Factors Affecting Mechanical Dough Development. II. Implications of Mixing at a Constant Rate of Energy Input[1,2]

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ABSTRACT

With a laboratory-scale programmed mixing unit, a system was devised for mixing dough at a constant rate of energy input, determined from the level of electrical energy indicated by a recorder linked to the mixer motor. For this technique the mixer speed was varied as required throughout mixing, in contrast to the normal "conventional" method where mixer speed remained fixed while rate of energy consumption varied with changing consistency of the dough during development. Mixing times were shorter in the "constant-energy" method, the percentage saving in mixing time being greater at higher speeds and for flours that in the "conventional" method remain at low consistency for a large portion of the mix.

When working with mechanically developed doughs at levels of absorption considered optimum at panning, we concluded that some flours require long mixing times at a fixed mixer speed to develop properly (1). Measurements made in this laboratory show that this does not always mean that high levels of energy must be imparted to the dough, but rather that the dough remains at a low consistency level for a large portion of the mix. Mixing time can be reduced by speeding up the mixer or by reducing absorption, but torque (consistency) levels become high near and at peak development; and, in a practical application, may exceed the capacity of a particular mixer motor or mixer design. When dough is at optimum absorption, the capacities of the mixer motor and mixer hardware are not being fully utilized for a large portion of the mix. It was therefore felt that if mixer speed could be varied so as to maintain a reasonably high constant rate of energy to the dough, considerable savings could result in mixing time.

This paper describes a system devised to mix doughs at a constant rate of energy input and presents results of a study carried out to compare this method with "conventional" mixing where mixer speed is maintained at a fixed level during mixing.

MATERIALS AND METHODS

A laboratory-scale programmed mixing unit described previously (2) was modified. Figure 1 shows schematically the mechanical and electrical components of the mixing and monitoring systems involved. Doughs were mixed with the programmed mixing unit which, apart from special switching provisions, consisted of a motor, varidrive, and mixer. Mixing speed (r.p.m.) was selected and could be varied by means of a potentiometer (speed selector) controlling the varidrive. The mixing unit was linked to both an energy-input meter and a recorder.

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[2]Presented at the 55th Annual Meeting, Minneapolis, October 1970.

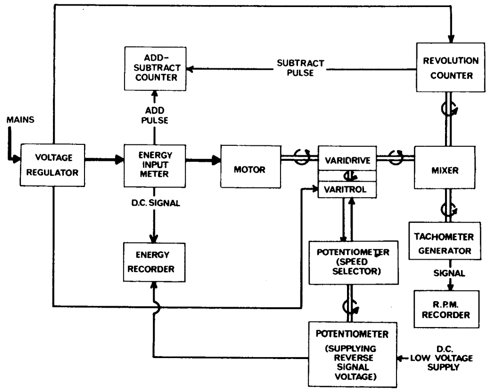

Fig. 1. Block diagram of system for mixing doughs at constant rate of energy input.

The energy required to run the mixer empty was zeroed out so that only the energy required to mix the dough was registered on an add-subtract counter. However, if the mixer speed is changed this normally results in a change in the zero value to the energy-input meter. A means of automatically maintaining a zero value on the add-subtract counter was devised for situations where the speed varies. The rate at which subtract pulses were relayed to the add-subtract counter was proportional to and controlled by the speed of the mixer. When mixer speed increased, the frequency of the add pulses to the counter increased in proportion to the additional energy required by the motor. At the same time, because the mixer drive was directly linked to the subtract-pulse switch (integrated with the revolution counter), the frequency of the subtract pulses increased and cancelled the add pulses. Therefore, the counter registered only the add pulses representing the net energy used in mixing the dough.

To maintain the "zero" at the recorder, a potentiometer was ganged to the speed selector potentiometer and calibrated so that a voltage opposing the signal voltage was applied to the recorder. The magnitude of the opposing voltage corresponded to that produced by changes in energy requirement to operate the mixer empty for the various speeds. Under these conditions, energy levels in terms of curve height were those of the mixing dough only and not combinations of mixing dough and changing base energy requirements.

On another recorder, the mixer r.p.m. was plotted against time through a tachometer generator attached to the mixer drive. A dough-development curve was thus obtained in terms of r.p.m.

A revolution counter that registered the total revolutions of the mixer blade during a mix provided information as to the possible relative mixing efficiencies of the "constant-energy" and "constant-speed" methods.

In the "constant-energy" technique the mixer speed was varied as required to maintain a constant level on the energy recorder. This was in contrast to the "conventional" mixing technique where mixer speed remained fixed while curve height varied depending on the degree and stage of dough development. Figure 2 shows examples of mixing curves using both mixing techniques where energy, in arbitrary units (upper curves) and r.p.m. (lower curves) were plotted simultaneously against time.

