defatted rice bran (DRB) was used for the preparation of the IDF by the method of Bunzel et al. (2003) with some modification. Briefly, 60 g of DRB were gelatinized in a 95 °C water bath for 10 min. The gelatinized DRB was then subjected to sequential enzymatic digestion with heat-stable α-amylase (1.8 mL, pH 6.0, 95 °C water bath for 20 min), alcalase protease (3.0 mL, pH 7.5, 60 °C water bath for 60 min) and amyloglucosidase (1.2 mL, pH 4.5, 60 °C water bath for 30 min), to remove starch and protein. After centrifugation (6800 × g, 10min, Hunan Yida Jinghua Instrument Co., Ltd.), the residue was washed with 60 °C distilled water twice and then dried at 40 °C in a GZX-9240 MBE electrothermal constant-temperature dry box (Shanghai Bo Xun Industrial Co., Ltd.) for 24 h to yield IDF. The dried rice bran IDF was ground using an FW80 disintegrator (Tianjin Taisite Instrument Co., LTD) and passed through an 80-mesh sieve to obtain a coarse powder. The coarse powder was further ground into fine and superfine power using an XDW-6BL vibrating superfine mill (Jinan Dawei Machinery Co., LTD) by regulating the grinding time. Each type of IDF powder was prepared in triplicate. All samples were sealed in polypropylene bags and stored at −20 °C until use.

2.3. Microstructure and particle size measurement of rice bran IDF

Transmission electron microscope (TEM) (SU-70, Hitachi, Japan) was used to observe the microstructure of the rice bran IDF. A specific surface and pore size distribution analyzer (ASAP2010, Micrometrities, America) was used to measure the particle size of the rice bran IDF.

2.4. Hydration and adsorption properties of rice bran IDF

The WHC, water retention capacity (WRC) and SC were determined according to a method reported by Raghavendra, Rastogi, Raghavarao, and Tharanathan (2004). The oil holding capacity (OHC) was evaluated using a method of Chau and Huang (2003). The nitrite ion adsorption capacity (NIAC) was estimated using a method proposed by Zhu et al. (2015).

2.5. Extraction of antioxidative components of rice bran IDF

In total, 1.0 g of IDF was mixed with 50 mL chilled 80% acetone aqueous solution (v/v), and the mixture was homogenized using a T25 digital ultra turrax (IKA Company, Germany) at 10,000 rpm for 5 min in an ice bath. After centrifugation at 8000 × g for 10 min at 4 °C, the supernatant was removed, and the residue was extracted again under the same conditions. The supernatants were pooled, evaporated at 45 °C and reconstituted to a final volume of 10 mL with MeOH as the free phenolics. The residue remaining after extracting free phenolics was then hydrolyzed with 40 mL of 2 M NaOH at room temperature for 1 h with continuous shaking under the protection of nitrogen gas. After the hydrolyzation, the pH was then adjusted to 1.0 with 6 mol/L HCl, and the mixture was extracted 5 times with ethyl acetate. The ethyl acetate phase was pooled, evaporated at 45 °C and reconstituted to a final volume of 10 mL with chilled MeOH as the bound phenolics. Both the free and bound phenolics were stored at −20 °C until further use.

2.6. Phenolic content and antioxidant properties of rice bran IDF

The total phenolic content was analyzed using the Folin-Ciocalteu colorimetric method described by Dewanto, Wu, Adom, and Liu (2002). The total flavonoid content was determined using the aluminum chloride colorimetric method as previously reported by Ti et al. (2014).

The DPPH radical scavenging capacity assay was performed according to a previously reported method by Gadow, Joubert, and Hansmann (1997). The ferric reducing antioxidant power (FRAP) was carried out using a method proposed by Benzie and Strain (1996).

2.7. Phenolic profiles of rice bran IDF

The phenolic compositions were determined by a method reported by Ti et al. (2014) with slight modification. Briefly, all samples were analyzed using an Agilent 1260 HPLC system (Waldbronn, Germany) equipped with a VWD detector and