A Modified Extensigraph Procedure for Measuring the Stretching Properties of Fermented Dough[1]

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ABSTRACT

A modified extensigraph procedure is described for measuring the viscoelastic properties of fermented doughs. The procedure involves processing doughs in a manner similar to a given baking method. Doughs are proofed on a modified extensigraph holder and stretched. Large differences were obtained in the extensigraph properties of doughs varying in inherent flour strength. Proof times and oxidation (bromate) level also had significant effects. Increasing proof time of fermented doughs before stretching resulted in a relaxation process similar to that usually obtained with unfermented doughs. Increasing bromate levels increased extensigraph height and decreased extensibility.

The extensigraph has been widely used for the study of the effects of inherent flour quality (Baker et al 1971, Oliver 1979), processing conditions (Fisher et al 1949, Webb et al 1970), and ingredients (Bennett and Ewart 1965), Tsen 1965) on the viscoelastic properties of wheat flour doughs. With a few exceptions (El-Dash 1978, Pizzinatto and Hoseney 1980, Varriano-Marston et al 1980), these studies were restricted to unleavened doughs.

We were interested in determining the effects of fermentation and ingredient levels on the rheological properties of doughs processed in a manner similar to a given baking procedure. However, initial studies showed that the normal extensigraph procedure (AACC 1962) was generally unsuitable for studying these effects because fermented doughs tended to tear in the extensigraph molder, and the conventional holders failed to accommodate the increased cross-sectional area of the fermenting dough pieces. A modified extensigraph procedure for 100-g flour doughs involving the use of a modified Grain Research Laboratory (GRL) molder and specially designed dough holder and dough loading apparatus is described. In addition, its use for measuring changes in viscoelastic properties of proofing doughs according to proof time, flour type, and oxidant level is demonstrated.

MATERIALS AND METHODS

Flours

The flours used were the same as those used in a previous study (Black et al 1981). They included a sample of Canada Eastern white winter wheat (CEWW) flour with a protein content of 8.7% (14% mb) and an extensigraph area of 70 cm^2, a sample of No. 1 Canada Western red spring wheat flour (No. 1 CWRS-13.5) with a protein content of 12.8%, an extensigraph area of 130 cm^2, and a 50:50 blend of the above flours, which gave a protein content of 10.8% and an extensigraph area of 105 cm^2.

Description of Loading Apparatus and Dough Holders

The three components of the dough loading apparatus and the modified extensigraph holder are shown in Fig. 1. The dough loading apparatus consists of the following.

Dough Holder Positioning Guide (Fig. 1A). The dough holder positioning guide was aluminum. The side plates ($6 \times 34 \times 172$ mm) were attached to the bottom plates ($8 \times 62 \times 172$ mm) with machine screws, resulting in a height of 27 mm from the top of the side plates to the top of the bottom plate. Two rounded slots (7×30 mm and 7×55 mm) with the center line corresponding to pin center lines were cut out of the bottom plate to allow the pins of the dough holder to pass through. Guide bars for mounting the holder were attached with machine screws to the side plates to raise the bottom plate to allow pin clearance between the bench top and the plate. The front guide bar dimensions were $6 \times 16 \times 132$ mm; each of the right-angle back guide bars had side dimensions of $3 \times 19 \times 132$ mm.

Dough Transport Screen (Fig. 1B). The dough transport screen was constructed of a piece of steel meshing (65×167 mm), which was spot welded to a loop of 6-mm stainless steel rod (extended approximately 25 mm past the edge of the screen at each end). The meshing was bent along its length to give a slightly concave shape to hold the dough, and appropriate holes corresponding to the pins of the dough holder were made by driving a tapered drift through the screen, thereby expanding the mesh opening to a diameter of 5 mm.

