Evaluation of

BARLEY QUALITY

- COLOR reflects harvest weather
- FERTILIZER affects barley skin quality
- CARELESS HANDLING - loss of grade

By O. J. Banasik[1]

THE introduction of Kindred "L" barley in the early 1940's ushered in a new era for North Dakota barley growers. The state is now a major malting barley producing area and has been one for nearly two decades. Recognizing the economic importance of this crop, the North Dakota Agricultural Experiment Station decided in 1947 to intensify the barley breeding program and begin a barley quality testing laboratory to provide a fairly rapid and accurate means of evaluating quality on early generation material.

Table I provides a "road map" to follow the testing of a hybrid barley until it has graduated as an acceptable malting variety. The "F" values refer to the generation or the number of crops or seeding periods the barley has gone through. Quality testing begins in the third generation, which is the earliest that barley can be reliably evaluated. Only those hybrids that have desirable agronomic characteristics

TABLE I.—**Steps in the Development and Quality Evaluation of a Malting Barley Variety.**

Breeding for Desirable Agronomic Characters.

1. Barley prediction tests, 2 ounces required at F_3 generations, data obtained: Barley nitrogen, barley extract, barley diastatic power, kernel assortment, 1,000-kernel weight.
2. Micro-malting tests, 2.8 ounces required at F_3 generations, data obtained: Kernel assortment, 1,000 kernel weight, test weight, alpha amylase, diastatic power, nitrogen, wort nitrogen, wort total nitrogen, extract.
3. Macro-malting, 12.4 ounces required at F_6 to F_8 generations, data obtained: Same information as micro-malts plus: Conversion time, coarse grind extract, wort color, ratio alpha/beta amylase, wort clarity.
4. Micro brews, 8.8 ounces of malt required.
5. Barley variety must satisfy these tests.
6. Pilot plant malts and brews, 20 to 30 pounds of barley required.
7. Plant malts and brews, carlot required.
8. Must be accepted by the maltsters and brewers.
9. Finally, variety is named and released.

[1]Assistant Cereal Technologist.

are retained for laboratory examination.

Until recently, the only reliable tests available were the prediction methods of Meredith and co-workers (1). They showed that it is possible to predict malting quality, malt diastatic power and malt extract of varieties and hybrid lines from barley analysis. A further advantage is that this method requires only a small amount of material, and may be made at an early stage in the production of new varieties. The general efficiency for selecting malts of high extract was 67 percent while for diastatic power it was 69 percent.

This represents a marked improvement over the 10 percent rating obtainable by random selection. These relatively simple tests will become widely used.

During the last decade only two barley varieties of acceptable malting quality have been released. They are Parkland and Traill which were selected for quality by prediction methods and were retested many times before being approved for release.

The two most recent additions in experimental methods for the evaluation of new barley varieties were mentioned at the 1956 meeting of the American Society of Brewing Chemists at St. Louis by the late John Parker. He stated, "The two most significant forward steps made in the last decade in barley improvement are: (1) the development of micro-malting tests this year at the North Dakota Agricultural College and (2) pilot brewing in 1951 at the Barley and Malt Laboratory, Madison, Wisconsin."

These techniques enable the plant breeder to test the malting and brewing qualities of hybrid selections in the early generations using samples as small as 80 grams (about 2.8 ounces) for micro-malting and only 4 to 5 pounds for pilot brewing. In earlier years 1 to 4 pounds of barley were needed for experimental malts and carlots for plant scale brewing tests.

Table I shows the data that can be obtained from malting and prediction tests. It is evident that the micro-malting gives more information than the prediction method, while macro-malting yields additional information. If the hybrids do not compare favorably with standard acceptable varieties they are eliminated, except for possible breeding material. This early screening enables a more through study to be made of barleys that might make a new variety. Not many pass the macro-malting stage. The time required and the number of samples tested to obtain a single satisfactory variety are very large. The cross from which Traill was obtained was first made in 1947. At present, this variety has advanced to step 6, in table I.

The standard micro-malting procedure is applied only to new barley hybrids that have been found most promising by the prediction and/or micro-malting method. About 300 grams (12.4 ounces) of barley are required; therefore, the test cannot be employed until fairly late in the barley breeding program.

