FLOUR AS A FACTOR IN BREAD FIRMING[1]

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ABSTRACT

The average crumb firmness and firming rates of bread made with ten commercial winter wheat flours having relatively small differences in protein and other analytical values and test baking results were found to be significantly different. Of the two flours showing extreme loaf compression values after 70 hours of storage, one had about a 14-hour softness advantage over the other.

Rate of bread firming was found to be significantly correlated with proof time; there was no significant correlation with the usual flour quality indices such as protein, ash, maltose figure, and amylograph values.

The bread produced for this study exhibited a systematic variation in intraloaf firming: loaf centers were significantly firmer than their ends. Intraloaf firming variations were attributed to differences in specific volume within loaves. The correlation coefficient of these two factors for seven sections in the loaves was 0.93**, significant at the 0.1% level.

Flour quality or strength is reported in the literature as being a prime factor in keeping quality of bread (6)[2]. Hutchinson[3] and Steller and Bailey (11) appear to have provided the most recent evidence in this area, finding that flours of higher protein content produced bread with better keeping qualities although, at least as far as the latter authors were concerned, not in a linear fashion. Working with synthetic dough systems, Bechtel and Meisner (3) and Prentice *et al.* (9) generally confirmed these views, showing that higher gluten content in their artificial flours led to enhanced keeping quality of bread.

The objective of the present work was to determine the extent of firming differences, if any, in bread made with a group of winter wheat flours having a limited range in protein values. It was also planned to relate any possible differences to commonly measured indices of flour quality. Winter wheat flours were selected for study since they are the type predominantly used by the baking industry in the production of white pan bread. Bread firming was employed as the criterion of keeping quality or staling, for the baking industry continues to recognize the impact of bread firmness on consumer acceptance.

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[2] Alsberg, C. L., Hutchinson, J. B., and Katz, J. R.; quoted in ref. 4, pp. 112-113.

[3] Hutchinson, J. B.; quoted in ref. 2, p. 114.

Materials and Methods

The ten flours used in this study were commercially milled in various parts of the southwest region of the United States. Analytical values for the flours are reported in a subsequent section.

Flour analyses as well as bread moisture contents were conducted by standard procedures (1); starch damage was determined by the Sandstedt and Mattern method (10).

A laboratory sponge-dough procedure simulating, insofar as possible, commercial practice was employed to make the bread. Details of the method have been reported elsewhere by the authors (8). Optimum dough mixing times, absorptions, and dough improver levels were predetermined for each flour.

Bread firmness was measured with a Baker compressimeter (7). Two slices from one end of the loaves were discarded, and compressions to a 5-mm. depression for the next seven sections, each two slices thick, were determined (loaves had total of 19 slices). The loaves, sliced and wrapped in waxed paper, were stored in a room maintained at 73°F. and 50% R.H.

Compressimeter tests were conducted on bread 24 and 70 hours after baking. Duplicate experiments were performed on different days. On each day, two doughs were made with each flour. One loaf from each dough was tested for firmness after 24 hours' storage; the other loaf from each of the two doughs was tested after 70 hours' storage. Thus, 40 doughs (80 loaves) were produced for the present study.

There were five main effects in this experimental design: flour source (fixed effect with ten levels); day of baking (random effect with two levels); time or duration of storage (fixed effect with two levels); dough (random effect nested within flour source and day of baking); and position of slice in the loaf (fixed effect with seven levels).

Specific volumes of the seven central loaf sections, 2 slices thick, were determined by placing the two slices, after they were weighed, in a calibrated plastic container (dimensions 13 by 13.5 by 3.5 cm.) and measuring their rapeseed displacement. A simple calculation then yielded specific volumes of the various loaf sections.

Results and Discussion

Flour Analytical Values and Baking Test Results. Averages of analytical values found for the flours, shown in the first five columns of Table I, are on the whole characteristic of a group of Southwest-milled flours. One flour, however, had a maltose figure of 379 mg.

