Two Grain Research Laboratory Research Mills and a Comparison with the Allis-Chalmers Mill[1]

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ABSTRACT

Two laboratory research mills with roll diameters of 6 in. (152 mm) and 10 in. (254 mm) were developed. They are very flexible and have a wide range of selections for feed rate, roll gap, roll speed, and roll differential. Changes from one set of selections to another can be made easily. A mill comparison study showed them to be comparable in performance to the Allis-Chalmers laboratory mill.

Evaluating the milling quality of various wheats grown in Canada and other countries in the world is one of the ongoing responsibilities of the Grain Research Laboratory (GRL). Most of the milling quality tests have been carried out using the Allis-Chalmers experimental mill. Over the years, this equipment has been improved in our laboratory with such modifications as new bearings, belt drives, and feed arrangements. Straight grade flour and semolina produced with this laboratory mill are comparable in quality and extraction to those produced commercially. Furthermore, precise milling procedures were developed and a control system introduced so that any mechanical or environmental changes could be detected. This precision and control were meant to ensure as much as possible that differences in milling quality were results of differences in wheat quality rather than of mechanical or other changes in the milling operation.

Notwithstanding this precision and control, laboratory milling is still far from perfect; its value and the importance of the data generated may be regarded as indeterminate (Shuey et al 1971). To improve the reliability of wheat quality evaluation, more knowledge, better experimental techniques, and improved laboratory milling equipment are continually needed. In addition, the relative importance of factors affecting the milling operation and milling results must be determined. This can be partly accomplished with the aid of versatile research mills that are easy to adjust and control. Two such mills have been developed in this laboratory, the GRL 6-in. (152-mm) and the GRL 10-in. (254-mm) laboratory research mills. This article describes them and presents results of a comparative study with the Allis-Chalmers laboratory mill.

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MATERIALS AND METHODS

The 6-in. Laboratory Research Mill

Four laboratory Allis-Chalmers roll stands, having rolls 152 mm in both diameter and length, were modified, rebuilt, and set up on individual stands (Fig. 1). The original babbit type of bearing was removed from the castings. The outside surfaces of these castings were machined to accept 12.7-mm steel plates to carry a flange type of bearing unit. These bearings are self-aligning and provide accuracy when aligning and setting the adjustable front rolls with the fixed back rolls. As a result, the running operations were improved considerably and wear and friction were reduced. Pivot points were remachined and new eccentrics installed to improve

Fig. 1. The Grain Research Laboratory 6-in. (152-mm) laboratory research mill.

roll adjustment. The original wooden housings were removed and replaced with modified housings veneered with stainless steel. Hoppers and vibrator feeders with variable transformer control were installed for each roll stand. All hoppers were fitted with adjustable feed gates to facilitate feed control. The roll stands were raised 110 mm, using blocks, to accommodate the collecting drawers located directly underneath the rolls.

Four individual stainless steel benches were built to support the roll stands. Each bench has a bottom deck to carry the drive and transmission. The original flat-faced pulleys were machined to accept Habasit belts 38.1 mm wide. Each roll stand was driven by two modified interconnected U.S. Varidrives, powered by a separate 1 HP motor, to provide independent roll speeds with a fast roll speed range of 150–1,500 rpm and a slow roll speed range of 115–1,150 rpm.

The 10-in. Laboratory Research Mill

Four custom-built roll stands, shown in Fig. 2, having rolls 254 mm in diameter and 152 mm in length were supplied by Ross Machine and Mill Supply, Oklahoma City, OK. We designed and equipped these roll stands with feed housings and hoppers having adjustable gates, controlled vibratory feeders, new spring loading, and sensitive roll adjusting and indicating hardware. The mills were mounted on four individual benches with bottom decks and collecting drawers similar to those of the GRL 6-in. laboratory research mill.

Components for the drives and transmissions installed on each of the bottom decks were supplied by Renold Canada Ltd. and consisted of a 2 HP 1,800 rpm motor, two each of Gerbing 75 WR and 75 WB drives, one Croft Unidapter gear reducer plus various gear belts, pulleys, etc. This equipment provided the same range of roll speed and differential selection as that of the GRL 6-in. mill.

Surfaces of Break and Reduction Rolls

The break rolls of both 6-in. and 10-in. mills were machined in the same shop using the same corrugating equipment and cutters. The first, second, and third break rolls were corrugated with 16, 20, and 24 cuts per 25.4 mm respectively (Allis sharp) and a spiral of 41.7 mm/m roll length.

