STANDARDIZED MIXING AND FERMENTATION PROCEDURE FOR EXPERIMENTAL BAKING TEST[1]

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ABSTRACT

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A standardized mixing procedure is needed to eliminate the personal judgment involved in determination of optimum consistency and mixing time of dough. Although the present test can be used with a wide range of dough consistencies from 400 to 600 farinograph units (FU), a consistency of 500 FU has been found to be optimum for pan bread. Since dough constituents influence mixing characteristics and rheological properties, all bread ingredients are added to a 300-g sample of flour with a predetermined amount of water in less than 30 sec. The dough is developed at 63 rpm and 30°C until it shows a drop of 10 FU after reaching maximum consistency (test optimum mixing time). Two 150-g pieces are rounded and molded in the extensigraph and placed in special pans for fermentation; after 105 min, the loaves are baked.

The determination of wheat and flour quality has long been of interest to cereal processors and a challenge to cereal chemists. Consequently, significant progress has been achieved in this area. Due to the complexity of flour quality, however, and the intermingling of numerous elements that contribute collectively to the overall quality of flour or wheat, no single test except a baking test can evaluate the overall baking quality of flour.

Although several baking tests have been developed, many workers have criticised the procedures (1–4). In a cooperative study for evaluation of flour strength, Kent-Jones and Geddes (1) evaluated some of these procedures. Geddes, who examined the procedures used in Britain, found that most of the baking procedures scarcely differentiate many flours that ought to be differentiated. Kent-Jones, who examined the baking test of the AACC approved methods (5) and certain supplementary procedures, concluded that the basic test does not give proper guidance in distinguishing flours normally milled in Europe and suggested the need for standardization of the baking test in some other direction. Blish (2) also recognized the need for a more standardized baking test in which the control and mechanization of all operations are fixed.

In a study of the most commonly used baking tests, objectively defined terms were found to be used rarely. Most workers, for example, refer to the water absorption of a dough as "absorption to suit" or "required" (6–10) or "add water to bring dough to desired consistency after mixing" (5). In many cases, the absorption value is determined from the handling characteristics of the dough or stated as "that amount giving a soft, pliable dough" (6,9,11–13). Dough mixing time and consistency are also usually undefined; when an attempt is made to be specific, they are fixed for a certain amount of time, regardless of the type of flour or ingredients, or they are determined mainly by the feel and appearance of the dough such as "when it clears the sides of the mixer" (6,9–17).

In light of this study, the conclusion has been drawn that the major problems encountered in the existing baking tests are: 1) failure to specify the intensity of

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mixing required to develop the dough, 2) lack of a scientific definition of the dough consistency at which the test is performed, 3) failure to report the exact water absorption used to bring the dough to this consistency, and 4) dependence on the personal opinion and experience of a baker. Other problems include such factors as manual manipulation of the dough and lack of standardization of temperature and ingredients used. A test method thus was designed to control these factors; the numerous experiments performed are summarized below.

MATERIALS AND METHODS

Apparatus Required

1. Brabender Farinograph with large (300-g) mixing bowl and Brabender Extensigraph, both adjusted as outlined in the AACC approved methods (5).
2. Baking pans of 2 XX tin (top, 14 × 6.8 cm; bottom, 13 × 5.5 cm; depth, 4.2 cm), flat tin pan (21 × 11 × 1 cm).
3. Baking oven with temperature control.
4. Bread-volume measuring apparatus.

Procedure

Bread Formula. Bread was prepared using the following general formula, as well as with variations:

Flour (14% mb)	100%
Salt	1.75%
Sucrose	5%
Fresh compressed yeast	3%
Hydrogenated shortening	3%
L-ascorbic acid	90 ppm

The flour used was untreated, unbleached straight-grade flour milled on a roller mill from a commercial blend of 50% imported Canadian wheat and 50% Brazilian wheat (ash 0.48%, protein 11.67% [N × 5.7] on 14% mb; water absorption 56.6). Moisture, ash, and protein contents were determined by standard AACC procedures (5).

Dough Mixing. The flour (300 g on 14% mb) was placed in a clean, dry farinograph mixing bowl (30° C) and covered with a plastic cover. The mixer was turned on at the lower speed (31.5 rpm) for 30 sec and at the fast speed (63 rpm) for 4.5 min to assume homogeneity of the sample and to allow the flour to attain the temperature of the mixer.

