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Effects of particle size on the quality attributes of reconstituted whole-wheat flour and tortillas made from it

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ABSTRACT

The objective of this study was to examine the effects of whole-wheat flour (WWF) particle size on the quality attributes of WWF tortillas. WWF samples of different particle size distributions from commercial U.S. hard white (median diameters: 175.7, 128.6, 120.0, 108.5 and 102.4 μm), hard red winter (median diameters: 173.7, 133.6, 124.3, 110.8 and 104.2 μm) and hard red spring (median diameters: 173.7, 132.1, 124.7, 112.9, 106.3 μm) wheat classes were obtained by fine grinding of bran and shorts and re-combining with the rest of fractions. For all three wheat classes, as WWF median particle size decreased, the L* (lightness) value decreased but the adjusted damaged starch, polyphenol oxidase activity, and a* and b* values increased. Mixolab data showed that development time decreased as WWF particle size was reduced, while stability time and starch retrogradation increased. As for WWF tortilla quality, the breaking force and extensibility increased with decreasing particle size from ~175 to 129–134 μm, but diameter and thickness were not significantly affected. The results indicated that reducing the median particle sizes of WWFs from ~175 μm to ~130 μm would significantly improve the WWF tortilla quality.

1. Introduction

Tortillas are thin Mexican flatbread made from wheat flour or corn, with excellent versatility for use in many dishes. As the fastest-growing bakery product in the U.S. market, tortillas are more popular than other types of ethnic breads in America (Tortilla Industry Association, 2016). Tortillas, burritos, and tacos account for about 8% of refined grain consumption in the diet of the U.S. population (USDHHS and USDA, 2010). Given that Americans are recommended to consume at least half of their grains as whole grains (USDHHS and USDA, 2015), incorporating whole-wheat flour (WWF) into tortillas is a practical approach to introduce more whole grains into the American diet and potentially increase whole grain consumption. Although WWF can provide more health benefits (Marquart et al., 2007), the high bran content presents many quality challenges in WWF tortillas, for instance, the larger the flour particle size, the harder and less extensible dough, and less shelf-stable tortillas (Barros et al., 2010). Therefore, strategies designed to improve the quality of WWF tortillas will certainly draw the attention of food manufacturers.

Milling is an important step in WWF production. While the milling procedures for refined wheat flour are well established, there is no standard method available for WWF (Doblado-Maldonado et al., 2012). Different milling techniques (e.g., stone, roller, hammer, and plate milling) result in WWF with various particle sizes and functionalities (Prabhasankar and Rao, 2001). While the typical particle size for endosperm (the main component of the straight-grade flour) is less than 150 μm, most bran particle sizes are generally larger than 500 μm before further fine grinding process (Rodriguez and Olivares, 2007). With fine grinding of bran particles, the median bran particle sizes are reduced to 90–440 μm (Zhang and Moore, 1997; Penella et al., 2008; Cai et al., 2014; Steglich et al., 2015). Wheat bran particle size is a critical component in WWF milling, due to its considerable influence on dough properties and quality of finished products, such as breads, noodles, crackers, and pastas (Noort et al., 2010; Chen et al., 2011; Li et al., 2012; Niu et al., 2014a; Cai et al., 2014; Steglich et al., 2015; Wang et al., 2016).

Abbreviations: ANOVA, analysis of variance; AX, arabinoxylans; DS, damaged starch; DS/TS, damaged starch/total starch; HRS, hard red spring; HRW, hard red winter; HW, hard white; L-DOPA, L-dihydroxyphenylalanine; μm, micrometer; PPO, polyphenol oxidase; SG, straight grade; SRW, soft red winter; TS, total starch; WA, water absorption; WWF, whole-wheat flour.

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To our knowledge, it is largely unknown how the WWF particle size affects the tortillas quality, especially on 100% WWF tortillas. Several researchers have reported the effects of refined wheat flour or barley flour particle size on tortilla. Wang and Flores (2000) sieved and separated refined flours from hard red winter (HRW), hard white winter (HWW), and soft red winter (SRW) into four different particle size fractions (<38, 38–53, 53–75 and > 75 μm). They found that tortillas made from the medium fractions (38–75 μm) of HRW and HWW had higher protein content, longer tortilla rupture distance and better foldability than the finest (<38 μm) or coarsest (>75 μm) fractions. However, for SRW flour, protein content increased with the increase in particle size, and tortillas made from <53 μm fractions had longer rupture distance. Mao and Flores (2001) found that as refined flour geometric mean diameter particle size decreased from 63.9 to 34.2 μm (flour 1), and from 71.2 to 37.7 μm (flour 2), the flour tortillas became less stretchable, firmer, but more rollable. Prasopsunwattana et al. (2009) enriched wheat tortillas with whole barley flour (WBF) of three different average particle sizes (237, 131 and 68 μm). With a smaller WBF particle size, protein, moisture content, and mixing stability decreased, while starch content, water absorption, and farinograph peak time increased.

Therefore, it is necessary to examine the particle size effect on the quality attributes of WWF and the baking performance of tortilla products given the emerging whole grain market. Results will provide millers and tortilla manufacturers with scientific evidence of a more optimal flour particle size range to improve the quality of WWF tortilla products. The aims of this study were to produce WWFs of different particle sizes, and to examine the particle size effects on flour properties and WWF tortilla baking performance.

