A METHOD FOR MEASURING STRENGTH AND EXTENSIBILITY OF BREAD CRUMB[1]

L. K. DAHLE and E. P. MONTGOMERY, Campbell Institute for Food Research, Camden, NJ

Cereal Chem. 55(2): 197-203

ABSTRACT

A method has been developed for obtaining textural measurements of bread crumb using the Instron tester. With a simple device, a bread slice is deformed to the point of visible rupture. Events are recorded on a strip chart. Peak resistance to deformation occurs at the point at which crumb visibly ruptures; it is a measurement of crumb strength. The distance through which the bread is deformed before visible rupture is a measurement of crumb extensibility. This test has been applied to different breads and to bread at different days of age, providing results on effects of aging, moisture, temperature, and a bread-softening agent.

Many devices and procedures have been reported for observing the changes that occur in bread as it ages (1). The most widely used procedure is crumb compressibility, for which the official AACC method employs the Baker compressimeter (2). This article describes a device and technique using the Instron tester, which offers a means of measuring textural parameters that have theoretical significance as well as practical usefulness in breadmaking.

MATERIALS AND METHODS

Device

Figure 1 shows the device that was fabricated for use with the Instron tester (Model 1130), which can subject a bread slice to combined compression, shear, and tensile forces. It consists of a 6.4-cm diameter steel cup, a 15 × 15-cm clear plastic platform mounted at the lip of the cup, and a 4.8-cm diameter disk attached to a 15-cm long shaft. The shaft and disk are mounted to the 2,000-g load cell of the Instron tester. Directly beneath this are the steel cup and platform.

Test Procedure

To conduct a test, a bread slice is centered over the cup on the platform. The Instron tester is activated, causing the shaft and disk to descend into the cup and deform and rupture the bread slice. The load cell detects the resistance-deformation, which is registered in a traced curve on the chart paper of the Instron tester. The crosshead speed and chart speed are both 10 cm/min.

Two measurements are taken from the curve. Peak resistance to deformation, which is shown by the maximum height of the curve, is expressed as grams force and termed "crumb strength." The distance from onset of deformation to the point of peak resistance is measured in millimeters and is termed "crumb extensibility." A typical curve is shown in Fig. 2.

[1]Presented in part at the 61st Annual Meeting, New Orleans, October 1976.

0009-0352/78/000024$03.00/0

© 1978 The American Association of Cereal Chemists

Bread Tests

Depending on the experiment and availability of bread slices, measurements of each slice of a set were taken and averaged. For studies of aging, a given number of wrapped loaves or slices were allowed to age at ambience; they were subjected to measurement at designated times. Statistical comparison of measured values was made in the initial large-scale testing of production bread.

Humidity Control

Environments of varying humidity were provided by placing water, saturated ammonium chloride solution, and saturated calcium chloride solutions in closed containers corresponding to equilibrium relative humidity values of 100, 79, and 32%, respectively. Bread slices were stored in these containers eight days prior to measurement.

Temperature Control

Bread slices were wrapped in aluminum foil to prevent moisture loss, placed in an oven at a designated temperature for 1/2 hr, and measured immediately.

Emulsifier Effect

To test the effect of an emulsifier on textural parameters, bread was prepared with shortening containing 0 and 10% glyceryl monostearate by the straight

