DETERMINATION OF MILLING QUALITY
OF F_3 GENERATION WINTER WHEAT HYBRIDS
BY THE MICRO-MILLING PROCESS

by

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INTRODUCTION

The development of the micro-mill attachment for the Buhler laboratory flour mill by the Western Regional Wheat Quality Laboratory at Pullman, Washington has made it possible to evaluate the milling quality of a variety or selection with as little as 100 grams of wheat. The data presented in this thesis represent the first attempt to use the micro-mill to determine milling quality of early generation hybrid wheat lines.

The original purpose of this study was to study the inheritance of milling quality and determine, if possible, the proportion of good and poor milling lines from a cross of good and poor milling parent varieties. At this time, milling quality was thought of as a single, quantitative characteristic. As the experiment progressed and the milling technique developed, it became apparent there were a number of factors comprising milling quality each of which should be considered and evaluated separately. These factors among others include flour yield, bran clean-up, flow behavior and the amount of shorts material. Other factors such as weight of bran, amount of first middlings and fluffiness of the shorts may be separate characteristics or further divisions of milling quality factors already mentioned.

A review of the literature reveals flour yield has been used almost exclusively as a measure of milling quality. In this study an attempt was made to measure flour yield, amount of first middlings produced, weight of bran and shorts material, bran clean-up and flow behavior from F_3 hybrid families of two winter wheat crosses of Brevor x Orfed-Elgin. Finally to evaluate each hybrid line for its milling quality, considering these factors, a method of scoring the hybrids was devised and is presented.

REVIEW OF LITERATURE

Considerable work has been done describing quality of wheat and flour but very little has concerned itself with the actual milling of wheat or in describing milling quality. As pointed out by Swanson (16, p.5) small experimental mills manufactured in the United States have undergone only minor changes since 1900. Procedures for making baking tests, determining flour strength, and other flour quality tests have undergone great changes.

Swanson (16, p.6) describes the milling of wheat as "the physical or mechanical process of separating the outside bran coat and germ from the inside endosperm and converting the latter into fine flour". Milling quality in wheat may then be defined as the ease with which large yields of flour are obtained. Thus two considerations of milling quality are: case of milling and large amounts of flour. Early work by LeClerc and Yoder (10, p.29) indicated environmental factors were more important than variety to physical and chemical characteristics of wheat.

There is a lack of information on the properties of milling quality in the literature. In the limited amount of milling quality investigations reported, the measure of quality has been yield of flour. Seeborg (13, p.5) was the only worker determining milling quality based on factors other than flour yield. No methods of determining bolting properties or evaluating bran and shorts materials was found and methods used by Seeborg on the Buhler mill were not directly applicable to the micro-mill.

Wheat characteristics studied in regards to flour yield have been kernel structure, kernel properties and varietal influence on flour yields.

Kernel Structure

Scot (12, p.374) gives the following analysis of a grain of wheat:

Bran, including seed coat, aleurone layer and pericarp	12.5%
Germ	2.5%
Endosperm	85.0%

This agrees with Swanson's (16, p.6) report of Fleurent's work with different varieties where he found an average of 13% bran, 2% germ and 85% endosperm. These proportions appeared rather consistent regardless of variety.

The thickness of bran was determined by Scot (12, p.378) to be 0.0031 inches. He also cites Shellenberger and Morgenson as finding this to be the average bran thickness of hard red winter wheat varieties. However, Scot found this to be a constant with the wheat varieties he was working with, and Shellenberger and Morgenson (15, p.29) recognized varietal differences.

Flour yield is an important factor in milling quality. The economic importance of getting as high a percentage of flour from wheat as possible, and still produce a high quality of flour, is shown in a chart by Dedricks (5, p.337). It requires an extra bushel of wheat to produce a barrel of flour from wheat yielding 60% flour as compared to wheat yielding 73% flour.

Most investigators have measured milling quality by flour yield. Other quality factors are recognized, but flour yield is the only one for which there have been accurate measuring methods. Using this factor as measure of milling quality, Barmore _et al_. (2, p. 1a) showed that bran thickness was unrelated to milling quality in seven wheat varieties. This substantiates work done by Crewe and Jones (4, p. 49) and Shellenberger and Morgenson (15, p. 29).

Kernel Properties

The size of the wheat kernel would seem to be an important factor in the percentage of endosperm. Swanson (16, p. 6) points out the expectation of the proportion of bran and germ to endosperm would be greater in small kernels than in large ones. Willard and Swanson (17, p. 150) found that small sound kernels will give as good flour yields as the same quality of large ones. Scot (12, p. 381) shows an increase in endosperm from 83.4 to 86.1 percent with volume increase of 200 grains from 21.4 to 41.0 cubic millimeters. This experiment was with sound kernels.

Swanson (16, p. 7) working with shrivelled kernels showed an increase in endosperm from 62.6 to 81.1 percent with increased volume of 1000 grains from 9.90 to 21.37 cubic centimeters.

