IS PROTEIN ENOUGH FOR ASSESSING WHEAT FLOUR QUALITY?

C.L. Reese, D.E. Clay, D. Beck and R. Englund
Research Associate II, South Dakota State University, Brookings, SD
Soil Scientist, South Dakota State Universtiy, Brookings, SD

ABSTRACT

The quality of wheat products such as bread, bagels, noodles or pizza that consumers purchase is based on the flour quality used in production. Flours with different characteristcs are needed to produce different products and flour quality is important to produce a quality end product. However, at the initial stage of flour production, wheat is sold on a grain protein premium basis by farmers to elevators and eventually millers. In many years, higher protein (> 15% protein) wheat can bring premiums whereas low protein wheat (14%) may be docked. Two tests, farinograph stability and alveograph-W, have been useful for targeting specific flour for specific products. Understanding the relationship between the different wheat quality indices is important for marketing purposes. Study objective was to determine the relationship between grain protein, farinograph stability and alveograph-W flour quality tests for two hard red spring wheat commonly grown in SD, Russ and Briggs. Findings showed that grain protein is only one test of flour quality. To accurately predict flour quality, additional information is needed. Nitrogen fertilizer generally increased grain protein. However N fertilizer did not have consistent effects on the farinograph stability or alveograph-W flour quality tests between the two varieties tested in this study.

INTRODUCTION

Majority of South Dakota hard red wheat (HRW) is marketed to Chicago or Minneapolis. South Dakota flour from HRW has milling quality that makes it uniquely suited for making high quality breads, bagels or pizza crusts (R. Englund, 2005).

There are numerous tests in the baking industry to determine wheat quality for making different food products. Among these tests are flour protein, ash content, falling number, flour color, farinograph, alveograph, mixograph, rapid visco analyzer, etc. This study examined the relationship between grain protein and (1) flour protein, (2) farinograph stability and (3) alveograph-W values. All these tests measure dough gluten strength.

What is gluten strength and how does it relate to flour protein? Wheat protein is primarily stored in the seed endosperm. Endosperm storage proteins can be grouped into either gliadins or glutenins. In order to understand how these proteins function with the addition of water, one must consider two actions that can occur when water is added to flour. The substance may become viscous (sticky), elastic or a combination of viscous and elastic. Viscous characteristics are derived from gliadin proteins and elastic properties from glutenin proteins. The resultant protein complex from mixing flour and water is a viscoelastic material called gluten. Flour elasticity is also flour strength; how much the dough can be mixed or stretched without breaking. Flour that can be mixed for long periods of time or stretched extensively without breaking is called high gluten flour. Production of breads, bagels or pizza crust requires high gluten flour. Flour quality tests that measure gluten strength in flour are farinograph stability and alveograph-W.

Farinograph testing describes how flour handles as dough in a mixer. Farinograph is measured in Brabender units (BU). Brabender units are arbitrary units that incorporate torque or dough resistance to mixing. Arrival time is time to develop dough to 500 BU on the farinograph. This is time needed for dough and water to mix together to develop strength. Peak time (minutes) occurs when the dough reaches maximum strength. Departure time occurs when the top of the curve leaves the 500 BU line (Figure 1). Stability is arrival minus departure time. Stability or tolerance is used as an indicator of overall flour protein quality. In figure 1, arrival time (minutes) is 3; peak is 5; departure is 9 and stability is 6. Bread, pizza or bagel flour farinograph stability should be > 18 minutes.

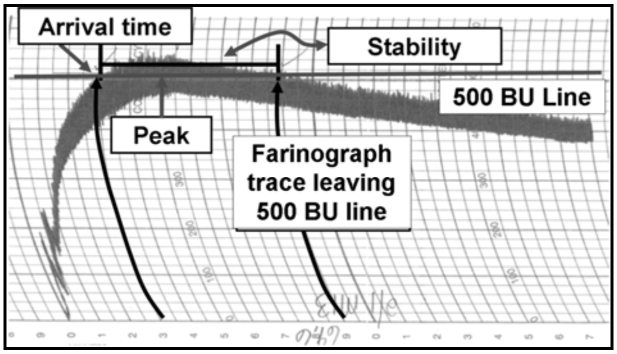

Figure 1. Farinograph sample where the 500 BU where arrival time, peak and stability are shown.