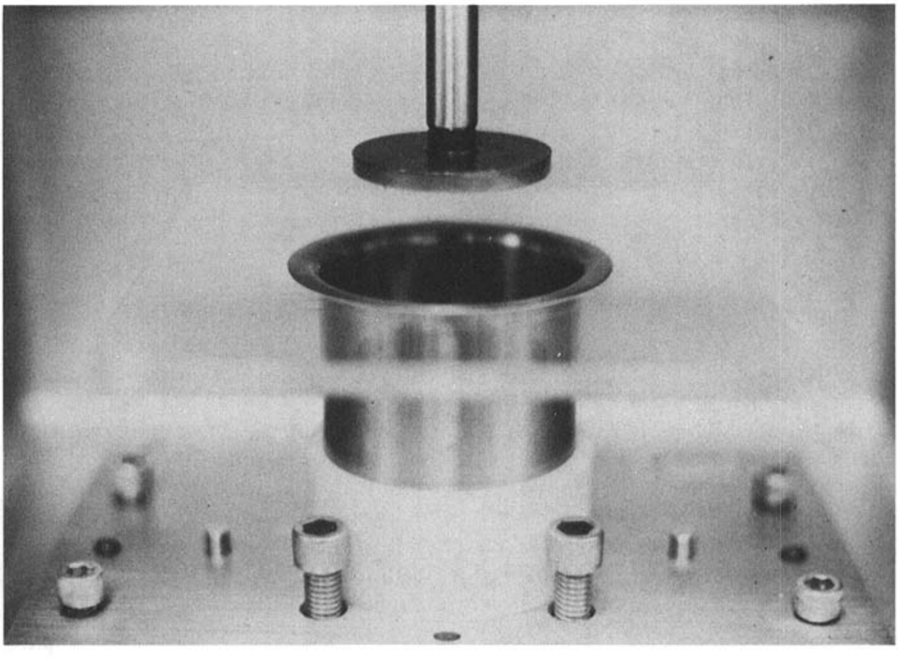

Fig. 1. Device for bread texture measurement. Plastic platform (15 × 15 cm) is mounted at lip of steel cup (6.4-cm diameter). Disk (4.8-cm diameter) is attached to shaft (15 cm long), which is mounted to Instron load cell.

dough method and at a shortening level of 3% of flour. Slices were measured initially and at three and six days of age.

RESULTS AND DISCUSSION

Figure 2 shows the typical response of a bread slice to deformation. It shows how crumb strength and crumb extensibility can be obtained. Structural collapse (actual rupture) of the bread is observed at the point of peak resistance.

The bread slice is subjected to compressive, shear, and tensile stresses in a manner similar to a punch and die technique that Voisey (3) described. Bread is

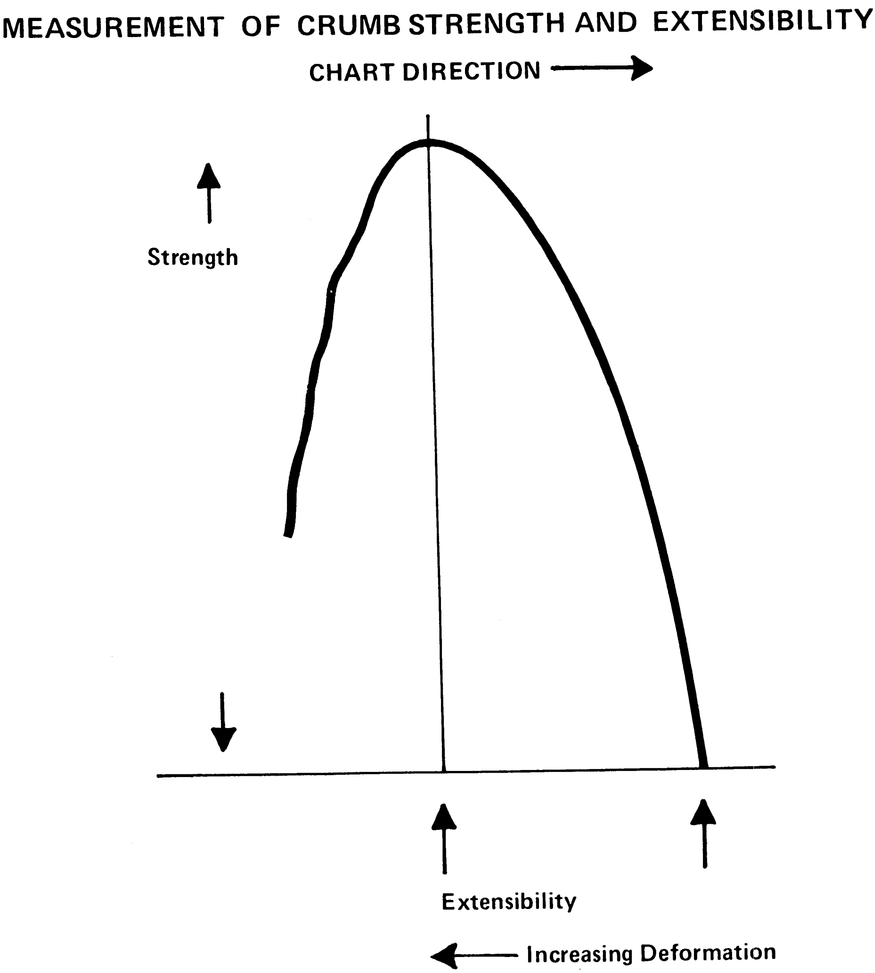

Fig. 2. Typical curve obtained from deformation and rupture of bread crumb. Height of peak denotes strength (maximum resistance before rupture). Distance through which bread is deformed before rupture gives extensibility.

compressible because of its cellular structure and also extensible because of the gluten matrix. The structural collapse seen at peak resistance to deformation indicates rupture of the gluten matrix.

