Implications of the Mechanical Development of Bread Dough by Means of Sheeting Rolls[1]

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ABSTRACT

The GRL-1000 laboratory dough mixer was used to premix bread-dough ingredients at slow speed prior to development for Chorleywood-type process bread by one of two methods. In the first method development was achieved with the GRL-1000 mixer at 105 r.p.m. In the second method a modified stand of sheeting rolls was used to subject the dough to a sheeting and folding treatment that proved capable of fully developing the dough after about 15 "folds" (each fold was equivalent to two consecutive sheetings through rolls set at 7/32 and 5/32 in., followed by folding in two and rotation through 90° ready for the next sequence of sheeting and folding). Mechanical efficiency of the sheeting rolls was determined so that net energy measurements made during sheeting could be compared directly with net energy data obtained with the dough mixer. Optimum dough development, as judged by dough-handling properties, mixing curves, and bread quality, was achieved by sheeting roll treatment with only 10 to 15% of the net energy required for peak development with the dough mixer.

Dough development for baking is normally carried out with dough mixers of a wide range of design, which knead, stretch, tear, shear or otherwise work the dough. In order to develop dough sufficiently for production of high volume, good quality bread in short baking methods such as the Chorleywood Bread Process, where no bulk fermentation is used, a mixer must be of sufficiently high speed and mixing efficiency that the minimum requirements for total energy input and rate of energy input can be satisfied (1).

Sheeting rolls offer an alternative means of applying work to a dough, although the concept of working doughs in this manner is not new. The judicious adjustment of roll-spacing permits the dough to be worked without the tearing action associated with high-speed mixing. Past (unpublished) work in this laboratory, where the breadmaking potential of Canadian wheats was examined for areas where the "dough brake" was used, suggested that sheeting rolls were most effective in developing dough.

The purpose of this paper is to describe results of a study where dough development with sheeting rolls was compared with mixer development. The baking method used was based on the GRL Chorleywood method which relies heavily for success on adequate dough development. Recent studies (2) on the mechanical efficiency of dough mixers of different design provided the basis for a method of determining the mechanical efficiency of a set of modified sheeting rolls. This was essential in order to obtain net energy values which could be compared with net energy measurements made during mixer-development.

MATERIALS AND METHODS

Modification of Sheeting Rolls

In this study a stand of National Manufacturing sheeting rolls (Teflon-coated, 3 in. in diameter and 6 in. long) was used. It was necessary to modify the drive for the following reasons:

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1. The belt-and-pulley drive connecting the gear box to the rolls required that two idler pulleys be used — one to ensure adequate surface contact of the belt to the pulley fastened to the rear roll, the other to permit tightening of the belt. The belt is normally adjusted quite tightly to prevent slipping, and energy measurements taken on units with factory-adjusted belts and with a cold gear box have shown that about two-thirds of the capacity of the 0.25-h.p. motor is used just to idle the sheeting rolls.

2. As roll-spacing is changed, pressure on the belt drive is increased or decreased depending on whether the back roll is moved toward the closed position or open position, respectively. This results in a corresponding change in the energy required to idle the rolls which must form the zero for energy measurements to dough.

The drive was changed to a chain-and-sprocket system, with the results shown in Table I. The power available for sheeting with the chain drive was almost double (141 watts vs. 86) that for the belt-drive system.

By using the chain drive, the sprocket on the back roll moves along the chain when the roll position is altered and creates only a very small change in pressure on the chain. This results in a very much lower shift in energy requirements to idle rolls at various spacings as compared with the belt drive. Figure 1 shows the modified drive for the sheeting rolls.

A coupling was attached to the front roll shaft so that the prony brake unit (1) could be connected directly (Fig. 2) for determining mechanical efficiency.

Mechanical Efficiency of Sheeting Rolls

Mechanical efficiency was determined using the GRL prony brake equipped with an electric clutch for loading, and the GRL energy-input meter for measuring electrical energy consumption of the motor driving the sheeting rolls. Energy expended by the clutch was calculated by the formula 2π Tn/36,700 where T is the torque in kg. cm., n is the number of turns of the clutch during the test, and 36,700 is the equivalent, in cm. kg., of 1 whr.