Test weight, as a function of the kernel properties, has long been considered a factor in flour yield. Swanson (16, p. 137) explains this relationship but states "that because of the several factors which influence flour yield, the potential flour yield cannot be computed accurately from the test weight". Scot (12, p.384) cites Bailey who also found a decrease of 1 pound per bushel resulted in a decrease in flour yield of 0.75 percent. Harris and Waldron (8, p.134) found no association between test weight and flour yield in spring wheat.

Variety Influence on Milling Quality

Zinn (18, p.530) is credited as being the first to apply statistical methods to pure line strains of wheat to show inherent quality factors in lines. Much of the work in analyzing quality until his time had been based upon the conditions under which the wheat had been grown rather than upon the variety of wheat. His data showed plainly that pure strains of wheat, isolated from commercial varieties, when grown under the same environmental conditions, show very distinct differences with respect to physical and chemical characteristics.

Ausemus _et al_. (1, p.549) found significant inter-annual and inter-station correlation coefficients for flour yield, giving a basis for considering flour yield to be inherent. However they warn that the expression of this character is so obscure by random environmental effects that its usefulness is limited. Hayes, Immer and Baily (9, p.1095) found inter-annual correlations of flour yield generally significant.

Bowman, Maharg and Poehlman (3, p.27) show definite varietal characteristics in that "Clarkan gave uniformily the lowest flour yields. .....This low flour yield from Clarkan has been observed in commercial mills, resulting from a thick bran, and fibrous endosperm which makes it difficult to bolt out the flour."

Millers generally recognize varietal differences in milling quality. Fifield et al. (6, p.33) reports on 44 varieties of wheat comparing their milling and flour quality characteristics.

The Northwest Crop Improvement Association (11, p.4) classified commercial varieties grown in the Columbia Basin for milling desirability after a survey of milling operators in the area. Their survey showed millers preferred the varieties: Elmar, Triplet and Golden, and considered Brevor, Marfed and Rex as the most undesirable.

Methods of evaluation of varieties for milling quality, based on more factors than flour yield are being devised by the Western Wheat Quality Laboratory at Pullman, Washington. Seeborg (13, p.2) reports a method of scoring varieties for milling quality with weighted values for flour yield, flour ash content, milling time, percentage of patent flour and percentage of moisture required for proper milling.

MATERIALS AND METHODS

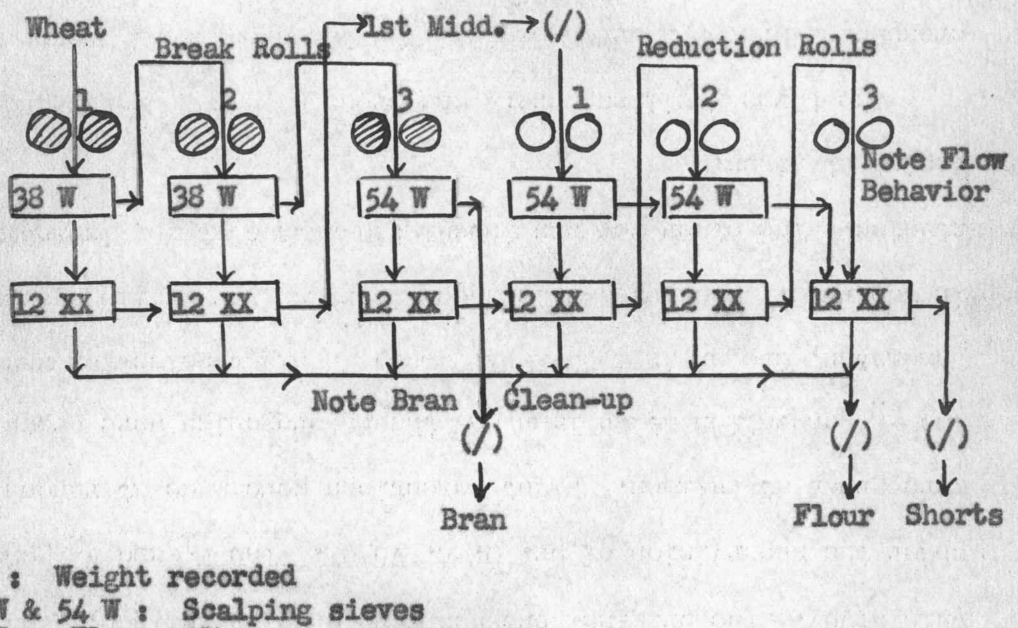
Three families of 310 F_3 lines of winter wheat were used in this study. The original crosses were made at Pullman, Washington under the supervision of O. A. Vogel. The F_1 and F_2 generations were grown at Pullman. Plant selections were made at random from the F_2 generation at Pullman and the F_3 progenies were grown at Pendleton, Oregon in 1950-1951. Each F_2 plant selection was seeded in two rows. One row was for seed increase for milling quality studies. The other row was inoculated with smut for isolating smut resistant lines.

