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Degree of starchy endosperm separation from bran as a milling quality trait of wheat grain

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ABSTRACT

Easy and clean separation of starchy endosperm from bran during milling could have a significant contribution to the increased flour yield. Starch content and DMSO extractable content of bran were determined as the estimates for remnant endosperm content of bran for 61 and 100 soft red winter (SRW) wheat genotypes grown in 2013 and 2014, respectively. DMSO extractable content was found to be more reliable in the estimation of remnant endosperm content of bran than was starch content with better reproducibility. Flour yields of the 2013 and 2014 SRW wheat varieties tested ranged from 65.1 to 72.4% (w/w), and 63.6–73.9% (w/w), respectively. The remnant endosperm content of bran estimated using the DMSO extractable content ranged from 33.9 to 43.6% (w/w) and 35.4–47.4% (w/w) for the 2013 and 2014 crops, respectively. The remnant endosperm content was significantly related to flour yield with a correlation coefficient of $r = -0.54$ ($P < 0.001$) from the 2014 crop, which was greater than that for any other grain characteristics including test weight, kernel hardness, and kernel weight. The degree of endosperm separation varied with different wheat varieties, different bran pieces and even different parts of the same piece of bran.

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1. Introduction

Flour yield is an important wheat quality trait that not only determines profits for milling industries, but also indirectly affects the quality of end-products. Flour yield is highly heritable and is the primary quality trait evaluated in wheat breeding programs (Souza et al., 2012). Much effort has been devoted to the identification of genes that control the flour yield of wheat (Breseghello and Sorrells, 2006; Breseghello et al., 2005), with no perceivable success. The genetics of flour yield is difficult to precisely define, mainly due to the complexity of the linkage between genetics and the grain characteristics influencing flour yield. A single grain trait is often regulated by multiple genes and consequently is linked to a number of quantitative trait loci (QTLs).

Physical, biochemical and morphological grain characteristics, e.g. test weight, kernel weight, kernel size, and kernel hardness, are known to influence the flour yield of wheat. Test weight, a.k.a. bulk density, is an important index of the density and the soundness of kernels, but is not always a good indicator of flour yield. While some researchers showed that flour yield increased with test weight (Dziki and Laskowski, 2005; Ohm et al., 1998), Lin and Czuchajowska (1997) reported a positive correlation between test weight and flour yield for soft white winter wheat but not for white club wheat. Similar uncertainty was found in other kernel characteristics, including 1000 kernel weight (Dziki and Laskowski, 2005), kernel hardness (Martin et al., 2001; Ohm et al., 1998) and kernel size. Kernel size is presumed to affect milling and baking quality, but the relationship is not definitive. Small kernels tend to be harder in kernel texture than large kernels, and thus negatively affect milling yield (Dziki and Laskowski, 2004; Sutton et al., 1992). Dziki and Laskowski (2004) reported that small kernels exhibited low flour yield with high ash content. Increases in flour yield and protein content corresponding to increased kernel size was reported by Sutton et al. (1922). Baasandorj et al. (2015) also observed that large kernels had higher flour yields than small kernels. Gaines et al. (1997) disputably reported no significant influence of kernel size on flour yield of soft wheat, although the degree of kernel shriveling showed a significant influence on flour yield. In addition to kernel characteristics, Gaines et al. (2000) reported that soft wheat cultivars with larger starch granules exhibited higher flour yields. They also observed the relationships of lower amylose content and higher total starch content with higher flour yield. In

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addition, it was found that a decrease in starch granule-bound puroindoline accounts for the increase in flour yield (Gaines et al., 2000).

Despite considerable efforts to improve wheat milling yield through advances in breeding, cultivation, and milling technologies, the theoretical maximum flour yield has not yet been achieved (Edwards et al., 2010). Our understanding of the biochemical and microstructural characteristics that affect flour yield is still superficial, and measurable grain traits for the effective selection of breeding lines for high flour yield need to be identified to efficiently and effectively predict flour yield.

Easy and clean separation of starchy endosperm from bran during milling would undoubtedly affect milling and flour yield, and is a more important issue for soft wheat than hard wheat, considering the lower tolerance for high bran contamination of products prepared from the former as compared to the latter. Endosperm separation index (ESI), the approximate quantity of endosperm remaining attached to bran, was calculated by subtracting the theoretical bran and germ contents (17% of the grain) from the actual content of bran and known to be related to flour yield (Yamazaki and Andrews, 1982). The ESI, however, suffers from inherent limitations: the use of fixed theoretical bran and germ contents in the calculation of ESI, and dependence of the ESI value on flour yield in the calculation. The endosperm content of bran could be an indicator of the degree of endosperm separation from bran during milling and eventually be used as an important grain milling trait.

Cell walls have significant impact on the texture of wheat grains and their fractionation process (Jamme et al., 2008). Wheat grain cell walls are composed of many polysaccharides, proteins, and aromatic compounds, which could influence disintegration of the endosperm and eventually affect flour yield. Arabinoxylans, the predominant cell wall polysaccharides, are concentrated between the nucellar epidermis and the outer periclinal aleurone cell walls (Jamme et al., 2008), and play an important role in tissue adhesion and thus affect the separation of cells during milling.