TABLE I

ANALYTICAL, BAKING, AND COMPRESSIMETER DATA FOR TEN WINTER WHEAT FLOURS

Flour	Flour Analytical Values					Baking Test Results				Baker Compressimeter Results		
	Protein[a]	Ash	Maltose	Amylograph	Starch Damage	Volume	Crumb Score	Proof Time	Loaf Moisture[b]	24-Hour Compression	70-Hour Compression	Average Loaf Firming Rate[c]
	%	%	mg	B U	%	cc		minutes	%	g	g	g/hour
1	12.2	0.45	283	413	7.5	2870	8.2	67.2	36.6	94.2	143.8	1.08
2	12.1	0.47	297	523	8.0	2808	8.1	63.0	36.4	97.4	138.1	0.88
3	12.3	0.47	379	300	8.3	2796	8.0	61.3	36.8	97.4	140.1	0.93
4	12.3	0.44	286	495	7.9	2768	8.3	65.5	36.3	99.5	149.6	1.09
5	12.2	0.44	300	460	8.4	2676	8.2	62.0	36.5	100.4	143.3	0.93
6	12.8	0.43	285	533	7.9	2865	8.1	63.4	36.9	101.6	144.6	0.93
7	12.4	0.43	290	623	8.7	2801	8.0	65.2	36.4	102.3	149.1	1.02
8	12.3	0.48	299	555	7.8	2786	8.0	63.0	36.9	102.3	144.4	0.92
9	11.4	0.45	308	470	8.6	2799	8.2	64.3	36.3	102.3	154.3	1.13
10	12.5	0.45	310	448	7.7	2806	7.8	64.3	36.2	102.6	148.9	1.01
Mean	12.3	0.45	304	482	8.1	2798	8.1	63.9	36.5	100.0	145.6	0.99

[a] Protein and other analytical test results are expressed on a 14% m. b.
[b] Determined 24 hours after baking.
[c] Loaf firming rate between 24- and 70-hour storage.

which was considerably higher than the mean result of 304 mg.; the high maltose figure was undoubtedly due to enzyme activity rather than excessive substrate (starch damage), since the starch damage value, 8.3% for this flour, was virtually identical to the mean of 8.1%, whereas the amylograph reading of 300 B.U. indicated a relatively high alpha-amylase activity compared to the mean value of 482 B.U.

Columns 6 to 9 in Table I present baking data obtained for the ten flours. The range between the highest and lowest loaf volumes was only about 7% of the mean loaf volume. Crumb scores showed only a small variation, as did proof times and loaf moistures.

These analytical and baking data demonstrate that the flours used for this study were typical Southwest-milled flours, exhibiting rather small differences in commonly measured indices of quality. All the flours were used successfully in commercial bread production.

Compressibility Test Measurements. The last three columns in Table I show the compression values of the loaves after 24- and 70-hour storage periods, as well as the average firming rate between these time intervals.

At the end of 24 hours, the range in compression values was 8.4 g.; after 70 hours' storage, there was a spread of 16.2 g. compression. Besides differing in absolute values, the data show that the flours did not possess the same rank in compression after 24 and 70 hours' storage, which may be taken as positive evidence of changing rates of firming for the breads made with the ten flours.

These data indicate no clear relationship between firming and flour protein values. For example, of the five flours having the highest firming rates, three had protein values greater than the mean value. Differences in flour other than protein content evidently have a bearing on the firming properties of bread made with the flour.

The significance of the compression data was tested by a variance-ratio test after analysis of variance, with results as shown in Table II.

TABLE II
STATISTICAL ANALYSIS OF CRUMB COMPRESSIBILITY DATA

Source of Variation	Degrees of Freedom	Mean Squares	F Values
Flour	9	828	14.8**
Day	1	4,247	75.8**
Time (of testing)	1	282,512	5044.7**
Position (of test slices)	6	7,309	130.5**
Dough	20	264	4.7**
Flour × day	9	288	5.1**
Flour × time	9	429	7.7**
Flour × position	54	50	0.9
Day × time	1	140	2.5
Day × position	6	126	2.3*
Time × position	6	97	1.7
Residual	437	56	
Total	559		

The first line of data in Table II shows that the flours were significantly different with respect to their influence on loaf firming, under the conditions of our experiment.

A comparison of the two flours showing extreme differences in 70-hour compression and firming rate values, flours 2 and 9, shows that the latter was firmer by 16.2 g. compression than the former. Assuming linear firming rates for these flours, a simple calculation indicates that flour 2 at 70 hours was as soft as flour 9 had been at 56 hours; hence flour 2 had about a 14-hour softness advantage at the end of the 70 hours. A 14-hour softness advantage in bread 3 days old is of considerable commercial importance. Since the flours selected for the present study represent a rather narrow sampling, bread firming differences due to flours commercially used in various parts of the country may be even wider than these results indicate.