Reduction roll surface is critical in laboratory milling. Because the frosted surface of the Allis-Chalmers mill was no longer available, the reduction rolls were ground with a "Cats Tongue" finish supplied by Modern Process Equipment, Inc., Chicago, IL. This surface provided a grinding quality similar to that of the Allis-Chalmers frosted surface. Each mill has only one pair of reduction rolls.

Sifter and Bran Finisher

Each laboratory research mill has a modified Allis-Chalmers box sifter. The sifter box was rebuilt using the original hardware, eccentrics, sifter mounts, etc. Each sifter has a 1/4 HP Zero-Max drive, model JK2, to control the sifting speed. In addition, a set of GRL sifters (Black et al 1980) and a Buhler MLU-302 Laboratory Impact Finisher were set up between the two mills (Fig. 3). These units were used by both mills.

Fig. 2. The Grain Research Laboratory 10-in. (254-mm) laboratory research mill.

Environmental Control

The mill room is independently electrically heated but is cooled from the building refrigeration system. The humidity is controlled through injection of steam supplied from the building steam generator. A thermostat, a humidistat, and a solid state electric heat control unit provide a wide selection of room temperature and relative humidity conditions.

Wheat Samples Used for Mill Comparison

Six samples of Canada Western red spring wheat were used for the mill comparison study. They were taken from quarterly cargo composites representing each of the top three grades from both Atlantic and Pacific ports. Various wheat data are shown in Tables I and II.

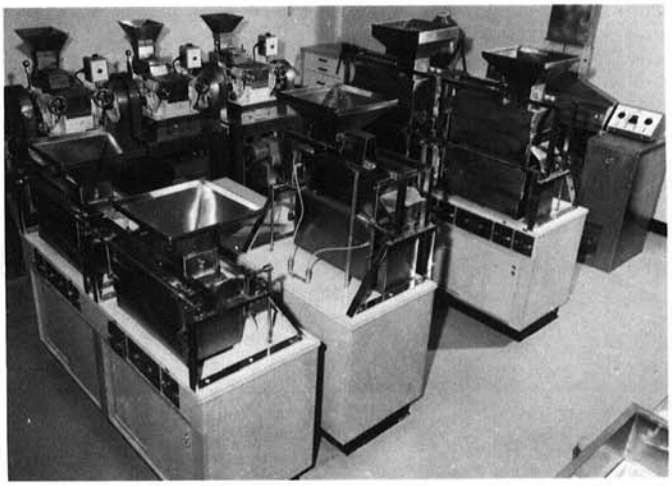

Fig. 3. The Grain Research Laboratory sifter.

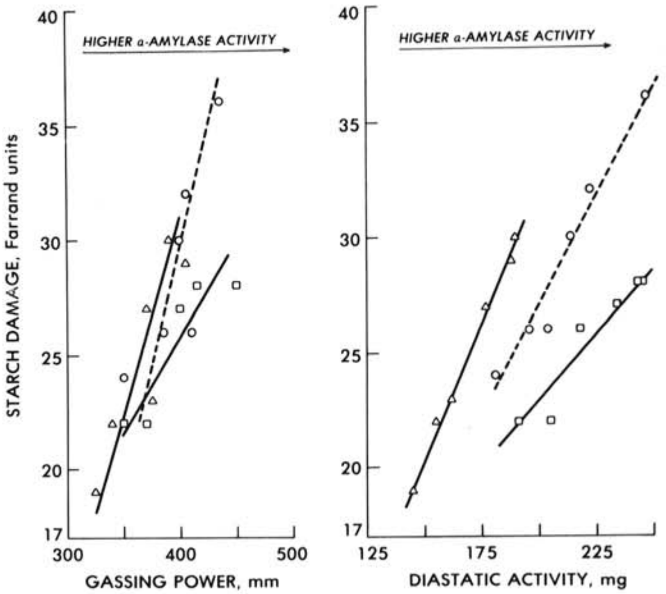

Fig. 4. Relationship between starch damage and gassing power and between starch damage and diastatic activity of flours from three laboratory mills. o---o = Allis-Chalmers mill, △—△ = Grain Research Laboratory 6-in. mill, □—□ = Grain Research Laboratory 10-in. mill.

