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Effect of corn bran particle size on rheology and pasting characteristics of flour gels ☆

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ABSTRACT

Dietary fiber in corn bran is known for its beneficial effects on human health and nutrition. Corn bran substitution has shown to affect batter viscosity, and volume, crumb grain, color, and texture of cakes. Purified food-grade corn bran was milled to pass through 80, 100 and 120 mesh sieve, resulting in corn bran powder of 177, 149 and 125 μm particle size, respectively. Blends of flour and 0%, 20%, 30% and 50% corn bran powders were used in the study. Reducing particle size of corn bran significantly increased hydration capacity of corn bran. Increasing corn bran in blends reduced the pasting profile of blends. The elasticity of gels decreased with increased corn bran replacement. This study will improve human health by characterizing the effects of functional ingredients in baked foods, and benefit the bakery industry by generating new understanding of products that offer healthy alternatives.

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1. Introduction

Development of wholesome fiber rich food products with acceptable functional and sensory quality is a major industrial concern, seeking to capture consumer's interest in healthy and functional foods. A number of studies have been made to increase fiber content in baked goods by addition of supplements from fruits (Chen et al., 1988; Wang and Thomas 1989; Carson et al., 1994; Sudha et al., 2007; Grigelm-Miguel and Martin-Belloso, 1998); legumes (Grigelm-Miguel and Martin-Belloso, 1998; Sosulski and Wu, 1988; Daubenmir et al., 1993; Collins and Post, 1981; Collins et al., 1982); psyllium (Park et al., 1997; Czuchajowska et al., 1992; Laurikainen et al., 1998); and grain by-products (Sekhon et al., 1997; Hudson et al., 1992; Newman et al., 1990; Rasco et al., 1990; Liu et al., 2011; Chaudhary and Weber, 1990; Rasco and Dong, 1992; Burge and Duensing, 1989; Gomez et al., 2010; Singh et al., 2012). Most of these studies showed that final products had low volume and acceptability at higher levels of enrichment.

Particle size is considered an important criterion for the raw ingredients and a major factor affecting the quality and taste of final food products. Particulate size is the most important determinant of functional characteristics of whey protein concentrates (Onwulata et al., 2004). Kerr et al. (2000) reported significant effects of particle size on the functionality of cowpea flour. Particle size is important in maintaining proper textural properties in extruded products as the particle size of the components used in many extruders feed formulations can vary greatly (Garber et al., 1997; Desrumaux et al., 1988).

The objective of this study was to elucidate the effects of corn bran particle size on its functional and pasting properties, and rheology of flour gels.

2. Materials and methods

2.1. Preparation of corn bran

Food-grade corn bran was obtained from Honeyville Food Products, Inc. (Brigham City, UT, USA). Bran was then size-separated using a sieve shaker (Ro-Tap Model RX-29, Laval Lab Inc., Laval, Canada) equipped with 30-, 45-, 60- and 80-mesh sieve. Bran samples (1.4 l; 616 g) were placed in a #1 high alumina grinding jar to which 50%/30%/20% by weight of 0.6/1.0/1.9 cm magnesia stabilized zirconia grinding media were added and placed on the rollers of a model #801CVM Long Roll Jar Mill (jar, media and mill were from US Stoneware Company, East Palestine, Ohio, USA) for 12 h at 60 rpm to produce the milled bran.

Milled bran was size-separated using a Ro-Tap® SX 30-16 test sieve shaker (W.S. Tyler Industrial Group, Mentor, OH) fitted with 100- and 120-mesh sieves (Humboldt Mfg. Co., Schiller Park, IL)

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and shook for 30 min. Fractions recovered were through the 45-, 80- and 120-mesh sieves.

2.2. Hydration of corn bran

Hydration property of dietary fiber is an important determinant of stool bulking effect in human gastrointestinal tract, which is due to the manner in which water is held, rather than the absolute amount held. Strongly bound water has been found to have no effect on stool weight, whereas loosely associated water readily increases stool weight (Collins et al., 1982). The maximum amount of water that the fiber can hold is a function of the fiber source and its chemical, physical and structural characteristics.

2.2.1. Swelling capacity

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 (Raghavendra et al., 2004).

Accurately weighed dry sample (1.0 g) was placed in a 10 ml graduated cylinder, 8 ml water was added and it was hydrated for 18 h. After 18 h, the final volume attained by fiber was noted. Swelling capacity was calculated by dividing the volume of sample after 18 h by the dry weight of original sample and reported as milliliter/gram.

2.2.2. Water retention capacity

Water retention capacity is defined as the quantity of water that remains bound to the hydrated fiber following the application of an external force (pressure or centrifugation) (Raghavendra et al., 2004) Accurately weighed dry sample (1 g) was taken in a graduated centrifuged tube, 8 mL of water was added and it was hydrated for 18 h, centrifuged (3000 g; 20 min) and the supernatant solution was removed. The hydrated residue weight was recorded. Water retention capacity was reported as milliliter/gram.

