An examination of the wheat meal fermentation time test as a tool for evaluating the quality of red hard winter wheat F2 derived lines
by Donald E Baldridge

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of Master of Science in Agronomy at Montana State College
Montana State University

Abstract:
This study was conducted to evaluate the usefulness of the wheat meal fermentation time test (doughball test) as a tool for the plant breeder. This test has distinct advantages in that it requires only a limited amount of wheat and is simple and rapid to perform.

Twenty-five F2 derived lines of hard red winter wheat from a cross between Yogo and selection 221 from a Turkey/Oro cross, were used in this study to measure the predictive value of the doughball test. The twenty-five lines were grown at four locations during the period of 1953 through 1956. The lines were again grown at Bozeman in 1957 and the grain produced was evaluated with farinograph and baking tests.

It was observed that a better relationship existed between doughball time and stability when the protein level of the grain was above 14 per cent. When the average doughball values were adjusted by regression to a uniform protein level, a significant correlation coefficient was obtained between time and stability.

The twenty-five F2 derived lines were screened on the basis of doughball data and seven selections survived the seven year by location evaluations. Of the seven lines chosen, five exhibited both good dough stability and loaf volume.

It was necessary to have doughball data from several locations for several years before a significant correlation was obtained between doughball data and stability. However, the lines having the best stability and loaf volume would have been selected had the doughball data been used. Irrespective of low correlation values, the doughball test was reliable means of predicting the quality of the hard red winter wheat lines used in this study.

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ABSTRACT

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INTRODUCTION

The wheat plant has a wide range of adaptation. There is evidence that wheat has been cultivated for over 6,000 years (18). A large assortment of different wheat types have developed through this period. This has come about as the result of natural selection and later by the application of scientific plant breeding methods.

The first wheat planted in this country was on one of the Elizabeth Islands off the southern coast of Massachusetts in 1602. Explorers and settlers from various European countries brought different selections of wheat to this country at various times, and plantings were made at several locations along the Atlantic Coast. Wheat was then carried inland by the migrating pioneers and was finally carried into the Mid-West and the Great Plains.

Fortunately for the development of hard wheat in the Great Plains, conditions in Russia caused a group of Mennonites to migrate to the United States in 1873. They brought with them some of the wheat they had been growing in their home land. Thus, the Turkey-type winter wheat was introduced into the United States.

This type of wheat was not received well by the millers because of its hardness and the bakers were not accustomed to the so-called "flinty gluten". (24). Nevertheless, the hard winter wheat, because of yield and adaptation, soon held a pre-eminent position in the Great Plains.

The growth habits and other characteristics of the wheat grown over the world are at present well known. There is no longer the same opportunity to bring in a wheat of a new type that will bring an end overnight to the problems associated with the milling and baking industry. Improvement is coming only through scientific advances in wheat breeding and quality evaluation. These changes are slow but continuous, and an abrupt change is not likely. The farmer, miller, baker, and consumer should realize that there is no known way to produce a wheat uniform in yield, test weight, grade, physical and chemical properties, or milling and baking quality.

The consistant production of a strong, good quality, high protein wheat is dependent upon the proper balance of the influence of environment and variety. A combination of circumstances sometimes can result in the production of less satisfactory wheat than is customary in spite of the variety, which causes a serious misfortune to the area. The development and release of a new variety will not necessarily provide a complete remedy. When the reasons for variations in quality are discovered, we will be in a better position to control the type of wheat that will be available for the milling and baking industry.

One of the earliest methods of evaluating baking quality was the use of the protein content of wheat. Wheat with high protein content has for a long time commanded a premium price. The protein content has been used extensively as a price determiner because it is a simple and inexpensive analysis to perform. The correlation of total protein content versus gluten strength, though not too accurate, has been used by millers, buyers and producers as a measure of quality in the trade.