Support Tray (Fig. 1C). The support tray was aluminum. Five 10-mm aluminum rods were screwed onto the base plate (115×170 mm). Two of the rods (length = 30 mm) fit into the blind holes of the dough holder (Fig. 2), and a third rod (length = 26 mm) supported the dough holder behind the opening where the extensigraph hook stretches the dough. The other two rods (length = 26 mm) secured a 47×75-mm plate of 6-mm aluminum to the base plate. This upper plate filled in the dough holder opening where the dough is stretched and provided support for the dough.

A general view of the dough holder is given in Fig. 1D, and the top and front edges are shown in Fig. 2. Dough holders were made from 6-mm aluminum plate. Two rows of round (3-mm diameter) pointed stainless steel pins (55 mm in length) were attached on either side of the center opening. The thickness of the edges of the opening was increased to 15 mm by attaching additional aluminum plate below the opening; the edges were rounded (r = 2 mm) to prevent tearing of the dough at these stress points. The width of the opening was 50 mm compared to the 35 mm of the conventional opening. Positioning pins were fastened using machine screws in the existing holes of the extensigraph cradle used to position the conventional dough holders (Fig. 3). Corresponding holes (11-mm

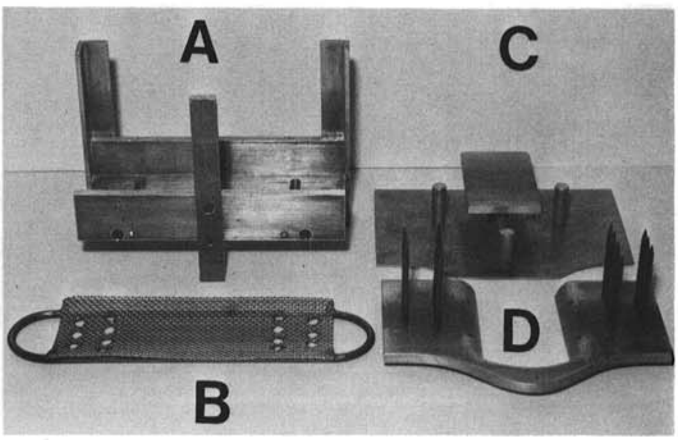

Fig. 1. Loading apparatus and dough holders. **A,** Dough holder positioning guide; **B,** dough transport screen; **C,** support tray; **D,** dough holder.

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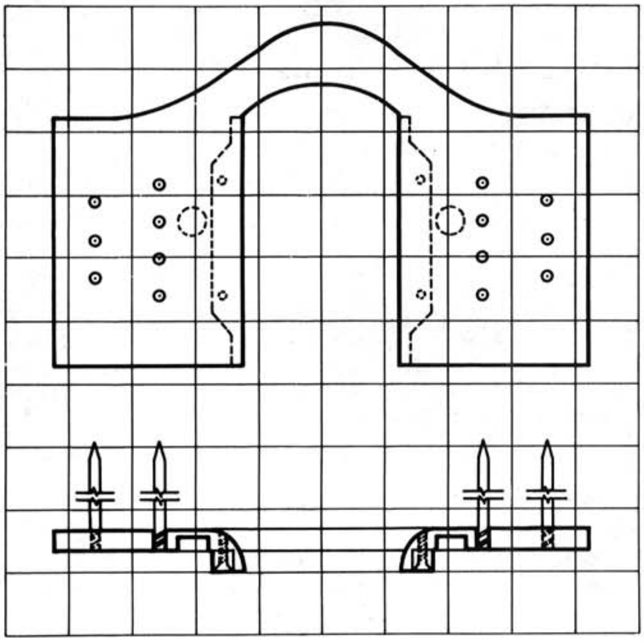

Fig. 2. Dough holder placed on a 20-mm grid. Front edge view (below), pin length = 55 mm. Top view shown above.

