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Protein characteristics of Chinese black-grained wheat

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Abstract

Protein properties of black-grained wheat (BGW) were compared with those of five carefully selected wheat controls (Taifen 1, Klasic, Yecora Rojo, Glenlea and Anza) in order to find potential uses for BGW. Protein content, mixing properties, gluten index and amino acid composition were measured. BGW whole meal had a higher protein content (17.71%) than was found in controls. Gluten index of BGW flour (69.74) was generally low compared to controls. Mid-line peak times determined using mixograph were significantly longer ($p < 0.05$) for most controls (5.41–6.27 min) in comparison to BGW flour (<3.00 min). Dough stickiness (223.76 g) of BGW was somewhat stronger than that of Klasic and CES flours. Total essential amino acid and total amino acid contents in whole meal were 4.45% and 15.74%, respectively, for BGW. The amino acid composition was relatively stable after high-temperature drying of wet BGW gluten. In vitro protein digestibility of BGW wheat meal was the lowest.

Keywords: Wheat; Black wheat; Protein; Digestibility; Gluten index; Mixing properties; Amino acid composition; Electrophoresis

1. Introduction

Black-coloured foods have a special place in Chinese food culture and enjoy wide acceptance in the marketplace. Many studies on black-seeded cereals have proven them to be associated with health and improved nutrition, and therefore form the basis for high value products, for instance, popular food products from black-grained rice and black-grained soybean (Lai, 1995; Lai & Zhang, 1995). In fact, since the 1970s the Wheat Biotechnology Laboratory of the Institute of Crop Genetics, Shanxi Academy of Agricultural Science, has been engaged in research leading to the development of black-grained wheat from previously existing blue and purple lines (Sun et al., 1996, 1999). After over 20 years effort a new black-grained wheat variety (BGW) has been developed and it is now available for utilization as a new raw food material for value-added products (Bai et al., 2000, 2002; Li, Sun, & Ren, 2004; Yang, Li, Chu, & Sun, 2001). Elemental Se content of BGW was high up to 1.04 mg/kg in comparison with 0.26 mg/kg of common wheat (Bai et al., 2000). Seed colour of BGW is visually black and the grain size is comparable to that of the controls chosen in the current investigation. The colour of wheat, usually white or red (although purple is known), is related to pigments in the seed coat. Basic wheat pigments include carotenes, xanthophylls and phenolic compounds (Beta, Nam, Dexter, & Sapirstein, 2005; Kruger & Reed, 1988). The main pigment component of BGW seed was an anthocyanin phenolic compound (Sun, Sun, & Wang, 2004). Anthocyanins are known to exhibit good antioxidant activity

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(Awika, Rooney, & Waniska, 2004). While there are several chemical components in wheat, traditional nutrients of major importance include starch and proteins. Among cereals, only wheat has the ability to form a strong, cohesive dough due to the uniqueness of its proteins.

Evaluation of protein properties includes determination of amino acid composition, molecular weights, protein digestibility, and gluten strength. Protein digestibility is essentially a measure of the rate of in vitro protein hydrolysis by digestive enzymes. It is also a factor most likely to affect amino acid availability since proteolysis is influenced both by the linear amino acid sequence and the tertiary structure of a protein (Gopal, Monteiro, Virupaksha, & Ramachandra, 1988). Gluten properties are associated with the end use of wheat flour. The total gluten content and composition in the wheat flour protein is of interest in the nutritional evaluation of the wheat accessions (Abdel-Aal, Hucl, & Sosulski, 1995). The gluten index is used as a measure of gluten strength. The objective of the study was to determine the protein properties of BGW and compare them to five carefully selected wheat controls. The results will be used to identify potential uses for BGW as raw material for food production.

2. Materials and methods

2.1. Materials

The samples used for the study comprised one black-grained wheat and five carefully selected commercial wheat reference samples used in bread and noodle production. Chinese black-grained wheat (BGW) and one commercial reference Taifen 1 wheat (TW) samples were obtained from Institute of Crop Genetics, Shanxi Academy of Agricultural Science, Taiyuan, China. Three commercial US cultivars, Anza wheat (AW, California), Klasic wheat (KW, California) and Yecora Rojo wheat (YRW, California), were supplied by the University of California, Davis. One commercial Canadian extra strong wheat Glenlea (GW, Manitoba) sample was obtained from Canada. All reference wheat samples with the exception of TW and AW are used for bread-making. TW and AW are used for noodle production.

Wheat flour was obtained by milling grain with a Quadrumat Junior laboratory mill (Brabender OHG, Duisberg, Germany). After separating wheat bran, wheat flour extraction rate ranged from 70% to 80%. Wheat whole meal was prepared by milling wheat grain with a Cyclone sample mill (Udy Corp., Fort Collins, Colorado, USA). Wheat whole meal included flour and bran.

Freeze-dried (FD) gluten was obtained by hand-washing the flour dough according to the method of Qiu (1998). Wet gluten was immediately frozen in liquid nitrogen and freeze-dried. Main steps during hand-washing were: first making 100 g flour to dough by adding adequate water (25–35 mL depending on the flour), resting the dough in a covered container for 2 h, and finally washing dough in 2000 mL water for 15 min at room temperature to remove starch. The washings were repeated three times.

Wet gluten yield and gluten index were determined by the machine washing Method 38-12 of the AACC (1995). Preparation of wet gluten was according to the method of Perten (1990). Briefly 10 g flour was mixed for 20 s with 4.8 mL of 2% NaCl solution, followed by washing for 5 min with 2% NaCl solution at a flow rate of 50–60 mL/min on a special 88-μm sieve using a Perten Glutomatic Gluten Index machine (Perten Instruments AB, S-141 05 Huddinge, Sweden). Afterwards, the wet gluten piece was centrifuged at 6000 rpm for 1 min on a special 600-μm metallic sieve using a Perten Centrifuge 2015 machine (Perten Instruments AB, S-141 05 Huddinge, Sweden). Wet gluten samples obtained from both sides of the sieve after centrifugation were dried at 150 °C (high temperature drying) using a special Perten Glutork 2020 dryer. The gluten that remained on top of the sieve after centrifugation was labeled as high temperature-dried (HTD) gluten 1. The gluten that passed through the sieve was labeled as HTD gluten 2. Total protein content of the above samples was analyzed by the AACC Method 46-11A (1995).

2.2. In vitro protein digestibility

Pepsin (Pepsin porcine gastric mucosa, 800–2500 units/mg protein, Sigma Chemical Co., St. Louis, USA) and trypsin (Trypsin from bovine pancreas, $\geqslant$10,000 BAEE units/mg protein, Sigma Chemical Co., St. Louis, USA) were used for in vitro protein digestibility (IVPD) studies. IVPD was determined by an improved method of Ramachandra, Virupaksha, and Shadaksharaswamy (1977) and Gopal et al. (1988). For pepsin, 50 mg of whole meal or dry gluten samples were weighed into a series of test tubes and 5.0 mL of 0.075 N HCl and 0.5 mL of pepsin solution (2.0 mg/mL) in 0.075 N HCl were added to each tube. The tubes were incubated at 37 °C and enzyme action was stopped at 30, 60 min and 24 h by addition of 5 mL of 10% (w/v) trichloroacetic acid (TCA). The reaction mixture was filtered through Whatman No. 1 filter paper, and the residue on the filter was washed with warm water. Nitrogen in the residue was estimated by the micro-Kjeldahl procedure (AACC Method 46-11A, 1995). For trypsin, the same IVPD procedure was conducted essentially as described for pepsin, except that incubation was in 0.1 M phosphate buffer, pH 7.6. IVPD was obtained by calculating the