This laboratory malting test consists of treating the barley in essentially the same manner as in industrial processing. However, there appears to be no set standard conditions under which the malt is produced, as each laboratory tends to follow its own preferred procedure. Harrison and Rowland (2) were the first to carry out routine malting tests in the laboratory, at the University of Manitoba in 1927. About two years later two malting

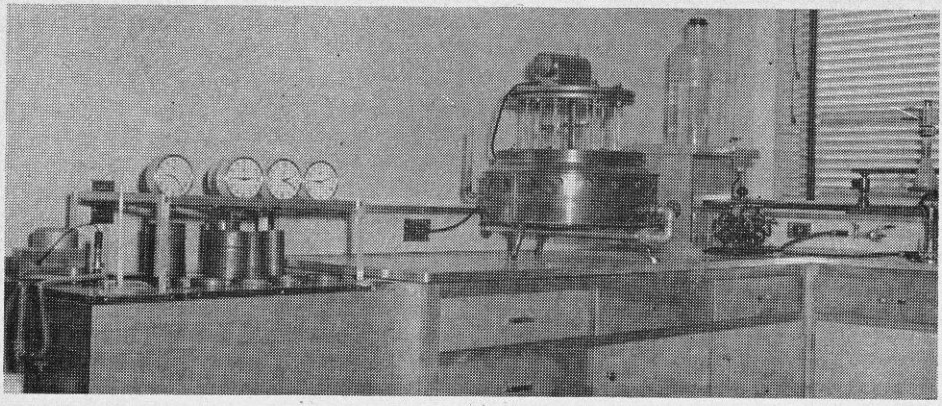

Figure 1.—Barley steep tank and mashing apparatus.

laboratories were established in the United States, one at the University of Wisconsin at Madison, and the other by the USDA in Washington, D.C.

The Malting Process

A thorough understanding of the process and the industrial implications is necessary to enable the plant breeder and the chemist to evaluate the new hybrids and provide the farmer with high yielding, disease resistant, malting varieties. The maltster and the brewer are the principal customers for malting barley, so the barley development program must fit their requirements.

Malting begins when water enters the grain during steeping. Figure 1 shows the experimental steep tank employed in the first stage of the malting process. The alarm clocks drop the samples of barley into the water at predetermined times so they will all come out together. The mashing apparatus for the determination of barley and malt extract is located on the bench to left of the steep unit.

Germination is apparent when the white point of the rootlet commences to emerge from the micropile end. The grain is ready for germination chambers when it reaches 45 percent moisture content. A warm steep water hastens absorption, thus stimulating metabolism. This causes an increased rate of carbon dioxide production which may lead to a stifling of the grain if the gas cannot escape. If uncontrolled, a proportion of the kernels may be killed or have their vitality damaged, resembling what follows pregermination and subsequent check to growth during storage. It is understandable, therefore, why a relatively low steep temperature is preferred, 55 to 60° F., to prevent undesirable biochemical changes. Even with normal steep temperatures, undisturbed grain may have its vitality impaired by accumulation of metabolic products, so some mode of aeration is needed.

The general metabolic story begun in the steep is continued as the barley is transferred to the germination chambers where it is grown under controlled temperature and humidity. The tall apparatus on the left side of figure 2 is the germination chamber for growing micro and macro - malts. The temperature is rigidly controlled at 60.8° F. and 100 percent relative humidity. A growth period of three days is required for micro-malts and six days for macro-

malts. A relatively slow start is most likely to give the desired even growth. Depending on their chemical composition, their dormancy and the steep treatment, different barleys will vary enormously in growth response. A plant malting of a new variety is made so that any unusual handling factors may be determined. If the results are not satisfactory, the new variety probably would be discarded.

In general, apart from dormant barley, the greatest difficulty is caused by samples with high nitrogen content, which apparently possess two conflicting characteristics. They have the greatest potentialities for enzyme production and, therefore, for metabolic activity, but are the most difficult to bring to a desired degree of modification. High nitrogen content is usually associated with barleys described as steely, which are transparent and are difficult to malt. To produce a malt from steely barley it is necessary to force the malt. However, unnecessary forcing is not efficient because it leads to a very appreciable loss of extract.

The third and final step of the malting process is approached when the acrospire of the grain has reached ⅔ to ¾ length of the kernel. The green malt is loaded into the kiln for the first stage of drying at a low temperature (85° to 105°F.). To the right of the germinator in figure 2 is the forced draft oven for the drying of experimental malts.

Removal of moisture from the malt involves several temperature changes, all carefully controlled. The initial heating causes a gradual weakening of the general metabolism, so that the enzyme systems are soon inactivated. The kilning treatment also develops color and flavor in the malt and, by removal of water, makes it stable and friable.