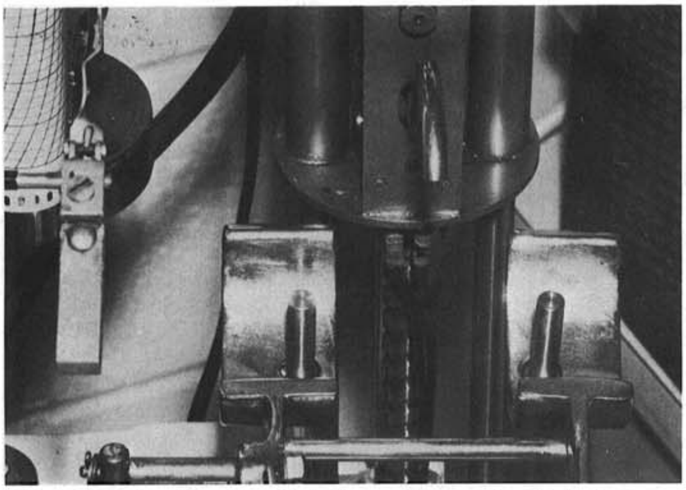

Fig. 3. Extensigraph cradle with holder positioning pins attached.

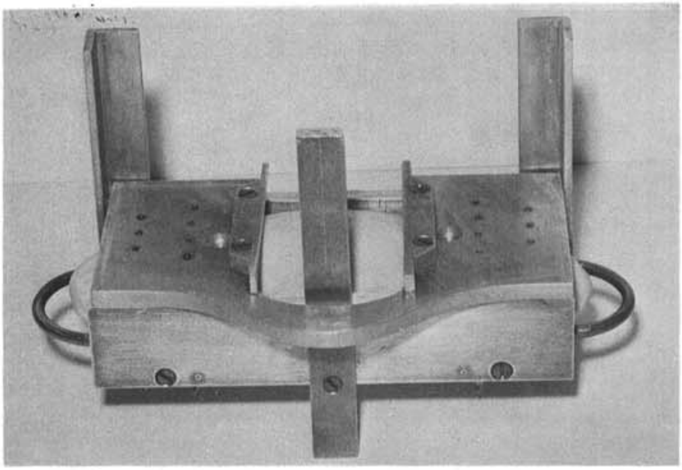

Fig. 4. First stage of loading dough showing inverted holder and dough piece in loading apparatus.

diameter, 4-mm depth) were drilled into the underside of the holder to fit the cradle pins and thus prevent the holder from moving during the stretching operation.

Molding and Loading of Doughs

The molded doughs for extensigraph testing were shaped so that they were 50% longer than doughs molded for a pup loaf pan. Weights governing the molding force imparted to the dough by the top roller of the GRL Molder were adjusted to provide the same unit dough weight as that used in the remix baking test (2.75 g/mm of finished dough length).

In loading the dough, the transport screen was placed inside the positioning guide and the molded dough centered on the screen. The dough holder was inverted and lowered using the angle-aluminum vertical supports as guides. The sharpened pins of the holder passed through the dough, the holes in the screen, and the slots in the bottom of the guide. The aluminum bars forming the front and back of the guide served as stops for the holder (Fig. 4). The complete assembly was inverted and placed over the support tray, and the holder, dough, and screen lowered as a unit onto the tray (Fig. 5). The guide and screen were removed. The finished loaded dough is shown in Fig. 6. After a rest period (proof), the dough holder was placed on the extensigraph cradle and the dough stretched.

Preparation and Stretching of Doughs

For demonstrating the use of the modified extensigraph procedure, three separate sets of experiments were conducted. For all experiments, 200 g of flour was used. Dough was processed at optimum water absorption (determined by dough feel at panning)