Of particular interest in this method is the response of the gluten matrix to the deforming force. As bread is deformed in this device, the disk applies a shear stress, inducing a shear strain as the bread is elongated in the space between cup and disk. It is likely that the gluten matrix bears the principal resistance of shear strain.

Table I shows measurements obtained from production lots of bread at different days of age. Statistical analysis (analysis of variance, Duncan's multiple range test) showed that extensibility was different at zero, three, and five days' age at 95% confidence interval; strength was different at five days' age, but difference of strength at zero and three days' age was not statistically significant. Bread seemed to decrease steadily in extensibility and increase in strength at the latter part of the aging period.

TABLE I
Aging Change in Production Lots of Bread

Production Lot	Extensibility (mm)[a]			Strength (g)[a]			Extensibility Change (%)		Strength Change (%)	
	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5	Day 3	Day 5	Day 3	Day 5
1	6.2	6.0	5.1	359	345	399	−3	−18	−4	+11
2	7.2	6.6	5.7	338	343	348	−8	−21	+1	+3
3	6.2	5.2	4.8	306	328	378	−16	−23	+7	+24
4	7.1	6.2	5.5	317	322	348	−13	−23	+2	+10
5	6.1	5.2	4.9	328	352	383	−15	−20	+7	+17
6	5.9	4.9	4.5	369	367	446	−17	−24	−1	+20
7	6.8	6.0	5.6	346	369	373	−12	−18	+7	+8

[a]Measurements are averages of 60 slices (ten slices from each of six loaves). From each production lot a total of 18 loaves was allowed to age at ambience.

TABLE II
Comparison of Commercial Breads

Brand	Slice Thickness (mm)	Extensibility (mm)[a]			Strength (g)[a]		
		Day 0	Day 3	Day 6	Day 0	Day 3	Day 6
A	9	13	10	8.2	520	450	560
B	9	9.1	8.0	7.4	350	370	475
C	11	13.5	9.9	8	485	425	430
D	14	16.5	15.3	12.7	285	320	380
E	16	21	18.2	16.5	415	430	415

[a]Measurements are averages of six random slices taken from single loaf allowed to age at ambience.

Starch retrogradation plays an important role in crumb firming. Schoch (4) determined that the linear glucose polymer (amylose) probably retrograded early at the time of baking and that the branched glucose polymer (amylopectin) retrograded more slowly into the more rigid crystalline form and contributed to the crumb firming that accompanies aging. This effect likely contributes to the increasing crumb strength values that this method measures as bread ages.

More recently, moisture dislocation between the gluten matrix and starch component of the crumb has been considered. Willhoft (5) indicates that moisture migrates from protein to starch and that both this and starch retrogradation are important factors in crumb firming. This effect likely contributes to the decreasing crumb extensibility values that this method measures as bread ages.

Table II shows comparison of measurements of commercial breads. The measurements ranged from more extensible to less extensible crumb and from weak to strong crumb. Differences in slice thickness prevent accurate

TABLE III
Aging Changes of Bread in Differing Humidity Environments

Equilibrium Relative Humidity (%)	Extensibility Change (%)[a]		Strength Change (%)[a]	
	Day 5	Day 8	Day 5	Day 8
100	−27	−36	+22	+18
79	−28	−35	+14	+29
32	−42	−41	+46	+65

[a]Measurements are averages of five random slices taken from a single loaf held in each of the humidity chambers.

TABLE IV
Texture Change of Bread at Different Temperatures

Temperature (°F)	Extensibility (mm)[a]	Strength (g)[a]
45	6.4	471
	6.7	516
	6.4	506
72	7.1	344
	7.2	354
	7.4	340
160	10.3	224
	11.9	242
	10.4	220

[a]Measurements are averages of five random slices from a single loaf, each wrapped in aluminum foil and held 1/2 hr at given temperature just prior to measuring.

comparison between some of the breads.

