OTTAWA MICRO FLOUR MILL[1]

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ABSTRACT

A micro flour mill was built for the rapid milling of small samples of wheat. It consists of four stands of rolls with two breaks and two reductions. The roll units are superimposed upon each other with a bran bolter below the second break unit and a flour bolter located at the bottom of the mill. Each roll unit has a fixed roll and a spring-loaded adjustable roll. Four wheat samples of 100 g. or less may be milled at one time.

In preliminary trials free-milling hard wheats yielded about 60 g. of flour per 100 g. of wheat in 7 minutes' mill-run time. Ten minutes' mill-run time increased the yield to 65 g. or more. Softer wheats required 13 minutes for the higher flour yields. Milling losses were in the order of 3 to 4 g. Flour ash was about 0.48%. The effective mill capacity was 18.4 samples per hour for the 10-minute and 14.6 samples for the 13-minute mill-run schedules.

The need for producing flour from small samples of wheat for quality tests has been recognized for many years. Various methods ranging from the adaptation of burr and roll grinders with subsequent sieving operations (1,3,4,5) to the use of laboratory flour mills employing some of the basic operations of commercial mills (2,6) have been described in the literature.

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A mill similar to the design of Shoup *et al.* (7) was constructed by R. H. Cunningham at the Research Station, Winnipeg. This was found useful in the development of the mill at Ottawa for the milling of small samples of wheat into flour for screening plant breeders' selections for quality in early generations and for use in genetic studies of quality components. The main considerations for the new mill were that it be designed to handle 100-g. samples or less with a minimum of manual labor, and that this operation should be accomplished as rapidly as possible in order that many samples can be milled in a short time. The extraction percentage and the grade of flour should be a good representative of the wheat sample.

Description and Construction

The mill consists of four stands or units of rolls with two break and two reduction pairs. These four units are superimposed upon each other, with a bran bolter below the second break unit and a flour bolter located at the bottom of the mill. The rolls are grooved to receive divider plates which divide the mill into sections to accommodate the milling of four samples of wheat at one time. This principle was used in the design of Shoup *et al.* (7). The wheat is fed to the first break unit at the top of the mill by the mechanical vibrator feeder. The mill, which weighs about 1,000 pounds, stands 66 in. high and measures 22 by 30 in. at the base and is powered by a 1½-h.p. motor. A view of the completed mill is shown in Fig. 1; Fig. 2 is a diagrammatic representation of the operational principles of the mill.[2]

The samples are fed from four individual stationary hoppers to a four-sectioned vibrator feeder (Fig. 3). The vibrator feeder is oscillated 1/32 in. at a rate of 2,000 cycles per minute. The feed rate can be adjusted to deliver a 100-g. sample from in 2 to 8 minutes.

The basic design and construction of each of the four roll units is identical. Figure 4 shows a partially assembled roll section. The 6-in.-diameter rolls are grooved for divider plates and each run has approximately a 1½-in. roll face. Each roll unit has a fixed roll and a spring-loaded adjustable roll.

To provide for parallel setting and clearance of the rolls, the adjustable roll is supported by two pivoted bearing holders whose positions are independently regulated by screw adjustment rods. As the side plates and bearing holders for the roll units are matched or jig-bored, no vertical tramming of the rolls is necessary. Once rolls

[2] Scale drawings are available from the Engineering Research Service, Research Branch, Dept. of Agriculture, Central Experimental Farm, Ottawa.

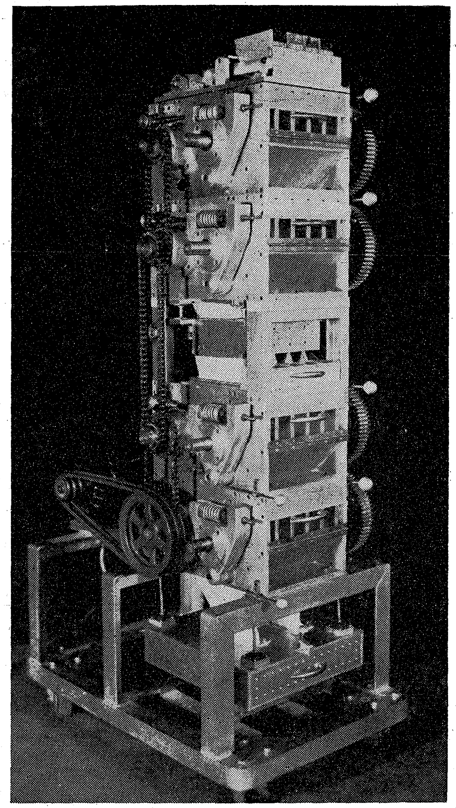

Fig. 1. Ottawa Micro Flour Mill without guards on sides.

are in position, further clearance settings may be made by a set-screw stop on a throw-out mechanism which moves both adjustable bearing holders simultaneously.

