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MANAGING THE RISK OF LOW FALLING NUMBERS IN WHEAT

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Managing the Risk of Low Falling Numbers in Wheat

Grain is purchased at a discount when falling numbers are below 300 seconds (sec). This can result in serious financial losses for farmers. This article addresses many commonly asked questions about the Hagberg-Perten Falling Number test, and provides some suggestions for reducing losses due to low falling numbers.

What is the Falling Number test?

The Hagberg-Perten Falling Number test is used to measure damage to starch in flour (Perten 1964). Low falling numbers result from high levels of the enzyme alpha-amylase (Perten 1964; Kruger and Tipples 1980; Yu et al. 2015). Alpha-amylase catalyzes cleavage of starch chains. This starch damage leads to poor end-use quality of wheat products including bread, noodles, and cakes (Farrand 1964; Batey et al. 1997; Gooding and Davies 1997). For example, Japanese-style sponge cakes show an increasing tendency to fall with increasing levels of alpha-amylase (Figure 1).

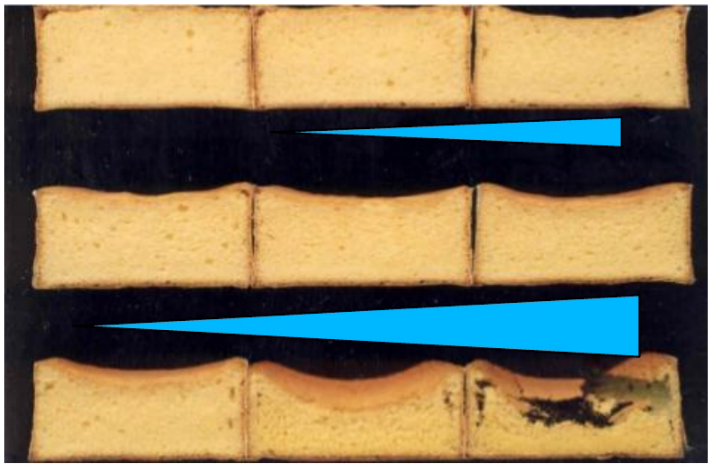

Figure 1. Sponge cakes fall with the increasing alpha-amylase content that can come from pre-harvest sprouting. Image reproduced with permission from C. Morris, WWQL, USDA-ARS, Pullman WA.

The falling number test is based on the principle that starch damage from alpha-amylase reduces the ability of wheat flour to "gel." During the test, a flour/water mixture is heated and stirred, like making gravy. Once the mixture has been stirred for exactly 60 sec, the falling number instrument measures the length of time in seconds needed for the stirrer to fall through the mixture (also see the video What is the Falling Number Test?). With more starch damage, the mixture is thinner, and the stirrer falls faster. The lowest possible falling number is 60 sec (the length of time the gravy is stirred). Grain with a falling number below 300 sec is typically discounted in the Pacific Northwest (PNW). The goal is to keep the falling number of PNW wheat higher in order to compete well in the export market.

What is pre-harvest sprouting?

Pre-harvest sprouting is the initiation of grain germination while still on the mother plant (Lunn et al. 2001). Germinating seeds make alpha-amylase. This alpha-amylase cleaves starch chains into sugars that can be used to fuel seedling growth.

Why don't all mature seeds sprout right away in the rain?

Some wheat varieties can germinate immediately after the grains mature, while some cannot (Tuttle et al. 2015). Varieties that are unable to germinate immediately after maturity are considered dormant or "asleep." There are two ways to break the dormancy of such varieties. The first is to store them dry so that they "after-ripen"; this period of dry storage can range from two weeks to one year depending on the variety. The second way is to subject them to cold and wet conditions (wetness alone is not enough). Differences in seed dormancy explain 60–80% of the variation in pre-harvest sprouting susceptibility (DePauw and McCaig 1991).

What kind of weather promotes pre-harvest sprouting?

Not all rainstorms induce pre-harvest sprouting. Cool weather combined with rain increases the likelihood of pre-harvest sprouting. If the temperatures are in the 80s when it rains, then wheat is less likely to sprout than if the temperatures are in the 60s (degrees Fahrenheit). Low falling numbers are also more likely when there are multiple rainy days in a row, as it is more likely that dormancy will be broken and germination started if the wheat stays wet longer. When conditions are cool and wet for an extended period of time, even cultivars that are highly resistant to pre-harvest sprouting will sprout.

How do you spot a sprouted grain?