TABLE I. COMPARISON OF POWER AVAILABLE FOR SHEETING DOUGHS FOR BELT DRIVE AND CHAIN DRIVE SYSTEMS

	Power in Watts
Motor only—rating	186
Motor only—run	90
Total to comply with rating 186 + 90 =	276
a) Belt Drive System	
Motor, reducer, and belt drive (cold)	230
Motor, reducer, and belt drive (warmed up)	190
Available for sheeting 276 - 190 =	86
b) Chain Drive System	
Motor, reducer, and chain drive (warmed up)	135
Available for sheeting 276 - 135 =	141

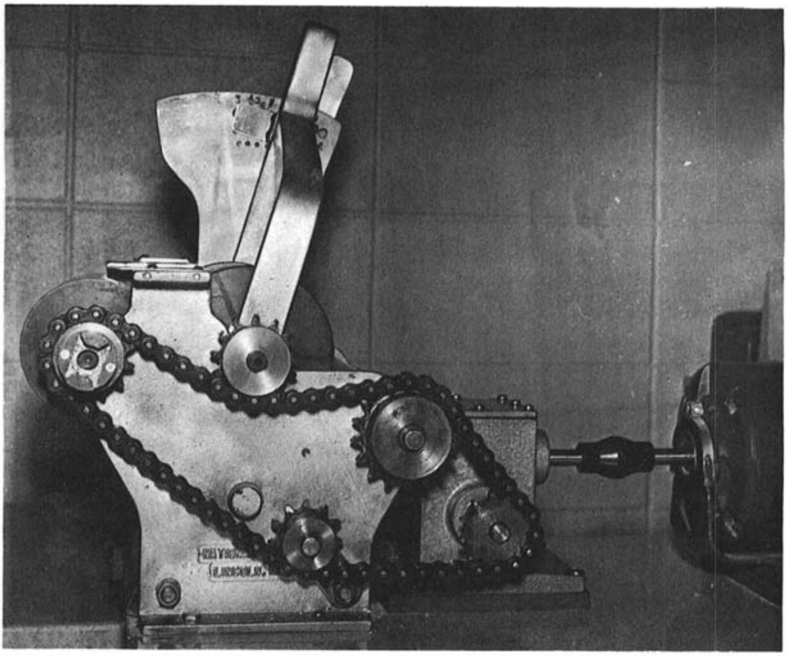

Fig. 1. Modified sheeting roll unit showing chain drive.

Flour

The flour used in this study was laboratory-milled from an average sample of No. 1 Canada Western Red Spring Wheat. Protein content (14% m.b.) was 12.5%, ash 0.43%, and starch damage 33 Farrand units.

Baking Method

The baking formula used was: flour, 600 g.; water, 64%; sugar, 2.5%; salt, 1%; shortening, 1.5%; yeast, 3%; malt syrup (250° L.), 0.3%; ammonium phosphate (monobasic), 0.1%; ascorbic acid, 75 p.p.m.; and potassium bromate, 45 p.p.m. Doughs were premixed for 1.5 min. at 45 r.p.m. in the GRL-1000 pin mixer (3) at a temperature of 74° F., then processed according to the scheme outlined in Fig. 3.

One-half of the premixed dough (the minimum dough size for the GRL-1000) was returned to the mixer for mixing at 105 r.p.m. The GRL energy-input meter (4) was used to make gross energy measurements during mixing. Net energy values were obtained by correcting for the mechanical efficiency of the GRL-1000 (3). Fig. 4 shows the premix and development curves for the flour used in this study. The mixer-developed dough was divided into three pieces for processing as pup loaves. Dough makeup and subsequent processing were the same for all loaves baked in this study and were as follows: Immediately after development and scaling, doughs were rounded, given 25 min. intermediate proof at 95°, then sheeted, molded with the GRL molder, panned, proofed 55 min. at 95° F., and baked 25 min. at 420° F.

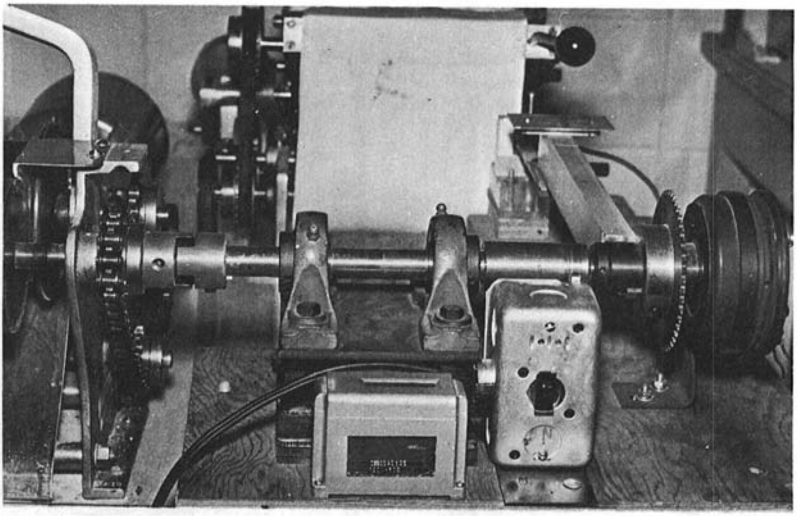

Fig. 2. Prony brake (right) for determining mechanical efficiency coupled to front roll shaft of sheeting roll unit.

