The Falling Number Test — What Is It and How Does It Work?

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The Northern Great Plains states of North and South Dakota, Minnesota and Montana are the primary producers of hard red spring and durum wheat. Traditionally, the flour derived from hard red spring wheat has been used domestically to produce specialty type bread products or to blend with winter wheat flour for conventional types of bread. Approximately 50 per cent of the hard red spring wheat produced goes into the export market. The exported wheat is regarded by many countries to be the "Cadillac" of bread wheats. Approximately 50 per cent of the durum wheat crop, which is grown predominantly in North Dakota, is used for the domestic production of pasta products, while the remainder is exported.

When sprouting occurs in spring and durum wheat, marketing of wheat, particularly in the export market, is threatened. Complaints about sprouted wheat appear to be greater from the export market than from domestic sources, although both markets will show concern for the problem. The reason for the greater concern in the export market is probably twofold. In European countries, many of the domestic wheats already have high alpha-amylase activity. The addition of sprouted wheat merely serves to compound the problem. In other countries, such as Japan, barley malt, which is a source of the enzyme alpha-amylase, is not added to the flour during milling as is done in the United States. Therefore, they are much more conscious of the level of sprouting in the wheat that they purchase.

With increased interest in the falling number test to detect sprout damage in wheat, several studies were conducted to evaluate this particular procedure and to elucidate factors which affect the falling number test. Medcalf et al. (9) found consistent differences among a group of six varieties of hard red spring wheat, indicating a definite varietal factor which affected falling number values. Also, location of growth and environmental conditions at harvest significantly affected the falling number values observed. In an investigation reported by Mathewson (7), falling number values for sprouted white wheat samples were found to be higher than those for hard red winter wheats at the same level of alpha-amylase. Both genetic differences and growth conditions were responsible for the differences in susceptibility.

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The Falling Number Instrument

The apparatus used for the falling number test is relatively simple. Figure 1 shows the latest model of the falling number instrument. It is a fully automated, electronically timed instrument with a digital readout. Similar to the older, manually operated model shown in Figure 2, the latest model consists of a heat source, a water bath and a lid designed to hold a dual cassette which holds the sample tubes in place and permits two falling number determinations to be performed

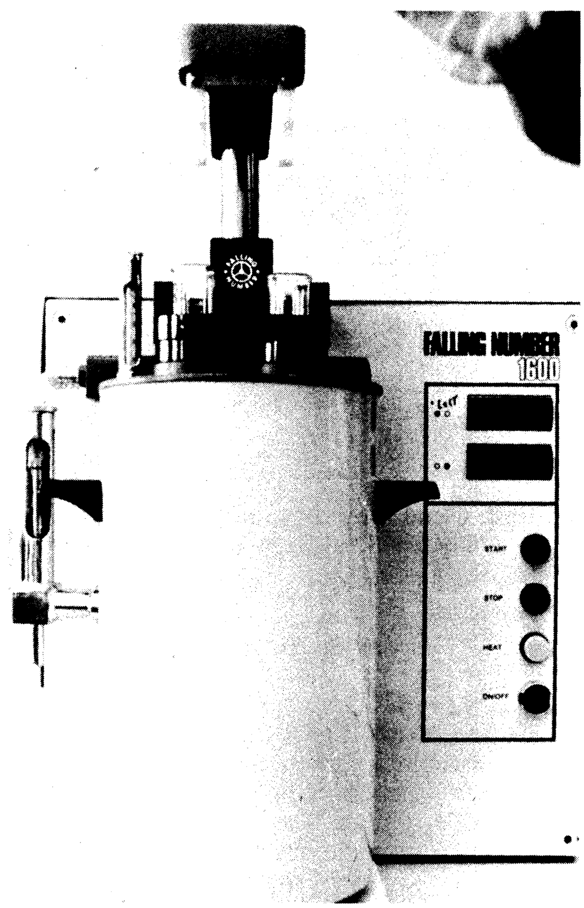

FIGURE 1. New Automatic Falling Number Instrument.

simultaneously. The other two pieces of equipment necessary to perform the test are precision test tubes and the stirrer-viscometer shown in Figure 3. The stirrer weighs exactly 25 g. and is designed to fall through the heated flour-water slurry (flour paste) a distance of 68-70 mm during the test.