Detailed milling and baking tests are the final and the most complete means of evaluating the quality of wheat. These procedures evaluate the wheat according to milling characteristics, flour yield, and the physical properties of the dough; such as, mixing time, water absorption, dough strength and loaf volume. The procedure is not adapted for use in the early stages of a wheat breeding program because it requires a relatively large sample (four to five pound minimum); thus, the progeny must be carried and increased several years without selection to obtain sufficient grain for testing.

Wheat breeding procedures produce large hybrid populations from each cross within a few generations. The quantity of seed from each selection or line increases very slowly because most of the seed is needed for reseeding in the field for further selection; consequently, the material must be carried in the field until about the seventh or eight generation before sufficient quantity of grain is available for large scale baking tests. The result is that many lines are carried along that could be discarded if the material could be evaluated correctly with a small amount of grain.

In this thesis problem, the wheat meal fermentation time test and protein test were evaluated. These data were also compared to the results obtained from baking evaluations. The data obtained from these comparisons were evaluated for the possibility of using the wheat meal fermentation time test as a tool for selecting desirable lines of hard red winter wheat in respect to breadmaking quality in the early generations of a breeding program.

REVIEW OF LITERATURE

Several factors are instrumental in determining the suitability of a particular wheat for a specific purpose. The chief factor is the proportional amounts of the various chemical components which make up the wheat kernel. Swanson (28) reports the average chemical components of bread wheat to be 13.4 per cent water, 1.8 per cent ash, 11.6 per cent protein, 2.1 per cent fat, 1.7 per cent fiber and 69.4 per cent carbohydrates. These chemical constituents in varying proportion make up the bran, endosperm, and germ of the wheat kernel.

The amount of protein is often considered of major importance and is used as a measure of strength in bread wheats. Protein in wheat is made up of gluten and gliadin in major proportions with albumin, other proteins, and amino acids present. The gluten and gliadin are referred to collectively as gluten. This water insoluble protein is the predominant constituent influencing the quality of wheat. It is the constituent that gives elasticity to the dough (28). Figure 1 is a graphic illustration of protein structure reproduced from Miller and Johnson's discussion on testing wheat for quality (14).

The quality of the protein has been found to be equally as important as quantity in producing a desirable dough. According to Swanson (28), weakness in wheat is due to three causes: 1. an adequate quantity of gluten but of inferior quality; 2. inadequate quantity of gluten; and 3. factors that influence or inhibit the activity of yeast.

Bayfield (1) reported that the strength of a wheat quality-wise is determined or influenced by gas production and gas retention. The production of gas (the result of yeast activity) is affected by the sugar content and diastatic activity of the wheat. Fat content and method of milling have also been found to influence the gassing powers of wheat (3). The retention of gas is directly affected by the elasticity of the dough which is a result of protein quantity, protein quality, enzyme activity, and ash constituents.

GLUTEN STRUCTURE

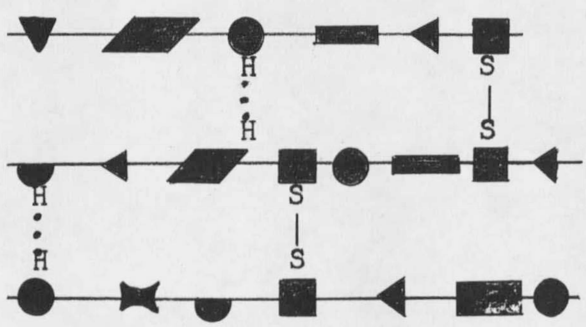

Figure 1. A graphic illustration of protein structure in dough. Each geometric symbol represents one of the 22 known amino acids. The H...H represents weak hydrogen bonding while S---S represents stronger chemical sulfur cross bonding between chains of amino acids. (14).

Quality is probably the most difficult to measure and interpret of all the characteristics that must be considered in a wheat breeding program. Micro-testing methods are in real need as a satisfactory aid in wheat breeding. They would enable the plant breeder to appraise more hybrids as to quality potential in the early segregating generations.