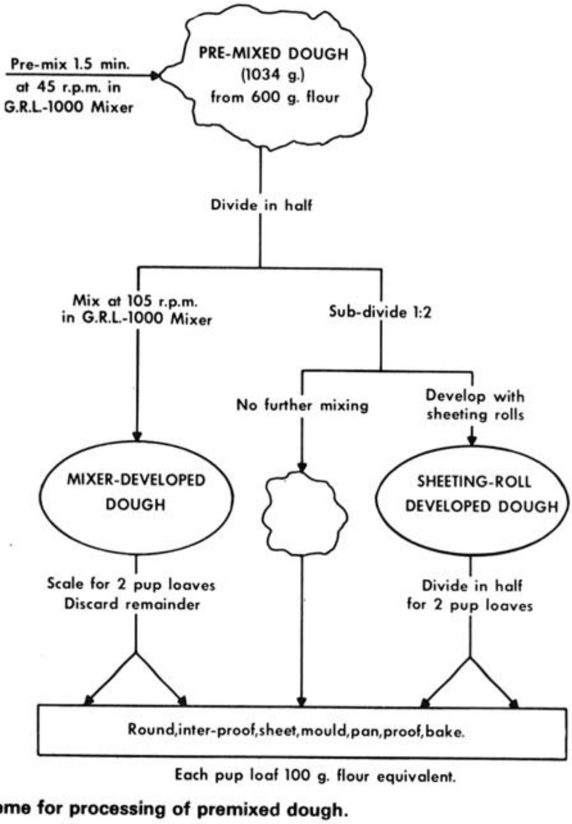

Fig. 3. General scheme for processing of premixed dough.

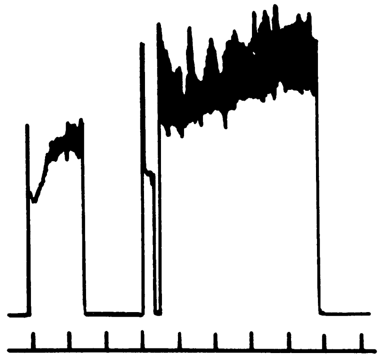

Fig. 4. Left, premix curve (45 r.p.m.) for 600 g. flour dough; right, development curve (105 r.p.m.) for 300 g. flour dough, using GRL-1000 mixer.

Dough Development Using Sheeting Rolls

The premix dough temperature of 74° F. was chosen to correspond with room temperature. This in turn determined the temperature of the sheeting rolls which remain fairly constant during sheeting operations due to the large heat sink provided by the steel rolls.

Half of the premixed dough was further scaled into two pieces. One piece, representing 100 g. flour weight, was processed into bread immediately with no further mixing or development. The other piece, representing 200 g. flour weight, was used for development with the sheeting rolls. After sheeting it was divided in two and processed as pup loaves.

Various combinations of sheeting roll settings and folding were examined. The most satisfactory settings (those which imparted the most work without tearing the surface of the dough) of 7/32 and 5/32 in. were selected. The dough was sheeted in the same direction through first the 7/32-in. opening and next through 5/32-in. opening, quickly folded in half, rotated 90°, and passed through the same two roll settings in the same manner as the first two sheetings. At this stage the dough was considered to have had four "sheetings" but only one "fold." Each

TABLE II. MECHANICAL EFFICIENCY FOR SHEETING ROLLS WITH CHAIN DRIVE AT VARIOUS LOADS

Torque of Rolls kg. cm.	Roll Speed r.p.m.	Motor Watts	Energy in whr./min. Equiv. at Rolls	Energy in whr./min. Energy Meter	Mechanical Efficiency %
11	82.5	35	0.155	0.584	26.5
21	82	68	0.295	1.134	26.0
30	81.5	100	0.419	1.690	24.8
40	81	140	0.554	2.295	24.1
50	80	180	0.684	2.995	22.8
60	79	230	0.811	3.837	21.1
80	77	310	1.054	5.143	20.5

subsequent fold was followed by two sheetings so that when calculating the complete history of a dough treated in this way the total number of sheetings = (2 × number of folds) + 2.