An alveograph mixes the dough and then spreads it into a flat disc that is secured. The instrument then blows a bubble in the dough and measures inflation pressure. Alveograph dough bubble physics are thought to correspond to bubble expansion in fermenting dough. This test provides data on how dough acts during fermentation. W-values represent total energy required to blow a bubble in the dough (Figure 2).

Millers use W-values as an indication of dough strength. Alveograph W- values range from 45 (soft wheat flours) to over 400 for extremely strong dough. Millers using SD HRW prefer W-values > 400.

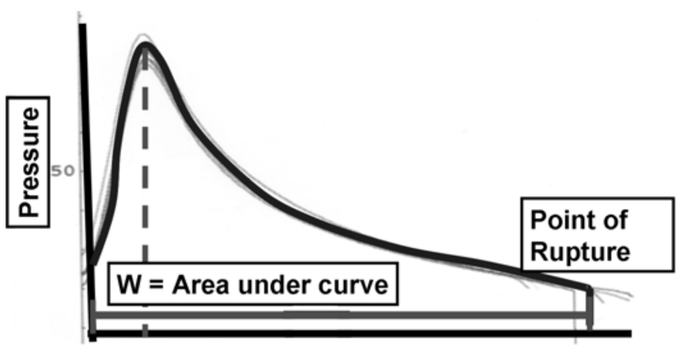

Figure 2. Sample alveograph output illustrating the W-value.

Study objective was to determine if grain protein can be used as an index to measure flour farinograph and alveograph milling properties for two different HRW varieties, Russ and Briggs, commonly grown in SD.

METHODS

Russ hard red spring wheat (HRSW) was grown in Pierre, SD, 2003 (one field), Pierre, SD, 2004 (two fields) and in Aurora, SD, 2005 (one field). Pierre 2004 fields were within 0.5 mile distance of each other. Briggs HRSW was grown in 2004 (one field) and 2005 (two fields) near Gettysburg, SD. Gettysburg 2005 fields were within 3 miles distance of each other. All fields were dryland except for the field at Pierre, 2003 and one field at Pierre in 2004 (Table 1). Irrigation was supplied at this site to bring growing season precipitation to 30 year average (16 inches).

All sites were no-till with the exception of Aurora 2005 which was received conventional tillage. Wheat varieties were planted in early April of each year. At each study site, soil samples were collected in spring and at harvest. Soil samples were analyzed for soil moisture (not presented), nitrate nitrogen (Table 1) and ammonium nitrogen (not presented). At each site, nitrogen fertilizer was applied at different rates in randomized complete block studies. Rates varied from 0 to 180 lbs N acres. Exact treatments not shown due to limited length of paper.

Table 1. Water source, soil test nitrate nitrogen, 0–24 inches, field average yield and grain protein for different study fields.

Site	Variety	Water	Spring NO3-N Soil Test	Yield	Protein
				13.5 % moisture	
			lbs/A, 0-24 inches	bu/A	%
Pierre 2003	Russ	Irrigated	68	55	15.3
Pierre 2004	Russ	Irrigated	60	59	14.3
Pierre 2004	Russ	Dryland	64	32	17.6
Aurora 2005	Russ	Dryland	69	40	15
Gettysburg 2004	Briggs	Dryland	35	68	14.7
Gettysburg 2005_1	Briggs	Dryland	30	42	14.5
Gettysburg 2005_2	Briggs	Dryland	8	42	14.5

Mean high temperature (^{O}F) are reported in Table 2 and mean monthly precipitation (inches) is reported in Table 3 for respective years and sites. Since the two fields at Pierre, 2004 and Gettysburg, 2005 were within 3 miles of each other; weather for these sites is reported as one value. Pierre 2004 rainfall was 7.5 inches which was 3.9 inches below the April– July average of 11.4 inches. Gettysburg 2004 rainfall for April-July was 14.5 in. and 9.5 in., 2005. Gettysburg 30 yr. average is16.0 in.. July was a hot dry month in Gettysburg, 2005 with a daily maximum high temperature 3^{O}F higher than average.

Table 2. Average temperature (^{O}F) for different locations. Thirty year (yr) average temperature in parenthesis.

Site	Variety	March	April	May	June	July
Pierre 2003	Russ	47 (46)	61 (60)	68 (71)	79 (81)	92 (89)
Pierre 2004	Russ	52 (46)	64 (60)	70 (71)	77 (81)	87 (89)
Aurora 2005	Russ	41 (40)	61 (56)	66 (69)	79 (78)	83 (83)
Gettysburg 2004	Briggs	60 (41)	64 (56)	74 (68)	75 (78)	85 (85)
Gettysburg 2005	Briggs	47 (41)	62 (56)	65 (68)	78 (78)	88 (85)

Table 3. Monthly growing season average rainfall temperature (inches) for different locations. Thirty year (yr) average precipitation in parenthesis.

