Methods of Quality Tests in Wheat Breeding

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A Japanese wheat variety, Norin No. 10, has recently been making contribution as a dwarf high-yield cross parent to the breeding of superior varieties in the United States, Mexico, India and Pakistan. In general, Japanese wheat varieties have such good characters as early maturity, dwarfness and high yield, but they are small in test weight, low in flour yield and of too extensible gluten.

Most of the wheat varieties now under cultivation in Japan are soft wheat, and hard spring and semi-hard ones are very small in number. Soft varieties are 8 to 10% in protein content and used mainly for making noodles.

The breeding objectives aimed at now are wheat varieties of early maturity, stiff culm, good quality and high yield. The good qualities, in other words, are high flour yield, white flour and rather elastic gluten.

This paper deals with the methods of quality tests for wheat breeding and outline of wheat breeding procedures in my laboratory. The available references on this subject are as follows: Agriculture, Forestry and Fisheries Research Council: Methods of quality tests for wheat. Results of researches 35, 70 pp, 1968 in Japanese; A.A.C.C.: Cereal Laboratory Methods (7th ed.), 1962.[1)]

Outline of the method of wheat breeding

The main objectives of breeding are of early maturity, stiffness of culms, good quality and high yield, and some other various characteristics such as disease-resistance are tested by characteristic tests.

Both the pedigree and bulk methods by artificial crossing are used for the breeding of wheat (Fig. 1). About 30 combinations of crossing are carried out every year.

In the pedigree method, about 50 plants per a combination are grown in the F_1 generation, and about 1,500 plants in the F_2 generation are cultured in a field infected with the yellow mosaic disease or under powdery mildew-inducing conditions to make the individual selection of plants resistant to these diseases. In the F_3 generation, about 200 lines of plants are cultured for line selection and individual selection in the selected lines. After the F_4 generation, line selection is repeated.

In the bulk method, the number of plants cultured in the B_1 generation is the same as that in the F_1 generation of the pedigree method, but in each generation from B_2 to B_5, 2,000 to 4,000 plants are cultured in bulk plots to harvest 1,000 to 2,000 heads and to make selection for spike shape, height of culms and earliness of maturity.

Head lines in the B_6 generation and derived lines in the B_7 generation are put to the purity test. In the B_8 generation the plants space-planted are grown according to B_7 -derived lines and individual selections are made. Pedigree lines are grown in the B_9 generation for the first time. After the B_9 generation pedigree selection is repeated according to the pedigree method.

