LWT - Food Science and Technology 82 (2017) 147–153

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Effects of flour particle size on the quality attributes of reconstituted whole-wheat flour and Chinese southern-type steamed bread

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ARTICLE INFO

Article history:
Received 1 December 2016
Received in revised form
23 March 2017
Accepted 10 April 2017
Available online 18 April 2017

Keywords:
Whole-wheat flour
Particle size
Flour quality
Chinese steamed bread quality
Crumb grain

ABSTRACT

In this study, reconstituted whole-wheat flour (WWF) samples of different particle sizes from U.S. soft white winter (median diameters: 164.0, 110.7 and 97.8 μm) and soft red winter (median diameters: 154.3, 112.8 and 99.9 μm) wheat cultivars were obtained by fine grinding of bran and shorts from roller milling and re-combining with the remaining fractions. Extensibility tests showed that reducing the particle size of WWF strengthened the gluten network of dough. Mixolab results indicated that reducing the particle size of WWF resulted in shorter development time and longer mixing stability of dough. Meanwhile, the starch hot-gel stability and retrogradation increased with the WWF particle size reduction. The Chinese southern-type steamed bread (STSB) making test showed that SB made from WWF of smaller particle size had a significantly larger specific volume than that made from WWF of larger particle size. C-cell analysis of the crumb grain of SB revealed that the grain cells became smaller with thinner cell walls as WWF particle size was reduced. These results indicate that reducing the particle size of WWF could improve the quality of Chinese STSB.

1. Introduction

Whole-wheat flour (WWF) can be produced by different milling procedures, such as single-stream milling (stone, hammer) or multiple-stream milling (roller) with recombination of mill fractions. Different milling techniques result in WWF of various particle sizes and functionalities (Maldonado, 2012). Previous studies have confirmed that bran particle size has a considerable influence on dough properties and quality of finished products. Some studies showed that reducing the particle size of bran had a beneficial effect on foods, such as Asian noodle, snack cracker and flat bread (Chen et al., 2011; Niu, Hou, Lee, & Chen, 2014a; Wang, Hou, Kweon, & Lee, 2016; Majzoobi, Farahnaky, Nematolahi, Mohamadi Hashemi, & Taghipour, 2013), while other researchers found that smaller bran particle size had a detrimental effect on bread quality (Cai, Choi, Hyun, Jeong, & Baik, 2014; Noort, van Haaster, Hemery, Schols, & Hamer, 2010; Zhang & Moore, 1999). These inconsistent observations might be caused by the different milling procedures used, bran particle size ranges, and end products made.

Chinese steamed bread (SB) is a fermented wheat flour product that is cooked by steaming. It is the most popular traditional fermented wheat food in China, representing approximately 40% of the country's wheat consumption (Hou & Popper, 2006). It is also widely consumed in other Asian countries, accounting for 5–15% of total wheat consumption, and has become increasingly popular in North America and some European countries. There are two major types of SB in China. The northern-type steamed bread (NTSB) has a very cohesive, elastic and dense texture. The southern-type steamed bread (STSB) is commonly known for a more open crumb structure, softer texture and a white surface, and it has long been popular as a “dim sum” item in Chinese restaurants (Hou & Popper, 2006). STSB typically requires a refined soft wheat flour of 7.5–9.0% protein (14% mb) to give a desired soft and elastic chewy texture.

Liu et al. (2015) reported that Chinese NTSB made from bran recombining processes had larger height/diameter and specific volume than those made from entire grain grinding processes. They attributed the results to the smaller particle size of WWF from whole grain grinding. As of yet, no research has examined the

Abbreviations: WWF, whole-wheat flour; SWW, soft white winter; SRW, soft red winter; SG, straight-grade.

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http://dx.doi.org/10.1016/j.lwt.2017.04.025
0023-6438/

quality of Chinese STSB made from WWF of different particle sizes. The aim of this study was to investigate the effects of WWF particle size on dough characteristics using Mixolab and extensibility tests, and on the quality characteristics of Chinese STSB.

2. Materials and methods

2.1. Materials

Two U.S. soft wheat cultivars, a soft white winter (SWW, Eltan) and a soft red winter (SRW, VAO5W), were used in this study. Their protein contents were 11.1% and 11.4% (dry basis), respectively. After cleaning, the two wheat samples were tempered in plastic bags at room temperature to 14.5% moisture and milled on a pilot-scale Miag Multomat mill (Buhler, Inc., Braunschweig, Germany) with a straight-grade (SG) flour extraction rate of 72.5 g/100 g for SWW and 72.7 g/100 g for SRW. The resulting bran, shorts, and red dog fractions were collected separately and weighed. The yield of each fraction was expressed as the percent of its weight in the total recovered product weight.

