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Effects of fine grinding of millfeeds on the quality attributes of reconstituted whole-wheat flour and its raw noodle products

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ABSTRACT

Effects of millfeed particle size on the quality of whole-wheat flour (WWF) and raw noodles were investigated. Four ranges of particle size distribution of millfeeds from hard red spring (median diameter: 307, 260, 225, and 178 μm) and hard red winter (median diameter: 319, 274, 235, and 185 μm) were obtained by fine grinding. For both wheat classes, the CIE L^* values of WWF decreased and a^* and b^* values increased with the reduction of millfeed particle sizes. WWF with finer millfeeds exhibited higher PPO activity than that with coarser millfeeds. RVA analysis showed that peak viscosity, trough, and final viscosity of WWF significantly decreased as the particle size of millfeeds reduced, while breakdown and setback values revealed no obvious trend. Reducing the particles of millfeeds not only significantly increased the Farinograph stability time of WWF dough, but also improved the whole-wheat noodle (WWN) brightness (L^*) at both 0 and 24 h. Texture profile analysis of cooked noodle indicated that hardness, springiness, cohesiveness and resilience values all significantly increased as the particle sizes of millfeeds were decreased. These results suggest that reduction of millfeed particle sizes before reconstituting WWF could provide beneficial effect on the quality improvement of WWN.

1. Introduction

Wheat bran and germ are major sources of dietary fiber and phytochemicals widely used in the food industry (Vetter, 1988). Since long-term intake of a diet high in dietary fiber and bioactive substances provides beneficial effects on the reduction of cholesterol levels and the risk of colon cancer, the importance of wheat bran and germ has increasingly been recognized in recent years (Dykes & Rooney, 2007; Lynnette & Philip, 1996; Okarter & Liu, 2010). Several studies have focused on the effect of wheat bran and germ addition on the quality of cereal products, such as bread, biscuit, and spaghetti (Chen et al., 2011).

Noodle is one of the most important parts in the diet of Asian people; an average of 20–50% of the total wheat flour consumed in many Asian countries is in the forms of noodles (Hou, 2010a). It has also become popular in many countries outside of Asia. To meet the growing demand for low-calorie and healthy food, the development of noodles made from whole-wheat flour (WWF) with high content of dietary fiber should be an effective way to promote high-fiber food consumption and change the dietary pattern of many consumers. Several studies have reported on the effect of grain bran addition on noodle properties. Reungmaneepaitoon, Sikkhamondho, and Tiangpook (2006) reported that substitution of wheat flour in noodle formulation with oat bran and oat bran extruded flour at 5, 10, and 15 g/100 g levels affected the physical, chemical, textural and sensory properties of instant fried noodles. Sievert, Pomeranz, and Abdelrahman (1990) observed that up to 8 g/100 g wheat bran imparted a brown color and a slightly gritty mouthfeel to Japanese udon noodles, and the texture of cooked noodles was negatively affected at this level of bran addition.

Wheat bran particle size is an important factor influencing the dough mixing properties and product quality. Zhang and Moore (1997) reported that fine wheat bran with mean particle size of 278 μm reduced dough mixing time and mixing tolerance compared to coarse bran with mean particle size of 609 μm, while Li, Kang et al. (2012) reported that the whole-wheat bread made from WWF of average particle size of 96.99 μm had better baking quality than those made from WWF of two other medium particle sizes, 50.21 and 235.40 μm. As of today, the effect of bran particle size on dough rheological properties and bread baking quality is still being studied by many researchers from different perspectives. Chen et al. (2011) investigated the effect of particle sizes (1.5–

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2 mm, 0.43–1 mm, and 0.16–0.43 mm) and addition levels (5–20 g/100 g) of wheat bran on the quality of dried white Chinese noodles (DWCN) by sifting and further grinding. The results demonstrated that the textural properties and sensory quality of DWCN showed a downward trend with increasing particle sizes, but there was no significant difference in the effect of particle size on the pasting properties of blends of wheat flour and bran. Besides this publication, there is little scientific information available on the impact of bran particle size distribution on the quality of Asian noodles, especially whole-grain noodles.

Millfeeds are coarse fractions after straight-grade flour (refined flour) is collected from the mill, and include wheat bran, germs, and some residual flour adhering to the bran and germs. To make WWF, millfeeds are further ground into desired granulations and blended with refined flour in the same proportions as yielded in the milling process. The objective of this research was to investigate the effect of millfeed particle sizes on the quality of whole-wheat raw noodles. More specifically, the color, polyphenol oxidase activity, starch pasting and dough mixing properties of reconstituted WWFs of varying millfeed particle sizes were determined and the color and textural parameters of whole-wheat noodle were evaluated with the expectation that the results could provide valuable direction/guidance for further quality improvement of whole-wheat noodles.