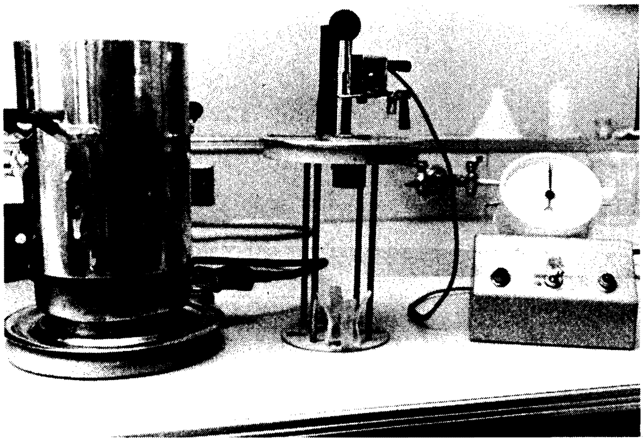

FIGURE 2. Older Semi Automatic Falling Number Instrument.

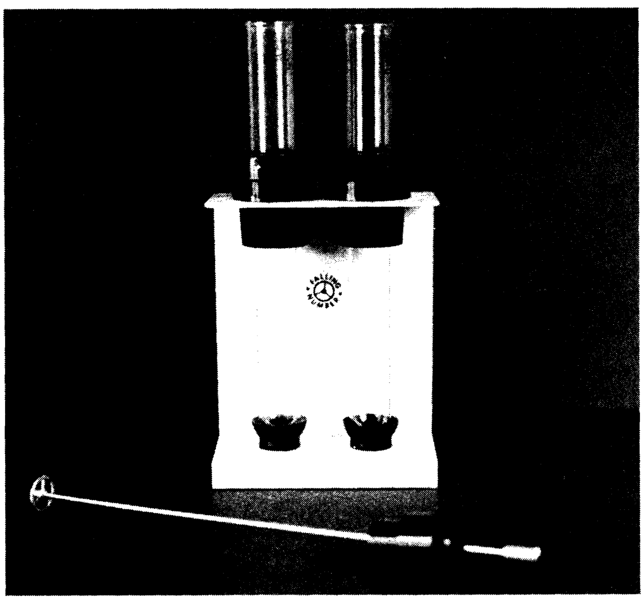

FIGURE 3. Close up of Stirrer-Viscometer used in the falling number test.

The Falling Number Procedure

Figure 4 shows a step by step diagram of the falling number test. Step 1 shows sample preparation. Sample size is of extreme importance when dealing with analysis of sprouted wheat. It is important to realize that in a small sample, only a few kernels of highly sprouted wheat can affect greatly its over-all enzyme activity. A representative sample of wheat is of utmost importance. A sample size of 200 g. is recommended for grinding.

The Falling Number Mill or a similar mill such as the Udy Grinder (used in our laboratory) can be used for

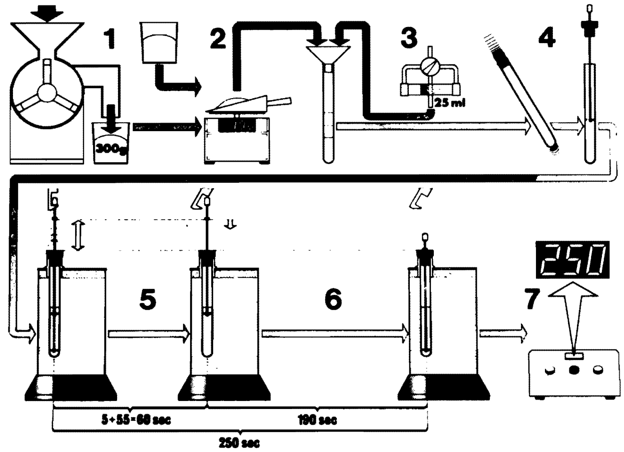

FIGURE 4. Step by step diagram of the falling number test procedure.

milling the sample. The particle size of the milled sample can be another source of variation. The type of mill and sieve size should be specified when reporting values.