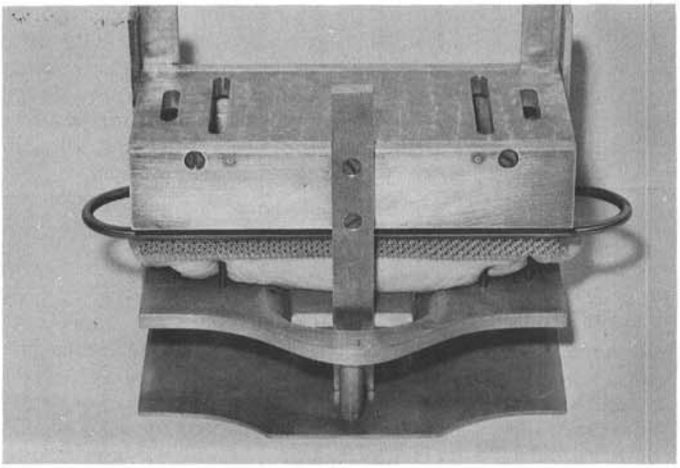

Fig. 5. Second stage of loading dough showing complete assembly, dough loader, dough, screen, and holder inverted and placed over dough support tray.

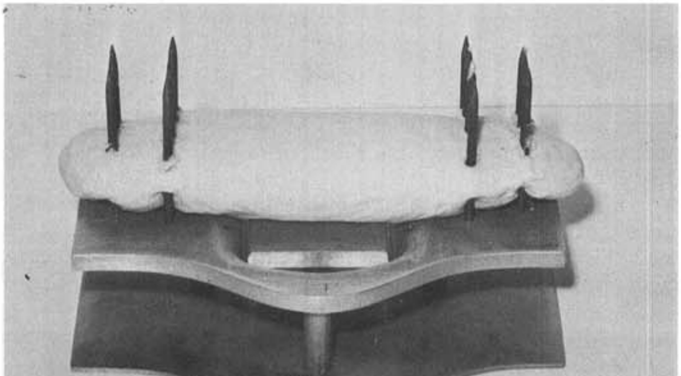

Fig. 6. Loaded dough and holder on support tray.

in a manner identical to the given baking procedure until the molding stage. Before sheeting, doughs were divided into two equal pieces representing 100-g flour doughs, and each piece was then sheeted and molded on the GRL Laboratory Dough Molder as previously described (Kilborn and Irvine 1963), except that doughs were molded to a length of 152 mm using a 150-mm top roller in place of the 100-mm roller normally used. The molded doughs were then clamped into the modified extensigraph holders and proofed at 30° C (90% rh) in a fermentation cabinet. Following proofing, doughs were stretched on the extensigraph according to standard procedure (AACC 1962).

For the first set of experiments, involving the effects of inherent flour strength on extensigraph properties, each of the three described flours were processed by the remix-to-peak procedure (Kilborn and Tipples 1981), scaled, sheeted, molded, and given a standard 55-min proof before stretching. For determining reproducibilities, 16 duplicate doughs (32 measurements) for each flour were measured over eight days.

For the second set of experiments, involving the effect of proof time on extensigraph properties, the No. 1 CWRS-13.5 flour was processed by the remix-to-peak procedure, except that proofing times were varied from 0 to 155 min. For determining reproducibilities, three duplicate doughs (six measurements) were measured over a three-day period for each proof time.

For the third set of experiments, involving the effect of oxidation (bromate) level on extensigraph properties, the No. 1 CWRS-13.5 flour was processed by a modified AACC straight dough procedure with 0, 7.5, and 15 ppm bromate. The modified procedure used at the Grain Research Laboratory used formulas, equipment, and processing conditions similar to the remix and remix-to-peak procedures. In the GRL procedure, ingredients used were 100 g of flour (14.0% mb), 3.0% yeast, 2.5% sugar, 1.0% salt, a variable amount of potassium bromate, 0.1% ammonium phosphate (monobasic), and 0.6% malt syrup (60° L).

Ingredients were mixed at low speed (68 rpm) for 2.5 min in a GRL mixer at 30° C. Doughs are punched (rounded) seven times, after which they are fermented 1 hr 45 min at 30° C and punched 21 times. They are then fermented 50 min at 30° C, punched 12 times, and recovered 25 min at 30° C. The dough is then sheeted and molded by the GRL molder and proofed 55 min at 30° C. They are then baked 25 min at 220° C.