The first pair of break rolls are cut Allis Sharp 20 corrugations per in. and with a 1-in. spiral per 12 in. The rolls are operated dull to sharp with a differential of 2:1, a high-speed roll traveling at 500 r.p.m. The second pair of rolls are identical except they are cut 24 corrugations per in. The two pairs of reduction rolls are mat-finished and are operated with a differential of 2:1, the high-speed roll being operated at 500 r.p.m.

The bran bolter is located below the second break rolls. The stock is channeled to and from the bran bolter by nylon stockings. The separation of the four samples is maintained through the bran bolter. The coarser bran particles are removed by a 24 by 24 wire mesh sieve (aperture 0.0342 in.) which is vibrated 1/8 in. at a rate of

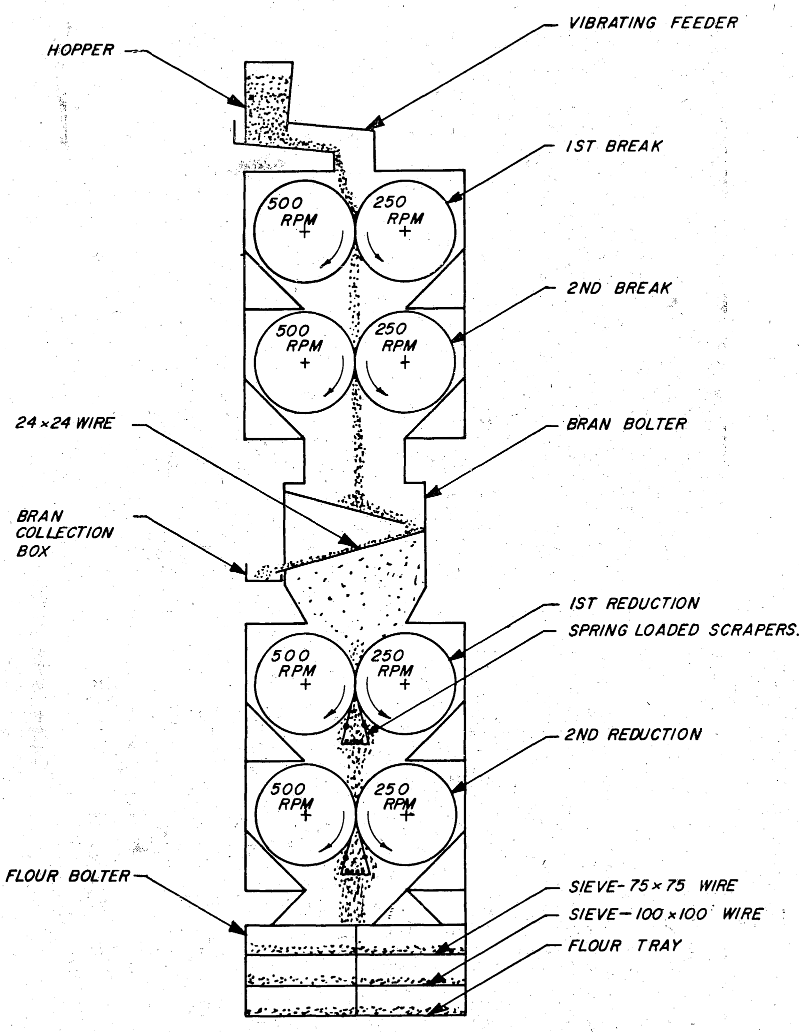

Fig. 2. Diagrammatic sketch showing operational principles.

1,500 cycles per minute. The bran removed from each sample is collected in a tray having four separate compartments.

The material which passes through the bran sieve continues to the reduction rolls. Spring-loaded plastic scrapers prevent any build-up of flour on the reduction rolls. Doors are provided front and back of each roll unit to facilitate cleaning after the stock has passed through the rolls. Brushing and low-pressure air may be employed for this operation.