It takes a lot of rainfall to make a seedling visibly sprout out from a wheat spike (about 3 days of constant rain at 70°F). But you can see visible signs of sprout in as little as 24 hours if you look closely at an individual grain. You can sometimes see a small root protruding from the germ-end of the grain (Figure 2). Such grain can have a very low falling number (under 200 sec). As the sprouted grain dries, the root can shrink back into the grain leaving behind a small crack or crater at the embryo/germ end. Sometimes this cracked end breaks, leaving behind a germ-less grain. A magnifying glass can be useful in spotting these early signs of sprouting.

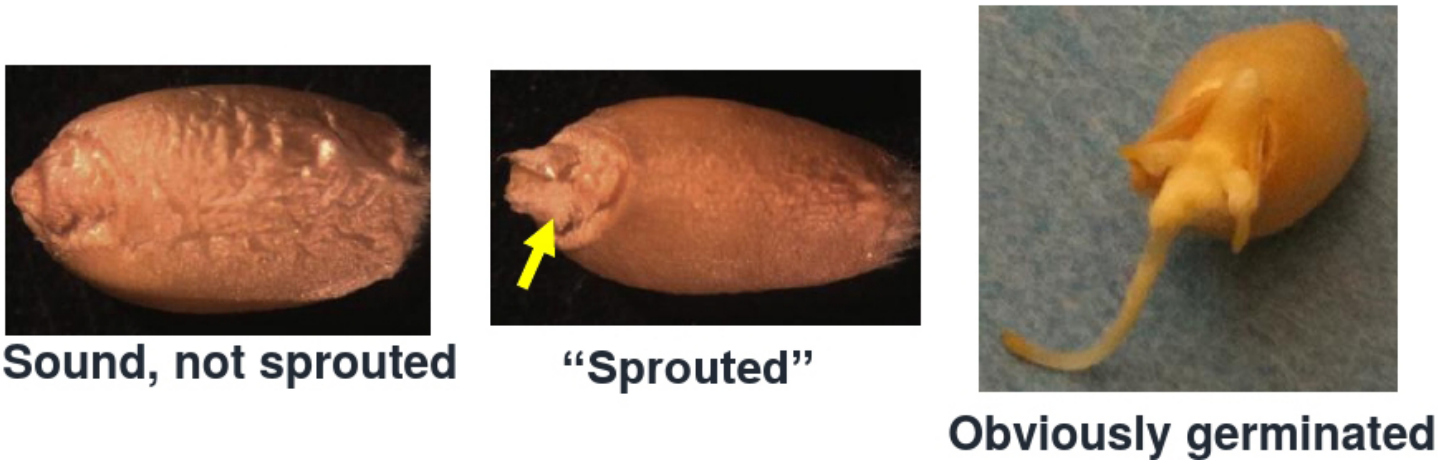

Figure 2. A sprouted grain with a seedling root just poking out of the grain is not obviously germinated, but has low falling numbers and high amylase. Photos by S. Martinez and C. Steber.

Why do we see low falling numbers in wheat that is not visibly sprouted?

The germination process begins before the wheat seedling pokes out from the grain. The enzyme alpha-amylase can be produced before the grain is visibly sprouted. This is why you can sometimes have rained-on grain that has a falling number below 300 sec, but is not visibly sprouted. The other possible explanation is that the low falling numbers were not caused by sprouting.

Is pre-harvest sprouting the only possible cause of low falling numbers?

Pre-harvest sprouting in response to rain is not the only possible cause of low falling numbers. Low falling numbers (200–300 sec) can also be caused by what is called late-maturity alpha-amylase (also called LMA; Mares and Mrva 2008). The production of this alpha-amylase is caused by heat shock or cold shock during late grain maturation (26 to 30 days after pollen shedding). Late-maturity alpha-amylase causes low falling numbers in grain that visually appears to be sound. Thus, big temperature fluctuations can cause low falling numbers in susceptible cultivars, even without rain. While late-maturity alpha-amylase has been a problem in Australian wheat since the early 1990s, genetic susceptibility was discovered fairly recently in PNW wheat. Some late-maturity alpha-amylase-prone lines include Bruehl, Jasper, SY-Ovation, and Alturas.

Why are falling number measurements so variable?

Multiple factors conspire to cause a high degree of variation in the falling number measurement. This can be very frustrating because the difference between 300 sec and 297 sec could result in a serious loss of revenue for a farmer. The variability in falling numbers comes in part from the test itself and in part from biological variation. There can be small differences in the time it takes a technician to shake a sample and place it in the water bath resulting in small differences in the falling number. The falling number is also partly dependent on differences in grain moisture content, altitude, and atmospheric pressure. Operators do their best to minimize sources of variation by following standard protocols (AACC 1999), but some variation is inevitable. Some of the variation is also due to the biology of the wheat itself. Differences in moisture, temperature, and crop maturity dates on different parts of a farm can result in differences in falling number in different lots of grain from the same farm. For example, wheat in a draw may be more sprouted because it stays wetter and cooler longer than wheat on a hilltop. Thus, sampling from a different part of the field may give different numbers. Some farmers hope to get a better falling number by having the test repeated. It is important to keep in mind that a second test may give either a higher or a lower falling number.

