A Dough Sheeting and Molding Property Indicator[1]

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ABSTRACT

An instrument that measures the sheeting and molding properties of doughs is described. The Grain Research Laboratory sheeting and molding property indicator consists of two sensing components, a force transducer, and a potentiometer with the associated electronics. The force transducer is attached to the pivoted frame supporting the movable roller of a National 1-lb sheeter. Force developed by passing dough through the sheeting rolls is measured by the force transducer, allowing measurements of maximum and average sheeting force, sheeting work and dough length. The potentiometer is attached to the Grain Research Laboratory molder and allows the measurement of dough volume after molding. Comparison of the sheeting properties of doughs made with flours from a No. 1 Canada Western red spring wheat and from a 1:1 blend of this wheat and a Canada Eastern white winter wheat showed large significant differences in maximum and average sheeting force, dough length, and sheeting work at each of the three sheeting gaps utilized. In addition, large differences in sheeting properties were evident between the doughs when sheeting gaps were varied. However, significant differences in the molding volumes of the two wheat flour doughs were not evident under the processing conditions used.

In baking tests, the assessment of handling properties during sheeting and molding is generally made by the baker or operator. The usefulness of the assessment depends on how well the operator discerns the character of the dough and on how well he translates that observation into appropriate descriptive terms. Terms such as "tacky," "sticky," "dry," etc. are relatively simple and easily visualized by someone not actually making the assessment. However, for properties relating to resistance in extension, extensibility, softness, and gas retention after sheeting, the magnitude in different doughs is difficult to describe and to quantitate.

Although operator comments are quite valuable in the overall assessment of dough characteristics, the apparatus described here

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was constructed to explore the possibility of extending information on dough character during sheeting and molding by the addition of more objective measurements that would provide a definable scale. These measurements include dough length, force and work during sheeting, and dough volume after molding.

MATERIALS AND METHODS

The analytical, physical, and baking properties of the unbleached straight-grade flours used in the present study are shown in Table I. The red spring wheat flour was milled on a laboratory Allis-Chalmers mill from a sample of No. 1 CWRS-13.5, a Canada Western red spring (CWRS) wheat obtained from a terminal elevator at Thunder Bay. The soft white winter wheat flour used for blending was obtained from Reed Milling Company, Mississauga, from a blend of Canada Eastern white winter (CEWW) wheats.

For demonstrating the use of the Grain Research Laboratory (GRL) sheeting and molding property indicator, doughs were prepared with either 200 g of CWRS wheat flour or 200 g of a 1:1 blend of CWRS and CEWW wheat flours by the GRL remix baking procedure (Irvine and McMullan 1960, Kilborn and Tipples 1981). Following mixing, punching, fermentation, remixing, and proofing, the doughs were sheeted three times at 8.7, 4.8, and 3.2-mm spacings through National 1-lb sheeting rolls (adjusted for a 13.2-cm width) and molded on the GRL molder (Kilborn and Irvine 1963).

RESULTS AND DISCUSSION

The GRL Sheeting and Molding Property Indicator

The GRL sheeting and molding property indicator consists of two sensing components—a force transducer and a potentiometer, the associated electronics, and a chart recorder. For the measurement of sheeting properties, a force transducer was fabricated using strain gauges bonded to a stainless steel strap (25 × 125 × 3 mm). The strap was attached to the pivoted frame supporting the movable roller on a National 1-lb sheeter (Fig. 1). It was positioned so that one end (the free end) of the strap contacted the pin-stop governing the roll gap instead of the frame itself providing this contact. Shims were used between the force transducer and the frame to build up the fastened end and produce a difference of 9.0 mm between the surface in contact with the pin-stop and the original contact point of the frame. This, in effect, offsets the roll position by one of the equally spaced holes used in the pin-gauge arrangement that sets the roll gap. Force developed by passing dough through the rolls is reflected at the force transducer in contact with the pin-stop. The distance between the roll shaft center and the pivot center of the frame was 17.5 mm. A hole drilled in the frame handle 245 mm from the pivot provides a 14:1 ratio in force signal calibration, using a string pulley and weight arrangement as described by Voisey et al (1966), ie, a 1-kg force applied at the hole is equivalent to a 14-kg force applied to the roll.

For the measurement of roller height during molding, a 2,000-ohm conductive plastic potentiometer was attached to the GRL molder (Kilborn and Irvine 1963) with the shaft fastened in a hole drilled in the end of the calibration weight shaft. The movement and rotary position of this shaft is proportional to the height of the top roller of the molder. The top roller is of constant weight and rides on top of the dough piece being shaped. Therefore the height (diameter) of the rotating dough is indicated by the position of the slider of the potentiometer. Because the dough piece is restricted in length by guides, dough diameter is related to the volume of the dough piece and may serve as an index of dough volume after sheeting.