The three families were: one cross of Uma x Brevor and two crosses of Brevor x Orfed-Elgin. The two crosses of Brevor x Orfed-Elgin had different parent plants. Differences in smut reaction indicated these crosses produced families with different characteristics so that one cross was labeled Brevor x Orfed-Elgin (A) and the other, Brevor x Orfed-Elgin (B).

The parent varieties Uma, Brevor and Orfed-Elgin Selection 1 were grown with the F_3 plant rows at Pendleton in 1950-1951. The parent varieties were harvested to be used as check varieties during the milling operation. The fact that the parent plants used for the crosses were not saved and this material increased and used as the parental varieties is regrettable.

Milling of the hybrids and parents was done on the micro-mill attachment of the Buhler mill at the Western Wheat Quality Laboratory at Pullman, Washington in January, February and March of 1952. The micro-mill attachment for the Buhler laboratory flour mill has been described by Seeborg, Shoup and Barmore (14, p.304). It allows the milling of a 100 gram sample of wheat in place of the usual 2400 gram sample. This is accomplished by reducing the grinding surface of the mill rolls and modifying the sifting operation. The elevators and feeders of the Buhler mill are eliminated. The wheat and stocks are fed by hand and collected in trays placed under the rolls. Sifting is done on a separate laboratory shaker. The shaker is controlled by an automatic timer to give uniform sifting time.

The wheat samples in this study were tempered to 14% moisture for 72 hours prior to milling. This is the usual moisture content for soft white wheat. The 100 grams of clean tempered wheat were milled as shown in the flow diagram in Figure 1.



(/) : Weight recorded
38 W & 54 W : Scalping sieves
12XX : Flour silk

Figure 1. Flow diagram of wheat samples on Buhler micro-mill.

The scalping and sifting was done on a 14 inch square laboratory shaker running at 220 r.p.m. The stock from the break rolls was sifted 20 seconds on a 38 W gauge sieve. Material remaining on this screen became the stock for the next break and finally the bran. Middlings, passing through the 38W screen, were sifted for an additional 40 seconds on 12 XX flour silk. Material remaining on this sieve was stock for the reduction rolls and finally became the shorts. Flour is collected by passing through the 12 XX cloth at all sifting operations and is weighed after the third reduction.

Because of an irregular amount of flour loss as dust in the mill, the flour yield of each sample is calculated by subtracting the total weight of the bran and shorts from the original 100 gram sample.

Flour left on the bran is easily seen and the sample was classified as having poor bran clean-up if the bran was white. The rate at which the reduction stocks fed into the mill rolls was used as a measurement of flow behavior. A line with sharp stocks fed easily and quickly, while a fluffy stock was slow. These two measurements are recognized as arbitrary tests, subject to the judgment of the operator; however, it is easy to identify extreme varieties. Also the consistency rating of the parent varieties during the milling operation is an indication of the accuracy of these measurements.

In order to detect differences in the milling operation, if they should occur, a set of the three parent varieties was milled on alternate days of milling. The parent varieties and selections were identified only as laboratory numbers at the time of milling so that identification of the parent varieties could be checked.

Milling quality may be defined as the accumulation of several characteristics determining the reaction of the wheat variety in the mill. To be rated a good milling variety, it must produce a high percentage of flour, a small amount of bran and shorts and have a good flowing behavior so that flour may be obtained easily.

In order to evaluate each hybrid a scoring formula was devised following the example of Seeborg (13, p.1) which would indicate those hybrids with the best milling quality. This consisted of adding a numerical value of 10, 15, 20 or 25 points for poor, fair, good or excellent rating of bran clean-up and flow behavior to the flour yield and dividing this sum by the total of bran and shorts weights. A variety yielding 67.5 percent flour with bran clean-up and flow behavior both rated as good would score:

$$\frac{67.5\text{(flour)} + 20\text{(bran clean-up)} + 20\text{(flow behavior)}}{20.5\text{ (bran weight)} + 12.0\text{ (shorts weight)}} = 3.31$$

A flour yield of 67.5 percent would be considered a minimum acceptable based on the lines milled in this study. A rating of good for bran clean-up and flow behavior should also be minimum rating for acceptable varieties. Thus a score of 3.31 would be considered the lowest acceptable score.

Seed of the F_2 plant selections to be tested for smut resistance were dusted with chlamydospores of bunt (<u>Tilletia</u>

caries) race 16 prior to seeding. These smut balls were supplied by C. S. Holton, U.S.D.A. Pathologist, Pullman, Washington. The percentage of infection was estimated to the nearest 10 percent shortly after heading time.

The associations of milling quality characteristics were determined by correlation coefficients calculated from two-way frequency tables, as explained by Goulden (7, p.75). The associations between smut reaction and milling quality factors of a hybrid line were also calculated.