What can farmers do to reduce economic losses due to low falling numbers?

Harvest wheat quickly after maturity. Harvesting wheat quickly after maturity reduces the chances of rain damage.

Wheat loses more dormancy the longer it is left mature in the field, increasing the chances that it will sprout if it rains (Figure 3). Thus, the severity of the sprouting problem depends on the timing of the rain event relative to when the wheat reached maturity. Don't harvest too early, however. Green kernels have high alpha-amylase activity (and can cause lower falling numbers) because the enzyme helps provide fuel for grain development. Never combine wheat that is yellow with green wheat. Wait for rained-on wheat to dry before harvesting to avoid germination during storage.

Plant wheat cultivars with genetic resistance to pre-harvest sprouting and late-maturity alpha-amylase. Past pre-harvest sprouting events can be used as an indicator as to which cultivars have more genetic resistance to sprouting. For example, there were major sprouting events in Fairfield, Lamont, Pullman, and other locations in 2013. The falling numbers of cultivars grown in the Washington State University Cereal Variety Testing Trials during 2013 and subsequent years can be found on the Falling Numbers website. The falling number versus yield tool on the Falling Numbers website can help growers take both yield and falling numbers into account when choosing a cultivar.

Examples of cultivars with better sprouting tolerance include Cara, Coda, Mary, Masami, Puma, and Skiles. Sprouting-susceptible cultivars include Bruehl, Xerpha, AP-Legacy, WB-Junction, Curiosity, and Bruneau. Ongoing research is aimed at developing better wheat cultivars with genetic resistance to pre-harvest sprouting and late-maturity alpha-amylase. It should be noted that while higher seed dormancy provides pre-harvest sprouting tolerance, it can cause problems with poor emergence. This is especially true in dry, deep planting conditions if sufficient after-ripening has not occurred.

Avoid mixing sprouted grain with unsprouted grain. Because alpha-amylase is an enzyme catalyst, a little bit of enzyme can cause serious falling number problems (Kruger and Lineback 1987). For example, mixing equal amounts of 200 sec grain with 400 sec grain will not give you a load with a falling number of 300 sec. Instead you will end up with a falling number well below 300. Thus, "blending" grain with different falling numbers is more risky than blending grain with different protein content.

Store mildly sprouted grain. Some research suggests that falling numbers increase during storage (Gras et al. 1994; Karaoglu et al. 2010). It appears that the alpha-amylase enzyme is degraded over time. This occurs at lower temperatures in the 70s, but is accelerated by higher temperatures (as high as 100°F; Andrew Ross, personal communication). If the falling number is moderately low (220–300 sec), it can help to store grain for a few months to see if the falling number rises. Storing badly sprouted grain does not improve falling numbers, either because there is too much alpha-amylase present or because starch damage has