Site	Variety	March	April	May	June	July
Pierre 2003	Russ	0.5 (1.2)	2.5 (2.0)	3.8 (3.1)	1.6 (3.5)	1.4 (2.8)
Pierre 2004	Russ	2.3 (1.2)	0.3 (2.0)	2.8 (3.1)	2.4 (3.5)	2.0 (2.8)
Aurora 2005	Russ	0.5 (1.3)	1.9 (2.0)	3.8 (3.0)	6.0 (4.2)	3.5 (3.1)
Gettysburg 2004	Briggs	2.5 (1.2)	1.7 (1.9)	3.7 (2.9)	4.3 (3.1)	4.8 (2.6)
Gettysburg 2005	Briggs	1.5 (1.2)	1.5 (1.9)	3.1 (2.9)	3.7 (3.1)	1.2 (2.6)

Central SD has an semi arid climate where snowfall is important to spring wheat production. Snow was received during the winter (November–February) previous the growing season at Pierre 2003 (11.1 inches total); Aurora 2005 (13.1 inches total); Gettysburg 2004 (11.3 inches total) and Gettysburg 2005 (8 inches). Little or no snow was recorded at Pierre in 2004. The yearly average snowfall for Aurora is approximately 40 inches and is about 28.3 for Pierre, SD in central SD where the Pierre and Gettysburg fields were located (http://www.noaa.gov/). Previous season snowfall has been below normal at all sites over all years.

Grain samples were collected at harvest using a plot combine. Grain protein (average moisture 12%) was measured using an INFRATEC 1229 Grain Analyzer, Foss Tecator (Hoganas, Sweden). Grain samples were sent to CII labs, Kansas City, MO for flour quality analysis of flour protein, farinograph and alveograph.

RESULTS AND DISCUSSION

Grain and flour protein were correlated to each other (Figure 3). For both Russ and Briggs, grain protein was higher than flour protein (Figure 3). The relationship between grain and flour protein is stronger between Russ than Briggs.

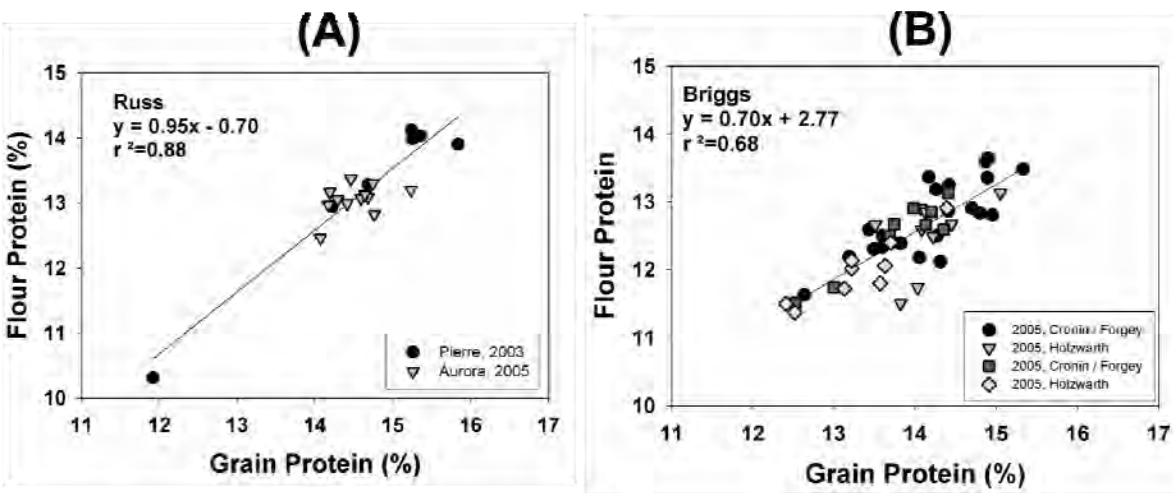

Figure 3. Linear regression and correlation coefficient results for flour protein predicted as a linear function of grain protein for Russ (A) and Briggs (B).