The large buret with automatic zero adjustment was filled with water at 30° C; salt and sucrose were dissolved in 50 ml of the water, while yeast and ascorbic acid were suspended in another 50 ml of the water. The chart paper was adjusted to 0 min and the mixer was turned on (63 rpm) while the sugar-salt solution was being added to the right front corner of the bowl, followed immediately by the yeast suspension and other minor ingredients. Approximately 25 ml of the water remaining in the buret was used to rinse the sugar-salt and yeast containers to assure quantitative addition to the flour. Enough water was added to center the curve on the consistency line desired, which varied with the experiment from 400 to 600 farinograph units (FU). When hydrogenated shortening was used, it was added immediately after the addition of all other ingredients, including the water. When more than 30 sec elapsed for addition of all ingredients, including water and shortening, if any, or if the amount of water was not correct to center the curve on the consistency line required, the test was repeated so that addition of all ingredients took place within a 30-sec period and the curve was centered on the desired consistency line.

When the dough began to form, the sides of the mixer bowl were scraped down and the mixer covered. Mixing time depended on the experiment. To evaluate the effect of mixing time on the bread dough properties and bread quality, three samples of dough containing all of the baking ingredients were used, all at a consistency of 500 FU. The first dough was mixed only until the arrival time, when the top of the farinogram reached the 500-FU line. The second dough was mixed until a drop in consistency of 10 FU was evident after the maximum development of the dough (Fig. 1); this test optimum mixing time is referred to as the test time. The third dough was then mixed until the time to breakdown, i.e., until the center of the farinogram curve was centered at 470 FU.

Dough Scaling and Shaping. Immediately after stopping the mixer, two pieces of dough (150 ± 0.1 g) were scaled off and rounded for 20 revolutions in the extensigraph. The dough balls were carefully placed (with the broken side of the ball toward the operator) on the precleaned molder unit of the extensigraph and rolled into cylindrical test pieces that were placed in lightly greased baking pans.

Dough Fermentation. The two baking pans of dough were placed to ferment in one of the holding chambers of the extensigraph over the flat pan, which was filled with 25 ml of distilled water to maintain the humidity of the holding chamber. The length of fermentation time (minutes from the end of the shaping

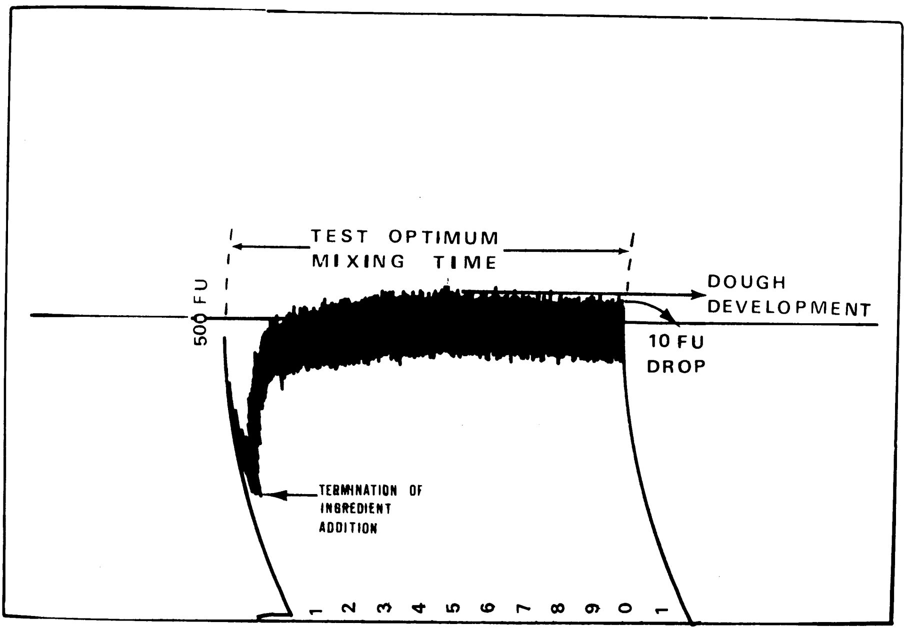

Fig. 1. Typical baking test farinogram showing test optimum mixing time.

of dough until dough was placed in the oven) was varied (60–135 min) according to the experiment.

Dough Baking. After the required fermentation time, the bread was carefully transferred to the baking oven and baked at 220° C for 20 min.