Considering the complex nature of quality coupled with various definitions and criteria of quality, it would appear that quality evaluations cannot be made on an individual plant basis.

Reitz (19) defines quality as the characteristic or combination of characteristics determining the degree of acceptability, usefulness, and value to the user. Those who test the wheat breeders' samples for quality are concerned mainly with determining whether grain from a variety is fitted for its intended uses. The plant breeder needs a more measurable attribute than good or bad, and he needs these separated from the modifying effects of environment. Most perplexing are the opposite views expressed by bakers about a flour intended for the same use. This leads to a great deal of confusion when the breeder asks representatives of the trade for an appraisal of a new variety of wheat.

Some wheat breeders are forgoing preliminary yield tests in favor of quality prediction tests in the F_4 generation. Several laboratories are investigating a number of quality prediction tests. Some feel that the expansion test of Miller, et al. (15) offers some real promise at the present time.

Schlehuber (21) in his discussion of wheat quality in North America points out that twelve to fifteen years ago flour yield was not thought especially important, and the emphasis was on testing the flour by baking and judging the results chiefly on the basis of loaf volume and water absorption. In the last five years the emphasis has changed somewhat with availability of physical dough-testing apparatus to the stressing of dough mixing properties. More and more reliance is being placed upon physical dough-testing data.

Some new concepts about quality that are contrary to what was believed only a few years ago as listed by Reitz (19).

1. Every use does not require a narrow range of quality.
2. Mixing time has little relationship to bread loaf volume potentialities.
3. Thick bran does not necessarily account for poor milling quality.
4. Hard red winter and hard red spring wheats on equal protein basis may have equal inherent breadmaking quality.
5. A white wheat variety may produce excellent bread if it is in a suitable protein range.

Reitz (19) also suggests that breeding should be done for wheats that posses quality safety zones. In other words, a selection or variety would be extreme in characteristics that could be readily modified. He presents the following list:

1. Mixing time: Breed for long time, shorten by blending.
2. Flour color: Breed for light yellow, make lighter by bleeching.
3. Protein content: Breed for high level, reduce by blending.
4. Kernel hardness: Breed for very hard, soften by tempering.
5. Test weight: Breed for heavy.
6. Flour yield: Breed for high flour yield and price wheat on this basis not on test weight.
7. Mixing tolerance: Breed for tolerance that is separate from mixing time.

8. Loaf volume: Breed for high volume with fine texture.

Pinchney and others (17) found variations in gluten quality that were independent of protein quantity but affected loaf volume and sedimentation values in much the same way. These workers, however, found that loaf volume was more closely correlated with sedimentation value than with protein content when the gluten quality was quite variable.

The wettability of flour by water or its absorption is one of the most important characteristics of flour. The water forms a film on the surface of the flour particles. This water film gives the dough its plastic or moldable properties. Part of the water is firmly absorbed on the surface of the starch granule and part on the protein particles.

A dough made from an 11 per cent protein flour having 13.5 per cent moisture and using 60 per cent absorption, together with normal amounts of sugar, salt, shortening, and yeast will have the following approximate percentage composition according to Swanson (30).

Water	43.4
Starch	40.5
Protein	6.4
Sugar	2.9
Fat	2.5
Salt and Ash	1.4
Other	2.9

When water is added to flour, it will penetrate the particles very slowly; hence, mechanical action is necessary to form a homogeneous dough. In a well-mixed dough the water forms a continuous liquid phase--part being absorbed on starch and protein, and part held in a capillary state (30).

The protein molecules or particles which are elongated or branched form strands or fibrils. It is these strands that form into a three-dimensional network. The starch granules, covered with films of water, are enmeshed in this network. The yeast grows in the dough and forms gas bubbles which increase in size and thus produce the open texture in bread. The gas retentive properties of the cell walls are due to the water absorbed on the three dimensional network and the embedded starch. The mobility in this network allows the bubbles to increase in size and thus produce the raised dough.