2. Materials and methods

2.1. Materials

Three U.S. wheat classes, hard red spring (HRS), hard red winter (HRW), and hard white (HW) commercial wheat samples were kindly provided by the Federal Grain Inspection Service (FGIS, Portland, OR) and Ardent Mills™ (Denver, CO). Protein contents of HRS, HRW, and HW wheat grains were 14.4%, 11.6%, and 12.4% (12% mb), respectively. Calcium acid pyrophosphate (Levona® Brio) was offered by ICL Food Specialties (St. Louis, MO). Sodium bicarbonate (powder ACS) was purchased from ChemProducts (Portland, OR). Salt, Crisco® vegetable shortening, and sugar were purchased from a local supermarket (Portland, OR). Sodium stearoyl lactylate (SSL) was from Corbion (Kansas City, KS). Potassium sorbate and calcium propionate were obtained from Muhlenchemie GmbH & Co KG (Ahrensburg, Germany).

2.2. Reconstituted WWF preparation

The procedures for preparing reconstituted WWFs are shown in Fig. 1. Three wheat samples were each tempered to 16% moisture level in two steps (15.5% + 0.5%) and milled into straight-grade (SG) flours of 69.93 g/100 g for HRS, 71.64 g/100 g for HRW, and 73.58 g/100 g for HW extraction rates on a pilot-scale Miag Multomat mill (Buhler, Inc., Braunschweig, Germany) at the Wheat Marketing Center (Portland, OR). Bran, shorts, and red dog fractions were collected and weighed. Yield of each fraction was expressed by the percent of its weight in the total recovered product weight. For the preparation of non-ground WWF, all mill fractions were blended according to their respective yields during milling.

To prepare for WWF of reduced particle sizes, the bran and shorts were dusted using a laboratory bran finisher (Model MLU-302, Buhler Inc., Braunschweig, Germany) to remove attached flour from them. Then bran and shorts were each ground 1 to 4 times using a Perten 3100 laboratory mill (Perten Instruments, Hägersten, Sweden). To obtain a finer particle size fraction, 4th grinding bran and shorts were each ground with a blender (Vitamix Corporation, Cleveland, OH) prior to further fine grinding for the 5th time in the Perten 3100 laboratory mill. Since there was very small difference in flour particle size when grinding 3 or 4 times, these two treatments were combined as one sample - 4th grinding. Afterwards, non-ground, 1st, 2nd, 4th, and 5th grinding bran and shorts were combined with bran-dusted flour, shorts-dusted flour, red dog fraction, and SG flour, based on their original yields during milling to obtain reconstituted WWFs (WWF-0, 1, 2, 4 and 5).

Fifty grams of each reconstituted WWF was separated by a Ro-Tap testing sieve shaker (Model R-30050, W.S. Tyler®, Mentor, OH) for 20 min using 45, 75, 106, 150, 212, 300 and 500 μm sieves, and the remaining weight on each sieve was recorded. The mass median particle diameter (μm) of each WWF was calculated by the sum of each sieve average particle size (μm) multiplied by relative particle weight percent (%) (Penella et al., 2008).

2.3. WWF analysis

The damaged starch (AACCI 76–30.02) and total starch (AACCI 76–13.01 with a Megazyme Total Starch Assay kit) contents of WWF and SG flour were determined according to the AACC International Approved Methods. In order to eliminate the influence of bran and germ in WWF, adjusted damaged starch (DS/TS) was expressed as the percent of damaged starch (DS) in the total starch (TS). Flour color was measured using a Minolta Colorimeter (Model CR-410, Konica Minolta Sensing, Inc., Japan) according to the AACCI Method 14–30.01.

The polyphenol oxidase (PPO) activity of WWF and SG flour samples was determined following the methods described by AACCI 22–85.01 and Niu et al. (2014a), with some modifications. A 0.1 g WWF sample was placed in a standard 15 mL centrifuge tube containing 10 mL of 10 mmol/L L-DOPA (L-dihydroxyphenylalanine) made up in 50-mmol/L MOPS buffer (pH = 6.5). After being stirred on a touch stirrer (Model 232, Thermo Fisher Scientific, Waltham, MA) for 10 s, the slurry was incubated on a

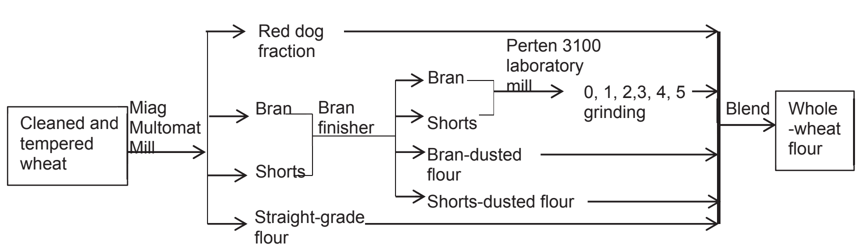

Fig. 1. Flow chart of preparing reconstituted whole-wheat flour (WWF) with different particle sizes. 0, 1, 2, 3, 4, 5 grinding: bran and shorts were separately ground for 0, 1, 2, 3, 4, and 5 times.