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Grinding of maize: The effects of fine grinding on compositional, functional and physicochemical properties of maize flour

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ABSTRACT

The particle size of maize flour has a significant effect on its functional and physicochemical properties. In this study, maize grits were ground for various time intervals (3.5, 4, 5, 6, 10 and 14 min), and grinding effects on compositional, functional and physicochemical properties of maize flour were evaluated by using rapid visco analyzer (RVA), differential scanning calorimeter (DSC), sodium dodecyl sulphate polyacrylamide gel electrophoresis (SDS-PAGE) and other chemical methods. The results showed that grinding could effectively pulverize the flour particles. As particle size decreases, the damaged starch and amylose content, gelatinization degree, hydration capacity, water solubility index and water absorption index were significantly ($P < 0.05$) increased. Grinding caused reduction in trough viscosity, final viscosity and peak time and an increase in peak viscosity and breakdown of maize flours. The starch isolated from different time treated maize flour exhibited a decrease in transition gelatinization temperature (T_o, T_p and T_c) and gelatinization enthalpy, whereas grinding treatments have no effects on protein content and protein primary structure of maize flour. Grinding treatment changes in the damaged granules and particle size distribution are responsible for the different maize flour properties.

1. Introduction

Maize or corn (*Zea mays* L. ssp. *mays*) is a cereal grain that is widely cultivated at all over the world. The corn has been widely used as feed for livestock, forage, silage and grain, and it is also a kind of important industrial raw material, with many industrial uses including transformation into plastics, syrups and alcohol for biofuels. In addition, corn is also widely used for human nutrition because of its specific physicochemical properties such as high starch content, proteins with a low content of α-gliadin fraction, no gluten, dietary lipids, hypoallergenic, many valuable compounds (flavonoids, rutin), trace elements, dietary fiber and delicate flavor (Wójtowicz et al., 2013). It is flexible in the production of food products, such as popcorn, polenta, tortillas, mush, breakfast cereals, snack foods, bakery products, cornmeal, pastas, etc. Besides carbohydrates and protein fortification, maize also provides many other nutritional benefits including organic compounds and minerals with potential benefits to health. These compounds may act as antioxidants, cofactors for antioxidant enzymes or indirect antioxidants, (Hänsch and Mendel, 2009). .

Grinding is a unit operation widely used in the food industry, and it is the common method for food powder processing (Lee et al., 2013). Grinding involves a gradual size reduction process to obtain a suitable size of particles for food processing. Particle size reduction can lead to a great many influences on structure and surface area of particles, and brings some new outstanding physicochemical characteristics due to the increase of a particle's surface area (Protonotariou et al., 2014).

However, although grinding is necessary to reduce particle size, size reduction induced by grinding is accompanied by an increased level of starch damage by the disruption of the granular structure, which negatively affects flour performance in many final products (Yamazaki, 1959; Tran et al., 2011). It has been suggested that flour particle size, damaged starch and protein quality and quantity have effects on the baked products (Guttieri et al., 2001). Starch damage can alter the granule surface characteristics by increasing the hydrophilic bonds and thus increase the water absorption capacity of the flour (Saad et al., 2009). Furthermore, a certain amount of

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damaged starch granules exhibits a higher swelling and gel formation ability due to the destruction of the forces which prevent granules from swelling in water (Tester, 1997). Nowadays, eating habits of people all over the world have been changed from eating traditional foods to eating non-traditional foods, such as fast food and extruded snack foods, etc., which are normally made with maize grains or cornmeal. In recent years, maize flours have deepened understanding of the development of gluten-free products for people with coeliac disease, whom are intolerant to certain peptides present in gluten, a protein found in the endosperm of some cereals such as wheat, barley and rye (de la Hera et al., 2013a). It is well known that the milling process and the resulting particle size distribution of cereal flours affects the quality characteristics of the food product (Bolade et al., 2009; de la Hera et al., 2013a). In the present study, the maize grit was ground at various time intervals to produce maize flour with different particle diameters, then the effect of particle size, main composition, protein components, molecular weight (Mw) distribution of corn protein, gelatinization and pasting properties, and the functional characteristics such as gelatinization degree, hydration capacity, water solubility index and water absorption index were investigated. The information obtained from this study will be helpful in the development of maize-based products.

2. Materials and methods

2.1. Materials

Corn grit with a diameter about 1.5–2.5 mm was purchased from the local market (processed by Xi'an Baqiao Jing Cang Bao Corn Development Products Factory, Xi'an, China), with starch, protein, fat and moisture contents of 72.33%, 8.54%, 0.24% and 16.9% (dry basis), respectively. Other chemical reagents used in this study were of analytical grade.