Based on grain protein content, both varieties would receive premium payments. However, grain protein may not always indicate high quality flour (Figure 4 and 5). Over years and sites, farinograph stability and alveograph W-values were correlated with grain protein for Russ but not Briggs (Figures 4 and 5). Farinograph stability and alveograph W-values increased under drought conditions for Russ when 7.4 in rain was received in 2004 (Fig. 4A & 5A). Johansson (1999) documented that during dry grain-filling periods with 24-hr day temperature average of 68^{O}F, Swedish varieties that contain high molecular weight glutenin subunits produced high gluten flours.

Temperatures at the end of June and throughout July 2005 at Gettysburg were above normal and precipation was lacking. However when Gettysburg rainfall decreased from 17 inches in 2004 to 12 inches in 2005, no apparent change in the linear relationship between grain protein and farinograph stability or alveograph-W values were observed.

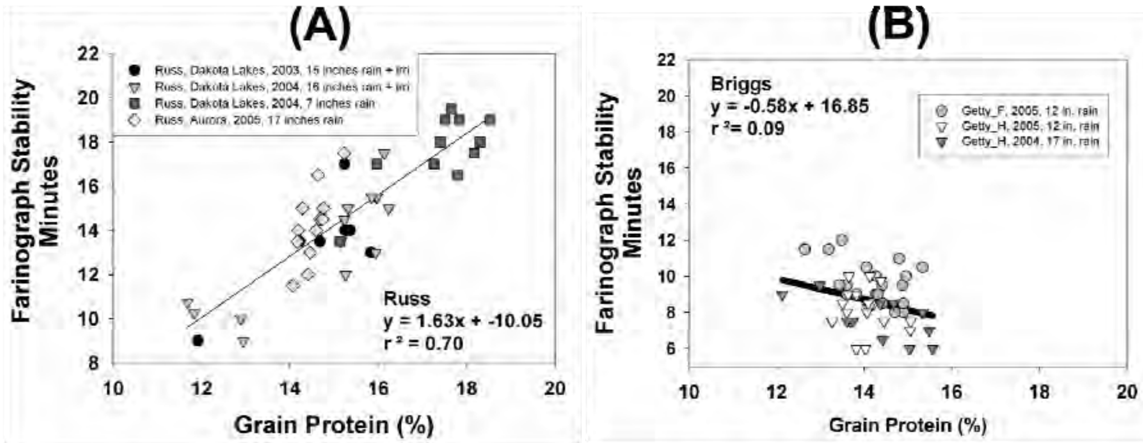

Figure 4. Linear regression and correlation coefficient results for farinograph stability as predicted as a linear function of grain protein for Russ (A) and Briggs (B).

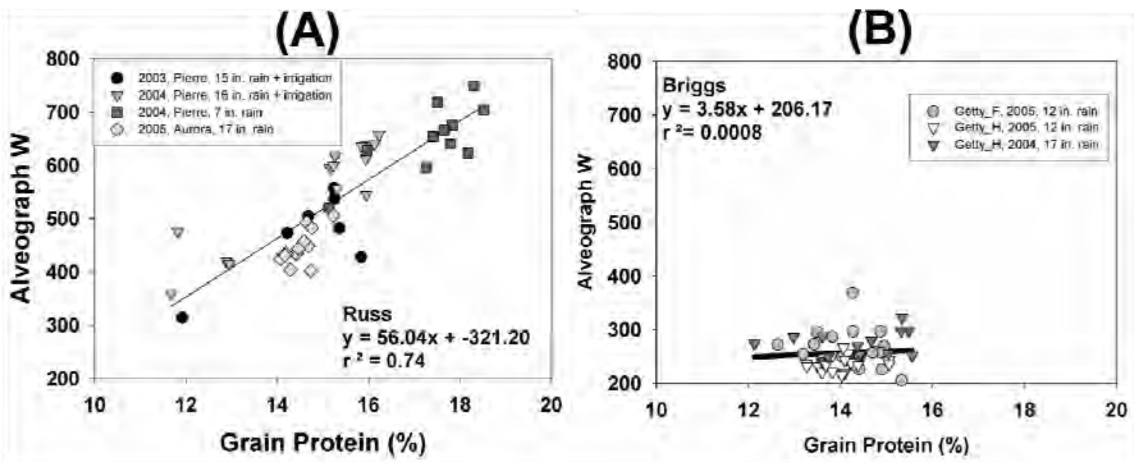

Figure 5. Linear regression and correlation coefficient results for alveograph-W as predicted as a linear function of grain protein for Russ (A) and Briggs (B).