EXPERIMENTAL RESULTS

The uniformity of the milling technique is shown by the consistency of data obtained from milling the parental varieties. Experimental data on flour yield, weight of shorts and bran, bran clean-up and flow behavior and milling scores of the F_3 progenies and the parental varieties are presented in that order. Following these, the association between the different quality characteristics and smut reaction are reported.

Testing Milling Techniques

Data from the parent varieties were found to be consistent between milling dates. The average flour yields, weight of shorts and bran clean-up of each parent at three milling dates are shown in Table 1. The analysis of variance, presented in Table 2, shows significant differences to occur only between varieties. The fact that no differences occurred between milling dates and the sampling error was low, lends confidence to the milling technique.

The results presented in Table 1 show Orfed-Elgin to have the highest flour yield and Brevor to be the lowest in flour yield. Orfed-Elgin and Uma were equal in the amount of shorts produced and Brevor produced the most shorts. Uma produced the cleanest bran and Brevor had much the poorest bran clean-up.

The hybrids from the Uma x Brevor cross were milled first. These were harder in texture than was expected, and tempering to 14% moisture proved to be too low. The middlings failed to reduce properly and resulted in low flour yields. All hybrids had excellent flow behavior and bran clean-up, but it is believed differences in milling quality were hidden by the improper moisture content.

TABLE 1

AVERAGE FLOUR YIELD, WEIGHT OF SHORTS IN GRAMS AND RATING OF BRAN CLEAN-UP OF PARENT VARIETIES MILLED AT THREE INTERVALS

	Milling Date	Uma	Brevor	Orfed x Elgin	Milling Average
Flour Yield	1	67.1	63.7	68.5	66.4
	2	68.6	63.7	68.6	67.4
	3	68.6	64.6	70.4	67.9
Varietal Average		68.1	64.0	69.2	
L.S.D. (5%): 1.22 grams					
Weight of Shorts	1	13.1	14.6	12.7	13.4
	2	11.8	14.5	12.5	12.9
	3	12.4	14.7	11.0	12.7
Varietal Average		12.4	14.6	12.0	
L.S.D. (5%): 1.49 grams					
Bran Clean-up	1	4.5	2.0	3.8	3.4
	2	4.5	2.3	3.8	3.5
	3	5.0	2.0	4.0	3.7
Varietal Average		4.7	2.1	3.8	
L.S.D. (5%): 0.3					

TABLE 2

ANALYSIS OF VARIANCE OF FLOUR YIELDS, WEIGHT OF SHORTS IN GRAMS, AND BRAN CLEAN-UP RATING FOR THE THREE PARENT VARIETIES

	Degrees of Freedom	Mean Squares		
		Flour Yield	Shorts Yield	Bran Clean-up
Milling Dates	2	6.6220	1.7895	.1945
Varieties	2	89.1786**	22.3837**	20.8611**
Dates x Varieties	4	1.1619	1.7369	0.1528
Samples	27	3.1232	2.9915	0.1574
Total	35			

**Exceeds the 1% level of significance.

The Brevor x Orfed-Elgin hybrids had textures more typical of soft white wheats and the tempering to 14% moisture was satisfactory. Good differentiation was obtained in the milling of these hybrids. Frequency tables have been prepared for several of the milling quality characteristics, and the distribution of the F_3 lines within a family compared to the distribution of samples within the parental varieties.

The mean of the two crosses of Brevor x Orfed-Elgin differed significantly in flour yield, first middlings, shorts and bran, as seen by comparing the standard error of the means. Testing the families by means of the "t" test also showed them to be different, thus confirming what was earlier detected with the smut reaction. Therefore, the data from the two crosses are not combined.

Flour Yields

The frequency distribution of flour yields of the 12 samples of parent varieties and the F_3 hybrid lines of the Brevor x Orfed-Elgin crosses are shown in Table 3. Cross A had lines which yielded as low as the poorest sample of Brevor and as high as the best sample of Orfed-Elgin. Eleven lines had flour yields exceeding the mean of Orfed-Elgin, the better parent.

Cross B did not produce lines with as high a flour yield. None of the lines was better than the mean of Orfed-Elgin. One line produced less flour than the poorest sample of Brevor.

Weight of Shorts

The distribution of the yield of shorts produced by the samples of parent varieties and F_3 lines is shown in Table 4. Cross A again had lines which ranged from the extreme samples of each parent. There were a total of 40 lines with less shorts than the mean of Orfed-Elgin parent.

The average amount of shorts produced by lines from Cross B was greater than from the lines of Cross A. Seven lines from Cross B had more shorts than the poorest samples of Brevor. Even so, 31 lines from Cross B produced less shorts than the average of Orfed-Elgin.

