Small-Scale Milling to Estimate the Milling Quality of Soft Wheat Cultivars and Breeding Lines[1]

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ABSTRACT

Flour yield from 20-g milling in a modified Brabender Quadrumat Jr. mill was correlated significantly with straight-grade flour yield and endosperm separation index data from an Allis-Chalmers milling of soft wheat. Adjusting the yield from the small-scale milling to a uniform grain moisture content improved the relationship with endosperm separation index. The procedure provides a means of evaluating milling quality potential in soft wheat breeding lines at an early stage of development.

A recent publication (Yamazaki and Andrews 1982) described a modified Allis-Chalmers mill to obtain milling quality data from soft wheat. Millings made with this mill confirmed the heritable nature of straight-grade flour yield and of a milling factor called endosperm separation index (ESI). This index estimates the ease or difficulty in separating bran and endosperm during milling. Flour yield can be varied within limits during milling by changing the number of reduction and/or low-grade passes, depending on the appearance of the stock; however, ESI, which can be computed after the first reduction pass, is less susceptible to manipulation and can therefore reflect the nature of the wheat to a greater extent than yield. This difference was shown in the error mean square values for yield and ESI. Thus, ESI appears to be a key property through which varietal soft wheat milling quality can be estimated.

A quality-evaluation procedure for early-generation screening is available and is based on a few key tests done on a small quantity (25 g) of grain (Yamazaki and Donelson 1972). All the tests, however, bear on baking quality potential. The verification that ESI is a varietal trait and also is associated with varietal flour yield potential makes possible the development of a small-scale milling procedure that yields results correlating with ESI. These results could correlate with flour yield and milling quality potential and can supplement microtest evaluations of baking quality potential.

Several workers have described mills that grind 100 g of wheat or less and are therefore smaller than the Buhler or Allis-Chalmers mills used to produce flour for testing. An early mill described by Geddes and Frisell (1935) consisted of two stands similar to those of an Allis-Chalmers mill but with roll surfaces reduced to 1 in. A rotating sifter (bolter) completed the assembly. A Hobart grinder was employed by Finney and Yamazaki (1946) to produce flour by a three-stage grinding procedure. A soft wheat composite milled by the technique yielded 65.7% flour with 0.45% ash. Kemp et al (1961) constructed a specially designed mill consisting of two break and two reduction rolls for simultaneously processing four samples of 100 g or less. Their data indicated soft wheat flour yields ranging from about 50 to 65%.

A commercially available mill, the Quadrumat Jr., was described by Shellenberger and Ward (1967). This compact unit provides for three grinding passes and for the collection of low- and high-ash flours and bran. A Quadrumat Sr. mill has one unit for break passes and one unit for reduction passes. Details of a modified Quadrumat Sr. mill are given by Jeffers and Rubenthaler (1977) in their discussion of controlling mill temperature to improve flour yield uniformity.

Everson and Seeborg (1958) studied the mode of inheritance of milling quality, measured by separation of endosperm and bran (Seeborg and Barmore 1957), using a custom-fabricated mill (Shoup et al 1957) adapted for simultaneously grinding five 5-g samples. The wheat was passed through two sets of break rolls, and the bran was weighed. By the implied relation between milling quality and flour yield (as a complement of bran yield), they concluded that inheritance of bran-endosperm separation was complex, involving more than four genic factors.

We developed a procedure for estimating milling quality in soft wheat that utilizes a modified Quadrumat Jr. mill and requires only 20 g of wheat. Flour yield was compared with wheat milling data obtained with an Allis-Chalmers mill (Yamazaki and Andrews 1981).

MATERIALS AND METHODS

A Brabender Quadrumat Jr. mill was modified in the following manner. The lower portion (screen and tray) of the unit was removed, and the upper section (roll) was mounted on a wooden platform so that a steel beaker could be placed under the ground meal exit hole. Rolls with 31, 36, 38, and 40 corrugations per inch replaced the ones originally provided with the unit, and the roll spacings were set at 0.039, 0.007, and 0.0025 in. for the first, second, and third passes, respectively, at room temperature. The front cover was replaced by a plastic sheet ¼ inch thick, with holes drilled at appropriate places to enable brushing out after a sample was milled. Two 100-watt light bulbs, placed near the facing, heated the rolls overnight. Before each day's run, about 1,000 g of scrap wheat was milled to condition the mill.

