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Predicting water absorption of wheat flour using high shear-based GlutoPeak test

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ABSTRACT

Selection for water absorption, a fundamental wheat quality parameter, has been a challenge in wheat breeding programs due to limited wheat materials available for milling and consequent time-consuming farinograph test. Hence, a high shear-based method, which requires 8 g of flour and less than 10 min per test, was proposed to predict flour water absorption using the Brabender GlutoPeak instrument. Highly significant positive linear relationship ($r^2 = 0.97$) was found between GlutoPeak maximum torque and farinograph water absorption for 83 flour samples prepared with Bühler test mill from wheat lines under evaluation in the Canadian wheat variety registration trials. Similar strong correlation ($r^2 = 0.96$) was obtained from flours ($n = 63$) prepared with Quadrumat Junior laboratory mill using small amount of wheat. Flour prepared either with Bühler test mill or Quadrumat Junior mill can be used for predicting water absorption effectively. GlutoPeak maximum torque was found to be independent of dough strength ($r^2 = 0.02$) as measured by extensigraph. GlutoPeak test can be a powerful tool for rapid and reliable prediction of water absorption of wheat flour.

1. Introduction

Wheat flour water absorption (WA), also known as water hydration or water binding capacity, has long been considered as one of the most important quality parameters in determining the functional properties of flour (Bushuk and Békés, 2002). Fundamentally, WA is defined as the amount of water required during mixing to achieve a desired dough consistency at optimal gluten development. Depending upon the wheat class and variety, WA can vary greatly and closely relates to the flour end-use applications. Hard wheat flour with higher water absorption is preferred for producing high volume pan bread with improved dough handling properties, fermentation and proofing tolerance, bread/dough yield and final product attributes (e.g., better taste, soft crumb structure and delayed staling) (Puhr and D'Appolonia, 1992), whereas soft wheat flour with lower water absorption is commonly used in cake, cookie, and pastry formulations (Guttieri et al., 2001).

WA is a function of flour components capable to be hydrated and their specific water binding capacity. Extensive research has shown that the relative amounts of damaged starch, pentosan, and protein in flour contribute positively to WA (Jelaca and Hlynka, 1971; Preston et al., 2001; Primo-Martín and Martínez-Anaya, 2003; Rakszegi et al., 2014; Tipples et al., 1978; Tömösközi et al., 2002; Yao, 2014). Wheat kernel size, starch granule size distribution, and volume fractions of large flour particles can also affect absorption (Morgan et al., 2000; Yao, 2014). Protein quality, as reflected by the viscoelastic properties of dough, can be a factor affecting WA in baking. Elastic dough with low stickiness can usually take more water in commercial baking than weak dough.

To meet customer expectations for end-use performance, wheat varieties registered for production in Canada are categorized into appropriate market classes based on their functional characteristics. When evaluating candidate lines in variety registration trials, quality traits including flour WA are assessed and compared to the approved check varieties. There is variation in WA requirement between western Canadian wheat classes. Canada's premium class of wheat, Canada Western Red Spring (CWRS), is characterized by its superior water absorption capacity, whereas Canada Prairie Spring Red (CPSR) wheat class can have slightly lower WA than CWRS. The Canada Western Hard White Spring (CWHWS) wheat

Abbreviations: CNHR, Canada Northern Hard Red; CPSR, Canada Prairie Spring Red; CWHWS, Canada Western Hard White Spring; CWRS, Canada Western Red Spring; CWRW, Canada Western Red Winter; FAB, Farinograph Absorption; QJ, Quadrumat Junior; R_{max}, maximum resistance to extension; T_{max}, Maximum Torque; WA, Water Absorption.

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class was created in 2000 and improvement in WA is being targeted in new variety development. Significant efforts have also been put into improving the flour WA of Canada Western Red Winter (CWRW) wheat class, which usually exhibits much lower water absorption than CWRS.

The Brabender® farinograph has been the most commonly used instrument for measuring WA of wheat flour. It measures the resistance encountered by the rotating blades during dough mixing. Dough consistency is a function of the relative amount of water and the degree of gluten development or breakdown. The resulting Farinograph absorption (FAB) reflects the amount of water that is required for a constant weight of flour to obtain a standard dough consistency (i.e., 500 BU) at full/peak gluten development under mixing. It is often necessary to make more than one attempts to determine the amount of water needed to achieve the target dough consistency. However, in wheat breeding programs, use of the farinograph to conduct phenotypic selection of lines with desirable WA capacity is time-consuming, labor intensive and requires milling of large grain samples, which is not possible due to limited materials available in earlier generations (Tsilo et al., 2013). Therefore, establishing a rapid and reliable method which requires only a small amount of grain to predict WA would be essential for breeders to select for this important quality trait as early as possible in breeding programs.