TABLE 3

FREQUENCY DISTRIBUTION OF FLOUR YIELDS IN GRAMS OF PARENTS AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951 AT PENDLETON, OREGON

Parent or Cross	Number of Lines per Class Interval												Total Lines	Mean (grs.)
	61.5	62.5	63.5	64.5	65.5	66.5	67.5	68.5	69.5	70.5	71.5	72.5		
Orfed x Elgin						1	2	2	5		1	1	12	69.17 ± .48
Brevor	1	1	5	4	1								12	63.75 ± .32
Brevor x Orfed-Elgin (Cross A)	2		11	7	12	23	13	16	14	4	5	2	109	67.18 ± .23
Brevor x Orfed-Elgin (Cross B)	6	9	8	11	17	18	15	14	6				104	65.84 ± .22

TABLE 4

FREQUENCY DISTRIBUTION OF YIELD OF SHORTS IN GRAMS OF PARENTS AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951 AT PENDLETON, OREGON

Parent or Cross	Number of Lines per Class Interval										Total Lines	Mean (grs.)	
	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5			
Orfed x Elgin	1		1	3	4	2	1				12	12.08	±.45
Brevor					2	1	5	1	3		12	14.67	±.41
Brevor x Orfed-Elgin (Cross A)	3	4	14	19	19	23	17	6	4		109	12.68	±.17
Brevor x Orfed-Elgin (Cross B)			9	22	19	21	10	10	6	7	104	13.50	±.14

Bran Weight

The frequency distribution of bran weight of the parent varieties and the F_3 lines from two crosses are presented in Table 5. Lines of Cross A ranged from as low in bran weight as the best sample of Orfed-Elgin to nearly as heavy a weight as the heaviest Brevor sample. Six lines had bran weight less than the mean of Orfed-Elgin.

Cross B lines produced more bran weight. None of the lines produced a lower bran weight than Orfed-Elgin. The average weight of all lines was slightly less than the mean of the Brevor parent.

First Middlings

The frequency distribution of the samples of parent varieties and F_3 lines for weight of first middlings are shown in Table 6. A heavy weight of first middlings indicates a fast release of the flour and usually an easier milling variety.

Cross A had lines equal to the best sample of Orfed-Elgin in this respect. The poorest lines, while not as low as the poorest sample of Brevor, were lower than the average of Brevor samples. There were 14 lines which produced more first middlings than average of the Orfed-Elgin samples.

Lines from Cross B in general produced less first middlings. Three lines produced as low as the poorest sample of Brevor. Only two lines exceeded the average of the Orfed-Elgin samples.

TABLE 5

FREQUENCY DISTRIBUTION OF BRAN WEIGHT IN GRAMS OF PARENTS AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951 AT PENDLETON, OREGON

Parent or Cross	Number of Lines per Class Interval										Total Lines	Mean (grs.)
	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5		
Orfed x Elgin	2	1	6	3							12	18.9 ± .15
Brevor					1	1	4	1	2	3	12	21.5 ± .24
Brevor x Orfed-Elgin (Cross A)	2	4	10	11	20	26	21	10	5		109	20.30 ± .09
Brevor x Orfed-Elgin (Cross B)			3	8	8	21	31	21	10	2	104	20.88 ± .08

TABLE 6

FREQUENCY DISTRIBUTION OF WEIGHT OF FIRST MIDDLINGS IN GRAMS OF PARENTS AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951 AT PENDLETON, OREGON

Parent or Cross	Number of Lines per Class Interval								Total Lines	Mean (grs.)
	38.5	40.0	41.5	43.0	44.5	46.0	47.5	49.0		
Orfed x Elgin					4	4	3	1	12	46.1 ± .43
Brevor	1	2	1	6	2				12	42.3 ± .54
Brevor x Orfed-Elgin (Cross A)		3	5	21	40	26	13	1	109	44.71 ± .17
Brevor x Orfed-Elgin (Cross B)	3	4	29	34	19	13	2		104	43.07 ± .18

Bran Clean-up

The frequency distribution for bran clean-up of the parent varieties and F_3 lines is shown in Table 7. Both crosses had a greater number of lines with poor clean-up than with good bran clean-up. None of the F_3 lines were superior to Orfed-Elgin for this characteristic.

TABLE 7

FREQUENCY DISTRIBUTION OF BRAN CLEAN-UP OF PARENT VARIETIES AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951

Parent or Cross	Number of Lines per Class Interval				Total Lines	Mean
	Poor(2)	Fair(3)	Good(4)	Excellent(5)		
Orfed x Elgin		2	10		12	3.83 ±.01
Brevor	12				12	2.00 ±.00
Brevor x Orfed-Elgin (Cross A)	38	55	16	0	109	2.80 ±.07
Brevor x Orfed-Elgin (Cross B)	24	67	13	0	104	2.89 ±.06

Flow Behavior

Again, both crosses had a similar distribution for this characteristic as shown in Table 8. Each cross had a greater number of lines with excellent flow behavior than with poor flow behavior.