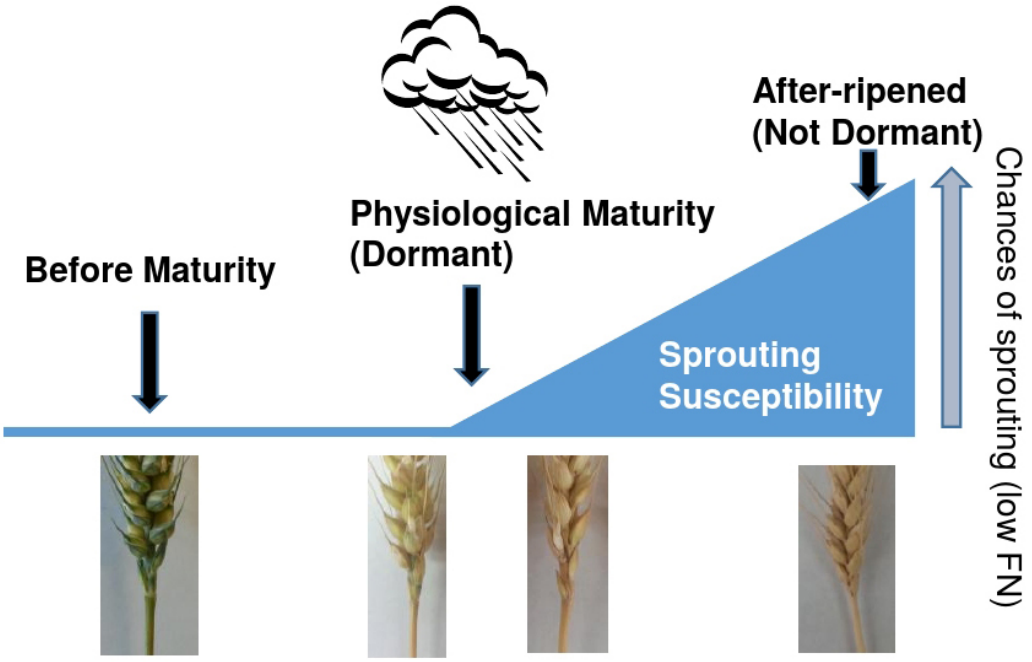

Figure 3. The chance that rain will induce sprouting and low falling numbers (FN) increases the longer the wheat "after-ripens," or sits dry on the mother plant after the wheat matures (turns yellow). Dormancy and sprouting tolerance are lost as the wheat stands in the field. Thus, there may be differences in apparent resistance to low falling numbers in different years depending on the timing of the rain event relative to crop maturity.

already occurred. For example, the Steber lab has a sample of sprouted Bruehl from 2013 that has maintained a falling number of about 145 sec over three years of storage at room temperature.

Additional Resources

Steber, C.M., M.O. Pumphrey, and A.H. Carter. Falling Number Data website.

Bettge, A. What is the Falling Number Test?

References

AACC (American Association for Clinical Chemistry). AACC International Method 56-81.03. 1999. Determination of Falling Number. Physicochemical methods.

Batey, I., B. Curtin, and S. Moore. 1997. Optimization of Rapid-Visco Analyser Test Conditions for Predicting Asian Noodle Quality. *Cereal Chemistry* 74(4): 497–501.

DePauw, R.M., and T. McCaig. 1991. Components of Variation, Heritabilities and Correlations for Indices of Sprouting Tolerance and Seed Dormancy in *Triticum* spp. *Euphytica* 52(3): 221–229.

Farrand, E. 1964. Flour Properties in Relation to the Modern Bread Processes in the United Kingdom, with Special Reference to Alpha-Amylase and Starch Damage. *Cereal Chemistry* 41(98): 98–111.

Gooding, M.J., and P.W. Davies. 1997. Wheat Production and Utilization: Systems, Quality, and the Environment. CAB International.

Gras, P., M. Bason, and J. Tomlinson. 1994. Effect of Storage and Thermal Treatment on Quality of Rain-Damaged Wheat. *Proceedings of the 6th International Conference on Stored-Product Protection* 1235–1237.

Karaoglu, M., M. Aydeniz, H.G. Kotancilar and K.E. Gercelaslan. 2010. A Comparison of the Functional Characteristics of Wheat Stored as Grain with Wheat Stored in Spike Form. *International Journal of Food Science & Technology* 45(1): 38–47.

Kruger, J., and K. Tipples. 1980. Relationships between Falling Number, Amylograph Viscosity, and Alpha-Amylase Activity in Canadian Wheat. *Cereal Research Communications* 8(1): 97–105.

Kruger, J.E., and D.R. Lineback. 1987. Carbohydrate-Degrading Enzymes in Cereals. In: J.E. Kruger and D.R. Lineback, eds. Enzymes and Their Role in Cereal Technology. 117–138. AACC Monograph Series.

Lunn, Major, B.J., P. Kettlewell, and R.K. Scott. 2001. Mechanisms Leading to Excess Alpha-Amylase Activity in Wheat (*Triticum aestivum* L.) Grain in the U.K. *Journal of Cereal Science* 33(3): 313–329.

Mares, D., and K. Mrva. 2008. Late-Maturity Alpha-Amylase: Low Falling Number in Wheat in the Absence of Preharvest Sprouting. *Journal of Cereal Science* 47(1): 6–17.

Perten, H. 1964. Application of the Falling Number Method for Evaluating Alpha-Amylase Activity. *Cereal Chemistry* 41(3): 127–140.

Ross, A. 2016. Personal communication. Professor of Crop and Soil Science and of Food Science and Technology, Oregon State University.

Tuttle, K. M., S.A. Martinez, E.C. Schramm, Y. Takebayashi, M. Seo, and C.M. Steber. 2015. Grain Dormancy Loss is Associated with Changes in ABA and GA Sensitivity and Hormone Accumulation in Bread Wheat, *Triticum aestivum* (L.). *Seed Science Research* 25(02): 179–193.

Yu, N., R. Laurenz, L. Siler, P. Ng, E. Souza, and J. Lewis. 2015. Evaluation of Alpha-Amylase Activity and Falling Number Around Maturity for Soft White and Soft Red Wheat Varieties in Michigan. *Cereal Research Communications* 43(4): 672–681.

Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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