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GlutoPeak method improvement for gluten aggregation measurement of whole wheat flour

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ABSTRACT

A shear-based device, the GlutoPeak, was developed to measure the aggregation behavior of gluten. In this study, the GlutoPeak testing method was improved and applied for the gluten aggregation evaluation of whole wheat flour (WWF) of different particle size ranges. The sample/solvent weight ratio, mixing speed, and testing temperature were adjusted to different levels for obtaining more repeatable Peak Maximum Time (PMT) and Maximum Torque (MT) using two commercial WWF samples. The temperature had a greater effect on the repeatability of the PMT, while the sample/solvent weight ratio and mixing speed had lower impact on the repeatability of both PMT and MT. Another four commercial wheat samples were milled to WWFs of different particle size ranges. The gluten aggregation of the WWF was measured using the improved GlutoPeak parameters, which were 8-g WWF and 10-g 0.5 mol/L $CaCl_2$ solvent with a mixing speed of 3000 rpm and test temperature of 20 °C. The PMT significantly decreased (with the exception of SW) and MT significantly increased with a decrease of WWF particle size. Compared to the Mixolab and Farinograph tests, the GlutoPeak method took less time and provided significantly different ($p < 0.05$) results for WWFs of different particle size ranges.

1. Introduction

Whole wheat flour (WWF) is milled from the whole grain kernel that contains bran, germ, and endosperm, thus, it provides a highly nutritious and inexpensive source of protein, carbohydrates, dietary fiber, and various minerals. Considerable scientific research has confirmed the positive effects of WWF products intake on human health (Liu, 2007; Okarter & Liu, 2010). United States Department of Agriculture (USDA) recommends that Americans should consume at least half of their grains as whole grains (USDA, 2015), and outlines the whole grain-rich criteria for national school meals (USDA, 2016). Along with the increasing health awareness of consumers and recommendations of scientists, a large market demand for various WWF-based products is expected in the near future (USDA, 2015; Zong, Gao, Hu, & Sun, 2016).

One of the major challenges of WWF application is the influence of wheat bran, which results in changes in dough rheological properties, and further affects the qualities of food products (Cai, Choi, Hyun, Jeong, & Baik, 2014; Niu, Hou, Lee, & Chen, 2014; Steglich, Bernin, Moldin, Topgaard, & Langton, 2015; Wang, Hou, Kweon, & Lee, 2016). Many studies have been conducted to reduce the influence of bran in products by adding vital wheat gluten, enzymes, and adjusting the particle size of bran (Katina, Salmenkallio-Marttila, Partanen, Forssell, & Autio, 2006; Penella, Collar, & Haros, 2008). Compared to other methods, adjusting the particle size of bran is more natural and cost effective.

Several rheological instruments, such as the Mixograph, Mixolab and Farinograph, have been developed and applied to dough systems (Huang et al., 2010; Koksel, Kahraman, Sanal, Ozay, & Dubat, 2009; Manthey & Schorno, 2002; Vizitiu & Danciu, 2011). However, it is difficult for those instruments to detect meaningful differences in dough rheological properties for WWFs of different bran particle size ranges. Previous studies reported no significant effects of bran particle size regarding water absorption in the Farinograph (Noort, van Haaster, Hemery, Schols, & Hamer, 2010; Zhang & Moore, 1997), and dough development time in Mixograph (Cai et al., 2014) and Mixolab (Liu, Hou, Lee, Marquart, & Dubat, 2016) of WWFs.

Recently, a new technique has been investigated as a more efficient and rapid predictor of wheat flour functional quality (Chandi & Seetharaman, 2012; Marti, Cecchini, D'Egidio, Dreisoerner, & Pagani, 2014; Melnyk, Dreisoerner, Bonomi, Marcone, & Seetharaman, 2011).

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The GlutoPeak is a rapid shear-based device that measures the aggregation behavior of gluten for evaluation of wheat flour quality. By mixing appropriate amounts of flour and solvent at a certain speed, gluten is separated by the paddle rotation, resulting in aggregation. At this point the gluten aggregate mass exerts a resistant force on the paddle resulting in the generation of a torque curve. The curve records the complexity of aggregation and breakdown of the gluten by providing Peak Maximum Time (PMT, in min) and the Maximum torque (MT, in Brabender equivalents, BE). High sensitivity, short analysis time and small sample requirements are key features that make the GlutoPeak method valuable to flour quality evaluation. In a recent study, GlutoPeak PMT was proposed as an alternative approach to mixograph and gluten index tests to evaluate the gluten strength of durum wheat (Sissons, 2016).

Various settings for the GlutoPeak test including the sample to solvent weight ratio (8 g/10 g–9.4 g/8.6 g), solvent type (water, $CaCl_2$), mixing speed (1900 to 3000 rpm), and testing temperature (35–45 °C) were used in previous researches (Marti, Augst, Cox, & Koehler, 2015; Melnyk, Dreisoerner, Marcone, & Seetharaman, 2012; Melnyk et al., 2011) for different varieties and protein contents of wheat flour. Melnyk et al. (2011) studied the influence of the Hofmeister series on gluten aggregation, and recommended calcium chloride ($CaCl_2$) as the solvent due to its significant reduction in time to gluten aggregation. Chandi and Seetharaman (2012) studied the gluten aggregation of refined and whole wheat flours (WWFs) by adjusting the testing parameters of the GlutoPeak and found a significant influence of flour–-solvent interaction on MT. There was no significant influence of flour weight and mixing speed for WWFs. However, the relatively minor adjustments of the GlutoPeak testing parameters limited the opportunity to find a better setting. Also, there was no report on the repeatability of the test results, which could significantly influence the evaluation of the gluten aggregation properties of WWFs of different particle size ranges.