Nitrogen had been reputed to be an important factor that impacts wheat quality. The Gettysburg sites had initial low soil test nitrate nitrogen (Table 1). Common knowledge when growing spring wheat in SD is to add additional nitrogen fertilizer to increase protein. While we observed that increasing fertilizer increased grain and flour protein for both Russ and Briggs, increasing fertilizer did increase the flour quality tests farinograph stability and alveograph-W for Russ but not Briggs.

These studies suggest that climate, nitrogen management and variety interact to affect flour quality. Other studies by Johansson et al. (1996, 1999, 2002, 2004), Souza et al. (2004) and Guttieri et al. (2005) support this conclusion. Johansson et al. (2002) documented that grain protein concentration is determined by genetics and influenced to a large extent by nitrogen, water access and temperature. Protein extractability and concentration are influenced by both genetics and environment such as weather or nitrogen fertilizers (Johansson et al., 2004). Souza et al. (2004) noted that cultivar selection has the greatest impact on varieites grown in the semiarid US Pacific Northwest with location and nitrogen management secondary. Guttieri et al. (2005) observed that genotype, N fertilizer and irrigation affected grain protein concentration and affected peak flour pasting viscosity and final flour pasting viscosity in hard wheat varieties grown in the US Pacific Northwest.

SUMMARY AND CONCLUSIONS

Finding from this research showed that grain protein is only one measure of flour quality. To accurately measure flour quality, additional tests are necessary. Millers that we are collaborating with suggent that farinograph and alveograph should be considered for hard red spring wheat from South Dakota since this grain is primarily used in bread, bagel or pizza flour production. These products require high gluten flours. In both varieties investigated in this study, additional N fertilizer increased grain protein. However, the additional N had mixed results on farinograph stability and alveograph-W values.

REFERENCES

Englund, R. 2005. SD Wheat Commission. Personal Communication.

Johansson, E., M. Preito-Linde, and G. Svensson. 1996. Quality evaluation of D zone omega gliadins. Plant Breeding. 115:57-62.

Johansson, E. and G. Svensson. 1999. Influences of yearly weather variation and fertilizer rate on bread-making quality in Swedish grown wheats containing HMW glutenin subunits 2+12 or %+10 cultivated during the period 1990-96.

Johannson, E., H. Nilsson, H. Mazhar, J. Skerritt, F. MacRitchie and G. Svensson. 2002. J. Sci. Food Agric. 82:1305-1311.

Johansson, E., M. Preito-Linde, and G. Svensson. 2004. Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars. J. Plant. Nutr. Soil Sci.. 167:345-350.

Guttieri, M.J., R. McLean, J.C. Stark and E. Souza. 2005. Managing Irrigation and Nitrogen Fertility of Hard Spring Wheat for Optimum Bread and Noodle Quality. Crop. Sci. 45:2049-2059.

Souza, E.J., J.M. Martin, M.J. Guttieri, K.M. O'Brien, D.K. Habernicht, S.P. Lanning, R. McLean, G.R. Carlson and L.E. Talbert. 2004. Crop Sci. 44:425-432.

Wheat and Flour Testing Methods: A Guide to Understanding Wheat Flour Quality. 2004. Wheat Marketing Center. Portland, Oregon, USA.

AKNOWLEDGEMENTS:

Thank you to Cronin Farms, Dan Forgey farm manager, Gettysburg, SD; Ralph Holzwarth, Gettysburg, SD and Dwayne Beck, Dakota Lakes Research Farm, Pierre, SD.

Funding provided by South Dakota Wheat Commission, South Dakota State Univ. Experiment Station, Upper Midwest Aerospace Consortium, USDA-CREES, NASA and EPA.

PROCEEDINGS
OF THE
WESTERN NUTRIENT
MANAGEMENT CONFERENCE

Volume 7

MARCH 8-9, 2007
SALT LAKE CITY, UTAH

Program Chair:
John Hart
Oregon State University
Corvallis, OR
(541) 737-5714
john.hart@oregonstate.edu

Publicity Chair:
Richard Koenig
Washington State University
Pullman, WA
(509) 335-2726
richk@wsu.edu

Coordinator:
Phyllis Pates
International Plant Nutrition Institute
Brookings, SD
(605) 692-6280
ppates@ipni.net