Table III shows the effect of equilibrium relative humidity conditions. As would be expected, the bread stored at lowest humidity had greatest decrease of crumb extensibility and largest increase of crumb strength. The hydration condition of the gluten matrix would be expected to influence its extensibility, being less extensible in a dryer state.

Table IV shows the effect of temperature on crumb extensibility and strength. Crumb extensibility increased and strength decreased as temperature increased. Higher temperature conditions were similar to those that are commonly used to soften breads in an oven prior to serving. The gluten matrix may be principally involved in this change, considering the short time employed for temperature elevation.

Table V shows the effect of monoglyceride, a bread-softening agent, on texture and aging change in bread. Monoglyceride did not greatly affect the extensibility changes; increase of crumb strength was greater at late age in bread not containing monoglyceride. Strandine and co-workers (6) considered that monoglyceride complexed with soluble linear amylose and thus inhibited its cementing action between starch granules and gluten matrix, thus contributing to increased crumb softness or retarded crumb firming. Also, monoglyceride that is bound to starch granules would inhibit its water uptake, thus allowing greater retention of water in the gluten matrix; this would contribute to retarded crumb firming.

Bushuk and Mehrotra (7) recently reported that bound water in bread decreases with storage time. They observed that little change of bound water occurred until after four days of storage, at which time it began to decrease. This corresponds to our observation that crumb strength tended to increase mainly in the latter part of the aging period. That the amount of bound water would affect gluten matrix properties seems reasonable, and the textural parameters that this procedure measures must relate to the condition of the gluten matrix.

Further research will relate texture measurements available through this procedure to sensory perceptions. Combined factors of crumb strength and crumb extensibility may be suitable expressed as a ratio, which would correlate with sensory perception and be similar to a shear modulus of rigidity that can be calculated for some material (3).

TABLE V
Effect of Monoglyceride on Texture and Aging Change of Bread

Glyceryl Monostearate	Initial Extensibility (mm)[a]	Initial Strength (g)[a]	Extensibility Change (%)[a]		Strength Change (%)[a]	
			Day 3	Day 6	Day 3	Day 6
0	4.8	343	−25	−33	+56	+128
10% of shortening	4.9	272	−30	−36	+65	+ 85

[a]Measurements are averages of five random slices from single loaf allowed to age at ambience.

Apart from theoretical aspects, the procedure offers potential as a tool for monitoring bread production on the basis of textural quality. Comparisons of bread on various production days reveal differences of crumb strength and crumb extensibility, with moisture content remaining constant. Wide variation is seen in crumb extensibility. These differences might be attributable to processing variables or ingredient variables. This procedure can be used for checking changes that processing or ingredient variables induce and can be a useful tool for checking the effect of a new ingredient or additive.

In summary, this procedure for measuring some textural parameters of bread quality appears to be potentially useful for both theoretical studies and as a practical control test procedure.

Literature Cited

1. MAGA, J. A. Bread staling. Crit. Rev. Food Technol. 5: 443 (1975).
2. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Approved methods of the AACC. Vol. 2, (1969) Method 74-10, approved April 1961. The Association: St. Paul, Minn.
3. VOISEY, P. W. Engineering assessment and critique of instruments used for meat tenderness evaluation. J. Text. Stud. 7: 11 (1976).
4. SCHOCH, T. J., and FRENCH, D. Studies on bread staling. I. The role of starch. Cereal Chem. 24: 231 (1947).
5. WILLHOFT, E. M. A. Recent developments on the bread staling problem. Baker's Dig. 47(6): 14 (1973).
6. STRANDINE, E. J., CARLIN, G. T., WERNER, G. A., and HOPPER, R. P. Effect of monoglycerides on starch, flour, and bread. A microscopic and chemical study. Cereal Chem. 28: 449 (1951).
7. BUSHUK, W., and MEHROTRA, U. K. Studies of water binding by differential thermal analysis. III. Bread studies using the melting mode. Cereal Chem. 54: 326 (1977).

[Received March 25, 1977. Accepted October 3, 1977]