TABLE 8

FREQUENCY DISTRIBUTION OF FLOW BEHAVIOR OF PARENT VARIETIES AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951

Parent or Cross	Number of Lines per Class Interval				Total	
	Poor(2)	Fair(3)	Good(4)	Excellent(5)	Lines	Mean
Orfed x Elgin			5	7	12	4.58 ± .15
Brevor	10	2			12	2.17 ± .11
Brevor x Orfed-Elgin (Cross A)	8	46	41	14	109	3.56 ± .08
Brevor x Orfed-Elgin (Cross B)	5	38	46	15	104	3.68 ± .08

Milling Score

Samples of parent varieties and hybrid lines were scored for milling quality, considering several quality factors. The frequency distribution of the samples of parent varieties and F_3 lines for their milling scores is presented in Table 9.

Cross A had lines which ranged from the best samples of Orfed-Elgin to the poorest sample of Brevor. There were 23 lines from this cross rated as better than the mean of the Orfed-Elgin samples, and 27 lines with milling scores greater than 3.31, the minimum score to be acceptable.

Lines from Cross B tended to be more intermediate in milling quality with a greater number of lines falling between the means of the two parents. Seven lines rated better than the mean of Orfed-Elgin and 10 lines scored above 3.31.

TABLE 9

FREQUENCY DISTRIBUTION OF MILLING SCORE OF PARENT VARIETIES AND F_3 PROGENIES OF TWO CROSSES OF BREVOR X ORFED-ELGIN GROWN IN 1951

Parent or Cross	No. of Lines per Class Interval							Total Lines	Mean
	2.1	2.4	2.7	3.0	3.3	3.6	3.9		
Orfed x Elgin				1	2	7	2	12	3.55 ±.07
Brevor	1	10	1					12	2.40 ±.04
Brevor x Orfed-Elgin (Cross A)	3	13	19	32	19	18	5	109	3.04 ±.03
Brevor x Orfed-Elgin (Cross B)		14	33	36	15	6	1	104	2.91 ±.03

A summary of milling quality factors of the 10 F_3 hybrid lines with the highest milling score from each cross with the parent varieties is given in Table 10. The line with the highest milling score, No. 1207, does not have the best quality of any of the factors studied. It ranks second in flour yield to No. 1259. It has good flow behavior where several other lines and the parent, Orfed-Elgin, have excellent flowing properties. It has good bran clean-up which is not equal to Uma. It has more bran weight than No. 1201, and more shorts than No. 1241. It does, however, represent the best combination of quality factors.

TABLE 10

TEN HYBRIDS FROM EACH CROSS OF BREVOR X ORFED-ELGIN WITH THE HIGHEST MILLING SCORE AND THEIR MILLING DATA AS COMPARED TO THE PARENT VARIETIES

Hybrid No.	Flour Yield grs.	Flow Behavior	Bran Clean-up	Bran Weight grs.	Weight of shorts grs.	Milling Score
Cross A:						
1207	72.2	good (20)	good (20)	19.0	8.8	4.04
1260	70.9	excel.(25)	good (20)	19.5	9.6	3.98
1240	71.7	good (20)	good (20)	19.0	9.3	3.95
1259	72.6	good (20)	fair (15)	20.5	6.9	3.93
1241	71.4	good (20)	good (20)	20.0	8.6	3.90
1208	70.4	good (20)	good (20)	19.0	10.6	3.73
1201	70.2	good (20)	good (20)	18.5	11.3	3.70
1252	69.0	excel.(25)	good (20)	20.0	10.9	3.69
1261	71.1	good (20)	fair (15)	19.5	9.4	3.67
1192	69.8	good (20)	good (20)	19.0	11.2	3.64
Cross B:						
1427	69.8	excel.(25)	good (20)	20.5	9.7	3.80
1430	68.9	excel.(25)	good (20)	19.5	12.6	3.66
1436	69.5	good (20)	good (20)	19.0	11.5	3.59
1468	67.6	excel.(25)	good (20)	20.5	11.9	3.48
1466	68.7	good (20)	good (20)	20.0	11.3	3.47
1465	68.6	good (20)	good (20)	19.5	11.9	3.46
1474	68.6	good (20)	good (20)	19.5	11.9	3.46
1487	66.9	excel.(25)	good (20)	20.5	12.6	3.38
1512	69.1	good (20)	fair (15)	19.0	11.9	3.37
1414	69.0	good (20)	fair (15)	21.0	10.0	3.35
Parent Varieties:						
Orfed-Elgin	69.2	excel.(25)	good (20)	18.9	12.0	3.62
Uma	68.1	excel.(25)	excel.(25)	19.5	12.4	3.57
Brevor	64.0	poor (10)	poor (10)	21.5	14.6	2.40

Association of Characteristics

Correlation coefficients were calculated to determine if an association existed between any of the quality characteristics studied and particularly if some of these quality factors were associated with flour yield. The data showing these relationships are presented in Table 11. The sign of correlation (positive or negative) was the same for each pair of factors in both crosses, except for one pair. However, the degree of associations was somewhat higher in Cross A than in Cross B.