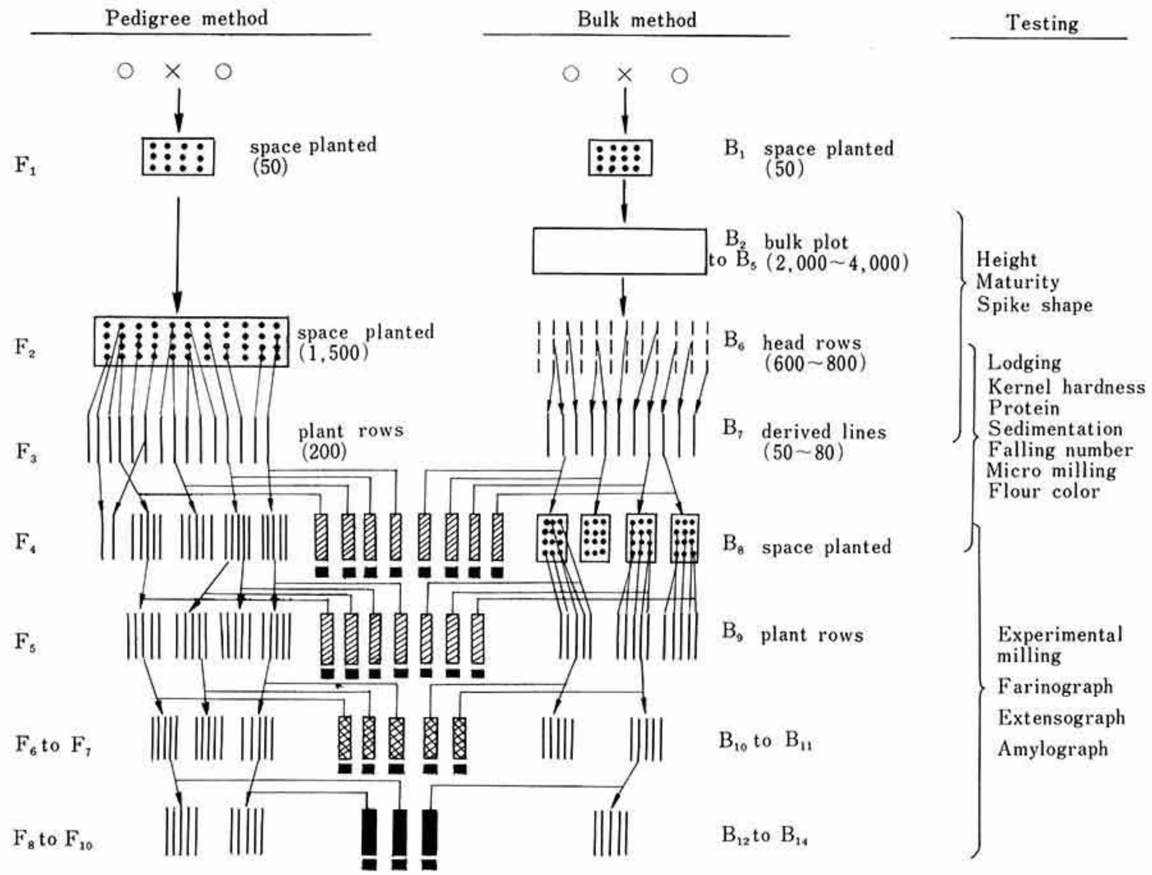


Fig. 1. Diagram of the pedigree and bulk methods.
▨ : Preliminary yield test, ▩ : Ecological adaptability test, ■ : Yield tests and Local test of adaptability ▬ : Characteristic tests for selection.

The characteristic test, preliminary yield test, ecological adaptability test, yield test and local test of adaptability are made in succession after the F_4 and B_8 generations as shown in Fig. 1.

F_2 individuals, F_3 lines, B_6 head lines and B_7 derived lines are subjected to various quality tests in the early generations of breeding as mentioned below, and after the F_4 and B_8 generations many quality tests are conducted by utilizing products in yield tests.

The lines which are expected to be new varieties in the near future are put to a quality test at the Food Research Institute by the use of products in the local test of adaptability.

Various methods of quality tests in the early generation of breeding

In the individual selection, the material available for tests is of small amount of about 100 grains per plant, so tests are limited to the measurement of kernal hardness, glassiness percentage and protein content. In the line selection or derived line selection 100 to 500 g. of the sample are available to examine milling property, color of flour, sedimentation value and viscoelasticity of dough.

1) Kernel hardness

The hardness of wheat kernels is an important character to be tested. It has an influence on the qualities of flour, bread and cookie. Ikeda (1961)[5] proposed to examine the amount of hard crystalloidal particles contained in kernels with a microscope in the breeding of hard wheat varieties. If kernels contain little amount of the particles, they cannot be expected to be used as material for making bread.

In the breeding of soft wheat varieties, the pearling index is used as a criterion of selection for hardness. This index is represented by the percentage of the weight loss of wheat grains measured after they are pearled with a pearler for barley for a fixed time. The weight loss is in inverse proportion to hardness.

Yamazaki *et al.* (1968)[9] proposed a micro-test method by using at least 16 g. wheat grains for selection in the early generations of breeding. This is a method to test the fitness of wheat to baking cookies by a combination of the pearling index, the flour yield test with a Quadrumat Jr. mill and the micro alkaline water retention capacity test.

2) Protein determination and sedimentation test

Protein content is an important characteristic for flour processing. But an easy and rapid measuring method is necessary to use this characteristic as a criterion of selection. A UDY-Protein Analyzer and a Prometer on the market can be used conveniently for the measurement.

