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Relating Wheat Quality to End-Product Quality

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Introduction

Millers in the export market have shown a growing preference for Canadian and Australian wheat over U.S. wheat over the past two decades. The primary reason for this assessment is because Canada and Australia have cleaner wheat (i.e. low dockage) with a more consistent quality profile. Overseas millers do not feel that the U.S. FGIS wheat grades and standards are an appropriate indicator of end-use quality. They want more information on dough and flour properties and are concerned about the variability in quality, both within and among lots (Wilson and Dahl).

To compete in this market, the U.S. needs to show that it can provide clean wheat with consistent functionality traits. Unfortunately, there is no easy way to test functionality. There are several tests that can be done to test the functionality of wheat, flour made from that wheat and dough made from that flour (e.g. alveograph, farinograph, falling number, etc.), but these tests take several minutes and are not practical for most country elevators.

Testing systems for other wheat characteristics are faster, but due to high testing equipment costs, they have not been widely implemented. One trait-testing example is the Single Kernel Characterization System (SKCS), which takes approximately three minutes to assess the weight, size, moisture and hardness of each kernel in a 300-kernel sample. A report is then generated that gives the mean and standard deviation of the sample. The whole kernel near-infrared (NIR) technology, used to quickly test protein quantity, is also being utilized to some degree at the elevator level (Gaines, et al, Baker, Herrman and Loughin). However, both of these tests require equipment that may cost thousands of dollars. Many elevators are reluctant to make such an investment without a good notion of the economics returns the collected information will provide.

Analysis of Wheat Quality

The SKCS and the NIR are two testing methods that can be performed in a timely enough manner to be done at a country elevator. While these tests provide some measures of expected milling and flour characteristics, they do not indicate all the flour, dough and baking quality characteristics that millers and bakers want to know. In order for either of these testing methods to be useful to elevator managers in indicating wheat's dough and baking quality, elevator managers would need to know which wheat quality factors affected the different flour, dough and baking functionalities.

To determine the effect of wheat quality on end-use functionality, an analysis was completed on a data set containing wheat quality information and results of flour and dough testing and baking evaluation for Oklahoma wheat.

The Data

The data used for this analysis came from samples that were collected from the five wheat-producing Agricultural Statistical Districts in Oklahoma, as determined by the Oklahoma Agricultural Statistics Service. After being graded by the FGIS Grain Inspection Licensed Office in Enid, Okla., the wheat samples were then taken to the OSU Wheat Quality Lab for quality testing. Historical data includes the 2000, 2001, 2002 and 2003 harvests. Results of these tests are published yearly in the Wheat Quality Crop Survey developed by the OSU Food & Agricultural Products Center.

The data consisted of seven different quality characteristic categories (FAPC) for each of the five districts:

1. Wheat grade characteristics (test weight, damaged kernels, foreign material, shrunken/broken kernels)
2. Wheat non-grade data (dockage, moisture, protein, kernel hardness, kernel weight, kernel diameter)
3. Milling quality characteristics (flour yield, falling number, wet gluten, gluten index)
4. Flour properties (protein, ash content, moisture)
5. Dough properties determined via farinograph testing (peak mixing time, stability, absorption rate)
6. Dough properties determined via alveograph testing (tenacity, extensibility, strength, configuration ratio)
7. Baking evaluation (internal characteristics, loaf volume)

Due to poor production conditions, samples were smaller in size and fewer in number in 2000. The data had missing values for wheat grade data in 2002; however, the other six categories were reported. Ideally, the researchers would have preferred to have data from more than four crop years that had been collected using a consistent sampling procedure for each region/year. However, only the data used for this study was available.

The Model

Ten PROC MIXED models were run using the SAS® statistical software and the previously described data. The models were designed to determine if flour and dough characteristics are functionally related to production region, crop year and wheat grade and non-grade characteristics. In other words, flour and dough characteristics (independent variables) were modeled as a function of region, year and wheat grain characteristics (explanatory variables). Year and district were defined as "class" variables (i.e. all the data observations fell into one of four crop years and one of five districts), and the remaining 12 explanatory variables in the models were continuous variables (i.e. they could be any value within a wide range of numbers). Tables 2, 3 and 4 summarize the results of the models.