TABLE 11

CORRELATION COEFFICIENTS (r) FOR TESTS OF ASSOCIATION OF CHARACTERISTICS IN F_3 CROSSES OF BREVOR X ORFED-ELGIN CROSSES GROWN IN 1951 AT PENDLETON, OREGON

Characteristic	First Middlings	Bran Clean-up	Smut Infection	Flow Behavior
Cross A:				
Flour Yield	.349**	.573**	.565**	.367**
Total Shorts	-.179	-.421**	-.413**	-.234**
Bran Weight	-.378**	-.414**	-.538**	-.411**
Flow Behavior	.439**	.410**	.307**	
Cross B:				
Flour Yield	.268**	.137	-.034	.078
Total Shorts	-.288**	-.151	.114	-.004
Bran Weight	-.281**	-.085	-.094	-.268**
Flow Behavior	.195*	.243*	.091	

*Exceeds the 5% level of significance.
**Exceeds the 1% level of significance.

Flour yields and the weight of first middlings were positively correlated in both crosses. In Cross A flour yields were significantly associated with the bran clean-up and flow behavior. The better the bran clean-up and flow behavior; the better the flour yield of a line.

The weight of shorts were negatively correlated with the bran clean-up, flow behavior and weight of first middlings. This was also true of the weight of bran. Thus a line with poor bran clean-up tended to produce more shorts, heavier bran and be slower milling.

Flow behavior was positively correlated with weight of first middlings and bran clean-up, indicating lines which released flour quickly and had good bran clean-up were likely to have good flowing behavior.

The percent of smut occurring in the smut inoculated row of a hybrid line was found to be associated with the quality factors in the F_3 lines from Cross A, but not in Cross B. The correlations between smut infection and flour yield and flow behavior were positive, indicating lines with the greatest smut susceptibility had the highest flour yields and best flow behavior.

The correlations between smut infection and yield of shorts and bran weight were negative, indicating lines with the greatest smut susceptibility produced the least amount of shorts and bran.

DISCUSSION

The micro-mill attachment for the Buhler laboratory flour mill has proven satisfactory in determining the milling quality of small samples of wheat. In previous experiments conducted at the Western Regional Wheat Quality Laboratory at Pullman, Washington, Seeborg, Shoup and Barmore (14, p.307) found it capable of detecting varietal differences in milling quality by magnifying the poor milling qualities of a variety. During the milling operations for the present study, the parent varieties were milled under laboratory numbers to determine if the quality factors were measured in a consistent manner. It was found, after a short time of experience with the mill, that it was possible to identify the parent varieties by their behavior. This gave further indication of the value of the micro-mill in detecting good and poor milling qualities in lines and selections of wheat.

One of the most serious problems facing the plant breeder in his search for superior varieties with desirable agronomic characteristics, disease resistance and good milling quality, has been the lack of a suitable descriptive test for milling quality which could be applied to small samples. Previously, it has been necessary to have large quantities of wheat to be milled in commercial flour mills before the milling quality of the variety was satisfactorily determined. This required the plant breeder to increase a large number of lines and use large amounts of space in hopes of having good milling selections re-

remaining after he had discarded lines with other undesirable characteristics.

This was the first work attempting to evaluate and describe the milling quality of early generation hybrid lines. If this procedure proved satisfactory it would allow the selection of lines with good milling quality early in the breeding program and thus save the plant breeder time and space in his quest for improved varieties.

The possibility of selecting a line with improved milling qualities in any of the factors studied can be seen in the frequency tables by the number of lines equal or better than the quality of Orfed x Elgin, the better parent. Cross A had lines equal to or exceeding the quality of Orfed x Elgin in each of the factors studied. Cross B did not produce as many good milling lines as Cross A. This would indicate the parent plants used for Cross A were superior to the plants used in Cross B for developing better milling varieties.

As the result of an oversight, seed of the parent plants was not increased for use as check varieties. The differences found between the two crosses of Brevor x Orfed-Elgin used in this study, illustrate the need for knowing not only the quality of the parental varieties but accurately determining the quality of each of the parental plants. Certainly in future studies of this nature, precaution should be taken to keep and increase the parent plant seed so that this material may be used to determine the "true" quality of the parent varieties.

Since none of the hybrid lines was superior in all of the quality factors studied, the best line would be the one with the best combination of quality factors. In order to arrive at a numerical value which would measure the differences between the hybrid lines, it was necessary to weight the different quality factors. The values assessed to the factor were the data obtained from the milling operation. The formula was devised to compare by ratio the flour yield, flow behavior and bran clean-up to the weight of bran and shorts. Empirical testing of scores obtained for the parent varieties ranked these varieties in the proper order for known milling quality. Further analysis of scores obtained on hybrid lines with one outstandingly good factor showed this method of scoring the lines to detect differences between hybrids with nearly equal milling quality.