RESULTS

Mechanical Efficiency of Sheeting Rolls

Results of mechanical efficiency studies with the sheeting rolls are shown in Table II.

Torque levels above 40 kg. cm. represented overload situations based on the motor rating. For practical purposes where the motor is not overloaded, roll speed may be considered as 82 r.p.m. and the mechanical efficiency as 25%.

Dough Development Using GRL-1000 Mixer

Table III gives bread data for doughs mixed to four different stages of development and Fig. 5 shows internal longitudinal sections through loaves. Dough A was given no mixing other than the 1.5 min. of premixing at 45 r.p.m. and was grossly undermixed. Bread was low in volume and poor in appearance, crumb texture, and crumb color.

A mixing time of 4.5 min. and an energy level of 2.8 whr. per lb. were required to develop the premixed dough to peak consistency at 105 r.p.m. (dough D). This dough produced bread of high volume and satisfactory external and internal characteristics. Doughs B and C were mixed to energy levels corresponding to the range in energy imparted with sheeting roll development. Both doughs were greatly undermixed with respect to peak dough development and produced bread of inferior quality.

Dough Development Using Sheeting Rolls

One factor that was of interest to us during this study was absorption. In our laboratory use of the dough brake has always been associated with low absorption (e.g. 50% instead of 60%) due to difficulties inherent in handling. Initial experiments were carried out at lower absorption levels but it was subsequently found that a baking absorption of 64% (the same as for the GRL Chorleywood Process with the GRL-1000 pin mixer) could be used for sheeting roll development provided that due care was taken, particularly during the first few sheetings when the dough was grossly undermixed.

Figure 6 shows a recorder trace obtained from monitoring the energy to the sheeter motor for the maximum number of sheetings attempted in this study—40

TABLE III. BREAD AND MIXING DATA FOR DOUGHS PREMIXED 1.5 min. AT 45 r.p.m. AND MIXED AT 105 r.p.m. FOR VARIOUS TIMES IN GRL-1000 MIXER[1]

Dough	Mixing Time at 105 r.p.m. min.	Net Energy whr./lb.	Loaf Volume cc.	Loaf Appearance	Crumb Texture	Crumb Color
A	0	0.1 (from premix)	600	5.0 old	4.5 co	5.0 dy
B	0.5	0.2	685	6.0 old	5.5-o	5.5 dy
C	1.0	0.6	740	7.0	6.0-o	6.5 dy
D	(peak) 4.5	2.8	940	8.5	6.5-o	9.0

[1]co = coarse, open; dy = dull yellow; o = open.

TABLE IV. BREAD AND NET ENERGY DATA FOR DOUGHS PREMIXED 1.5 min. AT 45 r.p.m. IN GRL-1000 MIXER, THEN SUBJECTED TO SHEETING ROLL TREATMENT (ALTERNATE PASSES THROUGH 7/32 AND 5/32 in. SETTINGS FOLLOWED BY ONE FOLD AND TURNING AT 90° PRIOR TO NEXT PASS)

No. of Sheetings	No. of Folds	Elapsed Time min.	Net Energy whr./lb.	Loaf Volume cc.	Loaf Appearance	Crumb Texture[1]	Crumb Color
12	5	0.7	0.07	770	7.0	6.0	7.0
22	10	1.5	0.17	875	7.5	6.5-o	8.0
32	15	1.9	0.25	925	8.5	6.8-o	8.2
42	20	2.4	0.39	935	8.5	8.0	9.0
62	30	3.7	0.47	910	8.0	8.5 sgh	9.2
82	40	5.5	0.61	880	7.2	9.0 sgh	8.8

[1]o = open; shg = small gas holes.