Milling

For the mill comparison study the Allis-Chalmers mill with established flow and settings was used as the standard. The roll spacings were: first break, 1.55 mm; second break, 0.356 mm; and third and fourth breaks, 0.076 mm. A gradual reduction system was used; the roll spacing was adjusted for the first three reductions to 0.102, 0.063, and 0.038 mm, respectively. Setting the single pair of reduction rolls is a manual operation in which a fixed scale and a movable pointer indicate the relative roll spacing. The GRL 6-in. rolls were adjusted to give approximately the same release at each grinding stage and the same flour yield as the Allis-Chalmers laboratory mill. Using the 6-in. mill as a secondary standard, the GRL 10-in. rolls were matched to give the same surface speeds (Table III) and further adjusted to provide similar release at each grinding stage. Roll spacing was set mechanically, using a feeler gauge, and final roll adjustments were made to match the standard release on each grinding stage.

All three mills used the same flow diagram with GRL sifters (Black et al 1980). Wheat samples were cleaned, scoured, and tempered 18 hr to 16.5% moisture. The amount of wheat milled was 2 kg, based on 14% moisture to the first break, and a straight grade flour was produced.

Flour Quality Tests

The analytical and rheological tests of flour were the same as described by Holas and Tipples (1978). Analytical results for wheat are reported on a 13.5% moisture basis and for flour, on a 14% moisture basis.

RESULTS AND DISCUSSION

The results of the mill comparison study using six wheat samples are shown in Tables I and II. In general, total flour yield, flour protein, wet gluten, yellow pigment, bread appearance, crumb structure, crumb color, and baking absorption were similar for all three mills. The 6-in. experimental mill gave a slightly higher yield of bran finisher flour and lower values for gassing power and diastatic activity than did the other two mills. Flour ash was lower but starch damage, baking strength index (Tipples and Kilborn 1974), and farinograph absorption were higher and farinograph development time was longer for the Allis-Chalmers mill. The 10-in. mill gave slightly poorer flour color and a lower loaf volume than did the other two mills.

A closer examination of Tables I and II reveals that although the 6-in. and 10-in. mills gave similar flour starch damage values, their gassing power and diastatic activity results differed. Furthermore, although the values of the gassing power and diastatic activity tests for the Allis-Chalmers mill and the 10-in. mill were similar, the corresponding starch damage levels were quite different. Values for tests such as diastatic activity, maltose value, and gassing power are a function of both starch damage and α-amylase activity, and an increase in either of these causes an increase in test results (Tipples 1969). Thus, higher values of gassing power and diastatic activity for the 10-in. mill flours compared with those of the 6-in. mill flours were probably caused by relatively higher levels of α-amylase activity. On the other hand, similar gassing power and diastatic activity results for the Allis-Chalmers and 10-in. mill flours were probably a net result of lower α-amylase activity in flours milled from the Allis-Chalmers compensating for the lower starch damage values of the 10-in. mill flours. Fig. 4 shows the relationships between starch damage and gassing power and between starch damage and diastatic activity for the three mills. The diastatic activity level in flours was highest with the 10-in. mill, lower with the Allis-Chalmers mill, and least with the 6-in. mill. Figure 4 also

TABLE I
Wheat, Milling, Analytical, Physical Dough Testing, and Baking Data for Wheat Samples (Atlantic Cargo Composites) in a Mill Comparison Study

	Canada Western Red Spring Wheats[a]								
	No. 1 (13.5)			No. 2 (12.5)			No. 3		
Property	Allis-Chalmers	6-in.	10-in.	Allis-Chalmers	6-in.	10-in.	Allis-Chalmers	6-in.	10-in.
Wheat[b]									
Weight per hectoliter, kg	82.5	...	...	81.3	...	...	80.1	...	...
Weight per 1,000 kernels, g	28.2	...	...	29.0	...	...	28.6	...	...
Protein, %	13.8	...	...	12.8	...	...	13.1	...	...
Ash, %	1.51	...	...	1.61	...	...	1.61	...	...
Falling number, sec	365	...	...	335	...	...	320	...	...
Flour yield, % (total)	74.5	74.9	74.8	74.7	74.7	74.5	72.3	72.4	72.1
Bran finisher flour, %	1.5	1.7	1.5	1.5	1.7	1.5	1.6	1.7	1.5
Flour[c]									
Protein, %	13.1	13.2	13.1	12.0	12.2	12.1	12.4	12.5	12.4
Wet gluten, %	39.4	39.0	39.0	36.5	36.5	36.3	36.8	37.8	36.9
Ash, %	0.47	0.47	0.48	0.49	0.50	0.50	0.52	0.53	0.52
Color, units	0.3	0.4	0.4	0.8	0.6	0.6	1.9	2.0	2.2
Yellow pigment, ppm	2.66	2.61	2.60	2.58	2.68	2.68	2.67	2.59	2.65
Starch damage, Farrand units	24	19	22	26	23	26	36	29	28
Gassing power, mm	350	325	350	405	375	415	435	405	450
Diastatic activity, mg	181	145	191	204	162	218	246	188	245
Bread (Remix)									
Loaf volume, cm^3	865	875	880	805	805	790	810	800	780
Appearance	8.2	8.0	8.0	8.0	7.8	8.0	7.0	7.2	7.5
Crumb structure[d]	6.8-o	6.8-o	6.8-o	6.5-o	6.5-o	6.5-o	6.5-o	6.2-o	6.2-o
Crumb color[e]	6.5-dy	6.8-dy	6.5-dy	6.0-dy	6.5-dy	6.0-dy	5.0-dy	5.0-dy	5.2-dy
Baking absorption, %	64.0	64.0	63.0	63.0	63.0	62.0	65.0	64.0	64.0
BSI[f]	100.2	100.5	101.9	102.4	100.6	99.6	99.6	97.5	95.8
Farinogram									
Absorption, %	64.1	63.8	63.1	62.8	62.1	63.7	66.9	65.9	65.6
Development time, min	5.25	5.25	5.25	4.50	4.25	4.25	5.25	5.00	5.00

