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# Effects of microfluidization on microstructure and physicochemical properties of corn bran

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ABSTRACT

Corn bran was treated by the microfluidization process and the resulting changes in its microstructure and physicochemical properties were examined. The results showed that the microfluidization process could effectively decrease particle size of corn bran and loosen microstructure of the bran matrix. This led to a significant decrease in bulk density and increases in specific surface area. The swelling capacity, water-holding capacity, oil-holding capacity, and cation-exchange capacity increased by 140%, 90%, 140%, and 90%, respectively, after a total of 8 passes through the $IC_{200}$ and $IC_{87}$ chambers. In addition, microscopic analysis revealed a gradual disintegration of original cell wall structure and the dissociation of different bran tissues as the extent of microfluidization treatment increased. Findings of this study highlighted the great potential of the microfluidization process in producing a high-quality fiber ingredient from corn bran.

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## 1. Introduction

Corn bran is an abundant but underutilized byproduct from corn milling industry. Dry-milled corn bran typically contains 70.6–86.3% insoluble fiber and 0.2–2.6% soluble fiber (Rose et al., 2010). Corn bran is also rich in phenolic antioxidants (Inglett and Chen, 2011) which have attracted extensive research efforts because many chronic diseases are believed to be closely linked to the process of oxidative damage to important biomolecules such as DNA, membrane lipids, and proteins through multiple mechanisms (Wilcox et al., 2004).

Although corn bran is probably the best source of both dietary fiber and bioactive phytochemicals among all the cereal brans (Rose et al., 2010; Vitaglione et al., 2008), incorporation of large amounts into food products is limited because of the resultant unpleasant gritty texture. Extensive particle size reduction using a traditional milling process such as ball milling or ultrafine grinding may reduce this effect; however, a combination of size reduction and material expansion would be a more effective method. Our previous study demonstrated that the microfluidization process could effectively break down wheat bran particles and expand the bran material due to the rapid release of high pressure at the end of the process (Wang et al., 2012). The expansion can loosen microstructure and increase porosity of the bran material. In the microfluidization process, the intensifier pump of a microfluidizer processor drives an aqueous suspension of solid particles at an extremely high speed through a fixed-geometry microchannel, creating high shear stress, impact force and hydrodynamic cavitation (Kasemwong et al., 2011). This process displays superior performance in terms of particle size uniformity and energy efficiency compared with the traditional high-pressure micronization technique (Chau et al., 2006) which works on a similar principle.

Particle size reduction and microstructure changes of insoluble dietary fibers can alter their physicochemical properties which are closely associated with their nutritional functionality. It was shown that particle size reduction through micronization significantly improved the hydration and oil holding capacities of insoluble fibers derived from carrot, carambola and orange (Chou et al., 2008; Wu et al., 2009). As a consequence, the micronized fibers exhibited greater cholesterol-lowering activities than their untreated counterparts. Insoluble fibers with high swelling and water holding capacity were reported to elevate digesta viscosity by decreasing the free water content in digesta and thereby retard the digestion and absorption of nutrients (Takahashi et al., 2009). By using *in vitro* colonic fermentation models, processed wheat, oat and rye bran fractions with smaller particle size increased short-chain fatty acid

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production compared to large-particle bran (Nordlund et al., 2012; Stewart and Slavin, 2009). The reason might be because the increased accessible surface area facilitated the bacterial enzymes to access fermentable carbohydrates. Previous studies on corn bran also showed that finely ground bran was more effective in lowering the plasma cholesterol concentration and was more easily fermented than bran of coarser particle size (Ebihara and Nakamoto, 2001). Additionally, the bioavailability of selected B vitamins (niacin, pantothenic acid and thiamin) to human subjects was improved with decreasing particle size of corn bran (Yu and Kies, 1993).

Our recent studies indicated that the microfluidization process was highly efficient in improving physicochemical properties (Wang et al., 2012) and antioxidant activities (unpublished data) of wheat bran. The information about the effects of this process on other cereal brans is also needed to broaden its application in producing high-quality fiber ingredients. The objective of this study was to investigate the effects of the microfluidization process on microstructure and physicochemical properties of corn bran.

## 2. Materials and methods

### 2.1. Materials and chemicals

Fine grind corn bran which was obtained from Cargill Dry Corn Ingredients, Inc. (Paris, IL, USA) was repeatedly ground using a Waring variable speed laboratory blender (Model MX-LB10S) and passed through a US standard No. 35 sieve with a nominal opening of 500 μm (Fisher Scientific Co., TX, USA). The bran samples obtained were sealed in air-tight glass containers and stored at −30 °C for future use.

Chemicals and reagents used for analysis were of analytical grade and purchased from Sigma–Aldrich (St. Louis, MO, USA) or Fluka/Sigma–Aldrich Chemie GmbH (Steinheim, Germany).