Modeling FAB of wheat flours has been the subject of previous studies (Rakszegi et al., 2014; Ram et al., 2005; Tipples et al., 1978; Yao, 2014). According to the multivariate functional relationship between flour WA capacity and relative quantities of hydratable components in flour and their specific water binding capacity, linear and stepwise multivariate regression models have been built from kernel size (Morgan et al., 2000), flour protein (Preston et al., 2001), damaged starch (Tipples et al., 1978), pentosans (Jelaca and Hlynka, 1971; Primo-Martín and Martínez-Anaya, 2003), soluble protein content (Rakszegi et al., 2014; Tömösközi et al., 2002) and volume fractions of large (or small) flour particles (Yao, 2014) to predict flour WA. Ram et al. (2005) demonstrated that solvent retention capacity profile (water, sodium carbonate, and sucrose) together with protein content explained a large amount of genetic variability in WA. However, depending on the samples selected, significant variation has been observed in prediction models that include a different number of independent variables. No universal model has been attained yet. Also, modeling of WA requires the measurements of flour components capable to be hydrated, such as protein, damaged starch and pentosans. Instead of focusing on the impact of individual hydratable components, development of an objective approach which measures the overall hydration properties of wheat flour could be more effective and reliable in elucidating wheat flour WA capacity.

Brabender® (Brabender GmbH and Co KG, Duisburg, Germany) has recently introduced the GlutoPeak device for the evaluation of wheat flour quality. Unlike other instruments for dough rheological properties, the GlutoPeak measures the aggregation/formation of wheat gluten proteins in a flour-water suspension under high-speed shearing action (Melnyk et al., 2011). Preliminary experiments in our laboratory with selected Canadian wheat genotypes suggest that there is a positive relationship between GlutoPeak maximum torque (T_{max}) and flour FAB, and the relationship appears to be independent of flour dough strength. In this study, we explore the potential of using high shear-based Brabender® GlutoPeak to rapidly predict FAB of common wheat flour, and examine if difference in flour intrinsic gluten strength can hamper the use of GlutoPeak for such application. Eighty-three candidate lines from seven Canadian wheat variety registration trials grown in 2015 were selected to establish and validate the relationship between FAB and GlutoPeak T_{max}. Flour samples were prepared from same wheat both with a Bühler test mill and a Quadrumat Junior (QJ) laboratory mill on a small scale basis (e.g. 160 g wheat) to accommodate the scenario of limited quantities of wheat typically encountered at the early stages of wheat breeding. The relationship between FAB of Bühler milled flour and GlutoPeak T_{max} of flours prepared by both Bühler test mill and QJ mill were investigated.

2. Materials and methods

2.1. Wheat samples and milling

Eighty-three candidate lines with a wide range of FAB (55.4–68.4%) and dough strength (maximum resistance: 316–919 BU) as measured by a modified extensigraph method (Suchy et al., 2017) were selected from 2015 Canadian wheat variety registration trials. A composite of each line was made from wheat grown at multiple locations across Western Canada. All composites were graded as No. 2 or better. Straight-grade flours were generated on an experimental Bühler test mill (AACC International method 26-21.02) at the Grain Research Laboratory of the Canadian Grain Commission (Winnipeg, MB).

For evaluation of the relationship between GlutoPeak T_{max} of QJ milled flour and FAB of Bühler milled flour, a set of 63 wheat samples from the original 83 candidate lines were chosen based on the availability of wheat. Tempering and milling of wheat were following AACC International method 25-50.01 using a QJ mill with modification. To improve milling efficiency and optimize flour extraction rate, the reel sifter originally supplied with the QJ laboratory mill was removed, whereafter the obtained whole meal was sifted through a Bühler MLUA GM sieve (Buhler AG, Uzwil) at an opening of 315 μm to prepare white flour by removing bran from the ground whole meal. The sieve was operated at 260 rpm for 1 min for each sieving. The milling yield of flour was within one percentage lower or higher than 75% (clean wheat basis).

2.2. Flour analysis

Flour protein, damaged starch and FAB of the Bühler milled flour were determined based on AACC International official methods 76-13.01, 46-30.01 and 54-21.02, respectively. Dough extensional properties were measured following a modified extensigraph protocol previously reported by Suchy et al. (2017). The maximum resistance (R_{max}) values are used to indicate dough strength.

2.3. GlutoPeak test

Gluten aggregation properties in water and flour slurry were measured by the GlutoPeak instrument (Brabender GmbH and Co KG, Duisburg, Germany) with a high shear-based method. In a typical experiment, 8 g of flour (14% m.b.) was dispersed in 10 mL of distilled water (14% m.b.) in a stainless steel sample cup. The speed was set at 2700 rpm for the rotating paddle. Temperature was controlled at 34 °C by circulating water through the jacketed sample cup. Preliminary tests found that a flour to water ratio of 8–10 (w/w) and mixing speed of 2700 rpm provided the most reproducible mixing curves for selected sample varieties (results not shown).

During the GlutoPeak test, the flour water slurry was subjected to intense mechanical shearing action created by high speed rotating paddle. The counter torque attributed to the flour hydration and gluten network formation upon mixing and the time required to reach peak resistance were registered in a torque curve. A typical mixing curve obtained from the GlutoPeak is displayed in Fig. 1. The resulting GlutoPeak parameters automatically analyzed by the GlutoPeak software include: 1) T_{max}, corresponding to the