After grinding, the entire 200 g of ground wheat is blended thoroughly and an aliquot (7.0 g) is weighed accurately and placed into one of the precision test tubes as is shown in step 2. The method is less sensitive if the sample weight is below 7.0 g. The test can also be performed on a flour or ground semolina. Step 3 consists of measuring exactly 25 ml distilled water with a pipet and dispensing it into the tube containing the flour sample. The tube is stoppered and shaken vigorously by hand for a prescribed number of times (Step 4) so that a uniform suspension is obtained. The stirrer-viscometer is then used to scrape down any slurry adhering to the test tube walls.

In the next step (5), the test tube with the stirrer-viscometer is placed in the cassette holder and inserted into the boiling water bath. At the same time the start button is pressed. From this moment on, the instrument automatically performs the remainder of the test, which consists of the stirring, dropping and counting steps. Before explaining what happens during these remaining steps, the importance of the boiling bath should be indicated. One of the factors which may lead to differences in values among laboratories is the boiling temperature of the water. The test procedure calls for rapidly boiling water in the water bath.

TABLE I. Effect of Temperature on Falling Number Values[1]

Temperature (°C)	Falling Number (sec.)
99.2	205
98.6	221
97.5	235
96.4	251
95.3	264
94.1	297
93.2	320

[1]Data from Medcalf et al. (8).
[2]Boiling point as measured at Fargo, ND, elevation 900 ft.

A mere 6°C difference in boiling temperature can affect the falling number values obtained by 115 seconds (table 1). This could be a significant factor when working with highly sprouted wheat.

During the stirring and dropping steps, with the cassette holding the tubes in place, the arm of the instrument automatically clamps onto the stirrer-viscometer. A 5-second delay preceeds the stirring step, which consists of moving the stirrer-viscometer in an up and down motion two times a second during a 55 second period. Exactly 60 seconds after immersion, the stirrer viscometer is released automatically in its highest position, as shown in step 6, and allowed to fall through the sample. When it has dropped the prescribed distance (70mm), the counter stops automatically and a digital readout gives the falling number value (Step 7). The falling number value is the total number of seconds from the time of immersion and start until the stirrer-viscometer has fallen the prescribed distance.

A blank determination using only distilled water would have a falling number value of 60. This value would represent the lowest reading one would ever obtain for a wheat sample. Falling number values range from 400-500 sec for sound hard red spring and durum wheat. Values below 300 sec. indicate some sprouting and higher levels of amylase enzyme. As the amount of sprouting in the wheat increases the falling number values decrease.

Figure 5 shows the contents in the falling number tubes after the completion of a test. The tube on the left contained a sound sample of wheat flour having a falling number value of 450. The tube on the right, having a falling number value of 61, contained a flour from highly sprouted wheat. This sample was much more water-like due primarily to the breakdown of the starch paste by the increase in the amount of amylase enzyme in the sprouted wheat.