Various tests or techniques have been developed to evaluate the quality of bread wheat using a relatively small amount of wheat. These tests would permit selection of breeding material on a quality basis in an early generation of the progeny from a cross.

The wheat meal fermentation time test, sometimes referred to as the time-test or doughball test, has been found useful in that it is simple and rapid; requires small quantities of labor, equipment, and material; equipment is inexpensive; and the grain sample required is relatively small (10 to 30 grams being sufficient) (28).

The wheat meal fermentation time was first developed in 1926 by H. A. Saunders in England. Pelshenke (23) in Germany modified the test by using the time result in conjunction with protein content in 1930. Cutler and Worzella (5) have outlined the test in detail and stress the use of clean, dry, sound grain when making the test. The wheat should be allowed to age at least six weeks and be inspected for disease, weevils, and other disorders before using. The samples should have the same time interval between grinding and analysis as the quality changes rather rapidly in ground material. A technique that has given good results is to grind the wheat the afternoon previous to the day that the test is to be performed.

The wheat meal fermentation time test is based on the length of time required for a ball of dough made from whole wheat meal to disintegrate in a beaker of distilled water. This test is referred to as the "Doughball Test", because of the ball of dough used in determining the values. The term "Doughball Test" will be used by the writer in the remainder of this discussion when referring to the wheat meal fermentation time test. Comparable values of baking quality are obtained in this test by measuring the disintegration time of the doughballs in minutes. A long time indicates a strong wheat and a short time is associated with weaker selections.

Cutler and Worzella (5) found that strains from the same variety differed genetically in baking quality and that these differences could be detected with the doughball test. They also obtained evidence that the relative quality of different wheats was maintained when those wheats were grown in different locations where they were exposed to different environmental conditions.

It is evident that inherent quality may be masked by laboratory procedure with varieties that show little difference in doughball time according to Swanson (27). However, the time test has proven successful in distinguishing the strong wheats from those which are inferior because of inherent quality.

Kolar (11) studied seventeen wheats in one group and eleven in another group with nine of them being common to both groups. A significant correlation between doughball time, loaf volume, and mixing tolerance was found. The doughball time and loaf volume correlation existed for two locations, but doughball time and protein content was not consistantly correlated. A definite association was found between doughball time and the quality evaluations by large scale baking tests. These data showed that wheats having the longest times were superior in quality to those having short doughball times. The middle class group could not be readily distinguished from each other by the time test. Superior wheats maintained their relative quality rating when grown under different environmental conditions.

Significant correlations between doughball time readings and loaf volume were felt to indicate that this test measures gas retention capacity to some extent. Protein content and doughball time correlated only to the extent that wheat with high protein had a greater gluten content and consequently had longer doughball times than wheat with a low protein content when the range was 8.4 to 9.4 per cent, but this was not true when the protein level was between 15.1 and 16.6 per cent.

Wheats that resisted disintegration for a longer time were also more tolerant to over mixing as indicated by the correlation of doughball time and mixing tolerance readings. Wheat that would rate fair and good could not be distinguished by the doughball time test.

Hayes, et al. (8) stated that one of the greatest difficulties in breeding improved varieties of wheat is the lack of a reliable method of estimating milling and baking quality when only a small quantity of seed is available. A test requiring only a small quantity of seed would be of great value to the plant breeder.

The requirements of a satisfactory test for quality in the early generations are:

1. The amount of grain required must be small.
2. It should be relatively simple and rapid.
3. The material and equipment should be inexpensive.
4. It should give an accurate evaluation of quality.

The doughball test appears to meet all of these requirements. There is no question about the first three and the time test data available seem to indicate that the very weak and extremely strong selections in a progeny can definitely be detected.