Nylon stockings conduct the finely milled stock into a four-sec-

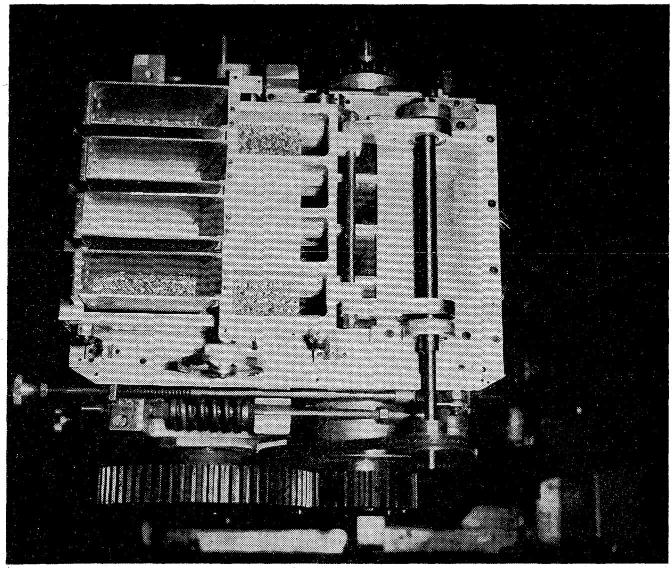

Fig. 3. The vibrator feeder arrangement at top of mill.

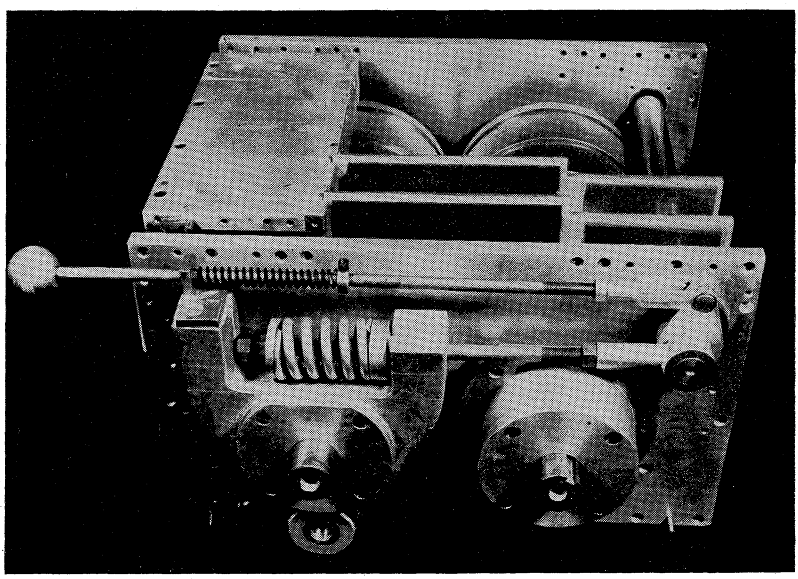

Fig. 4. Partially assembled roll unit showing divider plates.

tioned flour bolter. Final separation is accomplished by stainless-steel wire mesh sieves, 75 by 75 (aperture 0.0096 in.) and 100 by 100 (aperture 0.0055 in.). The flour bolter operates as a plansifter at 375 r.p.m. with a throw of 1/4 in. Small flattened chains attached to the sieve frames, which are free to sweep the face of the sieves, accelerate the bolting action. Flour which passes through the 100 by 100 sieve is collected in four individual collection trays. The sieves and the flour collection trays pull out as one unit. Duplicate sieve and tray units may be used to increase milling capacity.

Preliminary Trials

In establishing a procedure for operating the mill, several trial runs were made with samples of hard red spring, hard red winter, soft white spring, and soft winter wheat. The hard wheat samples were tempered to 15.5% moisture before milling and the soft wheats to 14% by adding sufficient water the previous day. Except where noted, 102 g. of tempered wheat were milled. The rate of the feed was adjusted to deliver the samples to the first break rolls in 3 to 4 minutes. The bran yields recorded in Tables I, II, and III are the overs from a 30 by 30 wire mesh sieve. This sieve was changed to a 24 by 24 wire mesh for the later trials. The yields of shorts recorded in Tables I to IV are the overs from the 75 by 75 and the 100 by 100 wire mesh sieves. The flour is the product bolted through the 100 by 100 wire mesh sieve which has an aperture width between that of a 9xx and 10xx silk bolting cloth.

TABLE I

YIELD OF PRODUCTS FROM 102 GRAMS OF TEMPERED WHEAT FOR A 7-MINUTE MILL-RUN (Six replications each roll position)

Roll Position	Bran [a]	Shorts	Flour	Total Products	Loss	Flour Moisture	Flour Ash
	g	g	g	g	g	%	%
1	22.1	14.2	60.9 ± 0.3	97.2	4.8	13.7	0.46
2	22.1	14.4	62.5 ± 0.3	99.0	3.0	13.8	0.47
3	22.1	13.4	62.1 ± 0.3	97.6	4.4	13.7	0.46
4	22.1	14.2	61.2 ± 0.3	97.4	4.5	13.7	0.47

[a] Overs on a 30 by 30 wire-mesh sieve.