The objectives of the study were to determine the variation in the degree of starchy endosperm separation from bran during wheat milling among soft red winter wheat genotypes, and the significance of the degree of starchy endosperm separation from bran for flour yield.

2. Materials and methods

2.1. Wheat samples

The study was performed in two experiments involving two different sets of wheat genotypes. For Experiment 1, grains of 61 soft red winter wheat genotypes grown in four regional and state performance trials in 2013 were selected with evenly distributed experimental milling flour yields ranging from 65.1 to 72.4% (w/w). Brans from a subset of 24 varieties with evenly distributed flour yields ranging from 65.1 to 72.2% (w/w) were selected and ground into powders for starch and arabinoxylan content analyses. For Experiment 2, grains of 100 soft red winter wheat varieties grown in 2014 in five different state performance trials were used. Wheat varieties were selected to represent a wide variation of flour yields ranging from 63.6 to 73.9% (w/w) in preliminary experimental milling.

2.2. Experimental milling

Wheat grain was tempered to 15% moisture for 48 h and milled. Milling was conducted on a modified Brabender Quadrumat Jr. mill (C.W. Brabender Instruments Inc., South Hackensack, NJ) at a controlled temperature of 21 °C and relative humidity of 55–60%. Milled products were recovered for sifting on a Great Western sifter box (Great Western Manufacturing Co. Inc., Leavenworth, KS) with screens of 471 and 180 μm openings, and separated into bran, middlings and flour. Flour yield was determined as the percent total flour weight (break flour + middlings) over tempered grain weight.

Brans of 24 genotypes representing a wide variation in flour yield were selected and ground using an Udy Cyclone Sample Mill (UDY Corporation, Fort Collins, CO) fitted with a screen with 0.5 mm openings, and sifted through a sieve of 0.5 mm openings to improve homogeneity of the ground bran. The ground bran was carefully recovered, rigorously blended in jars using a spatula and analyzed for starch and arabinoxylan contents.

2.3. Grain characteristics evaluation

Grain moisture was estimated using a Near Infrared DA7200 Analyzer (Perten Instruments, Springfield, IL). Softness equivalence was calculated as the percent break flour weight over total flour weight. Test weight of wheat grain was determined according to AACC Method 55-10.01 (AACC, 2002). Kernel weight and hardness were determined using a Perten 4100 Single Kernel Characterization System (SKCS, Perten Instruments, Springfield, IL).

2.4. Dimethyl sulfoxide (DMSO) extraction of bran

DMSO extraction of bran was conducted to estimate the remnant endosperm attached to bran after roller milling. Bran (approx. 2 g) was weighed into 95% (v/v) DMSO aqueous solution (30 mL) in a 50 mL test tube and incubated in a boiling water bath for 30 min. The test tube was then centrifuged at 1000 × g. Duplicate aliquots (1 mL) of the supernatant were transferred into pre-weighed test tubes. The DMSO extracts of bran were precipitated by the addition of 95% (v/v) ethanol (3 mL) and centrifugation. The supernatant was discarded, and the precipitate was re-suspended in 95% (v/v) ethanol (3 mL) and centrifuged. This was repeated once more. The precipitate was then dried for 30 min at 85 °C and for another 30 min at 115 °C. The weight of the DMSO extract of bran was calculated from the dried precipitate weight and expressed as a percentage over the bran weight.

2.5. Starch content of bran

Starch content of bran was determined using the Megazyme Total Starch Assay Kit (Megazyme International Ireland, Wicklow, Ireland) and procedure according to AACC Method 76.13 with modifications (AACC, 2002). Ground bran (approx. 100 mg) was added to a glass tube and wetted with 0.2 mL of aqueous ethanol (80%, v/v) to aid dispersion. The tube was stirred on a vortex mixer, and 3 mL of thermostable α–amylase reagent was added. The tube was placed in a boiling water bath for 30 min with stirring using a vortex mixer every 10 min. The tube was cooled to 50 °C; amyloglucosidase reagent (0.1 mL) was added, and the tube was incubated in a water bath at 50 °C for 30 min. Tube content volume was adjusted to 10 mL with distilled water, and the tube was centrifuged at 3000 rpm for 10 min. An aliquot (1 mL) of the supernatant was diluted to 10 mL with distilled water. An aliquot (0.1 mL) of the diluted solution was transferred into a test tube, and 3 mL of glucose determination reagent was added. The tube was incubated at 50 °C for 20 min and the absorbance was read at 510 nm using a Shimadzu UV-1800 Spectrophotometer (Shimadzu Corporation, Columbia, MD). Reagent blanks and glucose controls were used to establish a standard curve for glucose concentration.

For the grains of 100 varieties grown in 2014, starch content of bran was determined by DMSO extraction of starch from bran and