2.2. Preparation of reconstituted WWFs of different particle sizes

After milling, bran and shorts were dusted using a laboratory bran finisher (MLU-302, Buhler, Inc., Uzwill, Switzerland). To prepare WWFs of different particle sizes, bran and shorts were further each ground 1 to 4 times using a Perten 3100 laboratory mill (Perten Instruments, Hägersten, Sweden) equipped with a 0.8 mm mesh sieve. Since there was very small difference in flour particle size when grinding 3 or 4 times, these two treatments were combined as one sample '3rd grinding'. The resulting brans (no, 1st and 3rd grindings), shorts (no, 1st and 3rd grindings), bran-dusted flour, shorts-dusted flour, and red dog fraction were blended with the SG flour in accordance with their respective yields during milling to obtain reconstituted WWFs (WWF-0, -1 and -3). The particle size distribution and median particle diameter of SG flours and reconstituted WWFs were determined using a Ro-Tap testing sieve shaker (Model R-30050, W.S. Tyler, Mentor, OH, USA) according to the method described by Liu, Hou, Lee, Marquart, and Dubat (2016). The damaged starch (DS) content of WWF and SG flour was determined according to the AACC International Approved Methods (AACCI 76–30.02).

2.3. Extensibility measurement of dough

The extensibility measurement of dough was determined according to the method described by Londono, Smulders, Visser, Gilissen, and Hamer (2014). Dough samples were prepared in a Farinograph (Brabender, Duisburg, Germany) mixing bowl using 50 g flour and 1 g salt according to the AACC International Approved Method 54-21. The mixing time was based on the Farinograph development time.

Dough resistance to extension (maximum force) and extensibility (distance at maximum force) were measured using a TA.XT-Plus Texture Analyzer (Texture Technologies Corp., Hamilton, MA) equipped with a SMS/Kieffer dough and gluten extensibility rig (Model: TA-105). After mixing, dough was flattened by a rolling pin and placed onto the paraffin oil-coated, grooved base of a Teflon dough form. The upper block of the dough form was then positioned on top of the dough sample and pushed down firmly by tightening the clamp until the two blocks came together to produce dough strips. After the dough rested for 45 min on a form press in an enclosed plastic bag, dough strips were taken one by one and the extensibility measurements were taken. The testing parameters were: mode, measured force in tension; option, return to start; pre-test speed, 2.0 mm/s; test speed, 3.3 mm/s; post-test speed, 10 mm/s; target mode, distance; distance, 12 cm; trigger force, 5 g; and data acquisition rate, 200 PPS.

2.4. Evaluation of dough mixing and starch pasting properties

Mixing and starch pasting properties of dough were determined using the Mixolab analyzer (Chopin Technologies, Villeneuve-La-Garenne, France) according to AACC International Approved Method 54–60.01. The parameters obtained from the Mixolab included the percent of water required for the dough to produce a torque of 1.1 ± 0.05 Nm (water absorption, %), the time to reach maximum torque at 30 °C [C1 time (dough development time), min], the elapsed time that the torque was kept at 1.1 Nm (stability, min), weakening of protein network (C2, Nm), starch gelatinization (C3, Nm), stability of the hot formed gel (C3-C4, Nm), and starch retrogradation during the cooling phase (C5, Nm).

2.5. Chinese STSB preparation

The formulation of STSB prepared in this study was as follows: flour (SG or WWF), 400 g; instant dry yeast (SAF-Instant® Yeast, Gold Label, Lesaffre Yeast Co.), 4 g; sugar, 60 g; baking powder (double-acting), 4 g; shortening (Crisco), 16 g; and water (75% of Mixolab water absorption). Before dough mixing, sugar and yeast were dissolved in water (15 °C) separately. To begin dough mixing, sugar and yeast solutions were poured into wheat flour in the mixing bowl (N50, Hobart, Troy, OH, USA) with a flat beater. Mixing was conducted at speed 1 for 1 min, after which shortening was added and mixing continued for another 4 min. After resting in a plastic bag at room temperature for 10 min, dough was sheeted 10–12 times on the Oshikiri sheeter/molder (Model: WFS Moulder, Oshikiri Machinery Co., Kanagawa, Japan) until the dough sheet surface was smooth. Then the dough sheet was rolled into a cylinder and stretched by hand to a length of approximately 100 cm. Next, the dough was divided into pieces of 25–30 g and proofed in a fermentation cabinet (Model 505-SS 2/3, National MFG. Co., Lincoln, NE, USA) at 35 °C, 75% RH. Proof time was determined by dough volume increase. In this method, 25 g of SB dough was placed into a 45 mL plastic centrifuge tube (3 cm in diameter). The initial dough volume was approximately 21–22 mL. After proofing, the final dough volume reached 38 mL. At this point, the proofed SB dough was steamed for 12 min in a steamer (SelfCookingCenter, Rational USA Inc., Schaumburg, IL) and cooled at room temperature for 1 h before analysis.

2.6. Quality evaluation of SB

The specific volume of SB was determined using a laser volume analyzer (BVM-L370, TexVol Instruments Inc., Viken, Sweden) by dividing volume by weight. Structural characteristics of the crumb grain (area of cells, mean cell diameter and cell wall thickness) were evaluated using the C-cell food imaging system (Calibre Control International Ltd., Warrington, UK). The textural profile analysis (TPA) of SB was determined using the TA.XTPlus Texture Analyzer equipped with a 35 mm diameter acrylic cylindrical probe. SB was sliced horizontally and a flat piece of 15 mm thickness was compressed to 50% of its original height. The test conditions were: pre-test speed, 2 mm/s; test speed, 1 mm/s; post-test speed, 1 mm/s; and trigger force, 5 g.

2.7. Statistical analysis

All measurements were performed at least in triplicate. Statistical analyses were carried out with the software SPSS 16.0 for Windows using one-way analysis of variance (ANOVA). Duncan's