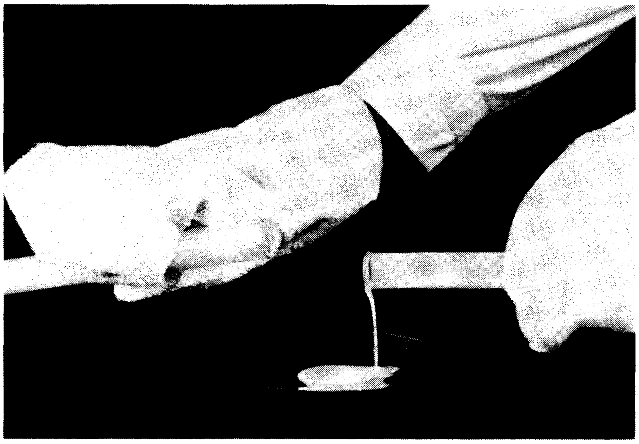

FIGURE 5. Falling number tubes at the completion of the test: left, flour form sound wheat; right, flour from highly sprouted wheat.

What's Happening?

The falling number test measures primarily the change in viscosity of a heated flour or ground whole wheat-water suspension due to enzymatic breakdown of starch by alpha-amylase. Flour derived from sound wheat contains ample beta-amylase but very little alpha-amylase. As a consequence the flour miller adds barley malt, a source of alpha-amylase, to flour that is sold to the baker. A certain level of alpha-amylase is beneficial in baking. When in excess it can be detrimental.

In looking at the effect of alpha-amylase on wheat starch, picture a chain as shown in Figure 6 with each link representing the sugar glucose. The initial products resulting from alpha-amylase action on the starch are sugars (oligosaccharides) of 6-7 glucose units in length. Cleavage or breakdown occurs at the glycosidic linkages in the interior of the chain. This shortening of the chain length is manifested by a rapid loss in viscosity of the starch solution. The loss in viscosity is such that the viscosity of a gelatinized starch drops 50 per cent when only 0.1 per cent of the glycosidic linkages are broken. With this in mind, it is easy to visualize how a highly sprouted wheat sample, which has a high level of alpha amylase activity, will react during the falling number test, whereas with a sound wheat sample, which has virtually no alpha-amylase present, this reaction will not occur. The contents of the falling number tube will be thick or viscous.

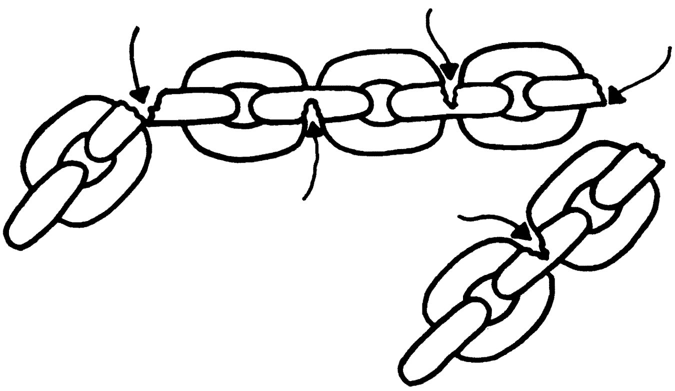

FIGURE 6. Pictograph showing cleavage of glucose chain at glycosidic linkages by alpha-amylase enzyme. ⟶ = point of enzyme attack.

Effect on Baking Quality

Sprouted wheat and its effect on end product use has been the subject of many studies dating back to the 1930's. Kozmin (6) reported on the stickiness and apparent dampness of the crumb of the bread baked from sprouted wheat flour. The direct cause of the stickiness of the crumb was believed to be excessive breakdown or degradation of the starch. So much starch was broken down that there was not enough left to bind all the water present in the dough through gelatinization during the baking process. As a result, the crumb appeared wet and sticky, not because there was too much water present, but because this water was not bound sufficiently by the gelatinized starch and formed, together with the sugars and dextrins, a sticky mass. Ibrahim and D'Appolonia (5) found a progressive decrease in falling number values and in amylograph peak viscosities in a series of sprouted wheat samples ranging from 0.4-12.3 per cent sprouting as determined by a licensed federal grain inspector (Table II). Although they found no detrimental

TABLE II. Effect of Sprouting on Falling Number and Amylograph Peak Height[1]

Sprouted Kernels (%)	Falling Number (sec.)	Amylograph Peak Height (B.U.)
0.4	280	660
0.5	198	340
0.9	178	240
2.3	102	120
3.7	123	140
4.8	101	80
5.3	83	80
12.3	65	20

[1]Data from Ibrahim and D'Appolonia (5).

effect on loaf volume of the bread baked from the sprouted wheat flours, they did report an effect on crumb color (grayer) and an inferior grain and texture particularly at the higher levels of sprouting.