Bread Quality Evaluation

Bread volume was determined by seed displacement in the volume measuring apparatus within 1 hr of baking. The specific volume was calculated and multiplied by 3.33 to result in a maximum of 20 points for bread with a specific volume of 6. Crust color (10 points), break and shred (5 points), and symmetry (5 points) were also considered as external characteristics of the bread loaf (maximum total of 20 points). The internal characteristics (35 points) included internal character of crust (5 points), crumb color (10 points), and grain and texture of crumb (each 10 points). Aroma (10 points) and taste (15 points) were also included to get a maximum total quality score of 100 points.

Evaluation of Load Extension Properties of Bread Dough System

Bread dough was prepared as outlined above. The dough was mixed with the predetermined amount of water needed to obtain the desired consistency of 400, 475, 500, 525, or 600 FU. Three different mixing times were used (arrival time, test time, and breakdown time). After the dough was mixed, two dough pieces of 150 ± 0.1 g were scaled off, rounded, and shaped with the extensigraph and then placed in the lightly greased dough holder. After 45, 90, and 135 min of fermentation, the dough load extension test was done and the resultant extensigram evaluated.

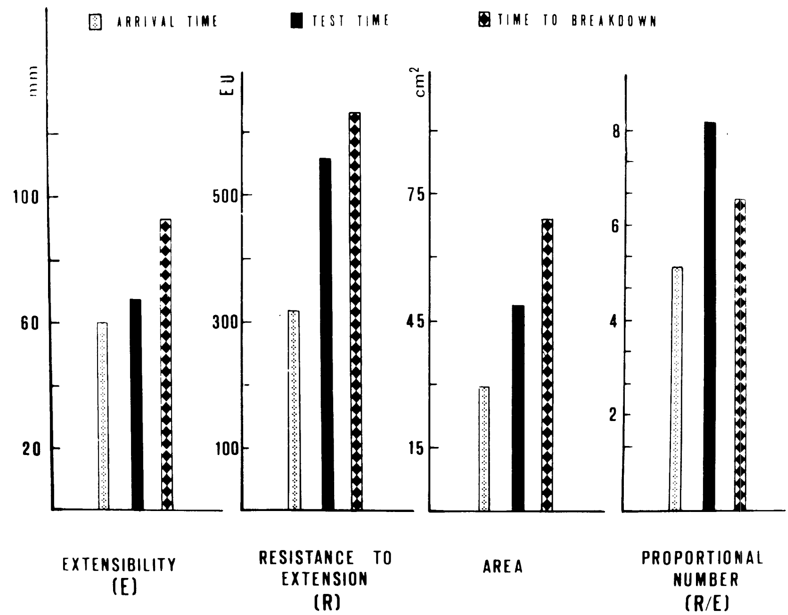

Fig. 2. Effect of mixing time on load extension characteristics of bread dough.

RESULTS AND DISCUSSION

Mixing Procedure

Mixing Time. Mixing of bread dough is essential to provide the physical contact between the molecules of gluten and other constituents of flour and those of the other ingredients added to the dough, as well as to provide the energy required to build up the gluten complex network capable of retaining gases produced during fermentation. The effect of mixing time on the bread dough load extension properties at 135 min of fermentation is presented in Fig. 2. Mixing the dough to arrival time (2.5 min) resulted in a weaker dough as evidenced by lower values for extensibility, resistance to extension, extensigram area, and proportional number. Although the dough mixed for 20 min (time to

TABLE I
Effect of Bread Dough Consistency on Water Absorption and Load Extension Properties

	Bread Dough Consistency (FU)[a]				
	400	475	500	525	600
Water absorption (%)	55.7	53.4	51.4	50.2	48.2
Extensibility (mm)	80	82	72	70	67
Resistance to extension (EU)[b]	370	555	520	590	595
Maximum resistance to extension (EU)	380	555	540	590	635
Proportional number	4.62	6.76	7.22	8.19	8.88

[a]FU = farinograph units.
[b]EU = extensigraph units.