[a] Wheats identified by grade and, where available, by protein content in percent.
[b] Results reported on 13.5% mb.
[c] Results reported on 14% mb.
[d] o = Open.
[e] d = Dull, y = yellow.
[f] Remix baking strength index.

TABLE II
Wheat, Milling, Analytical, Physical Dough Testing and Baking Data for Wheat Samples (Pacific Cargo Composites) in a Mill Comparison Study

Property	Canada Western Red Spring Wheats[a]								
	No. 1 (13.5)			No. 1 (12.5)			No. 2 (12.5)		
	Allis-Chalmers	6-in.	10-in.	Allis-Chalmers	6-in.	10-in.	Allis-Chalmers	6-in.	10-in.
Wheat[b]									
Weight per hectoliter, kg	82.7	...	...	83.7	...	...	82.5	...	...
Weight per 1,000 kernels, g	28.8	...	...	30.0	...	...	30.1	...	...
Protein, %	13.8	...	...	12.9	...	...	12.6	...	...
Ash, %	1.54	...	...	1.54	...	...	1.54	...	...
Falling number, sec	375	...	...	360	...	...	365	...	...
Flour yield, % (total)	75.6	75.5	75.5	75.4	75.6	75.5	75.2	74.9	74.7
Bran finisher flour, %	1.3	1.5	1.2	1.3	1.5	1.3	1.6	1.7	1.5
Flour[c]									
Protein, %	13.1	13.1	13.1	12.2	12.2	12.2	12.0	12.0	12.1
Wet gluten, %	39.9	39.0	38.3	36.3	35.6	36.2	35.5	35.4	36.1
Ash, %	0.45	0.47	0.46	0.46	0.48	0.48	0.49	0.49	0.50
Color, units	0.2	0.2	0.4	0.0	0.1	0.3	0.6	0.7	0.8
Yellow pigment, ppm	2.43	2.56	2.51	2.44	2.56	2.55	2.54	2.63	2.54
Starch damage, Farrand units	26	22	22	32	27	27	30	30	28
Gassing power, mm	385	340	370	405	370	400	400	390	415
Diastatic activity, mg	196	155	205	222	177	234	214	190	243
Bread (Remix)									
Loaf volume, cm^3	875	870	850	795	770	765	770	770	760
Appearance	8.0	7.8	8.0	7.8	7.8	7.2	7.5	7.5	7.5
Crumb structure[d]	6.5-o	6.5-o	6.8-o	6.8-o	6.5-o	6.8-o	6.8-o	6.2-o	6.2-o
Crumb color[e]	6.5-dy	6.8-dy	6.8-dy	6.0-dy	6.0-dy	5.5-dy	5.5-dy	5.5-dy	5.8-dy
Baking absorption, %	64.0	64.0	64.0	64.0	63.0	63.0	63.0	63.0	63.0
BSI[f]	101.3	100.8	98.4	99.3	96.2	95.6	97.9	97.9	95.8
Farinogram									
Absorption, %	64.7	63.8	63.9	66.0	64.7	65.0	65.4	65.7	65.3
Development time, min	5.25	4.75	5.00	4.75	4.25	4.50	4.75	4.75	4.50

[a] Wheats identified by grade and protein content in percent.
[b] Results reported on 13.5% mb.
[c] Results reported on 14% mb.
[d] o = Open.
[e] d = Dull, y = yellow.
[f] Remix baking strength index.

shows that the diastatic activity test is more sensitive in detecting the difference in α-amylase level than is the gassing power test and that the effect of α-amylase level tends to be more pronounced at higher starch damage values.

