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Impact of solid state fermentation on nutritional, physical and flavor properties of wheat bran

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ABSTRACT

To improve the nutritional, physical and flavor properties of wheat bran, yeast and lactic acid bacteria (LAB) were used for fermenting wheat bran in solid state. Appearance properties, nutritional properties, microstructure, hydration properties and flavor of raw bran and fermented bran were evaluated. After treatments, water extractable arabinoxylans were 3–4 times higher than in raw bran. Total dietary fiber and soluble dietary fiber increased after solid state fermentation. Over 20% of phytic acid was degraded. Microstructure changes and protein degradation were observed in fermented brans. Water holding capacity and water retention capacity of fermented brans were improved. Results suggest that solid state fermentation is an effective way to improve the properties of wheat brans.

1. Introduction

Interest in the development of whole grain has grown markedly as a result of increasing health awareness among consumers and food industry. The potential benefits of whole grain for human health have been demonstrated. According to previous studies, consumption of whole grain cereals can decrease the risk of diabetes, obesity, cardiovascular disease and some cancers (Aarestrup et al., 2012; Reicks, Jonnalagadda, Albertson, & Joshi, 2014; Ye, Chacko, Chou, Kugizaki, & Liu, 2012). The physiological effects were closely related to the nutritive ingredients such as dietary fiber, phenolic components and antioxidant present in bran and germ of wheat kernel (Beta, Nam, Dexter, & Sapirstein, 2005), while these parts were removed during the production of refined wheat flour. To make use of nutritional compounds present in wheat bran, bran was re-added into wheat flour as a complement to produce whole wheat flour, but it caused many negative effects on sensory quality, dough rheology and technological properties (Barros, Alviola, & Rooney, 2010; Schmiele, Jaekel, Patricio, Steel, & Chang, 2012; Sozer, Cicerelli, Heiniö, & Poutanen, 2014). The outer layers of grain contain cellulose and lignin, which influence both the taste and mouth feel. Bran supplementation usually weakens the gluten network structure and then affects the gas-holding capacity of the dough thus resulting in decreasing in volume and elasticity of baking food (Coda et al., 2014). Moreover, the shorter shelf-life of whole wheat flour compared with refined flour limits its use in food industry. There are lipids and lipid-metabolizing enzymes in wheat bran which lead to lipid degradation and rancidity during storage (Galliard, 1986). In the presence of oxygen, polyphenol oxidases (PPO) or tyrosinases catalyse the hydroxylation of monophenols to diphenols, followed by the oxidation of the diphenol to the corresponding quinone, most of which are subsequently polymerized to form dark pigments (Martinez & Whitaker, 1995; Matheis & Whitaker, 1984). Phytic acid (PA) is regarded as an antinutrient factor in wheat bran because of its direct or indirect ability to bind minerals and alter their solubility, functionality, digestibility and absorption, which affect the bio-availability of minerals (Dai, Wang, Zhang, Xu, & Zhang, 2007). Arabinoxylans (AXs) are major constituents of cell walls in cereal grains. They can be divided as water extractable arabinoxylans (WEAX) and water unextractable arabinoxylans (WUAX). WUAX are detrimental to bread making while WEAX with medium to high molecular weight have a positive impact on loaf volume (Courtin, Gelders, & Delcour, 2001). WUAX which make up 70% of wheat endosperm cell walls (Mares & Stone,

Abbreviations: CB, control bran (raw bran); AB, autoclaved bran; LFB, bran was autoclaved at 120 °C for 20 min and then fermented with LAB; YFB, bran was autoclaved at 120 °C for 20 min and then fermented with yeast; LYFB, bran was autoclaved at 120 °C for 20 min and then fermented with LAB and yeast at the same time.

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1973) can be hydrolyzed by endoxylanases causing them to lose their strong water holding capacity (Gruppen, Kormelink, & Voragen, 1993).

To solve the problems caused by added bran in whole wheat flour, many researchers have focused on modifying properties of wheat bran. Several studies have emphasized that high moisture fermentation of wheat bran with yeast or lactic acid bacteria (LAB), is an efficient pre-treatment method to improve technological, sensorial and nutritional properties of bran-containing products (Coda et al., 2014; Katina et al., 2007) as well as to degrade anti-nutritive factors such as phytic acid (PA), aiming at increasing mineral bioavailability (Magala, Kohajdová, & Karovičová, 2015). Bran fermentation increases the content and bioavailability of several functional compounds such as WEAX, total free phenols and soluble fiber (Katina et al., 2012; Manini et al., 2014). However, high moisture fermentation will cost vast energy to remove water before adding bran into wheat flour. To our knowledge, few publications have reported that fermentation in solid state can effectively alter properties of wheat bran. On the other hand, there are a lot of spoilage bacteria and fungi on bran surface after tempering process in production of refined wheat flour (Rosenkvist & Hansen, 1995), which increases the risk of its use because all of these microbes will grow during fermentation.

The aim of the current study was to modify autoclaved wheat bran by solid state fermentation with yeast and LAB. We compared the effects of spontaneous fermentation and fermentation with yeast or with LAB or with yeast and LAB on the nutritional, physical and flavor properties of wheat bran.