Table II also points up significant variation in compression due to the position of the test slices in the loaves. In other words, compression values within loaves was not constant. The manner in which the compression varied within the loaves is shown in Fig. 1. The points on this curve represent compression averages for all the loaves

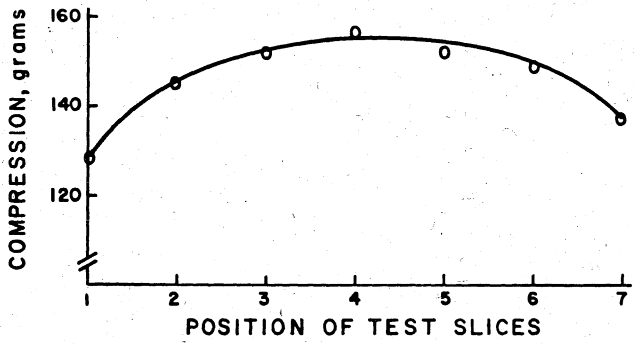

Fig. 1. Variation in crumb compressibility within the loaves. The first two slices from one end of each loaf were discarded; the firmness of the next seven two-slice sections was measured. The position of these sections, beginning with an arbitrarily selected end, forms the abscissa of this plot. Compression values are averages of all the loaves produced for this study.

tested, and show that the ends of the loaves were less firm than the center portion. Some commercial bread, made by both conventional and continuous processes, has been shown in our laboratory to exhibit similar compression variations.

Platt and Powers (7) suggested that firming differences within loaves might be due to moulding; dough ends were said to be less tightly moulded than dough centers. This explanation does not appear to be plausible, since we, as noted above, have found continuous-process bread also to show systematic variation in intraloaf firming.

An investigation conducted in our laboratory indicated intraloaf firming variation to be most likely a function of specific volume. Nine doughs were made employing a commercial flour milled from a blend of spring and winter wheats (12.1% protein, 0.44% ash on 14% m.b.). After 4 days' storage, the compression values and specific volumes of slices comprising the seven positions or sections were determined (one loaf from each of nine doughs for compression, the other set of nine loaves for specific volume). The average results are plotted in Fig. 2.

The correlation coefficient for these two factors was 0.93**, significant at the 0.1% level. This correlation is evidence that the observed variation in crumb compression is a function of specific volume. More dough appears to be concentrated in the center of bread pans than in the ends, with the apparent result that the dough at the ends expands to a relatively greater extent and ultimately exhibits less compression. These data emphasize the need for exercising great care in selecting portions of loaves for staling tests; more

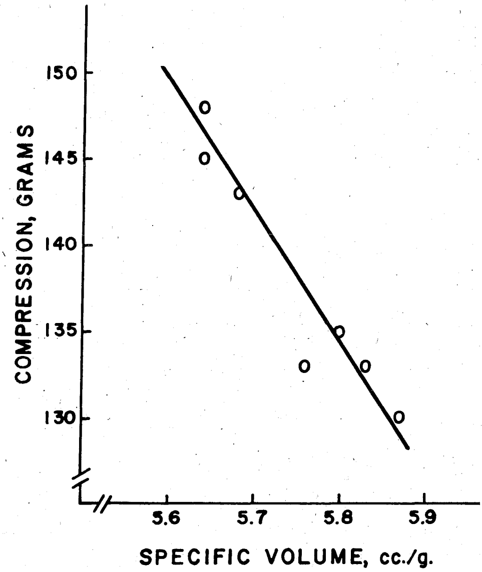

Fig. 2. Effect of specific volume on compression values of seven two-slice sections within bread (r = 0.93**).

variation could be encountered within loaves as a result of improper sampling than between loaves representing different treatments.

Correlation of Compression Results with Indices of Flour Quality. Since the flours made bread different in crumb firmness upon storage, a preliminary investigation was made on relationships between firmness and indices of flour quality. An electronic computer was available for this purpose; hence it was decided to calculate all possible correlation coefficients among firming, flour analytical values (protein, ash, maltose, amylograph curve height, starch damage) and test-bake results (loaf volume, dough absorption, mixing time, proof time, 24-hour loaf moisture).