TABLE II
Effect of Bread Dough Consistency on Bread Quality

	Maximum Value	Dough Consistency (FU)[a]				
		400	475	500	525	600
External characteristics						
Volume (sp vol × 3.33)	20	18.9	19.2	19.4	18.3	15.4
Other external characteristics	20	12	15	17	12	11
Internal characteristics	35	25	25	28	25	17.5
Aroma and taste	25	25	25	25	25	25
Total score	100	80.9	84.2	89.4	80.3	68.9

[a]FU = farinograph units.

breakdown) resulted in a higher extensibility, resistance to extension, and extensigram area than did dough mixed for the test time (12 min), the extension force required to extend the dough 1 mm (proportional number) was lower, indicating that overmixing exerted a weakening effect on the dough structure. Therefore, bread dough mixed to the test time exhibits the best properties for gas retention during fermentation.

This conclusion is in agreement with the overall baking quality of the bread. The specific loaf volume was higher for the test time (5.8 cm^3/g) than that for the arrival time and time to breakdown (4.5 and 5.1 cm^3/g, respectively). Moreover, the cell structure for dough mixed to arrival time was too tight, while dough mixed to the time of breakdown showed an open cell structure. The use of this test time as the optimum mixing time for dough therefore was selected for the baking test in this study. In this manner the dough is mixed to its optimum development, which will obviously vary with the type and quality of flour used.

Dough Consistency. Preliminary experiments indicated that bread made from dough with a consistency of less than 400 FU or more than 600 FU was of poor quality. Therefore, bread dough was made at five different levels of consistency within this range, namely, 400, 475, 500, 525, and 600 FU, to determine the optimum consistency of dough for producing the highest quality bread. Each dough was mixed to test optimum mixing time; this test time decreased as the consistency of the dough increased, indicating that mixing time is influenced by the dough consistency. It was found to be 15.5, 12.0, 11.5, 10.8, and 10.5 min for doughs with consistencies of 400, 475, 500, 525, and 600 FU, respectively.

The effect of bread dough consistency as a function of water absorption on extensigram properties at 135 min of fermentation is presented in Table I.

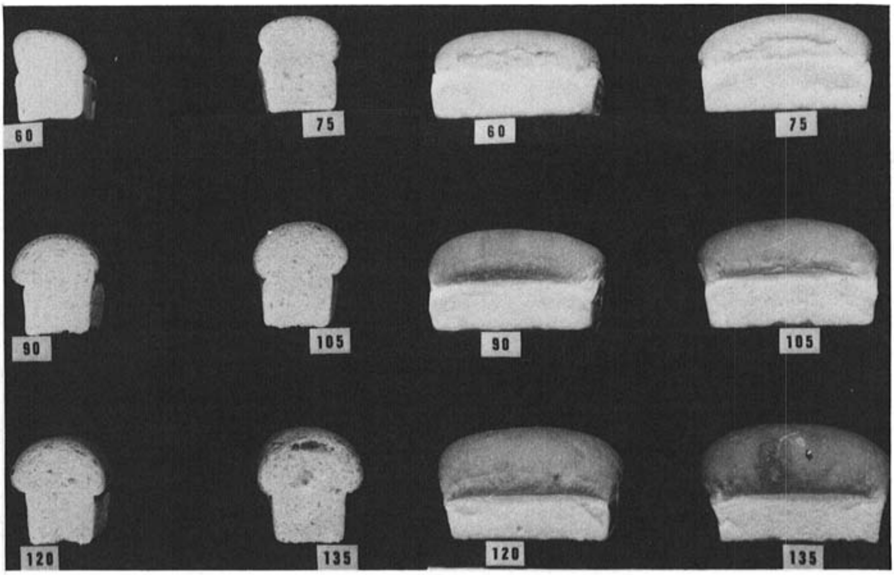

Fig. 3. Effect of fermentation time on external and internal characteristics.

Reducing the water absorption increased the consistency. A reduction in dough extensibility and an increase in resistance to extension and proportional number accompanied an increase in consistency.

The effect of dough consistency on bread quality is presented in Table II. Bread produced from dough with a consistency of 500 FU showed a superior quality, followed closely by that with 475 FU. Bread made from doughs with consistencies of 400 and 525 FU were about equal, although dough of 400 FU was found to be difficult to handle. Bread produced from a high-consistency dough (600 FU) showed a marked deterioration in quality. Therefore, a bread dough consistency of 500 FU was concluded to be the most suitable for examining the quality of flour under the conditions discussed in this study.