Following molding, doughs were clamped to the extensigraph holders and proofed for 55 min at 30° C. For determining reproducibilities, six duplicate doughs (12 measurements) were measured over three days.

RESULTS AND DISCUSSION

Two basic problems occurred when the viscoelastic properties of fermenting doughs were measured with the normal extensigraph procedure. One problem was that fermented doughs were sensitive to tearing in the extensigraph molder. This problem was overcome by using the GRL Laboratory Molder (Kilborn and Irvine 1963) to sheet and mold the doughs. A further advantage of the GRL molder is that the sheeting and molding action more closely approximated commercial processing conditions. The other problem was that the conventional dough holders supplied with the extensigraph were too narrow to accommodate fermenting doughs because the cross-sectional area of the dough piece increased with proofing. As the doughs increased in volume, the conventional clamps for holding the dough did not permit free expansion, resulting in a tendency for the doughs to flow to the center and out the ends of the holders. This type of distortion produces a large variation in the amount of dough actually being stretched. Although various modifications to the conventional holders were tried such as widening the opening and modifying the clamps, best results with fermenting doughs were obtained using the flat holder and loading apparatus described.

Effects of Flour Strength, Proof Time, and Oxidation Level on the Extensigraph Properties of Fermenting Doughs

To demonstrate the use of the modified extensigraph procedure, experiments were conducted to determine the effect of flour strength, proof time, and oxidation level on the extensigraph properties of fermented doughs. For determining the effects of flour strength and proof time, doughs were processed by the remix-to-peak procedure. This method is similar to the remix method (Kilborn and Tipples 1981) used extensively in Canada for baking quality evaluation, except that doughs are mixed to peak consistency after fermentation. For determining how the level of oxidation affects extensigraph properties, a modified AACC straight dough procedure was used because of its high sensitivity to oxidants.

Table I shows the effects of flour strength on the extensigraph properties of remix-to-peak processed doughs after the 165-min fermentation and the standard 55-min proof. As expected, extensigraph length decreased significantly (P = 0.01), and maximum height and area largely decreased in going from the strong No. 1 CWRS-13.5 wheat flour to the medium strength blend flour and finally to the weak CEWW flour. For the 32 doughs from each flour tested, reproducibility was very good. For extensigraph length, the coefficient of variability for the three flours averaged 5%, whereas corresponding values for maximum height and area were 8 and 11%, respectively. These values probably are only slightly higher than corresponding values of unfermented doughs using the normal extensigraph procedure.

Compared to corresponding values obtained with unfermented doughs using the standard AACC (1962) extensigraph procedure (Table I), the fermented doughs for all three flours had much shorter extensigraph lengths, much lower maximum heights (with the exception of the No. 1 CWRS-13.5 flour, which only showed a reduction of 40 BU), and much smaller areas. Although these differences may be partly due to differences in dough weight and ingredients, the major reason for these lower values is probably related to the well-known mellowing effect of fermentation. Studies by Pizzinatto and Hoseney (1980) showed similar effects with fermenting cracker sponges on the extensigraph.

Figure 7 shows the effect of proof time on the extensigraph

TABLE I
Effects of Inherent Flour Strength on the Viscoelastic Properties of Fermented Doughs Processed by the Remix-to-Peak Baking Method Using the Modified Extensigraph Procedure[a]

Extensigraph Property	No. 1 CWRS-13.5 Mean[b]	SD[c]	50:50 Blend Mean	SD	CEWW Mean	SD
Length (cm)	12.5(21.5)[d]	0.7	9.5(20.5)	0.6	6.7(18.5)	0.3
Maximum height (BU)[e]	399 (440)	26	230 (345)	17	112 (245)	12
Area	52 (130)	5	26 (105)	3	9 (70)	1

[a]Doughs stretched after 55-min proof.
[b]Mean of 32 results.
[c]SD = standard deviation.
[d]Bracketed values are for unfermented doughs using the normal AACC extensigraph procedure.
[e]BU = Brabender units.