The sedimentation test was developed by Zeleny as a method of synthetically evaluating the quality and quantity of gluten contained in flour. This method, by reading the swelling power of flour treated with an isopropyl alc. —lactic acid reagent as the sedimentation value was reported by Atkins *et al.* (1965) to be very suitable for the selection in the early generations of breeding, and its micro-methods were devised by Greenaway *et al.* (1966) and Kitterman *et al.* (1969).[6]

Osanai (1964)[8] considered that a compound character, yield × sedimentation value, represented the amount of protein production, and said that its use for selection was effective to obtain wheat varieties winning high marks for making bread.

3) Falling number determination

Japanese wheat varieties are mostly low in sprouting and in α- amylase activity. But they are apt to change possibly their quality or to sprout by rain, because their ripening period is in the rainy season. It has been found that imported wheat includes a large amount of sprouted grains, which caused a dispute. (Falling Number Subcommittee Report (1969)[4]).

Sprouted grains contain much α- amylase, and the falling number method is for their rapid measurement. This method was developed by Hagberg (1960, 1961) and Perten (1964), and added to AACC Method[1] 56–81 in 1968. A suspension of wheat meal contained in a large test tube is gelatinized for 1 min. with the viscometer-stirrer moving up and down at a fixed speed in a boiling bath and then the time needed for the falling of the stirrer from the uppermost to the lowermost (position) of the gelatin is measured. The sample needed for the test is 7 g. in amount. A test is finished within several minutes. This method can be used as substitute for the amylograph test.

4) Micro-milling test

Seeborg *et al.* (1951) succeeded in the mill-

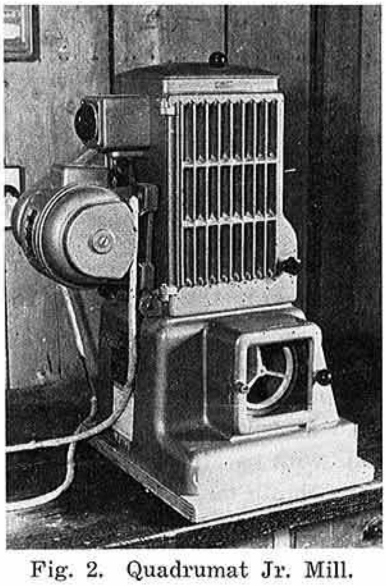


Fig. 2. Quadrumat Jr. Mill.

ing of such a small amount of wheat as 5 g. for the evaluation of milling property in individual selection. Recently, Yamazaki *et al.* (1968)[9] has reported the milling wheat of 10 g. with a Quadrumat Jr. mill (Fig. 2) for the cookie-baking test of soft wheat. In our laboratory, this apparatus is used for the milling wheat of 150 g. from lines and derived lines to evaluate milling property by the flour yield, the color of flour and the amount of bran included in flour.

5) Color of flour

In general, flour is requested to be white. The flour from Japanese wheat has a yellowish tinge more or less, because the bran is fragile and apt to mingle with flour (in milling), and the endosperm is a little high in carotenoid content. Selection for the color is made by the Pekar and the reflectivity tests.

In the Pekar test, sample flour is pressed upon a glass plate by the side of a standard flour to compare their colors. The yellowishness and lightness of color and bran specks can be observed well by this test.

In the reflectivity test, the reflectance of flour is measured at the wave length of 455 mμ and 554 mμ with a photoelectric spectrophotometer. According to Yasunaga *et al.* (1962)[10], the absorbance by the carotenoid in the endosperm is the maximum at 455 mμ on the spectral reflectance curve of flour, and the reflectance value increases with the whiteness of flour. The reflectance at 554 mμ shows the coloring of flour with admixed bran, and the value increases with the lightness.

Quality tests in the latter generations of breeding

After the yield test, 2 to 3 kg of the sample are used for these tests. Determinations about grains are the moisture content, ash content, crude protein content, test weight, 1,000 kernel weight and glassiness percentage. Milling is performed with a Buhler laboratory mill (Fig. 3) to obtain 60% flour, which is tested for the moistrue content, ash content, crude protein content and color of flour, and is used for farinograph, extensograph and amylograph tests.