Chemical Changes

Changes which make a permanent contribution to the character of the malt, as distinct from those which terminate with the loss of metabolic activity, include first the modification of cell wall and related materials. Those engaged in barley investigations use the all-inclusive term, "modification." Actually, no single

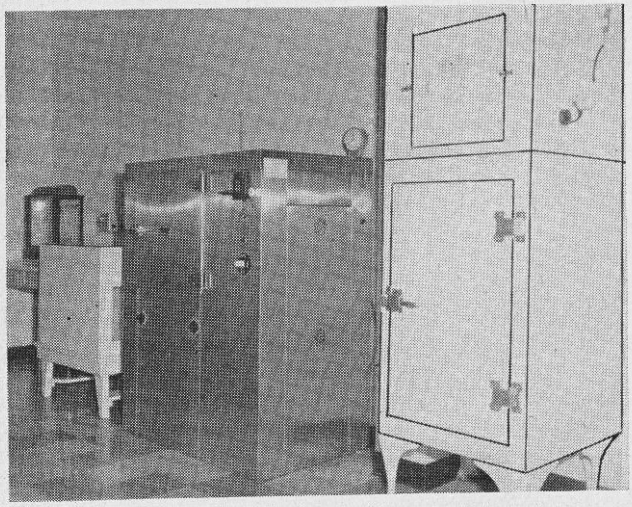

Figure 2.—Barley germinator and malt kiln.

determination adequately defines this property because modification includes changes of cell wall material, starch and protein. Cell wall dissolution is brought about by cytases which attack the endosperm cell walls, leaving a skeleton which is permeable to the starch splitting enzymes, thus facilitating starch breakdown.

Details of the mechanisms which effect starch modifications are unknown. The conventional view, that starch granules rendered more accessible by the action of cytases are attacked by amylases, cannot explain completely the conversion of starch into sugars such as maltose and glucose. The possibilities of sugar production are enhanced by the presence of limit dextrinase, which seems unquestionably to be an enzyme of green malt. When the two systems operate together the conversion of starch to sugar proceeds smoothly.

In the laboratory starch modification is measured by the differences between fine and coarse grind extract. A large difference between these two values indicates reduced modification. A poorly modified malt appears to be more vitreous, therefore, less permeable to enzymatic attack.

The measure of protein degradation or modification is the ratio of wort (or soluble) nitrogen to total nitrogen. A figure of about 36 percent may be taken as standard for modification when the determination is made under the set controlled conditions maintained in the laboratory malting process. These soluble, nitrogenous compounds are an essential component in extract because they subsequently supply yeast nutrient in the brewing process. The actual proportion should be within the narrow confines of 34 to 40 percent for a good malting and brewing barley.

Associated with the degradation of the various nitrogen fractions are carbohydrate splitting enzymes. The two most important are alpha and beta amylase. These two starch splitting enzymes are very different and serve two specific functions in the mashing of malt. Alpha amylase is a typical component of germinated barley, becoming strongly active after three or four days of malting and is characterized by its capacity to break the large starch molecule rapidly into many smaller aggregates, thus creating many points of attack for the beta component. The principal function of beta amylase is to split the starch aggregates into maltose. The activity of the two amylases is measured by determining the products of their hydrolizing action. It is important in the screening of hybrid barleys that they have sufficient diastatic and dextrinizing activity. These factors cannot be too low or too high and must be in the correct ratio for the hydrolysis of starch to be easily controlled in plant operation. Figure 3 shows part of the area in the laboratory where the activities of the amylolytic enzymes are assessed by chemical means.

Barley and Malt Requirements

To meet the needs of the maltster and brewer, barley must have the following requirements: (1) Be substantially 100 percent viable; (2) have the capacity, through adequate alpha amylase activity, to facilitate the breakdown of starch, and by cytolytic enzyme activity to accelerate the degradation of the nonstarchy components and so facilitate the action of other enzymes.

Each barley sample is a vast number of individual kernels capable of substantial variations. The work of the maltster and brewer is simpli-

fied enormously by maximum uniformity in the barley and in the finished malt. Therefore, the barley should, so far as possible, meet two further requirements. (3) It should have substantial uniformity of grain size and chemical composition. These needs are met best by the use of a pure variety, by individual samples which are graded for grain size and for readily determinable characters such as nitrogen content, and the different grades should be stored and malted separately. (4) Each sample should have completed its period of dormancy. With substantially 100 percent germination, growth is regular and even.