### 2.2. Microfluidization processing of corn bran

An M-110P Microfluidizer Processor (Microfluidics, Newton, MA, USA) was used for the processing. The raw corn bran prepared as above was dispersed in distilled water at a ratio of corn bran: water 1:50 (wt/wt). The suspension was then processed in a Microfluidizer with three sizes of interaction chambers, i.e., 300 μm ($IC_{300}$), 200 μm ($IC_{200}$) and 87 μm ($IC_{87}$) in diameter, at room temperature. Processing pressures were 159 MPa for $IC_{300}$ and $IC_{200}$ and 172 MPa for $IC_{87}$, respectively. Interaction chambers used in this study had a "Z" shape. Bran suspensions were processed sequentially through the $IC_{300}$ for two passes, $IC_{200}$ for 1 and 2 passes, and $IC_{87}$ for 1, 3 and 5 passes. One pass meant the sample went through the machine one time. The processed bran samples after designated passes were collected by centrifugation and freeze dried. The moisture content of the freeze-dried samples ranged from 3.5 to 5.3%. Dry samples were sealed in air-tight glass containers and stored at −30 °C for analysis. All experiments were performed in duplicate.

### 2.3. Analysis of particle size distribution

Analysis of particle size distribution was performed using a computer controlled bluewave laser particle analyzer (Microtrac, Montgomeryville, PA, USA). Particle size distribution parameters included calculated surface which provides an indication of the specific surface area; selected percentile points D10, D50, and D90 which, respectively, represent 10%, 50%, and 90% of the volume that is smaller than the size indicated; mean diameter of the volume distribution, and standard deviation (SD) which is one measure of the width of the particle size distribution. Each measurement was conducted in triplicate.

### 2.4. Light microscopy

The dry corn kernels were soaked overnight in distilled water and dried with a paper towel. The bran tissues with small amount of adhering endosperm were longitudinally sectioned using a sharp razor blade. The tissue samples were further free-hand sectioned transversely. The free-hand section of bran tissue, prehydrated ground raw and microfluidized corn bran samples were individually mounted in a drop of distilled water on a standard microscope slide and covered with a coverslip. All slides were examined in bright field using a Nikon Eclipse 55i light microscope (Nikon. Corp., Tokyo, Japan) equipped with a digital camera (Nikon Digital Sight DS-Fi1-L2) and digitized images were processed using Adobe Photoshop CS5 (Adobe Systems Inc., CA).

### 2.5. Confocal laser scanning microscopy

Confocal laser scanning microscopy (CLSM) was used to characterize the microstructure changes of corn bran after microfluidization treatment. The 3-D confocal images were acquired using an inverted microscope (Axio Observer Z1, Zeiss) with attached Zeiss LSM 700 META imaging system (Carl Zeiss, Jena, Germany). The native fluorescence (endogenous autofluorescence contained in the bran sample) was detected using two lasers as excitation sources and appropriate long pass filters (a UV argon ion laser, $\lambda_{exc} = 405$ nm; and a blue argon ion laser, $\lambda_{exc} = 488$ nm). Images were obtained serially by scanning the section with each laser beam in combination with an appropriate emission filter. Series of confocal images were recorded separately for each detection channel. Overlaying of the recorded images allowed simultaneous visualization of structures.

### 2.6. Measurement of bulk density

A weighed amount of corn bran sample (5.0 g) was carefully added into a calibrated 25 ml graduated cylinder. Pressure was applied manually until there was no further decrease in sample volume. The packed density was calculated as dry weight of sample per unit volume of sample (g $ml^{-1}$).

### 2.7. Measurement of hydration properties

Hydration properties including swelling capacity and water holding capacity were measured using previously reported methods (Chau and Huang, 2003) with minor modifications.

#### 2.7.1. Swelling capacity

Swelling capacity is defined as the settled bed volume occupied by a known amount of fiber ingredients under the conditions used. A weighed amount of dry bran sample (0.5 ± 0.001 g) was added into distilled water (20 ml) in a 25-ml graduated cylinder. The sample was stirred gently with a spatula to eliminate trapped air bubbles. The cylinder was then covered with parafilm and left undisturbed at room temperature overnight for complete hydration. The volume (ml) occupied by the settled sample was recorded. Swelling capacity was expressed as volume of swollen sample (ml) per gram dry sample.

#### 2.7.2. Water-holding capacity

Water-holding capacity is defined as the amount of water retained by a known amount of fiber ingredients under the conditions used. A weighed amount of dry bran sample (0.5 ± 0.001 g) was added into 20 ml distilled water in a 50-ml centrifuge tube. The sample was stirred and allowed to hydrate at room temperature for 24 h. After centrifugation at 2000 × g for 10 min, the supernatant