White Paper: Strategies to Reduce Economic Losses Due to Low Falling Number in Wheat

Summary of the Falling Numbers Summit, Feb. 16, 2017, Spokane, WA

Target Audience: Participants at Falling Number Summit, Press, Universities, Local, State & Federal Government Personnel, Growers, Grain Industry

Introduction: Untimely rain and temperature fluctuations caused increases in the starch-degrading enzyme alpha-amylase in Pacific Northwest (PNW) wheat grain and low values for the international grading standard Hagberg Falling Numbers (FN) test. Wheat grain must meet a minimum of 300 seconds in the FN test in order to be considered of good quality. Grain with low FN values is sold at a steep discount because the end-use functionality is compromised. Since 2011, low FNs have cost western farmers millions of dollars. Economic losses to the grain industry in 2016 alone exceeded $30 million and will likely approach $140 million in total. The two causes of low FNs in wheat grain are: 1) pre-harvest sprouting or germination on the mother plant due to rain before harvest, and 2) late maturity alpha-amylase (LMA) due to heat or cold shock during grain development. Grain industry representatives, including wheat commissioners, growers, millers, bakers, exporters, scientists, and extension personnel met in Spokane on Feb. 16 to share current knowledge, determine where more knowledge is needed, develop priorities for action and assign leaders to each priority action item. The focus of the meeting was on short (3-6 month) and mid-term (6 months to 2 years) strategies. This report identifies the strategies and outcomes from that meeting. Long-term strategies were also discussed and are reported at the end of this white paper.

Key Background points:

Low FN has a negative effect on wheat end use quality. Low FN is caused by alpha amylase breakdown of starch in the grain. The alpha amylase enzyme is required for wheat seed germination. Untimely release of alpha amylase prior to harvest is the key problem that reduces grain quality. The release of alpha amylase is caused by at least two physiological responses in the un-harvested wheat kernels. Preharvest sprouting (PHS) is a result of moisture and temperature conditions that result in germination of the grain on the plant prior to harvest. Late maturity alpha amylase (LMA) has been associated with rapid temperature change approximately 21 days after flowering. The distribution of alpha amylase in the kernel differs for the two causes of low FN. Components of wheat grain, including the starch composition, protein composition and concentration, starch molecular structure, lipid composition, and kernel weight may also have an impact on the FN.

Low FN affects baked products that require viscosity, such as cakes, and those that use flour as a thickener. The physiological response of the kernel components to PHS and to LMA may be different and may result in different effects on grain quality. Predisposition to low FN, whether caused by PHS or LMA, is under genetic control in wheat and can be manipulated both through conventional plant breeding and through the use of biotechnology.

The Hagberg FN test is determined according to FGIS Rule 9180.38 based on internationally standardized methods (ICC/No. 107/1; AACCI/No. 56-81.03; ISO/No. ISO/DIS 3093; and ASBC Barley 12-A). The FN test evaluates the viscosity of a whole-meal/water slurry based on the time needed for a pin to fall. The Perten FN machine (Perten Instruments, Springfield IL, USA) is the standard for the FGIS Rule. Other manufacturers include Chopin and Foss. Improvements to the standard protocol can be made through standardization of sampling, cleaning, and mixing procedures and better estimation of barometric pressure. Other methodologies, such as near infrared reflectance, may be able to predict the FN score with less accuracy but greater speed.

The growing environment plays a large role in the development of low FN due to both PHS and LMA. The role of the environment is complex because temperature, precipitation, soil characteristics, fertility and geographic location influence plant growth and development and may establish conditions for LMA and PHS to occur. Management inputs including fungicide, fertility, and drought, may also have an effect on the outcome of the test.

Problems with low FN have occurred regionally for many years but the grain trade was able to adjust within based on the volume and price of wheat available. It is critical that methods be developed to ensure that growers are able to identify if grain is likely to have low FN; grain handlers are able to accurately test for the problem; FN tests are consistent across laboratories; breeders develop high throughput evaluation and screening methods to select for improved varieties; and management inputs are identified and implemented.

Solution:
The goals and proposed activities to meet the challenge of reducing risk due to low Falling Number are organized as five questions:

1. How can the current FN test be improved?
Background: The current FGIS Rule 9180.38, describing the FN test is specific to the Perten machine. The rule is currently undergoing revision. Perten, Foss and Chopin all sell FN machines. FGIS has a lab monitoring program calibration protocol that ensures a 5% CV across FGIS Designated laboratories. Other labs that are critical to the flow of grain in the PNW are not part of this program. Other things that impact repeatability and reproducibility in the test are age of machine, service and maintenance and individual operator training and years of experience. The barometric pressure affects the outcome of the FN test but the current correction needs to be improved for areas between 1000-2000 feet. There are sampling issues for the FN test where a 7g sample represents a truckload of grain. The WSDA has done a great job of narrowing the gaps in repeatability and reproducibility in the WSDA labs. The Idaho labs are not FGIS designated labs while Oregon sends grain to the FGIS Designated labs. A standardization protocol that meets the benchmarks needs to be adopted and monitored in non-FGIS labs as well as in FGIS Designated labs.