Fermentation Procedure

In this study, a single-stage fermentation was used. During the development of the procedure, resting or fermenting the developed dough before dividing or rounding, even for short periods of time, was observed to result in a dough that was highly sensitive to mechanical handling. Deterioration in bread volume and quality manifested this. Tipples and Kilborn (18) reported a similar effect; they demonstrated that even a short rest period after development made dough extremely susceptible to an initial destructive or unmixing effect; their baking studies confirmed that a rest period exaggerated the unmixing effect observed.

Bread baked after various fermentation times (determined from end of mixing until dough was placed in the oven) from 60 to 135 min is shown in Fig. 3. The loaf volume score (specific volume × 3.33) increased linearly with an increase in fermentation time (Fig. 4). The rate of increase in bread volume score for the period between 60 and 75 min of fermentation was 0.05 points/min, and between

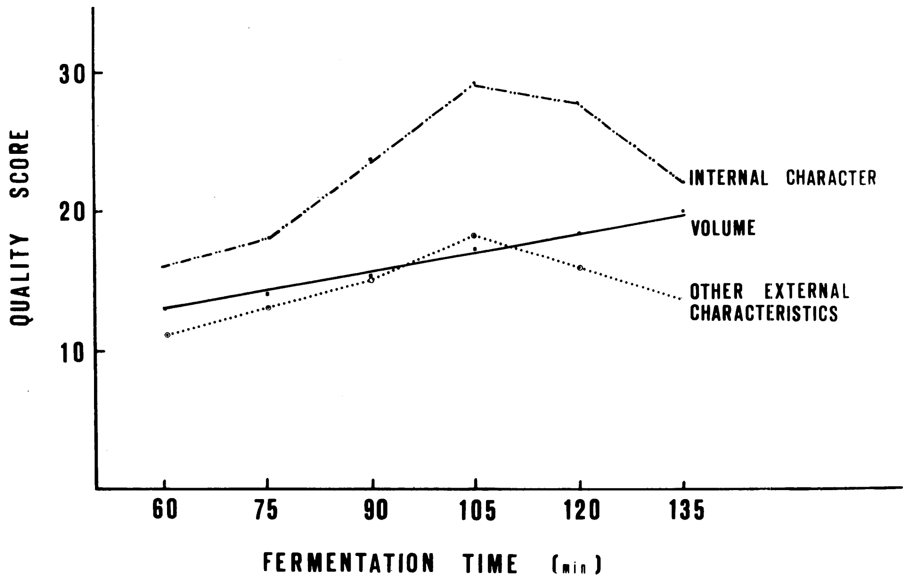

Fig. 4. Effect of fermentation time on bread quality.

75 and 120 min of fermentation, 0.1 point/min, dropping to 0.09/min in the last 15 min of fermentation. The internal and external characteristics showed their greatest improvement in quality score around 105 min of fermentation, with a longer fermentation time, however, causing a drop in bread quality and an open cell structure with the presence of holes. The conclusion was that the optimum fermentation time would be 105 min.

Baking Ingredients

The baking test proposed in this study was found to be sensitive to baking ingredients. As the results in Fig. 5 show, bread made from dough with 500-FU consistency and mixed for the test time using the basic formula of flour, yeast, salt, and sugar had a low specific volume and volume score as well as a low overall quality; this indicates that other ingredients are essential in the production of high-quality bread. Addition of L-ascorbic acid at 90 ppm improved the quality only slightly, but addition of 3% shortening or 0.5% CSL (calcium stearyl-2-lactylate) produced a pronounced enhancement of both loaf volume and overall bread quality. The addition of ascorbic acid in combination with shortening or CSL improved the quality even more; a typical loaf of bread produced from use of the procedure is shown in Fig. 6. The test sensitivity to other factors such as wheat class and grade, flour quality, and extraction ratio is under investigation.

Test Reproducibility

The specific volume was singled out as the most objective element in bread quality evaluation. This baking test was performed eight times within a one-week