2.3. Pasting properties of corn bran

Pasting properties of corn bran were studied using Rapid Visco Analyzer Model RVA-4 (Newport Scientific Ltd, Warriewood, Australia). Thermocline version 2.2 software package was used to obtain and analyze the data. Corn bran throughs of 45-, 80- and 120-mesh sieve were used as 20%, 30%, and 50% blends with cake flour. A 12% suspension of flour-bran blend in water was stirred at 960 rpm in disposable aluminum cans for 10 s and then the speed adjusted to 160 rpm. The suspension was equilibrated at 50 °C for a minute, heated to 95 °C at a rate of 12 °C/min., held at 95 °C for 2.5 min, cooled at 12ºC, and held at 50 °C for 2 min. The pasting temperature, peak viscosity, time to peak, breakdown, minimum viscosity, setback and final viscosity were recorded. The paddle was carefully removed from the can. Gel can was stored at 4 ºC overnight covered with paraffin film for further analysis.

2.4. Texture of corn bran gel

Texture of bran gel after RVA analysis was evaluated by measuring the maximum penetration force (g) using Texture Analyzer (TA XT2i Texture Technologies Corporation, Scarsdale, NY, USA.) reporting it as firmness of gel. The analyzer was set to run at a speed of 1 mm/s after a trigger force of 5 g was attained, the probe penetrated into the gel for a depth of 4 mm.

2.5. Rheological of corn bran gels

The rheological properties of bran gel were characterized on a Rheometrics LS1 controlled stress rheometer (TA Instruments, New Castle, DE, USA). Small amplitude oscillatory shear flow measurements of the storage modulus, G′, the loss modulus, G″, and the loss tangent, tan $\delta = G''/G'$ were obtained using 50 mm diameter parallel plates. Batter was placed between the plates and the gap was adjusted to 2 ± 0.5 mm. The batter was rested between plates for 1 min before testing so that residual stresses would relax. The frequency dependence of the moduli (G′ and G″) was measured (0.1–100 Hz) and 0.1% strain. The temperature was controlled at 25 ± 0.1 °C by a circulating water bath, and humidity covers were used to prevent drying of the sample.

2.6. Statistical analysis

All measurements were conducted three times, mean values are presented. Statistical analysis of data was carried out using PROC GLM in SAS Version 9.2 for PC Windows. *F*-test value was obtained and a multiple comparison test was performed on the means, using Duncan′s Multiple Range Test at 0.05 levels.

3. Results and discussions

Particle size distribution of corn bran is presented in Table 1. Particle sizes of corn that passed through US 120-, 80-, 45-mesh sieves after grinding were 125, 177, and 354 μm, respectively.

3.1. Effect of corn bran particle size on hydration properties of corn bran

Corn bran particle size effect on hydration properties and its comparison to flour are presented in Fig. 1. Corn bran had significantly higher swelling capacity (SC) and water retention capacity (WRC) than cake flour.

Table 1
Particle size distribution of corn bran.

Particle size (μm)	Total weight (%)
599	0.6 ± 0.2
354	61.2 ± 1.9
251	29.9 ± 0.2
178	5.6 ± 0.6
< 178	2.1 ± 0.6

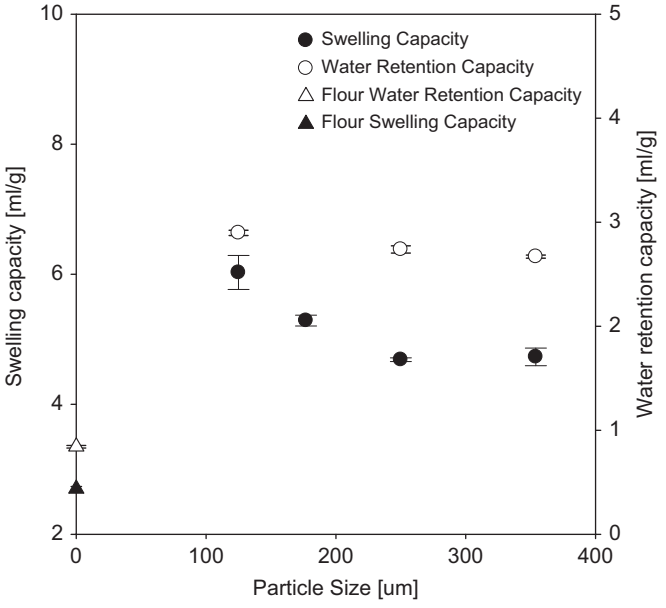

Fig. 1. Effect of particle size on hydration properties of corn bran.