Short and medium term goals:

1. The FGIS Rule (v 9180.38(5/2013) should be revised and revisions should become the standard across all testing labs doing testing for commercial uses.

2. A check sample service should be established for all labs that run FN would help standardize the method across testing labs whether they are "Designated" or not.

3. The standard protocol should be implementable on all versions of the instrument.

4. Benchmark metrics should be reduced from the current 5% CV to 1% CV for reproducibility and the current allowed 30 second difference between the two tubes in the FN test should be reduced to 10 seconds for repeatability.

5. The revised rule draft should be reviewed by the FGIS Designated labs and by the Milling company quality labs, State quality labs, University quality labs, the Western Wheat Quality lab, and the Wheat Marketing Center.

6. Effective training materials should be developed to convey updated rules and procedures to FGIS Designated and undesignated labs. This information should be conveyed to producer groups, regional grain commissions, and state departments of agriculture, within and outside of the FGIS system.

2. Can alternate technologies be used to measure FN?

Background: PHS has a direct effect on end-use quality. We don't know the effect of LMA on end-use quality. A rapid test is needed to increase the number of samples processed, the speed that results are achieved, and the ability to segregate grain. A more sensitive method to measure the alpha-amylase is needed because low FN values do not always indicate high amylase activity. NIR may provide a useful rapid, but less sensitive test. The ELISA method may provide a more rapid and sensitive test for alpha-amylase activity but more research is needed to determine the cascade of enzymes expressed during PHS and during LMA in order to create an ELISA assay that can differentiate between LMA and PHS.

Alpha-amylase activity in grain can be measured using the Hagberg FN test and using the rapid viscometer (RVA), stirring number, amylograph, Testogram, Megazyme and Phadebas test kits, and, possibly, a blood glucose meter. The stirring viscosity tests such as RVA and amylograph control the effects of the grain components like lipids and amylopectin on viscosity and remove the effect of barometric pressure. These tests remain important for end-users, whether the amylase activity is measured directly or not. The Testogram (Chopin) is a stirring viscometer with an FN equivalent result. A subsequent test for protease as well as amylase can determine is low FN is caused by PHS instead of LMA.

Short-term goals:

1. Evaluate stirring number and Testogram compared to Hagberg FN results.

2. Conduct a matrix comparison of various current tests. Determine which tests are most informative to determine quality of low FN grain.

3. Investigate how to control sampling issues – Steve Delwiche.

4. Determine if a rapid test such as NIR can be used to separate the very bad from the good, and maybe even the medium bad.

Medium term goals:

1. Develop and ELISA test for alpha-amylase. Contact Bayer to see if we can get access to the ELISA that they have developed. Craig Morris and Alex McGregor
2. Investigate the use of protease tablets to differentiate PHS from LMA.
3. Investigate the role of starch molecular structure, lipids, and proteins on product quality.

3. What are the relative roles of genetics and environmental effects on PHS? Can these be manipulated to reduce the incidence of low FN?

Background: Preharvest sprouting is a complex trait that is influenced by predisposition to PHS per se and by maturity, head structure, tiller number, and density of stand. Some quantitative trait loci have been identified. The breeding programs possess germplasm, genetic stocks and breeding lines that are segregating for genetic resistance. Significantly more standardized screening is needed. The bottleneck to effective selection and breeding is the screening to determine the phenotype so we can determine the genetic architecture of the trait. More research is needed to model the temperature and moisture levels needed to cause the problem in the field. More research is needed to identify environmental effects, whether it is fertility, or the duration of moisture or temperature needed to trigger PHS. This research needs to be done in the field and in controlled environments so that effective screening systems can be developed. At least with PHS, visual inspection can identify the problem, unlike LMA. Solutions for this question are merged with solutions to the next question.

4. What are the relative roles of genetics and environmental effects on LMA? Can these be manipulated to reduce the incidence of low FN?

Background: The genetic and environmental triggers leading to LMA are complicated and largely unknown, although some quantitative trait loci have been identified in Australia. We do know that LMA is associated with a daily temperature fluctuation of about 40 degrees F occurring 25 to 30 days after flowering. With LMA, the distribution of alpha amylase in the grain is patchy, rather than targeted to the embryo. There may be an impact of temperature stress on starch granule development and subsequent amylase in LMA? How do flour and starch properties interact with LMA? Are they the same as the effects of PHS or different problems? How does temperature combine with moisture to trigger LMA? What are the effects of cold vs. a late frost? There may be fungicidal interactions that increase predisposition to LMA, especially with the Strobilurins (vs. Triazoles) that seem to cause a hormonal interaction. The impact of nitrogen fertility on LMA is unknown.