Stickiness in the doughs and gumminess of the bread crumb were the major complaints of Japanese bakers following a collaborative study now in progress between the Cereal Chemistry and Technology Department, the Federal Grain Inspection Service, the Japanese Food Agency, and the Japanese Flour Millers Association. The study, now in its second year, was initiated to determine the maximum limit of sprout wheat flour which could be tolerated by the Japanese, using their baking procedures.

Normally, adjusting processing parameters such as water absorption, fermentation time, mixing and proofing times, and the addition of an oxidizing agent such as potassium bromate will greatly improve overall baking quality to an acceptable level according to U.S. standards. It also must be remembered that in this country, breadmaking flour is malted to give a specified alpha-amylase activity. When sprouting becomes a problem, millers often will blend a sprouted wheat flour with a sound wheat flour to achieve flour similar to a sound flour which has been malted. Although some European countries blend U.S. wheats with their domestically grown wheat, the Japanese use only U.S. grown spring and winter wheat for bread production. They do not incorporate barley malt at milling and they do not have the freedom to adjust their processing parameters since their baking procedure is somewhat different from that used in the United States. The Japanese are very sensitive to the taste and eating quality of their bread, so they are very vocal when they receive sprouted wheat.

Effect on Noodles and Pasta

Bean et al. (1), in studies with Western white wheat, have reported that flours with relatively low levels of amylase activity caused problems in the processing of noodle doughs. In the processing of macaroni, some difficulties in handling were reported by Harris et al. (4). Doughs made from blends high in sprout damage were crumbly and "short," although a dough of normal consistency could be made from them. These researchers found that shattering and checking in the finished product increased as the percentage of sprouted wheat was blended with sound wheat.

Dick et al (2) found that semolina milling yield and overall spaghetti quality were not significantly altered by sprouting on seven durum wheat cultivars which were sprouted under controlled field conditions even when falling number values indicated extensive sprout damage. Table III shows the effect of sprouting on durum wheat quality parameters vs. falling number values. Falling number showed significant negative correlations with damaged kernels and semolina bran specks and positive correlations with vitreous kernel content.

It was interesting to note that overall wheat grade was not correlated with falling number values even though the grading factors were significantly correlated. It was concluded that under artificial sprouting conditions the influence of sprouting on durum quality may not reveal a true picture. A number of durum wheat samples which had actual field sprouting were assigned per cent damage values by a licensed federal grain inspector. Donnelly (3) found that falling number values of these samples followed per cent damage reasonably well (Fig. 7). He also found spaghetti cooking quality, as expressed in terms of cooked weight, cooking loss and cooked firmness, with samples showing 10 per cent sprout damage or over, to be inferior to the sound samples. Some checking and cracking in some of the dried products after one week of storage was also reported. Based on the results of this study it was evident that either per cent damage or falling number could be used as an indicator of potential shelf stability problems.

TABLE III. Correlations Between Falling Number and Durum Wheat Quality[1]

Variable X	Variable Y	Correlation Coefficient R
Falling Number	Damage Kernels	−0.51**
Falling Number	Semolina Bran Specks	−0.38*
Falling Number	Vitreous Kernel Content	0.37*
Falling Number	Protein Content	0.31
Falling Number	Test Weight	0.19
Falling Number	Grade	−0.17

*Significant at 5% level of confidence
**Highly significant at 1% level of confidence
[1]Data from Dick et al. (2).