In operation, 20 g of wheat was weighed and fed to the mill inlet. The resulting meal was sifted on a 54-mesh wire screen (368-μm opening) mounted on a 10 × 10-in. frame and rotated for 1 min in a modified Great Western break sifter. The weight of overs on the screen was converted to percent flour yield, based on wheat weight. Standard deviation of weight of overs, calculated from 100 duplicated millings, was 0.075 g, corresponding to a flour yield standard deviation of 0.38%. The value of least significant difference for a single run was 1.1% and for duplicate millings about 0.8%. Weights of throughs were not as replicable as those of overs, primarily because of variable quantities retained in the mill even after brushing. Our standard deviation value appears reasonable when compared to our current standard deviation of 0.31% for a straight-grade flour yield from our Allis-Chalmers mill. Because flour hang-up varied, flour ash content value was considered uncertain and therefore was not determined.

Samples (196) of soft wheat breeder entries of the 1980 crop were milled both without tempering (moisture content of samples ranged from 9.9 to 12.3%) and after tempering overnight to 14.0%. Allis-Chalmers millings had previously been made of these wheats;

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thus, straight-grade flour yield and ESI data were available.

To determine the effect of grain moisture content on yield, subsamples of each of 20 wheats representing the spectrum of ESI (10 wheats) and of kernel textures (10 wheats) and previously characterized by Allis-Chalmers millings were used. Each wheat was divided into five sublots, and water was added in 1.0% increments to four of them, with the fifth (untempered) sample serving as control. The wheats were sealed in jars and equilibrated for at least one week. When the seals were broken for the first milling run, two samples were withdrawn and the jars recapped. One sample was milled immediately; the other was lightly ground and analyzed for moisture. In the moisture analysis, the samples were heated for 1½ hr at 140°C (AACC 1976). Moisture was not determined at the time of duplicate millings.

RESULTS AND DISCUSSION

The described milling procedure was the result of a series of trials evaluating the effects of roll corrugation, roll spacing, and screen mesh size used to differentiate among wheats considered to have variable millabilities as determined by Allis-Chalmers (or Allis) millings. The r value relating yield from 20-g millings with ESI for the 196 breeder entries of the 1980 crop was −0.791, a highly significant association. The r value was actually higher than the r value (−0.735) relating straight-grade Allis flour yield with ESI for a similar series of 223 1980 samples. The latter value (r = −0.735) is lower than values obtained for the 173 1980 crop entries (r = −0.931) and for the 242 entries of the 1979 crop (r = −0.828). This decline in correlation was attributed to our continuing effort to produce straight-grade flours of equal quality (ie, equal ash content) from wheats differing widely in milling response. This effort was made so that we could evaluate the baking quality of flours on an equitable basis. We obtained approximate ash uniformity by varying the number of reduction and low-grade passes as required by individual wheats. By doing this, however, we changed the normal flour yield for each wheat because we altered the natural relationship between ease of bran-endosperm separation and flour yield.

That this lowering of r value was due to our objective of obtaining uniform flour ash content could be shown by the improvement in correlation gained by recalculating straight-grade flour yield based on a uniform seven-reduction, one-sizing, and two low-grade passes for all wheats. These yields gave a correlation coefficient against ESI of −0.877, a considerable improvement over the r value of −0.735 for the same 223 samples of the 1980 crop milled to equalize ash content.

This comparison between yield from 20-g milling and ESI from Allis-milled flour was not equitable. The ESI values were obtained from millings of tempered wheat, whereas the 20-g milling yields were obtained for untempered wheats differing in moisture content. In addition, grain moisture content influences yield significantly.