There still remain, however, factors of economic and brewing significance. Maximum extract has always been desirable and extract figures for malts have tended to rise steadily, from 95 pounds per quarter (336 pounds malt) in the 1920's to around 100 pounds per quarter today. A barley with high extract potentialities is one with low nitrogen content. Since high nitrogen is likely to cause instability in beer a demand for a barley of low nitrogen content has developed. A reasonable nitrogen content in malting barley (6-row, midwest) would be in the range of 1.90 to 2.25 percent depending on climatic conditions and locations of growth.

To be acceptable for industrial use, barley must be appraised finally by the malsters and brewer. This can be done only by first running pilot malts and brews and, when enough barley is available, to actually process the raw material through a plant operation. It is not always true that an acceptable malt makes a good brew.

Besides chemical and biological requirements, barley has to meet certain grading factors. The traditional methods of assessing the malting quality of barley is by hand examination. For an expert, it is probably true to say that this is still the safest method, though it may—and usually now is—supplemented by laboratory tests. The physical tests can do what chemical examination cannot—they can assess with considerable certainty the degree of ripeness of the grain, the color and the appearance of the

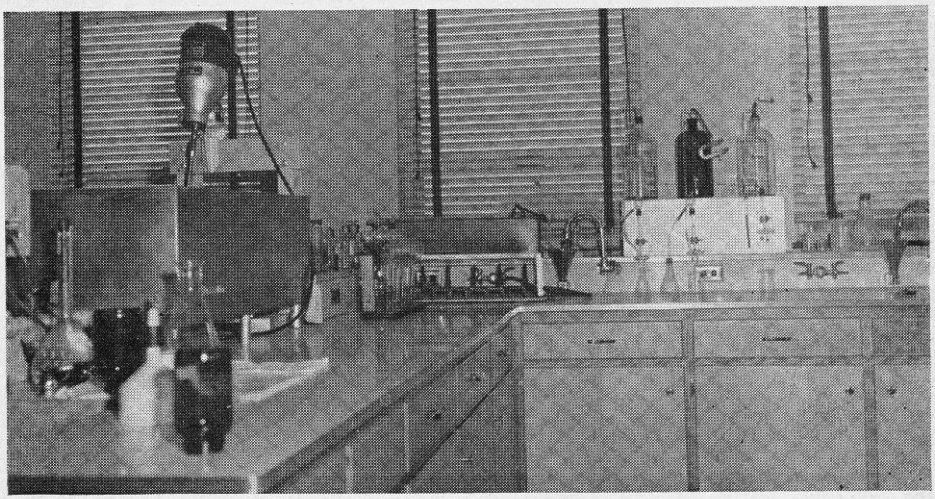

Figure 3.—Amylase analysis area and equipment of the barley laboratory.

skin. Color tends to reflect the weather conditions which prevailed around harvest time. Pale color indicates unduly rapid ripening (common in dry areas). A dark hue frequently results from unfavorable harvest weather with too much rain and too little sun. Pronounced staining may damage the germination of the grain, apart from the fact that the normal maturing will have been interfered with. Very wet weather may cause pregermination, a proportion of embryos being damaged or even killed when the grain is dried and stored.. Damp grain is an ideal host for the growth of mold bacteria.

If the skin is coarse (thick skinned), it is probable that too much nitrogen has been taken up, likely as a result of unwise use of nitrogen fertilizers. A cross section of these barley kernels shows a gray or steely appearance in the endosperm, and these do not malt well. The ideal is a thin-skinned, slightly wrinkled sample which, when cut crosswise, appears white and mealy in the endosperm. It may be noted that the terms "thick" and "thin" applied to the barley husk refer to visual impressions rather than to actual measurements.

The care which has been used in threshing is very important. Damaged kernels make ideal substrates for mold growth on the malting floor and while broken kernels can be removed by screening, kernels damaged at the tip cannot be separated. It is also not desirable that long lengths of awn should be left attached to the grain or that fragments of rachis with attached kernels should be present. The color, uniformity of grain size and evidence of threshing damage are of outstanding value in the assessment of quality.

Literature Cited

(1) Meredith, W. O. S., Sallens, H. R. and Rowland, H. Prediction of Malt Diastatic Power Barleys. Sci Agr. **22:** 761-771 (1942). ibid Prediction of Malt Extract of Hybrid Barleys. Sci. Agr. **23:** 355-361 (1943).

(2) Harrison, T. J. and Rowland, H. Laboratory Malting Equipment. J. Inst. Brewing **38:** 502-508 (1932).