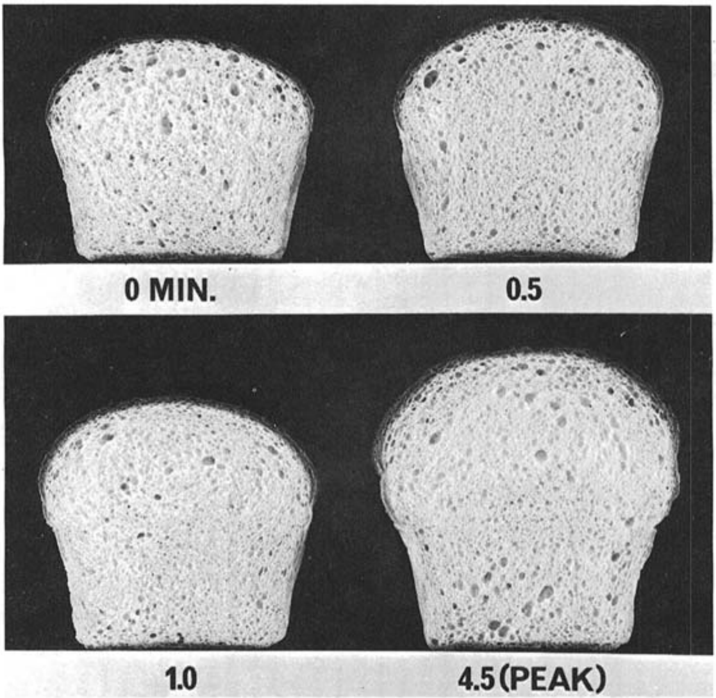

Fig. 5. Longitudinal sections through pup loaves baked from doughs premixed in the GRL-1000 mixer for 1.5 min. at 45 r.p.m. and subsequently mixed at 105 r.p.m. for 0, 0.5, 1.0, and 4.5 min. (peak dough development).

folds or 82 sheetings. The trace is made up of a series of peaks with each peak representing one pass through the sheeting rolls, and successive peaks representing alternate sheetings through settings of 7/32 and 5/32 in.

Peak height continued to increase for the first six folds and became more or less constant after about 12 folds. If peak areas were taken instead of peak height the development curve would be much smoother.

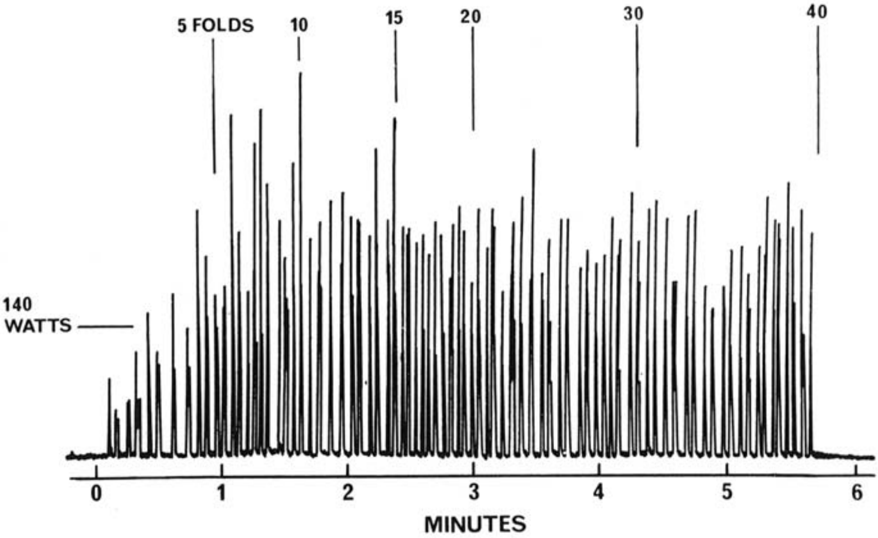

Fig. 6. Recorder trace of energy used by the sheeter motor during a series of 82 sheetings (40 folds) carried out on a dough piece (200 g. flour equivalent) scaled immediately after premixing.