2. Materials and methods

2.1. Raw materials

Active dry yeast (Commercial baker's yeast with high sugar tolerance) and LAB starter (*Lactobacillus bulgaricus* and *Streptococcus thermophiles* inside) used in this study were purchased from Angel Yeast Co., Ltd. (Yichang, China). Commercial wheat bran (protein 19.48 ± 0.67 g/100 g, dietary fiber 52.36 ± 1.15 g/100 g, the average particle size 250–425 μm) was provided by Xinfeng Flour Co., Ltd (Huai'an, China).

All chemicals, solvents and reagents used in this study were of at least analytical grade unless specified otherwise. All analyses were carried out at least in triplicate.

2.2. Inoculum preparation

0.1 g of LAB powder was incubated statically in 50 mL liquid MRS culture at 37 °C for 16 h and then the medium were centrifuged at 4000 rpm for 10 min. The precipitate was washed with saline twice and then was suspended in 50 mL sterile distilled water. Active dry yeast was used directly without incubation.

2.3. Solid state fermentation

To investigate the growth of yeast or LAB in solid state, two groups of bran were pre-treated before fermentation.

One group, bran without autoclaving was treated as follows:

(1) 20 g of raw bran with 20 mL sterile water was mixed well and fermented without any starter (spontaneous fermentation);
(2) 20 g of raw bran with 20 mL sterile water and 0.25 g active dry yeast were mixed well and fermented;
(3) 20 g of raw bran with 20 mL of LAB suspensions was mixed well and fermented;
(4) 20 g of raw bran with 20 mL of LAB suspensions and 0.25 g yeast were mixed well and fermented.

The other group, autoclaved bran (121 °C, 20 min) was treated as follows:

(5) 20 g of autoclaved bran with 20 mL sterile water and 0.25 g active dry yeast were mixed well and fermented;
(6) 20 g of autoclaved bran with 20 mL of LAB suspensions was mixed well and fermented;
(7) 20 g of autoclaved bran with 20 mL of LAB suspensions and 0.25 g yeast were mixed well and fermented.

The moisture content of all fermented samples was 50% (W_{bran}: V_{water} = 1:1). All samples were incubated in airtight bottles statically at 37 °C for 24 h and then dried by TG 200 rapid drier (Retsch, Haan, Germany).

2.4. Nutritional compounds

2.4.1. Water extractable arabinoxylans (WEAX)

The WEAX was determined following previous study (Douglas, 1981) by extracting 0.4 g of bran samples with 20 mL of distilled water at room temperature. The extracts were centrifuged at 5000 rpm for 10 min. 100 μL of supernatant, 100 μL of distilled water and 2 mL of freshly prepared reaction solution (1 g phloroglucinol in 5 mL anhydrous ethanol, 2 mL chlorohydric acid, 110 mL acetic acid, 1 mL 17.5 g/L glucose solution) were pipetted into stoppered glass tube. The tubes were vigorously boiling in water bath for 25 min and then cooled in flowing water immediately. The absorbance was measured at 552 nm and 510 nm successively. D-(+)-Xylose was used as standard. Calculate the content of WEAX by subtraction of the absorbance at 510 nm from 552 nm and comparison of the results with a standard curve and conversion of D-(+)-xylose to pentosan with a scaling factor (0.88).

2.4.2. Phytic acid degradation rate (PAD)

The determination of phytic acid was done according to the published procedures (Buddrick, Jones, Cornell, & Small, 2014). Samples (0.1 g each) of wheat bran were extracted with 40 mL 0.5 mol/L HCl for 3 h with a magnetic stirrer at room temperature. 2 mL of the extracts were centrifuged at 5000 rpm for 4 min. 0.5 mL of supernatant and 1 mL of ammonium iron (III) sulphate solution (0.2 g $NH_4Fe(SO_4)_2{\cdot}12H_2O$ in 100 mL 2 mol/L HCl) were mixed and incubated in a boiling water bath for 30 min then adjusted to room temperature. The tubes were centrifuged at 5000 rpm for 4 min. 100 μL of the supernatant and 150 μL of 2,2-bipyridine solution (1% 2,2′-bipyridine and 1% thioglycolic acid in distilled water) were mixed and immediately measured against distilled water at 519 nm and 25 °C with a microplate reader. Sodium phytate was used as standard. Phytic acid degradation rate (PAD) was calculated as following formula: PAD (%) = (m1 − m)/m * 100, where m1 = PA content in raw bran; m = PA content in fermented brans.

2.4.3. Total phenols

Total phenols content (TPC) was analyzed according to Folin–Ciocalteu Reagent colorimetric (Kim, Tsao, Yang, & Cui, 2006) with some modification. 0.2 g of each sample was extracted twice with 10 mL of 70% methanol for 10 min. The extracts were centrifuged at 5000 rpm for 10 min and the supenatants were gathered. 100 μL of extracts and 100 μL of distilled water were pipetted into another tube. Each fraction (0.2 mL) was mixed with 1 mL of the Folin-Ciocalteu regent and 0.8 mL of 7.5% sodium carbonate (Na_2CO_3) solution. The mixture was incubated in dark at 25 °C for 1 h and then the absorbance at 765 nm was measured.