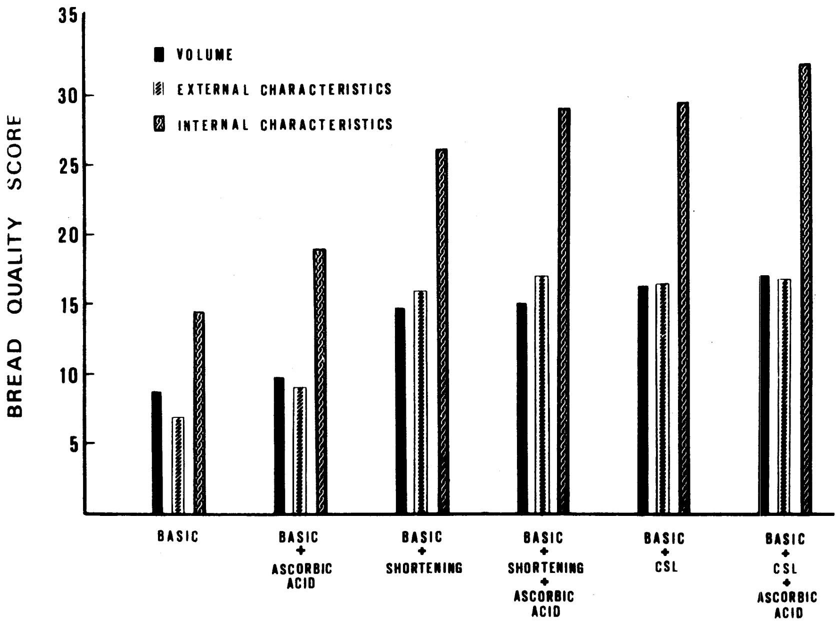

Fig. 5. Role of bread ingredients in bread quality as tested by proposed baking test.

period to test the reproducibility of the results. The flour used for this portion of the study was untreated, unbleached straight-grade flour from Brazilian-grown wheat (ash 0.53%, protein 10.65% [N × 5.7] on 14% mb; water absorption 56.0). The median specific volume was 4.83 cm^3/g, with maximum and minimum limits of 4.99 and 4.67 cm^3/g, respectively. The standard deviation was 0.0543, with a coefficient of variance of 1.13%.

CONCLUSIONS

A baking test with an objective mixing procedure can be performed as outlined in the **Materials and Methods** section; the following specifications are recommended:

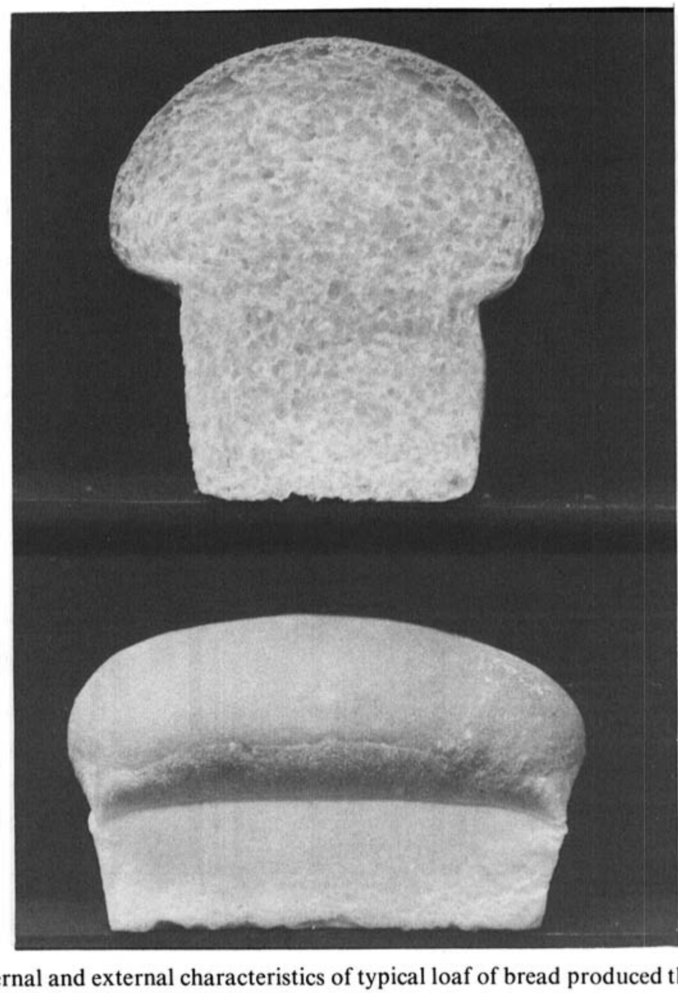

Fig. 6. Internal and external characteristics of typical loaf of bread produced through use of standardized method.

1. The water absorption of the dough is the amount of distilled water at 30° C that is required to center the farinogram curve of the bread dough on the 500-FU line.