The first trials were with a plump sample of hard red spring wheat. Six millings were made and the products from a 7-minute mill-run time are recorded in Table I. The yields of bran, shorts, and total products as well as flour moisture and flour ash are consistent for all roll positions and thus give confidence that comparable milling data can be obtained regardless of roll position. Mill loss per 102 g. of tempered wheat is low, since part of this loss may be attributed to moisture loss.

A second experiment was designed to determine the possibility of milling less than 100 g. of wheat. Drawing from the same sample referred to above, 100-, 75-, 50-, and 25-g. samples of tempered wheat were milled, and the data are recorded in Table II. The running time of the mill was 7 minutes in each case, as all four sample sizes were milled at the same time for each replicate.

TABLE II

YIELD OF PRODUCTS FROM 100, 75, 50, AND 25 G. OF TEMPERED WHEAT WITH 7-MINUTE MILL-RUN SCHEDULE

(Four replications each sample size)

Sample Size	Bran[a]		Shorts		Flour		Total Products		Loss		Flour Ash
	1[b]	2[c]	1	2	1	2	1	2	1	2	
g											%
100	23.0	23.0	14.1	14.1	59.3	59.3 $\pm$0.6	96.4	96.4	3.6	3.6	0.46
75	17.2	22.9	8.4	11.2	45.8	61.1 $\pm$0.6	71.4	95.2	3.6	4.8	0.46
50	11.2	22.4	4.4	8.8	31.1	62.8 $\pm$1.0	46.7	93.2	3.3	6.6	0.46
25	5.0	20.0	1.1	4.4	15.3	61.1 $\pm$1.8	21.4	85.6	3.6	14.4	0.50

[a] Overs on a 30 by 30 wire-mesh sieve.
[b] Actual yield in g.
[c] Calculated yield per 100 g. tempered wheat.

Variance analysis indicated no significant differences between roll position, replication, and calculated flour yield. The calculated flour yield per 100-g. sample was fairly uniform for all sample sizes in spite of a progressive increase in the calculated loss of total products as sample size decreased. It will be noted, however, that the calculated yield of shorts decreased with sample size, which would tend to offset a progressive decrease in the calculated flour yields. This would indicate that the clean-up on the shorts was more efficient with the smaller samples in the 7-minute mill-run and that the flour yields would have been progressively higher if the losses in total products were in proportion to the size of sample. One may conclude as well that an increase in flour yield would result from longer mill-run times for the larger samples. This led to the adoption of 10- and 13-minute mill-run schedules for the later trials. The good recovery of flour with sample size as low as 25 g. is worth noting.

A third experiment was set up in which samples of four varieties of hard red spring wheat were milled in a complicated test in which two variables were introduced. Two adjustments of the roll clearance in the second reduction unit were made, namely: 0.001 in. and $<$0.001 in. Speed ratios at 2:1 were maintained on the break roll units, but varied from 2:1 to 1¼:1 on the first and second reduction units. For each change, duplicate millings of the four samples were made, making sixty-four millings in all. Since the results indicated that varying the speed ratios on the reduction rolls and the roll clearances in the second reduction unit made little difference in the flour yields, the data are presented in Table III only for the 0.001-in. clearance and for the 2:1 speed ratios for the four roll units. The roll clearances were 0.007 in., 0.003 in., 0.002 in., and 0.001 in. for the

TABLE III
VARIETAL DIFFERENCES IN MILLING BEHAVIOR
(Two replications each variety)

VARIETY	BRAN [a]	SHORTS	FLOUR	TOTAL PRODUCTS	FLOUR MOISTURE	FLOUR ASH	FLOUR [b]
	g	g	g	g	%	%	%
A	37.6	7.4	55.3	100.2	13.8	0.45	62.6
B	24.0	7.5	67.3	98.7	14.0	0.46	70.7
C	22.1	6.7	67.8	96.5	13.5	0.51	72.7
D	30.4	7.1	60.5	98.0	13.8	0.48	65.0

[a] Overs on a 30 by 30 wire-mesh sieve.
[b] Milled in a Buhler laboratory mill; flour obtained in % of 1,000-g. samples.

first break, second break, first reduction, and second reduction units respectively. The four samples were tempered to 15.5%, and 102 g. of tempered wheat were milled. The mill had a running time of 13 minutes, since two of the samples did not mill as freely as the other two.