As yet, no definite conclusions can be made about the exact distribution of α-amylase in the wheat kernel (Reed and Thorn 1971). Engel (1947) found that the subaleurone layer (the outermost layer of starch cell of the wheat kernel) had the highest amylase content and that the localization of α-amylase was about the same as that of β-amylase. On investigating different milling fractions, Scholander and Myrbäck (1951) reported that the white flour fractions had a comparatively low α-amylase content, whereas the bran and germ were rich in α-amylase. The fact that the 10-in. mill flours were poorer in both flour ash and color than were the Allis-Chalmers mill flours indicated that the former had more bran contamination and hence higher α-amylase activity. Lower α-amylase activity of the 6-in. mill flours suggested that these flours contained less of the subaleurone layer than did flours from the other two mills.

The difference in starch damage produced by the three mills may be attributed to differences in the reduction roll surfaces or to slight differences in roll settings. As mentioned previously, the reduction rolls of the Allis-Chalmers mill have a frosted surface and those of the 6-in. and 10-in. mills have a "Cats Tongue" finished surface.

Baking absorption has been shown to be largely dependent on flour protein and a protein quality factor obtained by dividing wet gluten values by flour protein values (Tipples et al 1978). Flour protein and wet gluten values for flours obtained from the three mills were essentially the same (Tables I and II). Therefore the fact that little or no difference in baking absorption was found among flours from the different mills was not surprising. A higher farinograph absorption in flours obtained from the Allis-Chalmers mill was expected, because of higher starch damage values. Farinograph absorption is primarily a function of both flour protein and starch damage; an increase of either will increase the farinograph absorption (Farrand 1969, Tipples et al 1978).

TABLE III
Fast and Slow Roll Speeds of the Grain Research Laboratory 6-in. and 10-in. Experimental Mills

Speeds	m/min	6-in. (rpm)	10-in. (rpm)
Break rolls			
Fast	232	485	290
Slow	117	245	147
Reduction rolls			
Fast	320	670	400
Slow	232	485	290

In summary, two laboratory research mills with roll diameters of 6 in. (152 mm) and 10 in. (254 mm) have been developed. They are very flexible and have a wide range of selections in feed rate, roll gap, roll speed, and roll differential. The mills were comparable in performance to the Allis-Chalmers mill. The apparent difference in α-amylase activity in flours milled from the same wheat on the different mills is intriguing and merits further investigation.

LITERATURE CITED

BLACK, H. C., HSIEH, F. H., TIPPLES, K. H., and IRVINE, G. N. 1980. GRL sifter for laboratory flour milling. Cereal Foods World. In press.
ENGEL, C. 1947. The distribution of enzymes in resting cereals. Biochim.

Biophys. Acta 1:42.
FARRAND, E. A. 1969. Starch damage and alpha-amylase as bases for mathematical models relating to flour water absorption. Cereal Chem. 46:103.
HOLAS, J., and TIPPLES, K. H. 1978. Factors affecting farinograph and baking absorption. I. Quality characteristics of flour streams. Cereal Chem. 55:637.
REED, G., and THORN, J. A. 1971. Enzymes. Page 453 in: Pomeranz, Y., ed. Wheat Chemistry and Technology. Am. Assoc. Cereal Chem.: St. Paul, MN.
SCHOLANDER, H., and MYRBÄCK, K. 1951. Amylases in milling products. Sven. Kem. Tidskr. 63:250.
SHUEY, W. C., SPRICK, K. J., and GILLES, K. A. 1971. Milling evaluation of hard red spring wheats. Part I. Dollar value. Northwest. Miller 278:9.
TIPPLES, K. H. 1969. The relation of starch damage to the baking performance of flour. Bakers Dig. 43:28.
TIPPLES, K. H., and KILBORN, R. H. 1974. "Baking strength index" and the relation of protein content to loaf volume. Can. J. Plant Sci. 54:231.
TIPPLES, K. H., MEREDITH, J. O., and HOLAS, J. 1978. Factors affecting farinograph and baking absorption. II. Relative influence of flour components. Cereal Chem. 55:652.

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