The cereal chemists have been told by the breeders that micro-methods must be developed which will allow the testing of the grain from individual plants and still leave a remnant for planting. It has been stated, facetiously of course, that the utlimate is to develop methods for testing the quality of an individual seed and leave a remnant for planting (21). Some fine advances have been made in developing tests that use very small quantities of wheat, but these have been more useful in evaluating milling quality than baking quality. Seeborg and Barmore (22) describe a five-gram milling test which involves hydrating the samples to a 17.5 per cent moisture level; grinding them through two sets of break rolls;

and weighing the separated bran. These authors claim that two technicians can process 400 to 600 hydrated samples a day. Such a method is attractive to plant breeders and encourages them to devote more effort to breeding for better milling quality.

Methods described by Harris and Bruner (6) are being used at the North Dakota laboratory. The use of whole wheat mixograms for assessing mixing requirement in early generations is being explored. The search is under way for methods that will assess quality in the early generations. Research in wheat quality occupies a major portion of the improvement program of the bread wheats in the United States and Canada (21).

Shellenberger, et al. (25) in comparing micro-tests with standard methods, used loaf volume as the criterion of strength and found a close correlation between the loaf volume obtained by the AACC procedure and the micro procedure. These authors felt the relationship was sufficiently satisfactory to justify the use of micro baking for the purpose of screening wheat samples for strength in the early generations.

Tests for quality can be divided into two groups: (1) physical and chemical tests performed on the whole grain and (2) chemical, physicochemical, rheological, and baking tests performed on flour. Experimental milling tests provide information on the physical behavior of the grain during the milling operation. Milling quality tests evaluate such factors as tempering, power required in reduction, and flour yield. To be of good milling quality a wheat should have good bolting properties; that is, the flour should flow freely without a tendency to agglomerate. A good milling hard wheat should yield from 69 to 75 per cent of a 95 per cent straight grade flour with normal ash (14).

Other physical tests which measure factors affecting milling quality are test weight and kernel hardness. Test weight is related to flour yield and kernel hardness to the amount of power required to reduce the grain to flour.

Originally several flour constituents were regarded as factors related to flour quality. These included starch, protein, fats, and minerals. The tendency now is to confine the term strength to a description of protein quantity and quality.

The quantity of protein is generally determined by the Kjeldahl procedure. This test is precise, but does require elaborate equipment and time. There is a demand for a test that will give an accurate estimate of protein quantity quickly and simply. The amount of protein is generally accepted as the simplest and best single indicator of wheat and flour bread making quality (13).

The physico-chemical tests are generally simple, rapid, and have important advantages in routine laboratory testing. They are capable of showing differences between flours, but it is frequently difficult to correlate these differences with quality of flour for a given purpose.

Rheological tests are measures of the physical properties of the dough. Shortly after 1900 several instruments were devised to provide objective measurements of dough characteristics. These included the Brabender farinograph, mixograph, extensograph, extensometers, and several miscellaneous devices.

The Brabender farinograph is one of the most widely used physical dough testing instruments. It measures plasticity and mobility of dough subjected to prolonged, relatively gentle, mixing action at constant temperature. Resistance offered by the dough to the mixing blades is transmitted through a dynamometer to a pen that traces a curve on a moving chart. This chart is referred to as a "farinogram". A complete description of this machine is presented by Brabender (2).

The general farinograph practice has been to bring all doughs to a consistency of 500 Brabender units as a standard absorption by making a titration curve. Absorption generally increases in direct order with the increasing percentage of protein and improving gluten quality. Absorption is determined by adding enough water to give a standard consistency of 500 B.U. (Brabender units) at the peak of the curve. In addition to determining the quantity of water required, or the optimum absorption, the curve shows the amount of mixing required to develop the dough properly, and the behavior of the dough when mixed, or its stability. The behavior of the dough during mixing is measured by values referred to as stability and mixing tolerance index. Stability is defined as the time difference to the nearest one-half minute between the point where the top of the curve first intersects the 500 B.U. line, and the point where the top of the curve leaves this line after passing the peak. The M.T.I. (mixing tolerance index) is the difference from the top of the curve at the peak to the top of the curve five minutes after the peak (13).