Table 1. Quality Characteristic Definitions

Characteristic	Definition	Effect on Wheat/Milling
Test Weight	Bulk density measure; weight of a specific volume of grain	Provides rough estimate of potential flour yield
Damaged Kernels	Kernel defects due to heat, germ insect, frost, sprouting, and scab	Affects the appearance of flour, increases ash, decreases yield, or decreases sanitary quality
Foreign Material	All non-wheat material that remains in a dockage and shrunken and broken kernel free sample	Wheat must be cleaned of foreign material before it is milled into flour, if not, foreign material can decrease the quality of flour
Shrunken and Broken Kernels	Kernels that are broken or shrunken enough to go through a Number 2 sieve in a Carter Day dockage tester	Must be removed before milling; sold at a reduced cost in comparison to flour
Dockage	All non-wheat material that can be removed from a sample using FGIS approved procedures	Wheat must be cleaned of dockage before it is milled into flour
Moisture	Total percentage of wheat that is made up of water	Moisture content has inverse relationship with test weight
Protein	Wheat kernel substances containing nitrogen; varies in quantity and quality	Low quality or low quantity of protein can result in coarse texture and low quality bread
Kernel Hardness*	Average texture of wheat, hardness or softness determines if it is a hard or soft wheat	As hardness increases, so does the work or energy required to mill into flour
Kernel Weight*	Average weight of the individual kernels	Kernel weight, along with moisture effects protein
Kernel Diameter*	Average diameter of the individual kernel, indicates size	Kernel size impacts the ease of milling and particle size
Flour Yield	Percentage of flour recovered during milling; number of bushels of wheat required to produce a hundred-weight of flour	Helps determine the economic return to the miller
Falling Number	Indicator of sprout damage and flour's ability to set up	Falling number <250 results in gummy bread and flour unable to thicken in gravies or soups
Gluten	High-protein food product directly related to protein content	Effects dough strength, gas retention and controlled expansion, structural enhancement, water absorption and retention, and natural flavor
Ash Content	Inorganic material left after flour is burned	Component of extraction rate; influences flour color and quality
Peak Mixing Time	Time required for the flour to reach full development	Indicates optimum mixing time
Stability	Interval between the arrival time and the departure time	Indicates flour's ability to adjust to over and under mixing
Absorption Rate	Amount of water required to achieve maximum consistency	Determines optimal use of water
Tenacity (Denoted by P)	Peak height, maximum pressure required to produce bubble	Increasing P value causes product to be light or "fluffy"; high P values absorb large quantities of water
Extensibility (Denoted by L)	Extensibility of dough, how long it takes the bubble to burst	Impacts ability to rise
Strength (Denoted by W)	Baking strength of dough	Increasing W values indicate increasing dough strength
Configuration Ratio (Denoted by P/L)	Resistance related to time, indicates gluten behavior	Bread volume and well proportioned inside structure
Internal Characteristics	Crumb qualities including texture, grain, color, and shape	Determines end-use quality
Bread-Loaf Volume	Bread-making potential of flour	Higher loaf volumes indicate higher quantities of bread from a lot of flour

*Single Kernel Characterization System measurements taken from each kernel in a 300 kernel sample and reported as the mean of the sample.
Sources: Herrman et al; Gaines, et al; Call, Green, and Swanson; CII, 2004b; The Artisan; and

Conclusions

It must once again be noted that the availability of data placed some limitations on this analysis. The data were for only a four-year period and had some missing values. To improve the validity of the findings, testing needs to be completed more extensively within crop districts and over more crop years. Even with these limitations, the findings support the theory that significant differences exist between crop years and production regions. Results also indicate that many wheat grade and non-grade characteristics serve as limited proxies for flour and dough functionality traits.

Year/District Interaction was a significant factor for all functionality traits, indicating that there are differences in flour and dough quality associated with crop years and production regions. These findings may be due to the fact that growing conditions and planted wheat varieties differ among regions. Also, weather conditions vary from district to district and across years.

Table 2 shows that test weight and moisture were indicators for dough absorption, while dockage was an indicator of nothing. These grain characteristics are basic measurements taken at country elevators, but the correlation between absorption ability and test weight and moisture had not been previously determined. Dockage was not found to have a significant impact on any flour and dough characteristics, although that may be due to the fact that the samples had relatively low dockage levels to begin with.