2. The dough consistency should be 500 FU for dough that is formed by addition of all ingredients within 30 sec.

3. The test optimum mixing time is the time required to mix dough (formed by addition of all ingredients within a 30-sec period) at 63 rpm until a 10-FU drop is observed after reaching the maximum development.

4. The fermentation time is 105 min.

This procedure may be of interest to plant breeders, in wheat and flour marketing, and in research since it is an objective procedure with all factors specified and defined. This procedure eliminates dependence on the personal opinion of an expert baker to judge the absorption, consistency, and mixing time; it is therefore operable in any cereal laboratory. Moreover, the present test does not require development or purchase of new equipment, since the farinograph and extensigraph are already standard equipment in a cereal laboratory. Another practical benefit of such an objective procedure, which should be of great interest to the baker, is that since the dough consistency, mixing time, fermentation time, and temperature can be systematically controlled, the optimum combined conditions to deal with the inherent characteristics of a particular flour or flour mixture can be determined.

Literature Cited

1. KENT-JONES, D. W., and GEDDES, W. F. A cooperative study of the utility of different methods for evaluating flour strength. Cereal Chem. 13: 239 (1936).
2. BLISH, J. M. The present status of the "standard" AACC baking test. Cereal Chem. 13: 728 (1936).
3. SWANSON, C. O. Report of the 1935–36 committee on the experimental baking test. Cereal Chem. 13: 729 (1936).
4. KENT-JONES, D. W. The standard baking test under English conditions. Cereal Chem. 11: 57 (1934).
5. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Method 54-21, approved 1961; Method 54-10, approved 1961; Method 10-10, approved 1961; Method 44-15A, approved 1967; Method 08-01, approved 1961; and Method 46-10, approved 1961. The Association: St. Paul, Minn.
6. BARBER, J., and KENNEDY, B. M. Relationship among dough ingredients, water absorption, moisture content of bread and bread yield. Cereal Chem. 35: 201 (1958).
7. LEE, C. C. The baking quality and maltose value of flour irradiated with Co^{60} gamma rays. Cereal Chem. 36: 70 (1959).
8. OFELT, C. W., SMITH, A. K., and DERGES, R. E. Baking behavior and oxidation requirements of soy flour. I. Commercial full-fat soy flour. Cereal Chem. 31: 15 (1954).
9. FINNEY, K. F., and BARMORE, M. A. Yeast variability in wheat variety test baking. Cereal Chem. 20: 194 (1943).
10. HAYASHI, M., D'APPOLONIA, B. L., and SHUEY, W. C. Baking studies on the pin-milled and air-classified flour from four hard red spring wheat varieties. Cereal Chem. 53: 525 (1976).
11. KENNEDY, B. M., FLETCHER, L. R., and SABISTON, A. R. Studies on the incorporation of nonfat milk solids in whole wheat bread. I. Dough properties and baking tests. Cereal Chem. 31: 347 (1954).
12. SANDSTEDT, R. M., and FORTMANN, K. The relation of proteolysis to the characteristics of oxidation and reduction in doughs. Cereal Chem. 20: 517 (1943).
13. MILLER, B. S., and JOHNSON, J. A. High levels of alpha-amylase in baking. II. Proteolysis in straight and sponge doughs. Cereal Chem. 25: 128 (1948).
14. FINNEY, P. L., MAGOFFIN, C. D., HOSENEY, R. C., and FINNEY, K. F. Short-time baking systems. I. Interdependence of yeast concentration, fermentation time, proof time and

oxidation requirement. Cereal Chem. 53: 126 (1976).
15. RANHOTRA, G. S., and LOEWE, R. J. Breadmaking characteristics of wheat flour fortified with various commercial soy protein products. Cereal Chem. 51: 629 (1974).
16. SHOGREN, M. D., FINNEY, K. F., and HOSENEY, P. C. Functional (breadmaking) and biochemical properties of wheat flour components. I. Solubilizing gluten and flour proteins. Cereal Chem. 46: 93 (1969).
17. EL-DASH, A. A., and JOHNSON, J. A. Protease enzymes: Effect on bread flavor. Cereal Sci. Today 12: 282 (1967).
18. TIPPLES, K. H., and KILBORN, R. H. Factors affecting mechanical dough development. V. Influence of rest period on mixing and unmixing characteristics of dough. Cereal Chem. 54: 92 (1977).

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