The bran yields were lowest for samples B and C and highest for A and D. The lower flour yields for samples A and D reflected the higher bran yields for these two varieties. Corresponding wheats milled in a Buhler laboratory mill showed the same relationship in flour yields, thus indicating that the Ottawa micro mill gave similar information to the Buhler mill on the differences in the milling characteristics of these varieties.

A fourth experiment was conducted in which a hard red spring wheat sample and a soft white winter wheat sample were given 13-minute, 10-minute, and 7-minute mill-run times. The data are presented in Table IV.

The shorter mill-run schedules gave progressively higher yields of shorts at the expense of flour recovery for both samples. In addition the bran yields from the hard spring wheat sample were lower than from the soft winter wheat sample, thus contributing to lower flour recovery from the latter. The 7-minute mill-run time for the soft wheat sample is too short, as considerable flour was left unbolted on the 100 by 100 wire mesh sieve.

Four groups of samples representing different varieties and types grown in comparative test plots within each group were milled,

TABLE IV

MEAN MILLING YIELDS IN GRAMS FOR A HARD RED SPRING WHEAT SAMPLE AND A SOFT WHITE WINTER WHEAT WITH VARYING MILL-RUN SCHEDULES
(Eight replications each group)

MILL-RUN TIME	BRAN [a]	SHORTS	FLOUR	TOTAL PRODUCTS	LOSS
minutes					
Hard red spring wheat					
13	19.5	10.9	69.5 ±0.2	99.8	2.2
10	19.3	12.4	67.4 ±0.3	98.9	3.1
7	19.4	15.1	63.0 ±0.3	97.4	4.6
Soft white winter wheat					
13	23.5	6.9	65.1 ±0.4	95.3	6.7
10	24.1	10.2	63.2 ±0.3	97.4	4.6
7	24.8	21.5	51.8 ±1.9	98.3	3.7

[a] Overs on a 24 by 24 wire-mesh sieve.

TABLE V

FLOUR YIELDS IN GRAMS FOR DIFFERENT GROUPS OF WHEAT SAMPLES FROM 10- AND 13-MINUTE MILL-RUN SCHEDULES AND FROM A BUHLER LABORATORY MILL

GROUP	10-MINUTE	13-MINUTE	BUHLER-MILLED
Hard red spring			
A — 25 varieties	66.8	66.2	70.8[a]
B — 19 varieties	66.9	69.1	72.4[a]
Hard red winter			
C — 18 varieties	67.0	67.0	72.5[a]
Soft white spring			
D — 12 varieties	49.9	59.7	68.2[b]
Soft winter			
E — 8 varieties	55.4	65.9	71.2[a]

[a] Flour obtained in % of 2,000-g. sample.
[b] Flour obtained in % of 1,000-g. sample.

using 10-minute and 13-minute mill-run schedules. The mean flour yields are recorded in Table V along with the corresponding mean yields for the same wheat samples milled in a Buhler laboratory mill.

Groups A, B, and C gave almost the same mean flour yields for both mill-run schedules, but the softer types in D and E required the longer time for the higher flour yields. None of the yields was as high as that obtained with the Buhler laboratory mill, a reflection of the effect of the shorter system of the Ottawa micro flour mill.

Some indication of the mill capacity at 10- and 13-minute mill-run schedules was obtained with one series of spring wheat samples. Twenty-four samples were milled in 78 minutes with a 10-minute schedule and 24 samples in 98 minutes with a 13-minute schedule. The calculated rates are 18.4 samples per hour for the former and 14.6 samples per hour for the latter. Only the flour yields were recorded in these trials.

Discussion

The Ottawa micro flour mill was designed to mill small samples of wheat for quality tests on the flours. This is accomplished through the use of a short system requiring a minimum of manual labor and allowing for the recovery of a substantial proportion of the available white flour. The two-break system gives lower yields of bran for hard wheat than for soft wheat, and thus should be valuable in differentiating between hard and soft types. The mill should assist as well in distinguishing between free and less free milling wheats within the same class on the basis of flour yield. Since mill-run time for best results is a variable the choice of schedule will depend on the milling behavior of the samples. Sufficient time should be given in order that a good clean-up of the stock on the 100 by 100 wire-mesh sieve is obtained for the reference samples.

The principle of milling four samples at one time enables the operator to mill a substantial number of samples in a short time. While the mill is designed to handle individual samples of 100 g. or less, up to 400-g. samples may be milled at one time in increments of 100 g. each. Low mill losses and the easily accessible features for cleaning the mill are an asset for handling small samples.

The mill should be useful in wheat breeding programs, not only in assessing milling behavior but through subsequent tests on the flour produced by it. It should assist as well in genetic studies of quality components where large numbers of samples are required to be milled.

Acknowledgments

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