Most of the correlations were quite low. They are all, nonetheless, presented in Table III as a matter of general interest and to allow inspection of patterns or trends among the variables.

The single correlation involving crumb firmness that exceeded significance at the 5% level was that between average loaf firming and proof time (r = 0.75*). These data are plotted in Fig. 3.

Average proof times for the breads made from the ten flours did not vary more than 6 minutes, hence the relationship shown is interesting. The implication that shorter proof time *per se* leads to bread firming at a slower rate should probably be taken with caution, for increased yeast should lead to shorter proof time, and the efficacy of

TABLE III

CORRELATION COEFFICIENTS FOR COMPRESSION, FLOUR ANALYTICAL, AND TEST BAKING DATA

	MALTOSE	AMYLOGRAPH CURVE HEIGHT	STARCH DAMAGE	PROTEIN	ASH	PROOF TIME	LOAF MOISTURE	LOAF VOLUME	MIXING TIME	ABSORPTION
24-hour compression	–0.14	0.54	0.38	0.08	–0.27	0.21	–0.13	–0.25	0.16	0.55
70-hour compression	–0.29	0.28	0.28	–0.34	–0.45	0.48	–0.52	–0.02	0.45	–0.08
Average loaf firming rate	–0.25	–0.05	0.07	–0.48	–0.40	0.75*	–0.55	0.16	0.44	–0.50
Dough absorption	0.35	0.29	0.44	0.39	0.07	–0.57	0.52	–0.04	–0.10	
Mixing time	–0.42	0.59	0.14	–0.20	–0.08	0.63*	–0.50	0.19		
Loaf volume	–0.14	0.02	–0.43	0.22	–0.01	0.48	0.25			
Loaf moisture	0.21	–0.10	–0.16	0.40	0.30	–0.39				
Proof time	–0.63*	0.25	–0.33	–0.06	–0.41					
Ash	0.49	–0.33	–0.24	–0.27						
Protein	–0.12	0.16	–0.38							
Starch damage	0.29	0.17								
Amylograph curve height	–0.73*									

increased yeast to produce less firm bread appears to be questionable. Edelmann *et al.* (5) reported that bread made with 2% yeast was softer than that made with 1% yeast, but 3% yeast seemed to be not much more effective than the 2% level.

Two possible explanations appear for the relationship of proof time and average loaf firming rate. First, gluten quantity or the elusive protein quality factor mentioned by earlier workers may play a part. Thus, more or higher-quality gluten should have superior gas-retention properties which would lead to shorter proof times, as well

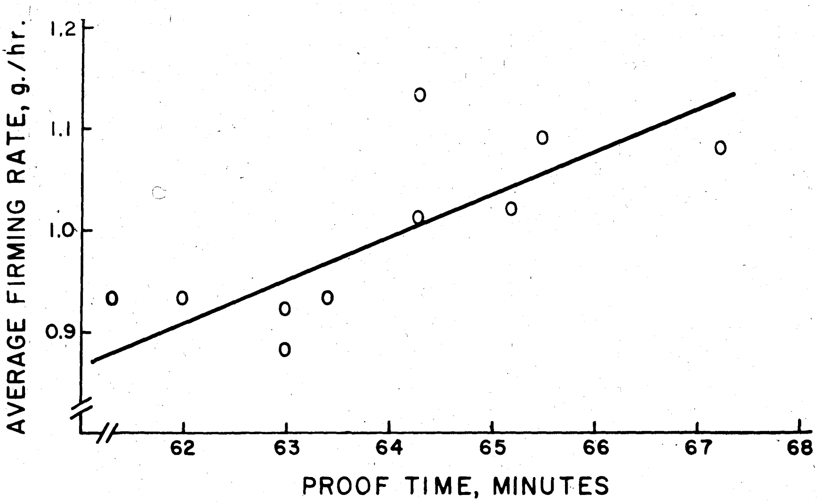

Fig. 3. Effect of proof time on average loaf firming rate (r = 0.75*).

as enhanced keeping quality of bread. Table III shows an inverse relationship between protein content and average loaf firming rate, tending to bear this out. Alternatively, shorter proof times may be a function of enzymatic activity. Increased levels of activity on the part of one or more of the dough enzyme systems might bring about some modification of dough structure such that a more rapid expansion occurs during proofing, concomitantly with a lessening of firmness in the resulting bread crumb. Current investigations in this laboratory may yield information on this point.

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