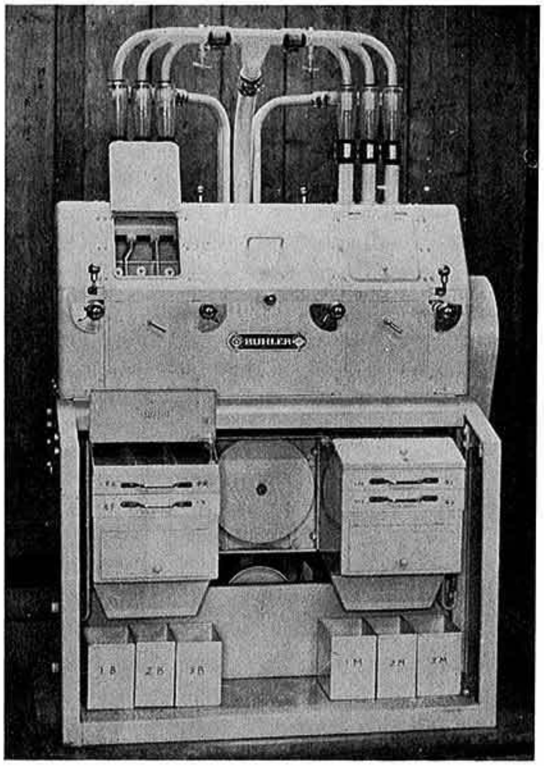


Fig. 3. Buhler laboratory mill.

1) Experimental milling

2 or 3 kg of grains are milled with a Buhler laboratory mill to calculate the flour yield from the amounts of flour, bran and shorts obtained. The ash contents of 60% flour and tail flour are determined and the ash content of straight flour is calculated. The milling score is obtained in the following way:

Milling score=100 − {(80 − flour yield)+50 (percentage of ash in straight flour − 0.30)}.

The milling property is evaluated by this score.

2) Farinograph

This apparatus is a kind of recording mixer, with which flour is kneaded with water until dough of a fixed consistency is obtained. And the change in consistency of the dough is recorded during the kneading (Fig. 4). Then it is possible to investigate the typing of strong and soft flours and the mixing tolerance

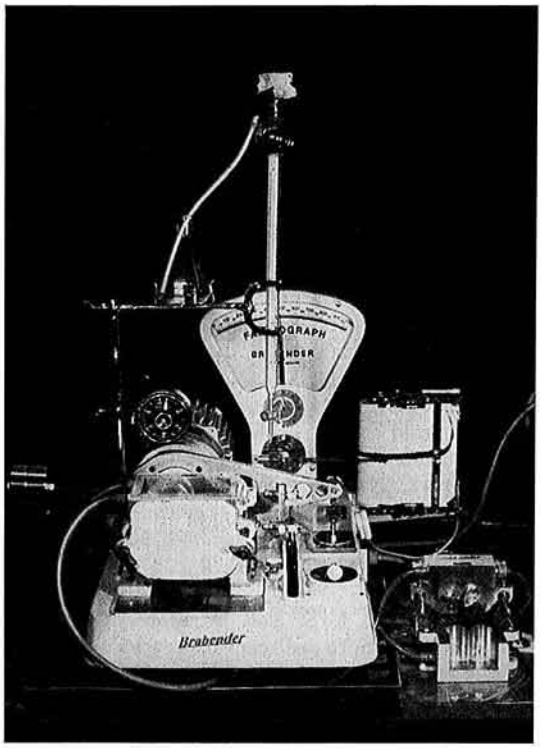


Fig. 4. Farinograph.

of flour. In addition, the absorption of flour can be estimated from the amount of water needed to obtain a fixed consistency of dough. The mixograph is also the same kind of the apparatus as Farinograph.