Associated Electronics

In addition to the primary sensing devices, all associated electronic modules were constructed in the laboratory. Their functions are illustrated in Fig. 2. The output from the strain gauge differential amplifier drives the chart recorder pen (Richen Denshi model SP-5 with pulse drive motor set at 1-V full scale deflection) through the normally closed contacts of the selector relay to measure sheeting length and force. For measurement of dough volume following molding, a precision voltage is applied across the top roller height potentiometer. The vertical movement of the top roller is thereby translated into a voltage at the slider of the potentiometer, the magnitude of which is related to the height of the roller. This signal voltage drives a differential amplifier that allows both offset and calibration. The output of the amplifier is connected to the normally open contact of the selector relay.

Because doughs are in contact with the rolls on any given

TABLE I
Analytical, Physical, and Baking Properties of Canada Eastern white winter (CEWW) and No. 1 Canada Western red spring (CWRS)

Properties	CEWW	Blend[a]	CWRS
Analytical			
Protein, %	8.7	10.8	12.8
Ash, %	0.46	0.43	0.39
Starch damage, Farrand units	4	18	31
Gassing power,[b] mm	335	390	410
Amylograph peak viscosity, BU	155	390	560
Physical			
Farinograph absorption, %	52.0	56.8	65.3
Farinograph dough development time, min	1.00	2.50	5.50
Extensigraph area, cm^2	70	105	130
Remix baking			
Loaf volume[c], cc	990	1,500	1,790
Appearance, units	4.0	4.8	7.0
Crumb structure, units	4.0-o[d]	6.8-o	6.8-o
Crumb color, units	5.0-d[e]	7.8	7.0
Absorption, cc	51.0	57.0	63.0

[a]Equal parts of CEWW and CWRS flours.
[b]After 6 hr.
[c]200 g of flour.
[d]o = open.
[e]d = dull.

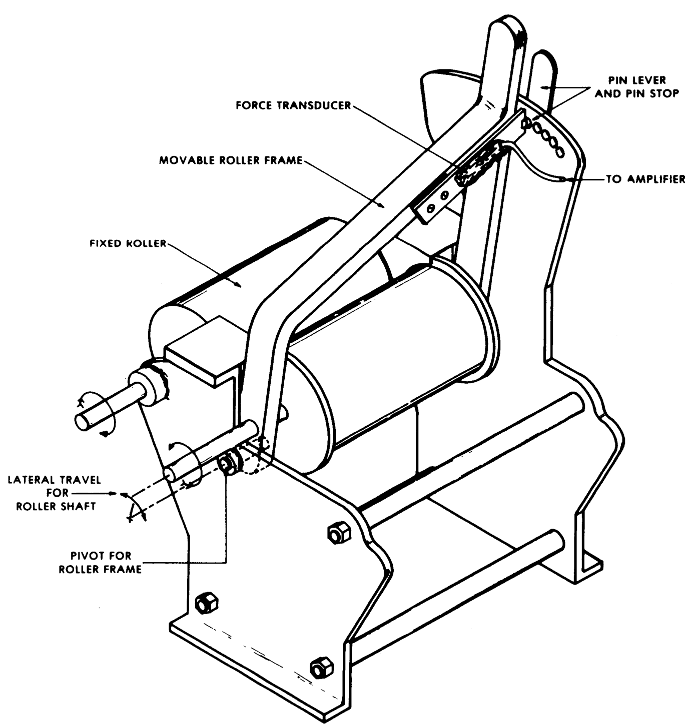

Fig. 1. National 1-lb sheeter, showing location of force transducer and associated equipment.

sheeting for only 3 sec or less, the chart paper had to be run at a relatively high speed to obtain a curve base large enough to show the time the dough was between the rolls. Time duration indicates dough length, ie, surface speed of the rolls is approximately 40 cm/sec. In trial runs, a chart speed of 20 mm/sec appeared to be sufficient.

To avoid excessive use of paper and inconvenience to the operator, the advancement of chart paper was automated. The chart step motor is driven from a square wave generator operating at a frequency of 335 ± 2 Hz. A trigger switch located on the roller frame of the sheeter and a trigger relay located in the selector box were wired in parallel and trigger a pulse relay located between the generator and the chart drive input. The pulse relay provides an "on" time that may be varied and set from 0.1 to 20 sec. About 4.5–5 sec was required to ensure the operator time to sheet the dough. This time also allows a "zero" base line to be established on the chart. The base line changes with a change in position of the sheeting roll in relation to the pivot of the roll support frame, ie, the support required of roller weight by the force transducer increases as the frame angle increases from the vertical.

Recording of the top roller height occurs when the molder is started. The button that starts the molder simultaneously energizes the selector relay that directs the signal from the height differential amplifier to the recorder pen drive. Chart drive may be started and timed manually from the switch trigger or automatically from the relay trigger.