In the constant-speed mix, dough consistency is low in the early stages of mixing and builds up to a peak corresponding to optimum dough development for that speed. The corresponding r.p.m. plot is essentially a straight line at the 120-r.p.m. level. Levels of energy and consistency in the "constant-energy" method were determined by the peak of the mixing curve in the fixed-mixing speed method. That is, rate of energy going to the dough was held throughout mixing at the same level as that indicated at peak dough development with conventional or constant-speed mixing. Mixer speeds were therefore higher during the early stages of mixing (in this case, 150 r.p.m.), and decreased as the dough approached optimum development. This gave a "development" curve in the r.p.m. plot.

Both mixing techniques were applied in a study of the mixing characteristics and baking performance of four flours in the Chorleywood process. Table I shows some characteristics of the four flours used. Samples 1, 2, and 3 were laboratory-milled from Canadian hard red spring wheat and Sample 4 was a 50/50 blend of hard red spring wheat flour with soft white winter wheat flour. Baking formula and method were as described previously (1).

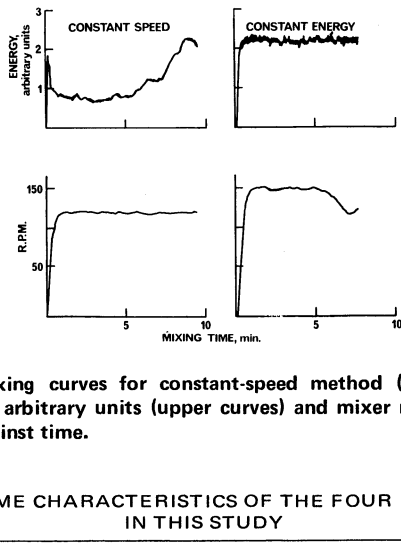

Fig. 2. Examples of mixing curves for constant-speed method (left) and constant-energy method (right). Energy in arbitrary units (upper curves) and mixer r.p.m. (lower curves) were plotted simultaneously against time.

TABLE I. SOME CHARACTERISTICS OF THE FOUR FLOURS USED IN THIS STUDY

Property	Flour Number 1	2	3	4
Protein, %	14.6	13.8	12.8	11.0
Ash, %	0.42	0.46	0.46	0.46
Gassing power, mm.	330	380	380	325
Starch damage, Farrand units	21	23	25	10
Farinograph absorption, %	64.4	63.8	63.6	54.2
Farinograph peak development time, min.	4.50	5.75	5.25	3.50
Chorleywood baking absorption, %	67	66	65	60
Energy for peak dough development, w-hr./lb.	4.0	5.5	4.5	3.0

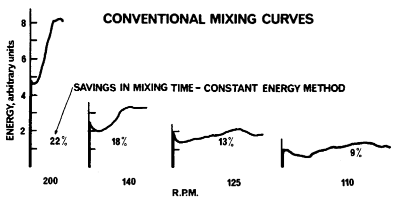

Fig. 3. Mixing curves obtained by "constant-speed" method for flour No. 2 at four speeds (200, 140, 125, and 110 r.p.m. from left to right). Energy-input level for all mixes was 5.5 w-hr. per lb. of dough.

RESULTS AND DISCUSSION

Figure 3 shows the mixing curves obtained by the "constant-speed" method for flour 2 using four speeds. Work (energy)-input level for all mixes was 5.5 w-hr. per lb. of dough. As mixing speed was reduced, the curves became flatter and the peak was less sharply defined. When the "constant-energy" technique was used, the saving in terms of percentage mixing time was greatest (22%) at the highest mixing speed of 200 r.p.m. and decreased with decreasing speed to 18% at 140 r.p.m., 13% at 125 r.p.m., and 9% at 110 r.p.m. At speeds much below 110 r.p.m. the conventional mixing curves were almost flat and consequently represented essentially a constant rate of energy input. There is therefore very little difference in mixing time between the two methods at slow speeds.

Table II shows the mixing times for four flours using both mixing methods at two speeds: The saving, expressed as percent mixing time, varied with both speed and flour, ranging from 13 to 22% at 140 r.p.m., and from 6 to 12% at 110 r.p.m.

The maximum speed required to maintain a constant rate of energy input varied with the mixing characteristics of the flour. For the flours tested the highest speed required was 175 r.p.m. at the 140-r.p.m. level and 125 r.p.m. at the 110-r.p.m. level.

The "constant-energy" technique produced a higher average speed compared with the "constant-speed" method, and this was accompanied by a reduction in the number of turns of the mixer blade for the same energy-input level. This was not unexpected because, as illustrated previously (1) with conventional mixing techniques, increasing mixer speed leads to a reduction in the total number of turns of the blade for a given energy level.