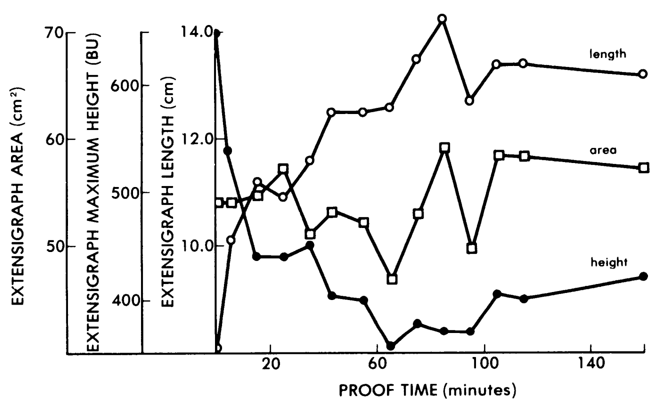

Fig. 7. Effect of proof time on extensigraph properties.

TABLE II
Effects of Bromate Level on the Extensigraph Properties of No. 1 CWRS-13.5 Wheat Flour Doughs Processed by the GRL Modified AACC Straight Dough Procedure[a]

Bromate (ppm)	Extensigraph Properties: Length (cm) Mean[c]	SD[d]	Maximum Height (BU)[b] Mean	SD	Area (cm^2) Mean	SD
0	13.3	0.8	400	39	61	6
7.5	12.6	1.0	455	38	63	9
15	11.3	1.0	491	32	64	6

[a] Doughs stretched after 55-min proof.
[b] BU = Brabender units.
[c] Mean of 12 determinations.
[d] SD = Standard deviation.

properties of the No. 1 CWRS-13.5 wheat flour processed by the remix-to-peak procedure. For the six doughs tested for each proof time, reproducibility was good. For extensigraph length, the coefficients of variability ranged from 1.5 to 11.0% (average 6.0%) for the 14 different proof times, whereas values for extensigraph height ranged from 4.0 to 12.5% (average 7.5%). For extensigraph areas, values were less reproducible and ranged from 5.0 to 20.5% (average 11.0%). The degree of reproducibility did not appear to be particularly dependent on proof time.

Fermented doughs stretched immediately after sheeting and molding were tough (high maximum height) and short (low extensibility). This result was similar to those obtained with unfermented doughs (Dempster et al 1952, Villegas et al 1963) and can be attributed to the strains introduced during the sheeting and molding stage. As proof times were increased to approximately 85 min, large reductions in extensigraph height and large increases in extensigraph lengths occurred. After 85 min, the changes were less pronounced. Changes also occurred in extensigraph area during proofing, although they did not appear to show a predictable pattern. Fermented dough curves (length versus time; height versus time) were not as smooth as that normally obtained with unfermented doughs (Dempster et al 1952), indicating that other factors may influence this relaxation process. One particularly important factor probably was the stress imparted to the proofing dough by yeast carbon dioxide production, which would alter the relaxation rate.

Table II shows the effect of oxidant (bromate) level on the extensigraph properties of the No. 1 CWRS-13.5 wheat flour processed by the GRL modified AACC procedure after a 55-min proof. As previously shown with unfermented doughs (Dempster et al 1952), increasing levels of bromate in the fermented dough gave significant reductions in extensigraph length and increases in extensigraph height. However changes in extensigraph area were not significant.

CONCLUSIONS

The modified extensigraph procedure allows the measurement of the viscoelastic properties of fermented doughs processed by specific baking procedures with good reproducibility. Extensigraph curves of fermented and unfermented doughs are sensitive to flour strength, proof time, and oxidation level. This modified extensigraph procedure will probably prove useful for studying changes in the viscoelastic properties of fermenting doughs under a variety of conditions.

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