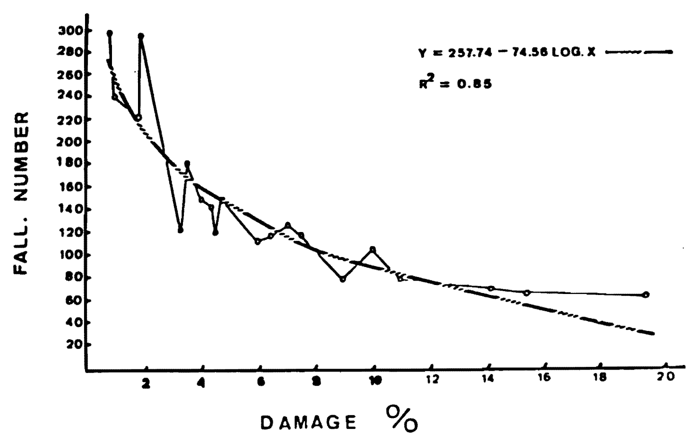

FIGURE 7. Graph showing correlation between per cent damage (sprout damage) and falling number values.

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TABLE IX. Germination Levels of 1980 Crop Samples

STATE	COUNTY	% GERMINATION*
North Dakota	Barnes	97.0
	Benson	90.5
	Cass	96.0
	Cavalier	69.0
	Dickey	89.5
	Grand Forks	93.5
	Griggs	96.0
	LaMoure	93.5
	Nelson	95.0
	Pembina	97.5
	Ramsey	54.5
	Ransom	92.5
	Richland	98.0
	Sargent	88.0
	Steele	96.0
	Stutsman	91.0
	Traill	95.5
	Walsh	89.0
Minnesota	Becker	92.0
	Clay	95.5
	Grant	95.0
	Mahnomen	96.5
	Norman	97.5
	Otter Tail	95.0
	Polk	95.0
	Traverse	93.5
	Wilkin	96.5
South Dakota	Brown	93.5
	Marshall-Roberts	89.5

*Average of duplicate 100 kernel samples held at room temperature for 48 hours in 0.75% hydrogen peroxide.

Summary

The 1980 six-rowed malting barley crop grown in North Dakota, South Dakota and Minnesota has an average protein content of 13.2 percent, an increase of 0.3 percent over 1979. Moisture levels and color were virtually unchanged. Test weights increased slightly and the level of plump kernels declined by 4 percent.

One factor which may have led to the very small increase in protein levels may have been the dramatic shift, seen this year, away from Larker to lower protein varieties such as Glenn and Morex. Had this shift not taken place, the average protein level of the 1980 would, most likely, have been higher.

It should be noted that samples were largely unavailable from areas in which the greatest weather damage occurred, as much of this production was not being accepted by elevators and thus will not be available for malting purposes. This report is, therefore, biased toward that part of the crop which was relatively undamaged and will be available for malting.

Acknowledgements

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Summary

In conclusion, although the falling number test offers the advantages of a simple, rapid, and fairly accurate method for measurement of sprout damage in wheat, there are certain disadvantages. It is vitally important to have a good understanding of the factors which affect the falling number test. These include varietal and environmental influences as well as operational factors. It must be remembered that the falling number value does not indicate the exact amount of amylase enzyme present in a particular sample. For instance, two samples of highly sprouted wheat could each give very low falling number values (near 60 sec.). However, one of the two samples could have 10 times more alpha-amylase enzyme present thn the other. Likewise, with falling number values above 400 sec. it may very well be that the response is not due to the absence of amylase enzyme but rather to a starch effect.

Other test methods and instruments for measurement of alpha-amylase activity which do not depend on starch viscosity but rather measure more directly the amount of alpha-amylase enzyme present in a wheat sample are being evaluated. Because of the importance of sprouting in hard red spring and durum wheat both in the domestic and export market, studies are being continued at North Dakota State University to better measure alpha-anylase activity in wheat and to elucidate the effects of sprout damage on biochemical constituents as well as on baking and pasta quality.

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