Predictive modeling is needed. An analysis of weather data, patterns or trends might predict where and when FN might be a problem and then the grain trade can proactively segregate on this basis? Can risk categories be established based on geography? Elevators are using this approach now – what environmental conditions are known to cause low FN and did these conditions exist in the year and/or area that grain is flowing from. A similar approach has been used to predict geographic areas where incidence of "DON", caused by *Fusarium* head blight, will is likely to be high.

Short-term goals

1. Coordinate a regional effort to categorize current varieties to low FN. Summarize the data over last 3 or 4 years.
2. Screen current varieties for PHS and LMA response using the spike-wetting test and assays in controlled environments.
2. There are numerous genotyped populations at the 3 universities. Choose 2-4 biparental populations by evaluating parents for LMA and PHS. Use them to map loci with significant influence on the traits.
3. Investigate the relationship between nitrogen application and FN.

Medium term goals

1. Define the timing and temperatures needed to induce LMA using one DH genotype – Camille Steber.
2. Investigate the effects of fungicide on LMA. - Juliet Marshall and Arron Carter.
3. Investigate whether germination or sprouting can be altered by inhibiting GA biosynthesis.
4. Modeling GXE. Build models to predict the risk of a specific variety in specific regions of the Pacific Northwest. Use modeling of climate combined with current data on FN to evaluate the risk of LMA and PHS. Identify the conditions needed to cause LMA – microclimates.

5. What are the best strategies for communication about the Falling Number issue?

Effective communication begins with comprehension.
What methods do we have to communicate?

- Low FN extension publication from WSU
- Wheat Life and Greensheets from WA
- WSU Wheat and Small Grains site
- Camille Steber Web site
- Telephone mode
- Wheat Marketing Center and US Wheat weekly harvest reports identify issues as they emerge (low FN and others
- Univ of ID low FN Q/A publication
- Idaho Wheat Commission videos
- Grower meetings
- Emerging Issues bulletin or timely/hot topics approach.

- Industry (such as McGregor) is a good conduit for information as well. They can carry this to growers they reach through their winter programs, variety plots etc.

Effective communication requires multiple methods and approaches. The cleanest form of information transfer is similar in format to the Wheat Quality guide. It is a brief, to the point, ranking of varieties. Variety rankings that are color-coded, such as a red, yellow, green chart would be useful to guide grower decisions. Perhaps there is a difference in communicating to the grower about such things as variety selection and preventative measures as opposed to communicating about the quality of the crop to buyers and customers. We need to avoid causing undue alarm to the buyer.

The high wheat prices and more isolated impact area of the past made low FN discounts more tolerable. The low price now and more widespread epidemic region for FN is why so much discounting is occurring and more difficult to absorb. More information is needed to determine variety response to LMA and PHS and relationship to crop maturity so that growers can make good varietal selections. How can a problem such as the widespread low FN epidemic of 2016 be anticipated and addressed proactively.

Communication also needs to include what the universities and USDA are doing to address the problem. What efforts are ongoing at FGIS, grain industry and research laboratories? Communication is important to inform requests for future funding to address the problem. Understanding what industry is doing and how growers can contribute or help.

Short and Medium term goals

1. Inform research so that the information gleaned is useable in form and function to growers and industry.
2. Investigate how can we use the current data and be more interactive or user friendly for a grower to make management decision. Develop a short-term variety rating (red, yellow, green) until a more robust model and system is available. This would be one more trait that a grower could use in selection process.
3. Make the information that is currently on the FN website more user friendly. Extract and provide in different format.
4. Communicate the right message – accurate, balanced. Seed sales are at risk. There are competing goals and priorities.
5. Identify questions about Low FN and inform research about short-term needs. These include impact of field variation, interplant variation, within spike variation, etc. in maturity and therefore LMA risk based on environment.
6. The low FN problem is being addressed by three universities, the USDA-ARS, state and FGIS laboratories. Identify how this is being addressed; a common message; and common goals and a timeline.

7. Put situation in perspective – what is driving the problem; how frequently has it happened in the past; why was it, or was not it, a problem in the past? Discern how to disseminate the info to be advantageous rather than liable.
8. Use multiple modes of communication; push information out in many different ways.

Identify what needs to be communicated? Who has this information? Who is best positioned to send the information out? Modes?

Falling Number Summit Follow up and Future plans

1. Distribute this White Paper and other summary documents and presentations from the Falling Number Summit event through multiple venues.
2. ARS Wheat Health, Genetics and Quality Research Unit will develop a web site linked to information on Falling Number issues and the information in #1 above.
3. A short term research coordination meeting will be held at Western Wheat Workers Meeting, May 31 to June 1, 2017 in Corvallis OR.
4. Research progress report and coordination, and information exchange will be held at the Tristate Growers meeting in Spokane in November 2017.

Submitted, 03/16/2017 by Kimberly Garland Campbell

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