The objective of the current study was to improve the GlutoPeak method for detecting the gluten aggregation of WWFs of different particle size ranges. The influences of sample/solvent weight ratio, mixing speed, and test temperature on the repeatability (as judged by the coefficient of variation) of PMT and MT were examined and evaluated. The same set of WWF samples was also measured using the Mixolab and Farinograph for comparison with the measurement of the improved GlutoPeak method.

2. Materials and methods

2.1. Materials

Two commercial WWF samples: hard red spring (13.8 g/100 g protein, 1.6 g/100 g ash, and 32.1 g/100 g wet gluten content based on 14 g/100 g mb) was purchased from the Archer Daniels Midland Company (Chicago, IL, USA); ultrafine soft white (9.7 g/100 g protein, 1.5 g/100 g ash, and 21.6 g/100 g wet gluten content based on 14 g/100 g mb) was purchased from the Ardent Mills (Denver, CO, USA). Commercial grain samples of hard white (HW), hard red winter (HRW) and hard red spring (HRS) were described by Liu et al. (2016), and soft white (SW) was described by Wang et al. (2016).

2.2. Preparation of WWFs

The preparation procedures of HW-, HRS- and HRW-WWFs of different particle sizes were described by Liu et al. (2016), and SW-WWF of different particle sizes was outlined by Wang et al. (2016). Wheat samples were milled on a pilot-scale Miag Multomat mill (Buhler, Inc. Braunschweig, Germany) to obtain straight-grade (SG) flours, and bran, shorts and red dog fractions. The attached flour from the bran and shorts fractions was dusted off by a laboratory bran finisher (Model MLU-302, Buhler, Inc., Braunschweig, Germany). The obtained clean bran and shorts fractions were separately ground 1 to 4 times using a Perten 3100 laboratory mill (Perten Instruments, Hagersten, Sweden). Since the particle sizes were similar for samples ground 3 and 4 times, the two were mixed as the 4th grinding pass sample. For the HW, HRS and HRW, bran and shorts of the 4th grinding pass were pre-ground in a blender (Vitamix Corporation, Cleveland, OH) prior to the 5th grinding to obtain finer particle sizes. The bran-dusted flour, shorts-dusted flour, red dog fraction, and SG flour were then blended with the non-ground, 1st, 2nd, 4th, and 5th (no 5th in SW) grind bran and shorts fractions, respectively, to make the WWF-0, 1, 2, 4 and 5 for HW, HRS and HRW, and WWF-0, 1, 2 and 4 for SW.

The particle size distribution of WWF was measured by a Ro-Tap testing sieve shaker (WS Tyler Incorporated, USA), and the median particle diameter was calculated as described in Penella et al. (2008).

2.3. Gluten aggregation testing in GlutoPeak

The gluten aggregation test was performed using the GlutoPeak (Brabender GmbH & Co. KG, Duisburg, Germany) equipped with a refrigeration and heating circulator (Julabo Inc, PA, USA). During operation, the testing chamber was first heated or cooled to a targeted temperature by the circulator. Weight of flour and solvent, test time (3 min) and mixing speed, and sample moisture content were entered into the parameter window of GlutoPeak program. WWF sample and solvent (0.5 mol/L $CaCl_2$ solution) were weighed separately and put together in the test cup, then mixed with the pre-defined mixing speed. The MT and PMT were recorded for evaluating the gluten aggregation of WWF sample.

As shown in Fig. 1, three stages of gluten aggregation testing of WWFs were conducted in this study. In the first stage, HW-, HRS-, HRW- and SW-WWF samples, which were prepared at the Wheat Marketing Center, were tested by using the recommended settings as reported by Chandi and Seetharaman (2012): 8.5-g WWF, 9.5-g 0.5 mol/L $CaCl_2$ solvent, 34 °C test temperature and 1900 rpm mixing speed. All measurements were conducted in three replicates in the first stage. In the second stage, two commercial WWFs (Hard Red Spring and Soft White) were selected for the improvement of the test parameters. Testing started with the following settings: 8-g WWF sample, 10-g solvent (0.5 mol/L $CaCl_2$), test temperature of 34 °C, and mixing speed of 1900 rpm. First, the test temperature was adjusted to 20, 25, 30 and 34 °C without changing the other parameters. Second, the test temperature that provided the most repeatable PMTs and MTs was selected, and the mixing speed was adjusted to 1,500, 1,900, 2500 and 3000 rpm without changing the flour/solvent weight ratio. With the confirmed appropriate test temperature and mixing speed, the flour/solvent weight ratio was adjusted to 7.5 g/10.5 g, 8 g/10 g and 8.5 g/9.5 g to identify the appropriate amount of flour and solvent. All measurements were conducted in five replicates in the second stage.

In the third stage, the MT and PMT of HW-, HRS-, HRW- and SW-WWF samples were measured following the improved parameters identified in the second stage. All measurements were conducted in three replicates in the third stage.

2.4. Measurement of WWF using the Mixolab and Farinograph

The rheological behaviors of WWF were measured using the Mixolab and Farinograph to compare with the gluten aggregation properties using the GlutoPeak. The test times of Mixolab and Farinograph are usually longer than 10 min. AACC International Approved Method 54–60.01 was used for the analyses of WWF in the Mixolab (Chopin Technologies, Villeneuve-La- Garenne, France). The C1 time, which represents the time for the dough to reach the maximum torque, was recorded (Huang et al., 2010). A Farinograph E (C.W. Brabender Instrument Inc., South Hackensack, NJ, USA) equipped with a 50-g mixing bowl was used to measure the dough development time according to the AACC International Approved Method 54–21.02.