2. Materials and methods

2.1. Materials

Two U.S. wheat classes, hard red spring (HRS) and hard red winter (HRW), were collected from export cargos by the Federal Grain Inspection Service (FGIS, Portland, Oregon). Protein contents of HRS and HRW were 15.56 g/100 g and 13.45 g/100 g (dry basis), respectively. The two samples were conditioned to 16 g/100 g moisture and milled into flour on a pilot-scale Miag Multomat mill (Buhler, Inc., Braunschweig, Germany) at the Wheat Marketing Center (Portland, Oregon), with straight-grade flour extraction rate of 71.63 g/100 g for HRS and 70.42 g/100 g for HRW.

2.2. Preparation of millfeeds

The resulting bran, shorts, red dog fractions were collected from the mill and blended according to their respective yields during milling to obtain millfeed fractions (original millfeeds). Millfeeds were further ground for one to four times using a Perten 3100 laboratory mill (Perten instruments, Sweden) equipped with a 0.8 mm mesh to achieve varying particle sizes. Various WWFs were prepared by combining fine-ground millfeeds with the straight-grade flour in accordance with their respective yields during milling. The particle size distributions of original millfeeds, fine-ground millfeeds, and reconstituted WWFs were determined using a Ro-Tap testing sieve shaker (WS Tyler Incorporated, USA). The mass median particle diameter was measured as described by Sanz Penella, Collar, and Haros (2008) with the following formula:

$$\text{Mass median particle diameter}(\mu\text{m}) = \sum[\text{sieve average particle size}(\mu\text{m}) \times \text{relative particle weight}(\text{g}/100\ \text{g})]/100$$

2.3. Assay of polyphenol oxidase activity

Polyphenol oxidase (PPO) activity of WWF samples containing millfeeds of varying particle size distributions was determined according to the method described by Anderson and Morris (2001) with some modifications. L-DOPA (L-dihydroxyphenylalanine) was used as the substrate of PPO in the measurement. Whole-wheat flour (0.2 g) was placed in a 15 mL centrifuge tube and 10 mL of 10 mmol/L L-DOPA in 50 mmol/L MOPS buffer (pH = 6.5) was added. After 10 s stirring on a touch mixer (Model 232, Fisher Scientific, Canada), the slurry was incubated at room temperature (22 °C) for 1 h on a rotating mixer (10 r/min) (Labquake model 415110, Barnstead/Thermolyne, Dubuque, USA), and centrifuged at 8000 × *g* for 3 min. The absorbance of the supernatant was measured using a spectrophotometer (Spectronic 20D, Milton Roy Company, Rochester, USA) at 475 nm. The blank sample was assayed without L-DOPA substrate. The PPO activity was calculated as difference in the absorbance of test sample and the blank, and expressed as Δ475/min·g flour.

2.4. Flour pasting properties

The pasting properties of starch in WWF samples were determined with a Rapid Visco Analyser (RVA, Model Super-3, Newport Scientific, Australia) using the AACC International Approved Method 76-21. 3.5 g flour sample (14 g/100 g mb) and 25 mL of deionized water were mixed to form slurry that was homogenized using the plastic paddle right before the RVA test. The test was conducted in a programmed heating and cooling cycle, and the RVA results were expressed in rapid visco units (RVU).

2.5. Farinograph water absorption and stability time measurements

The effect of millfeed particle size distribution on dough rheology during mixing was determined by a Farinograph (Brabender, Duisburg, Germany), following the AACC International Approved Method 54-21. Parameters measured were flour water absorption (percentage of water required to yield dough consistency of 500 BU) and stability time (time that dough consistency remains at 500 BU).

2.6. Preparation of whole-wheat raw noodles

Whole-wheat flour containing original millfeeds was found not suitable for producing noodles because the coarse bran particles severely disrupted the integrity of noodle texture, and caused too much breakage of noodle strands during cooking and had very rough and gritty mouthfeel when eating. Therefore, only reconstituted whole-wheat flours that contained fine-ground millfeeds were used to make noodles in the experiment. The fresh raw noodles were prepared through mixing and sheeting on a pilot-scale noodle line according to the procedure described by Hou (2010b). Whole-wheat flour (800 g, 14 g/100 g mb) was weighed and placed into a pilot-scale FR-E700 noodle dough mixer (Tokyo Menki Co., Ltd., Tokyo, Japan), and the correct amount of salt solution was added to achieve flour–water–NaCl weight ratio of 100:35:1.2. The blend was mixed for 2 min at 90 r/min, followed by mixing for 10 min at 120 r/min. After resting for 30 min in a covered container, the dough was passed through a pilot-scale noodle machine (WR8-100, Tokyo Menki Co., Ltd., Tokyo, Japan), and the final thickness of the noodle dough sheet was calibrated to 1.20 ± 0.03 mm after sheeting through six pairs of rollers. The noodle sheet was slit into 2.5 mm-wide and 300 mm-long strands with a #12 square type slitter. The fresh raw noodles were stored in plastic bags at 22 °C before analysis.

2.7. Color measurement

A Chroma meter (Konica Minolta CR-410, Japan) equipped with D50 illuminant was used to measure the color of WWF and noodle