Calibration

The three roll gap settings used for sheeting doughs (8.7, 4.8, and 3.2 mm) were examined for the error produced with the concomittant change in angle of the support frame with gap setting. With the frame positioned for the 4.8-mm gap, a 1-kg force (corresponding to a 14-kg force at the rolls) was applied at the calibration hole in the frame, and the strain gauge amplifier was adjusted to provide a 28-line (100 lines full scale) difference from where no force was applied. Roll gaps of 3.2 and 8.7 mm, produced 28.5 and 27.5 lines, respectively. Therefore an error of approximately 1.8% from the calibration position may be taken into consideration in measurements if required.

Another source of error is the flexing of the force transducer, which can lead to variations in the roll gap during sheeting. This was investigated using feeler gauges between the rolls. After calibration, a sufficient number of feeler gauges were inserted between the rolls to produce a pen response equivalent to 0.10 kg. An additional 0.10 mm was forcibly inserted, which produced a pen response representing a further 29 kg. Therefore, under sheeting conditions that produce a force of 29 kg on the roll, an error of 0.10 mm occurs in the gap setting. This error is not likely to be too significant in sheeting "normal" doughs. However, if reducing this error becomes important, the simplest approach would be to use a somewhat thicker force transducer having less flex.

Maximum sheeting force in the dough was obtained by measuring the maximum height of the curve in kilograms and converting to newtons (N = 9.807 kg). Work was obtained by measuring the area under the curve with a planimeter in kilograms per meter and converting to joules (J = 9.807 kg/m).

Metal cylinders of different diameters ranging from 30 to 60 mm were used between the rollers to calibrate the top roller height voltage signal so that each line on the chart paper equalled 1 mm, ie, 10 mV/mm of space between rollers. Dough volume (V) was obtained by using the formula $V = \frac{1}{4}\Pi h^2 w = 10.4 h^2$ where h = dough height (in centimeters) and w = roller width (13.2 cm).

Sheeting and Molding Properties of Doughs

Doughs prepared from CWRS wheat flour and from a 1:1 blend of CWRS and CEWW wheat flours by the remix baking procedure (Irvine and McMullan 1960, Kilborn and Tipples 1981) at optimum baking absorptions were used to demonstrate the use of the sheeting and molding property indicator. Loaf volumes obtained with the two doughs were 1,790 and 1,500 cm, respectively. Use of the property indicator had no noticeable effect upon final bread characteristics.

Figure 3 illustrates the measurement of the sheeting properties of the doughs. Properties measured included maximum sheeting force (in kilograms), dough length (in centimeters), and sheeting work (kilograms per centimeter) derived from the area of the curve. In addition, average sheeting force was calculated by dividing the work by the dough length. Table II gives the average and standard deviations in SI units for the sheeting and molding properties of nine doughs assessed on three different days.

As expected, the increasing sheeting force exerted on the dough as the sheeting roll gap was reduced resulted in large increases in dough length. The shorter length of the blend dough during the initial sheeting was probably a result of its smaller bulk (lower water absorption and less gas retention). However, after the third sheeting, the blend dough had a length similar to that of the CWRS dough. The larger increase in length of the blend dough is probably the result of its being "softer" than the CWRS dough. As shown by the standard deviations, good reproducibility of dough lengths was obtained with an average coefficient of variation of approxi-

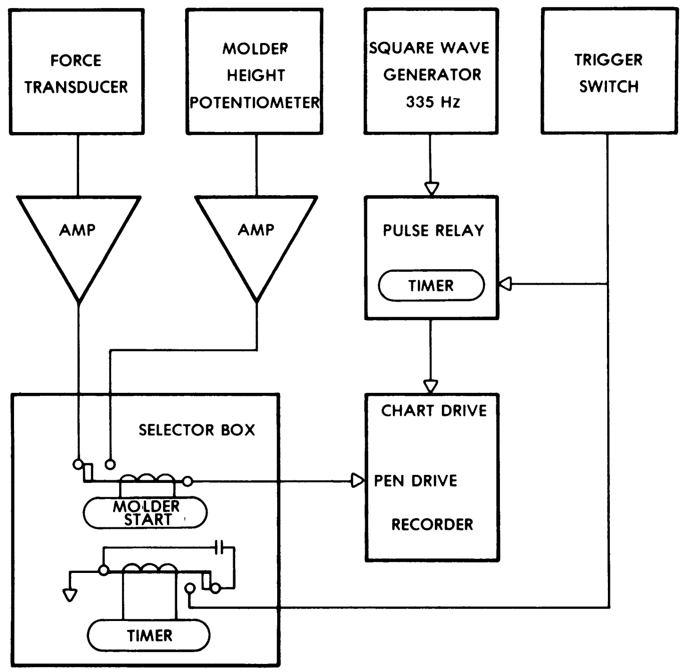

Fig. 2. Functions of the Grain Research Laboratory sheeting and molding property indicator modules.