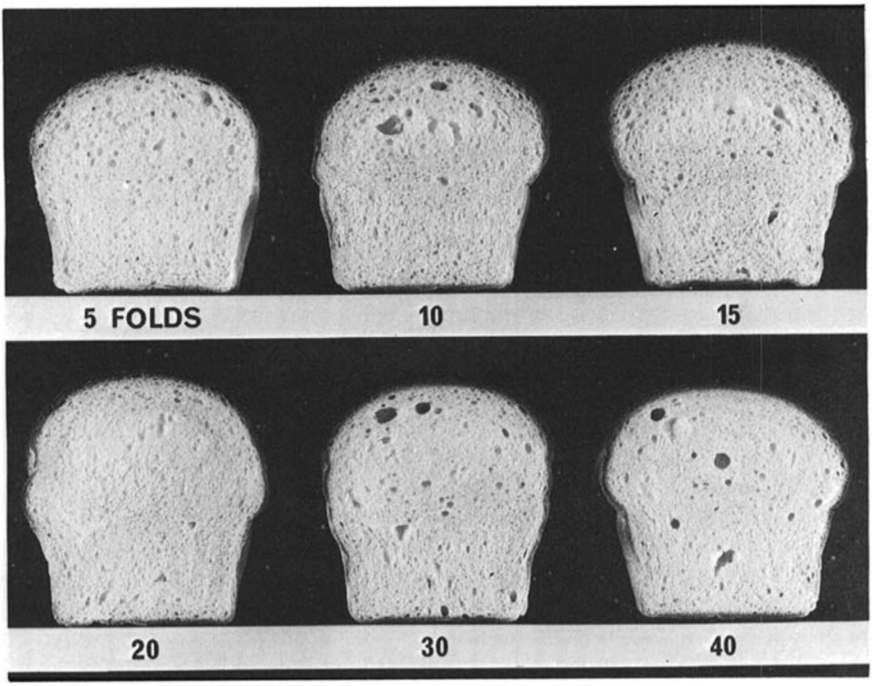

Fig. 7. Longitudinal sections through pup loaves baked from doughs premixed in the GRL mixer for 1.5 min. at 45 r.p.m. and subsequently subjected to the sheeting roll treatment indicated in Fig. 5 and Table IV.

Table IV lists energy and bread data for a series of doughs premixed 1.5 min. at 45 r.p.m. on the GRL-1000 mixer, then subjected to sheeting roll treatment. The energy required for manually handling the dough piece during the sheeting and folding operations was estimated by determining the work, in ft. lb., required to move the dough mass through a distance of 3 ft. per sheeting and converting this figure to whr. per lb. This energy value was about 0.0011 whr. per lb. per sheeting, but was not included in the net energy values listed in Table IV because it was considered not to contribute to mechanical dough development. Figure 7 shows the internal appearance of the six loaves for which data are given. Doughs receiving less than 10 folds gave bread of rather inconsistent loaf volume and appearance. Optimum conditions appeared to be between 15 and 20 folds. For 20 folds the total elapsed time for the sheeting roll development was 2.4 min. However, since each sheeting took only about 1 sec., the total time that the dough was being physically worked was around 45 sec. Net energy imparted to the dough was only 0.39 whr. per lb., or a little less than 15% of that required for peak development with the dough mixer. The bread baked from this dough was fully comparable to that baked from the mixer-developed dough and, in fact, was superior in crumb texture.

It was interesting to note that the rate of energy input by the sheeting rolls, at around 0.5 whr. per min., was only slightly less than the rate of energy imparted to the dough by the GRL-1000 mixer at 105 r.p.m.

Doughs receiving more than 20 folds began to trap bubbles or air which increased in number as the sheeting continued. This over-sheeted dough produced a number of small gas-holes in the bread crumb and the loaves developed the smooth, sharp-cornered crust characteristics normally associated with underoxidation.

DISCUSSION

Although this study illustrates the feasibility of making perfectly satisfactory no-bulk-fermentation bread without a dough mixer, obviously the technique would have no practical significance for developed countries unless the manual part of the operation could be mechanized. Certainly anyone who has seen bakers putting doughs through the large steel sheeting rolls or "dough brakes" that are fairly common in some parts of the world, for example in the Philippines, knows how much physical labor is involved in handling large pieces of dough in this manner.

An interesting aspect of this sheeting roll technique is the number of theoretical layers of dough that result. For example a treatment of 20 rolls produces over a million theoretical layers each about 0.0003 μ thick (the smallest starch granules in flour are around 5 μ in diameter). Because the dough is rotated after each fold, these layers would tend to become cross-hatched and emphasize the two-dimensional (rather than strictly uni-directional) nature of the sheet-like structure that is being promoted within the dough.

The finding that dough could be developed with sheeting rolls using only 10 to 15% of the net energy required with a dough mixer implies that the type of work being done on the dough with sheeting rolls is extremely useful and efficient work. Because this study was made using the GRL-1000 mixer for comparison purposes it is not possible to do more than speculate that the same generality could be extended to cover all mixers. However, although no comparative information is available for commercial mixers, the value of 5 whr. per lb. of (gross) energy recommended for the Chorleywood Bread Process (5), which undoubtedly includes a "safety cushion" to cover variations in flour properties and mixer efficiency, does not appear seriously out of line with the figures of 3.7 whr. per lb. gross energy and 2.9 whr. per lb. net energy required for peak development of the flour used in this study.

It is concluded that much scope may exist for modifications of mixer design to allow for the development of doughs in a more efficient manner.

Acknowledgment

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