2.2. Preparation of corn flours with different particle size

Corn grits were ground using a high-speed universal grinder (Laboratory-type, FW-400A, Beijing Zhong Xing Wei Ye Instrument Co., Ltd, Beijing, China), and the roll speed was 26000 rpm. For the preparation of ground kernels with different particle diameters, grinding was carried out on 250 g of corn grits for 3.5, 4, 5, 6, 10 and 14 min respectively.

2.3. Determination of particle size distribution of the corn flours

The particle size distribution of corn flour was analyzed by using a laser light-scattering particle size analyzer (Mastersizer-2000, Malvern Instruments Ltd., Worcestershire, UK). Ground corn flours samples (about 250 mg) were dissolved in 5 mL distilled water and mixed using a magnetic stirrer for 0.5 min at room temperature before measurement. The focal length of 100 mm and obscuration level of 20% were maintained during measurements on the analyzer. At least three parallel analyses were carried out for each sample.

2.4. Composition determination of corn flour

The amylose starch content, damaged starch content and protein content were determined by using the Chinese national standard methods GB/T 15683-2008 and 9826-2008 (Chinese national standard, 2008), and GB/T 5009.5-2010 (Chinese national standard, 2010), respectively, and the results were reported on a dry basis.

2.5. Determination of functional properties

2.5.1. Determination of gelatinization degree

The degree of gelatinization was measured according to Li et al. (2011), and with little modification. Corn flour samples (150 mg) were put into two graduated test tubes, respectively, one for preparing completely gelatinized samples and the other for test samples. A third empty tube was used for a blank test. Acetic acid–sodium acetate buffer (15 mL, pH 4.8) was individually added into three test tubes. The test tube with completely gelatinized sample was put in boiling water first for 1 h and with a shaking gently, then these tubes were heated at 40 °C water for 1 h after dropping 1 mL debranching enzyme (200 U/mL, sigma) and gently shaking after every 15 min. Thereafter, 2 mL $ZnSO_4 \cdot 10H_2O$ and 1 mM 0.5 N NaOH were added, and then enough deionized water was added to make a constant volume of 25 mL. The slurry was filtered with quantitative filter paper. All samples were heated in boiling water for 6 min after adding 0.1 mL filtrate and 2 mL sodium diethyl dithiocarbamate. Three samples were heated in boiling water for another 2 min after adding 2 mL Hager's picric acid reagent. Deionized water was added to a total volume of 25 mL after cooling and shaking the tubes sufficiently. The absorbance value (ABS) at 420 nm against a water blank with a Shimadzu UV-2550 spectrophotometer (Shimadzu Corporation, Kyoto, Japan) was measured. Degree of gelatinization (DG) was calculated as follows:

$$\mathrm{DG}(\%) = \frac{\text{ABS of test sample} - \text{ABS of control}}{\text{ABS of complete gelatinization sample} - \text{ABS of control}} \quad (1)$$

2.5.2. Determination of hydration capacity

The hydration capacity (water binding capacity) of ground corn flours was determined accordingly with the application of AACC 56-20 (AACC, 2000) standard methods.

2.5.3. Determination of water solubility index and water absorption index

The water absorption index (WAI) and water solubility index (WSI) of ground corn flours were determined according to the method of Anderson et al. (1969) using the centrifugal method with some modification. A corn flour (1.5 g, dry basis) sample was dispersed in water (18 mL) at 30 °C with gentle stirring for 30 min, and then centrifuged at 4000 rpm for 20 min. The supernatant was placed into an aluminum can and dried in the hot air oven at 105 °C for 3 h. The WAI and WSI were calculated as follows:

$$\mathrm{WAI}(g/g) = \frac{\text{Weight of wet sediment}}{\text{Dry weight of sample}} \quad (2)$$

$$\mathrm{WSI}(g/g) = \frac{\text{Weight of dry solid in supernatant}}{\text{Dry weight of sample}} \times 100 \quad (3)$$

2.6. Determination of pasting properties

The pasting properties of each corn flour suspension were measured using a rapid visco analyzer (RVA, Super 3, Newport Scientific Instrument and Engineering, Australia). Ground corn flours (3.0 g, db) were directly weighed into an RVA canister, followed by the addition of distilled water (25.0 ml). The paste was held at 50 °C for 1 min before heating to 95 °C at a constant rate of 12 °C/min, and then it was held at 95 °C for 2.5 min. After that, it