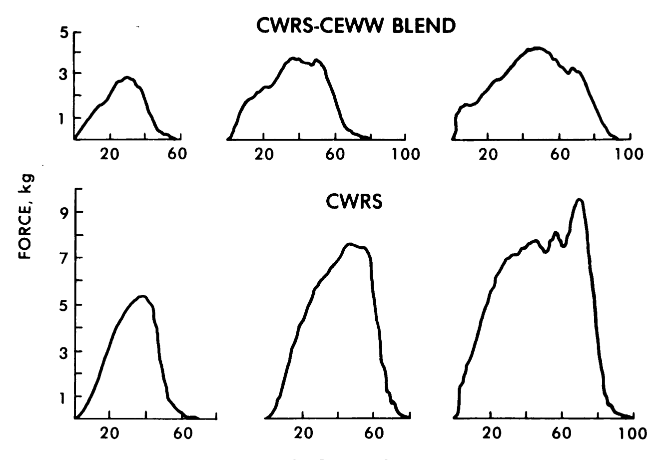

Fig. 3. Dough sheeting curves obtained for a No. 1 Canada Western red spring (**CWRS**) wheat flour and a 1:1 blend of CWRS and Canada Eastern white winter (**CEWW**) wheat flours with sheeting gaps (left to right) of 4.2, 3.7, and 2.8 mm.

TABLE II
Sheeting Forces and Molding Volumes[a] for Remix-Processed Doughs[b] Obtained with the Grain Research Laboratory Sheeting and Molding Property Indicator

		Dough from	
Sheeting	**Property**	**CWRS**	**CWRS:CEWW**
First	Dough length, cm	55.2 ± 1.8	49.2 ± 2.2
	Force		
	Maximum, N	53.0 ± 4.9	24.5 ± 4.9
	Average, N	33.3 ± 2.3	15.8 ± 2.5
	Work, J	18.5 ± 1.3	7.8 ± 1.6
Second	Dough length, cm	69.6 ± 2.2	67.4 ± 2.0
	Force		
	Maximum, N	76.5 ± 11.8	36.3 ± 6.9
	Average, N	48.8 ± 6.3	26.6 ± 4.7
	Work, J	33.9 ± 4.1	17.8 ± 3.1
Third	Dough length, cm	87.4 ± 2.0	87.6 ± 1.6
	Force		
	Maximum, N	81.3 ± 14.7	36.3 ± 5.9
	Average, N	56.5 ± 7.4	25.6 ± 3.9
	Work, J	39.4 ± 5.7	22.6 ± 3.4
	Molding volume, cc	563 ± 6.6	537 ± 9

[a] Mean and standard deviation.
[b] From No. 1 Canada Western red spring (CWRS) wheat and from a 1:1 blend of CWRS and Canada Eastern white winter (CEWW) wheats.

mately 3%.

Although the variability for measurements of maximum sheeting force, average sheeting force, and sheeting work was higher than for dough length, as shown by the standard deviations, differences in the sheeting properties of the two doughs and between progressive sheetings of the same dough were highly significant. The maximum and average sheeting forces for the CWRS dough for each of the three sheetings were approximately twice those of the blend dough. These differences are consistent with the greater dough strength of the CWRS flour (Table I), which, after fermentation, would be expected to have greater resistance to sheeting and a lower tendency for viscous flow than the blend dough would have.

Maximum and average sheeting forces also showed large significant differences between the first and second sheeting for both doughs, whereas smaller differences were evident between the second and third sheeting. Although the decrease in the sheeting roll gaps is probably partially responsible for the increase in the sheeting force values, "work-hardening" of the doughs also probably plays a major role. This conclusion is consistent with studies showing the ability of dough-breaks to develop doughs repeatedly put through sheeting rolls (Kilborn and Tipples 1974, Stenvert et al 1979).

Like maximum and average sheeting force, the sheeting work imparted to the CWRS dough was much greater than that imparted to the blend dough for each of the three sheetings. By analogy to mixing, the larger sheeting work input into the CWRS dough is consistent with the larger energy input required to develop doughs of stronger flours. In fact, the slight decrease in sheeting work evident between the second and third sheeting of the weaker blend dough may indicate that optimum sheeting development (gas retention properties) may occur after the second sheeting. This conclusion is supported by recent studies in our laboratory on the effect of dough sheeting properties upon bread quality with different levels of cysteine.[2]

Molding volumes of the two doughs obtained on the GRL molder are also included in Table II. Although the average molding volume of the CWRS dough was slightly greater than that of the blend dough, the difference was not significant at the 90% confidence level. Whether or not dough molding volumes will show significant differences due to variations in ingredients and processing conditions is a subject for further study.

[2] Unpublished data.

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