Future work may indicate changes in the values given each factor. The value given the flour yield has the greatest effect on the milling score. This was thought to be satisfactory as the maximum flour yield is sought by commercial millers regardless of the treatment necessary to obtain it. The ratings for bran clean-up and flow behavior were arbitrarily assigned and reflect comparative behaviors between hybrid lines. Increasing the weight of bran and weight of shorts decreases the flour yield and lessens the milling quality; hence, they were used as the denominator of the ratio, giving a high score for good milling quality and a low score for poor milling quality.

Using the milling score as an index of milling quality, Cross A produced 24.8 percent acceptable milling lines and Cross B had 9.6 percent acceptable. By concentrating his efforts on these lines, the plant breeder should enhance his possibilities of obtaining a satisfactory milling variety. The fact must be recognized, that as these are early generation hybrid lines, there will be continued genetic segregation and poor milling selections may be present. However, the plant breeder by making his selections from this concentration of good milling lines should have a better opportunity to have good milling qualities in his improved selections.

As mentioned previously, milling quality must be considered as the accumulative result of a number of characteristics. The plant breeder will need to know more about the possibility of combining the individual milling quality factors into one variety. Table 10 shows hybrid No. 1207 to have the highest milling score, but as pointed out hybrid No. 1207 does not have the best rating for any individual factor. If the best ratings for each factor were combined into one selection its milling score would be 4.52. This score would represent a decided improvement in quality. The plant breeder needs to know if these factors can be transferred in groups, or if he must select lines with one superior quality factor at a time.

The association of quality factors in Cross A would indicate a possibility of grouping the good milling quality factors. In Cross B the association does not exist and the differences found between the two crosses in the correlation of quality factors are unexplainable without knowing the quality of the original plant material. Knowledge of correlations between quality factors would be valuable in understanding the relationships of the various factors.

The association in Cross A between the quality factors and smut susceptibility might explain the failure so far to obtain good milling selections from a cross with Rex parentage. It is generally known that crosses with Rex have failed to produce satisfactory milling hybrids. The reason may have been because these lines were tested for milling quality only after the smut susceptible segregates were eliminated. It has been the practice of many plant breeders to eliminate smut susceptible segregates from a bulk hybrid in the early generations by inoculating the seed with smut spores. Had this been done to the two Brevor x Orfed-Elgin families studied in this problem, the number of acceptable milling lines would have been seriously reduced. Cross A had only 2 lines or 1.8 percent with an acceptable milling score with less than 10 percent smut. Cross B had 1 line or 1.0 percent with the combined factors, good milling quality and smut resistance.

The association between smut resistance and milling quality does not exist in all cases. When the good milling, smut resistant variety, Oro, was used as a parent with Alicel, one of the selections named Uma had smut resistance and excellent milling qualities. Neither can it be stated that it is the Rex smut resistance entirely which is associated with milling quality as Hymar derives its smut resistance from the same source as Rex and is a good milling variety. Thus the association can be separated and may be limited to cases where a smut resistant parent also has poor milling qualities. In these instances eliminating the smut susceptible segregates by smut inoculation may result in the elimination of most of the good milling segregates; as would have occurred to the crosses of Brevor x Orfed-Elgin studied here. More work along this line is needed to better understand this relationship.

Suggestions for additional studies made throughout this discussion come from the fact that the micro-mill opens a field of work never fully explored before in the study of milling quality. Here is a new tool for the selection of better milling varieties and an opportunity to further study the relationship of the components of milling quality.

SUMMARY

A total of 310 F_3 hybrid lines of winter wheat were milled with the micro-mill attachment for the Buhler laboratory flour mill. This attachment, developed by the Western Regional Wheat Quality Laboratory at Pullman, Washington allows the milling quality of a selection to be determined with a 100 gram sample of wheat.

The uniformity of the milling technique was shown by data obtained from parental varieties milled during the experiment.

Hybrid lines from two crosses of Brevor x Orfed-Elgin, properly tempered to 14% moisture, showed good differentiation in milling quality characteristics. Lines were found which ranged in quality from that of good milling parent, Orfed x Elgin, to Brevor.

Milling quality was shown to be a combination of individual quality characteristics. These factors were given weighted values and a formula devised to evaluate and rank the hybrid lines as to their over-all milling quality.

The two crosses produced different F_3 families as shown by a comparison of family means and their standard errors. Cross A produced the greater number of good milling lines. The differences in the two crosses could not be explained fully without the parent plant material.

Associations between quality factors were shown to exist. The good milling factors tended to be correlated in both crosses but were higher in Cross A.

In Cross A, an association between the milling quality factors and smut susceptibility raises the question as to the possibility of selecting for smut resistance having resulted in selection against milling quality in certain wheat crosses.

A discussion of the experimental results emphasizes the need for more work in this new field of research in milling quality.

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