TABLE II. MIXING TIMES FOR FOUR FLOURS BY TWO MIXING METHODS AT TWO SPEED LEVELS (EXPERIMENTAL MIXER)

Flour Number	Mixing Time (min.) 140 r.p.m. Constant speed	140 r.p.m. Constant energy	110 r.p.m. Constant speed	110 r.p.m. Constant energy
1	3.2	2.6 (18%)[a]	4.8	4.5 (6%)[a]
2	3.8	3.2 (18%)	5.4	4.9 (9%)
3	2.7	2.4 (13%)	4.4	3.9 (11%)
4	2.3	1.8 (22%)	3.2	2.8 (12%)

[a]Figures in parentheses show percentage saving in mixing time by the constant-energy method compared with mixing at constant speed.

TABLE III. LOAF-VOLUME DATA FOR FOUR FLOURS BY TWO MIXING METHODS AT TWO SPEED LEVELS (EXPERIMENTAL MIXER)

Flour Number	Loaf Volume (cc.)			
	140 r.p.m.		110 r.p.m.	
	Constant speed	Constant energy	Constant speed	Constant energy
1	955	990	945	955
2	1,005	1,000	950	930
3	885	885	850	850
4	820	830	800	790

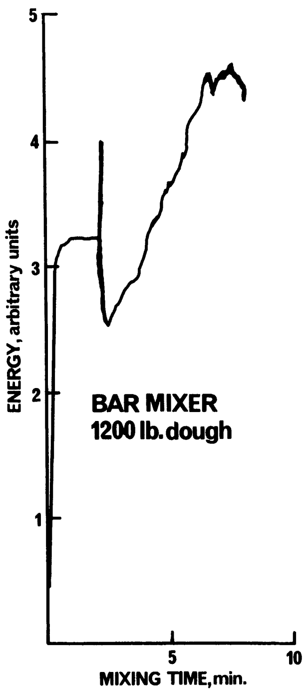

Fig. 4. Mixing curve obtained in plant bakery from a horizontal-bar mixer containing 1,200 lb. of dough at dough-up stage of sponge-and-dough process.

Table III shows the loaf volumes obtained from the four flours by the mixing conditions outlined in Table II. There was good agreement in bread volume between the fixed-speed and variable-speed (constant-energy) methods of mixing. Loaf volumes were slightly lower for the 110-r.p.m. level, which approached the critical mixing intensity (1) for these flours.

The practical significance of the savings in mixing time resulting from the constant-energy technique would depend, of course, on individual bakery considerations. That some parallel exists between mixing curves from laboratory-scale mixers and large commercial mixers is strongly suggested by Fig. 4.

This is a mixing curve obtained in a plant bakery from a horizontal bar mixer containing 1,200 lb. of dough at the dough-up stage of the sponge-and-dough process. The same principle of energy indication was used as with laboratory mixers. The change in energy requirement (consistency) of the dough with development is as evident here as it is with curves obtained from laboratory mixers.

While the term "constant rate of electrical energy" describes the method used, the direct measurement of torque might also be used, provided that it is taken at the motor output or at some other point where shaft speed is constant while the final output speed is varied. Where measurement has to be made from a shaft that varies in speed depending on mixer speed, a simple transducer (available commercially) that takes into account both torque and speed may be incorporated to provide a signal representing shaft power.

We have already established to our own satisfaction that there is a reasonable similarity in mixing-curve shape (for constant-speed mixes) for three different types of measurement with the National Mixograph:

1. Mechanical torque recording, which is standard with this instrument;
2. The use of strain gauges as torque sensors for recording by electronic means (3); and
3. The method used in this study of recording the energy to the mixer motor.

The method described for mixing at a constant-energy level ensures that maximum utilization is made of the power and mechanical capabilities of the mixer throughout the whole of the mixing period and not just when the dough is at its maximum consistency. The time saved by this method is dependent on the mixing characteristics of the flour used and on the speed of the mixer. The saving is greater at higher speeds and for flours that normally remain at a low consistency level for a large portion of the mix but develop to a high consistency.

Acknowledgment

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Literature Cited

1. KILBORN, R. H., and TIPPLES, K. H. Factors affecting mechanical dough development. I. Effect of mixing intensity and work input. Cereal Chem. 49: 23 (1972).
2. KILBORN, R. H., and TIPPLES, K. H. Improved small-scale laboratory mixing unit for production of continuous-type and batch mechanical-development-type bread. Cereal Sci. Today 14: 302 (1969).
3. VOISEY, P. W., MILLER, H., and KLOEK, M. An electronic recording dough mixer. I. The apparatus. Cereal Chem. 43: 408 (1966).

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