3) Extensograph

This is an apparatus to measure the dough extensibility and resistance to extension by stretching the dough of a fixed consistency

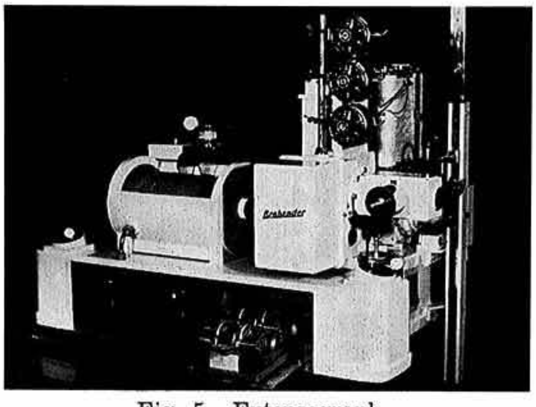


Fig. 5. Extensograph.

(Fig. 5). Then the change of internal energy with the lapse of time is examined. By this method more detailed information can be obtained about the influences of enzymes and of the oxidation-reduction system in the flour than by the farinograph method. The alveograph is of the same kind.

4) Amylograph

This is a kind of the outer cylinder rotating viscosimeter. A suspension of flour is heated or cooled at a fixed rate, and its changes in viscosity during the treatment are automatically recorded on the apparatus (Fig. 6). The

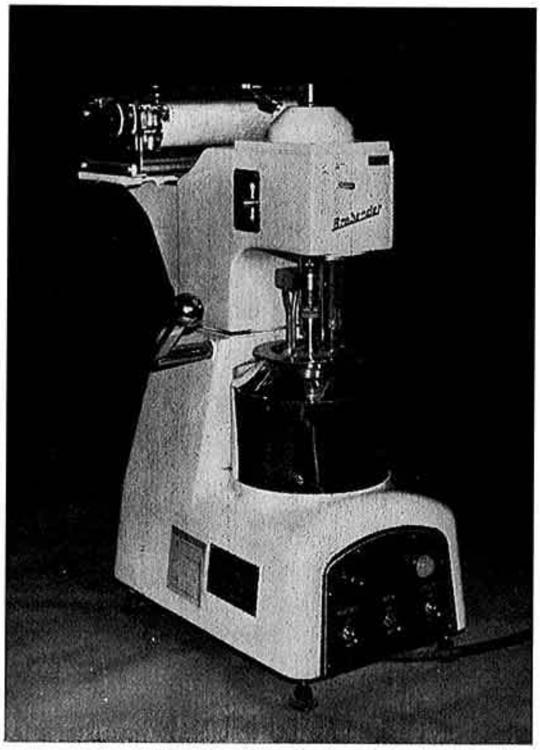
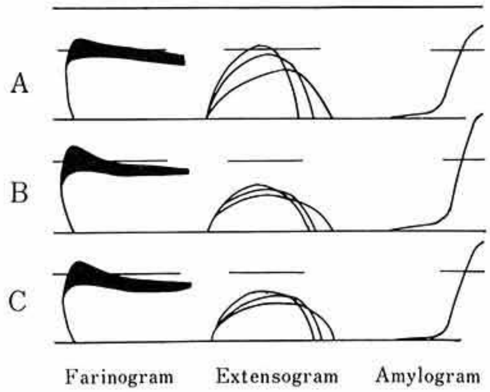


Fig. 6. Amylograph.

state of starch in the flour, especially the characteristic of α-amylase activity can be examined.

Recently, in Japan it has become necessary to present the data of milling and dough tests to examine prospective new wheat varieties. Brabender drawings in a few Japanese wheat varieties are shown in Fig. 7.

So far the explanation of various methods



A: Mikuni Komugi
B: Norin No. 68
C: Norin No. 61
Fig. 7. Brabender drawings.

and apparatus for the quality tests of wheat was given, but tests for making bread and noodles as well as baking cookies were left untouched. Many micro-tests have been already devised, but in Japan they are not in practical use for the selection of wheat varieties.

Japanese wheat probably will be used for noodle making in the future as ever, and it is required that gluten is not too soft, flour is white, damaged starch grains are small in amount, and enzymes are weak in activity. Though selection for these is not made at present, in the early generations after crossing good results were given of the selection of baking quality, by McNeal *et al.* (1967),[7] of soft wheat quality by Briggle *et al.* (1968)[3] and in drum wheat breeding by Bendelow *et al.* (1967).[2] Wheat will be effectively improved in quality by developing the micro-quality tests and applying them to the selection in the early generations of breeding.

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