Table I presents data concerning the effect of wheat moisture level on 20-g milling flour yield for 20 wheat samples, each at five moisture levels. For each wheat, the decrease in yield was related linearly to an increase in moisture content. Analysis of covariance indicated significant differences in slope among cultivars, but the differences could not be attributed to relative position of regression lines, endosperm separation index, kernel texture, kernel size, or age of sample. A test for homogeneity of regression showed that all but the lowest and two highest regression coefficients did not differ significantly from the mean slope of 1.45% change in yield per percent moisture content change. Because grain moisture content is an obvious contributor to yield, and because the apparent random distribution of slope 1.45% among the wheats tested could not be attributed to any known grain characteristic, a reasonable procedure was to determine the practicality of applying the mean slope adjustment to yield to determine the extent of improvement in association between ESI and a flour yield of 20 g for the 20 cultivars listed in Table I. When yield was adjusted to a grain moisture content of 11.0%, the r value for the relationship between flour yield and ESI was −0.957, a markedly higher value than the r value for the untempered grain (−0.917 for a moisture range of 10.8−12.1%).

Correlation computations for 20-g milling flour yield against ESI for the 196 samples of the 1980 crop, adjusted to 11.0% moisture content by using the mean slope above, increased the r value from −0.791 to −0.840. In a further test, 20-g millings were made of the same 196 samples after they had been tempered overnight to 14% moisture content. The correlation coefficient for yield against ESI for these tempered samples was −0.861, again an improvement over the coefficient of −0.791 for yield against ESI for untempered grain.

Because the r values relating yield and ESI for 20-g millings

TABLE I
Effect of Wheat Moisture Level on 20-g Milling Flour Yield for 20 Wheat Samples

Entry	Endosperm Separation Index (%)	Break-Flour Yield (%)	No. of Moisture Levels	Moisture Content Range (%)	Correlation Coefficient	Regression Coefficient[a]	Flour Yield Adjusted to 12% Moisture (%)
1[b]	7.3	28.2	5	10.9−14.5	0.992	−1.34	75.5
2	8.3	31.5	5	12.1−15.7	0.990	−1.22	74.7
3	9.2	28.2	5	11.6−15.2	0.996	−1.61	73.5
4	10.6	28.9	5	11.5−15.3	0.996	−1.66	71.9
5	11.1	31.4	5	12.0−15.7	0.998	−1.64	72.5
6	12.1	29.4	5	10.8−14.4	0.999	−1.49	71.2
7	13.2	31.8	5	11.0−14.7	0.999	−1.37	70.3
8	14.2	33.0	5	10.6−14.3	0.990	−1.36	68.8
9	15.6	31.1	5	11.2−15.0	0.990	−1.37	68.8
10	17.1	27.4	5	12.0−15.8	0.990	−1.80	67.1
11[c]	10.3	17.8	5	11.6−15.3	0.981	−1.17	71.3
12	10.5	20.0	5	11.2−15.1	0.977	−1.24	71.6
13	14.7	21.8	5	11.3−15.1	0.999	−1.52	69.5
14	12.3	25.8	5	11.3−15.1	0.994	−0.92	69.6
15	10.9	28.9	5	11.7−15.5	0.999	−1.86	71.8
16	10.8	30.8	5	11.6−15.4	0.986	−1.48	71.6
17	10.1	32.8	5	11.5−15.1	0.997	−1.60	72.5
18	9.8	35.7	5	11.6−15.2	0.997	−1.34	72.6
19	12.2	37.3	5	10.8−14.4	0.995	−1.16	71.0
20	11.0	39.0	5	11.3−15.2	0.997	−1.84	71.2

[a] Percent yield divided by percent moisture.
[b] Cultivars 1−10 selected on the basis of endosperm separation index.
[c] Cultivars 11−20 selected on the basis of Allis-Chalmers break-flour yield range (kernel texture).

adjusted to 11% moisture and for millings of tempered wheat did not differ greatly from each other, and because milling of untempered wheat followed by yield adjustment involves considerably less sample manipulation, we will most likely employ the moisture adjustment procedure to characterize the milling quality potential of small samples of soft wheat.

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