Protein was a significant indicator of quality for six out of 10 flour/dough functionality traits: falling number, peak mixing time, absorption, extensibility and flour strength. Although protein is not currently measured in most Oklahoma elevators, it is possible to expand protein testing throughout Oklahoma using NIR technology. Many elevators providing direct rail shipments of wheat to Mexico and Central/South American countries have incorporated NIR protein testing at the elevator level.

Table 3 shows that both single kernel hardness and the standard deviation of kernel diameter (i.e. the variation in kernel diameter across a 300-kernel sample) were indicators in at least five out of 10 flour and dough functionality traits. Single kernel hardness was a significant indicator of falling number, extraction rate, flour strength, peak mixing time, absorption, stability and dough tenacity. Variation in kernel diameter was shown to be a good indicator of dough stability, tenacity, extensibility and the tenacity/extensibility ratio.

Table 4 lists each of the significant wheat grade and non-grade characteristics and the flour and dough functionality traits that they impact. With a more complete data set expanded by number of samples tested and years covered, more extensive studies could be done to learn how much the end-use qualities of HRW wheat vary from region to region and from year to year. Plus, more concise "character mapping" could be developed to determine approximate levels of end-use characteristics given a set of grain characteristics.

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Table 2. Variations in Flour and Dough Functionality Traits as a Function of Production Region, Crop Year, Wheat Grade, and Non-Grade Measures (numbers represent the P-values of statistically significant correlations)

Grade, Non-grade, Kernel Uniformity Measures	Year/District Interaction	Test Weight (lb)	Dockage	Foreign Material	Shrunken and Broken	Damaged Kernels	Moisture	Protien
Falling Number	<.0001							0.0005
Extraction Rate	<.0001							
Peak Mixing Time	<.0001			0.0293				<.0001
Stability	<.0001			0.0178				
Absorption	<.0001							<.0001
Absorption 14 %MB	<.0001	0.0028					0.0016	<.0001
Tenacity	<.0001							
Extensibility	<.0001							<.0001
Flour Strength	<.0001							<.0001
Tenacity/Extensibility Ratio	<.0001							

*MB is moisture basis

Table 3. Variations in Flour and Dough Functionality Traits as a Function Single Kernel Characteristics (numbers represent the P-values of statistically significant correlations)

	Hardness	Hardness Standard Deviation	Weight	Weight Standard Deviation	Diameter	Diameter Standard Deviation
Falling Number					0.0011	
Extraction Rate	<.0001	0.011				
Peak Mixing Time	<.0001				0.013	
Stability	<.0001					0.0054
Absorption	0.0058					0.0046
Absorption 14 % MB	<.0001					
Tenacity	<.0001		0.0002			0.0029
Extensibility						0.0063
Flour Strength	0.0008					
Tenacity/Extensibility Ratio			<.0001			0.0023

*MB is moisture basis

Table 4. Wheat Production, Grade, and Kernel Uniformity Factors and the Flour/Dough Functionality Traits They Significantly Influence

Grade and Non-Grade Characteristics	Flour and Dough Characteristics
Year and District Interaction	Falling Number, Extraction Rate, Peak Mixing Time, Stability, Absorption 14% MB*, Tenacity, Extensibility, Flour Strength, Tenacity/Extensibility Ratio
Test Weight	Absorption 14% MB*
Foreign Material	Peak Mixing Time, Stability
Moisture	Absorption 14% MB*
Protein	Falling Number, Peak Mixing Time, Absorption 14% MB*, Extensibility, Flour Strength
Hardness	Falling Number, Extraction Rate, Peak Mixing Time, Stability, Absorption 14% MB*, Tenacity, Flour Strength
Hardness Standard Deviation	Extraction Rate
Weight	Tenacity, Tenacity/Extensibility Ratio
Diameter	Falling Number, Peak Mixing Time
Diameter Standard Deviation	Stability, Tenacity, Extensibility, Tenacity/Extensibility Ratio

*MB is moisture basis

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Samuel E. Curl, Director of Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Dean of the Division of Agricultural Sciences and Natural Resources and has been prepared and distributed at a cost of 74 cents per copy. MHG 0704.