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Dough Variation and Bread Quality

Emagene Faye Veal
Andrea Mackey

Agricultural Experiment Station
Oregon State University
Corvallis

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AUTHORS: Emagene Faye Veal, formerly Research Assistant and Andrea Mackey, Professor of Foods and Nutrition, Home Economics Research, Oregon State University.

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Introduction

Emphasis in commercial breadmaking is usually on flour quality especially with regard to quantity and quality of gluten. Development of good bread volume and grain depends, however, on many additional factors which are characteristically controlled in commercial baking. Among these are quality of ingredients, a balanced formula, use of flour improvers, optimum mixing time, and optimum fermentation temperature and time.

The theory of bread dough structure has been the subject of much research. Water added to flour to make a dough has special significance. It hydrates the gluten, penetrates the starch, acts as a solvent for sugar and salt, makes gas retention by the dough possible, and allows gluten strands and starch particles to slide on each other during enlargement of the gas cells (9).

Baker (1) has suggested that development of good bread texture depends in part upon uniform distribution during dough mixing of hydrated gluten nuclei contracted around air bubbles. He has suggested that such nuclei seed the dough with well-distributed air bubbles.

Oxidation during dough preparation is important, especially when unbleached flour is used, as shown by Todd, Hawthorn, and Blain (10). A batter process was patented by Rank and Hay (6) in which high speed mixing of part of the flour with all the water improved bread quality probably because of increased access of oxygen.

Conditions which favor bread quality in commercial production may not be best suited for use in the home. For example, a hard wheat flour having the amount and quality of gluten needed for commercial breadmaking may withstand more severe mixing treatment than all-purpose or family-type flour. Optimum conditions of dough temperature and time and speed of mixing are difficult to achieve under conditions of home baking.

This bulletin considers the effect on bread quality of extreme variations in mixing methods and temperatures during dough preparation when all-purpose flour commonly available to the homemaker is used. Such flour has a comparatively low percentage of gluten.

Procedures

Doughs were prepared in different ways. First, the flour-water ratio was varied in the first stages of preparation: (a) all water called for in the bread formula was first mixed with a small amount of flour to make a flour-water batter, 126.5% water based on the weight of flour; (b) all water was first mixed with a medium amount of flour to make a flour-water dough, 84% water based on weight of flour; (c) all water was combined with all flour and other ingredients needed to make a bread dough, 56% water based on the weight of flour. Second, each of the above batters and doughs was mixed until the gluten was developed to maximum at either medium speed or high speed. Third, each of the above variations was mixed at 10°, 25°, or 40° C. The stage of maximum development was selected since this would represent the most uniform wetting of flour for all conditions of flour-water ratio, speed of mixing, and temperature of mixing. Data as to gluten development under these various conditions are reported under results.

After they were developed the flour-water batters and flour-water doughs were combined with other ingredients necessary for bread doughs. Proportion of ingredients in bread doughs prepared by each process was the same. Each dough was then mixed to maximum gluten development.

The experimental design for preparation of the breads was a 3 x 3 x 2 factorial (three temperatures x three doughmaking processes x 2 speeds of mixing) using randomized order of preparation in a split plot (2). Three replications were carried out. The data were analyzed by analysis of variance (8).

Flour used was a blend marketed for family consumption in the northwest. It was made from Montana hard red spring and hard red winter wheats and Washington and Oregon hard white wheats. Protein content was 11.0% and ash, .38%. The other ingredients were compressed yeast, salt, cane sugar, hydrogenated vegetable shortening, and water. A laboratory size KitchenAid Mixer was used, having reported speeds of 180 r.p.m. at a machine setting of 6 and 280 r.p.m. at a machine setting of 10. The mixing blade of this machine revolves with a planetary motion.

The bread formula was as follows: flour, 225 grams; sugar, 6.7 grams; salt, 3.4 grams; shortening, 4.2 grams; yeast, 18 grams; water, 126 ml. The yeast was first liquified with the sugar and salt. These ingredients and the fat were added to the flour-water batter or dough which had been mixed to maximum gluten development. The remaining flour was then added and mixing resumed at 25° C.

until the dough showed maximum development. For preparing the straight dough, the liquified yeast, sugar, and salt together with the shortening were added all at once to the flour and water previously adjusted to one of the desired temperatures, 10°, 25°, or 40° C. Mixing was carried out at that temperature and at medium or high speed until the gluten had reached maximum development. In addition to the experimentally varied bread, a control loaf was prepared each day to serve as a reference for comparison in palatability judging. The dough for this bread was mixed at 25° C. using a modified sponge process.

Bread doughs prepared by each process were fermented, molded, proofed, and baked. Fermentation was carried out at 30° C. Readiness for punching of the fermenting dough was determined by the approximate height of the dough plus a finger tip test for lightness. At the end of the second rising the dough was molded into two 177 gram loaves. The shaped loaves, placed in small tin bread pans, were lightly greased, then proofed as described under fermentation. When the loaf reached a height of $3\frac{1}{8}$ inches it was baked at 401° F. (205° C.) for 30 minutes. Six loaves of bread, each representing one combination of speed and temperature of mixing were scored at one sitting by six judges. Each experimental sample was compared with the control. The scoring range was 1 to 9 with a score of 5 representing equal value, higher than 5 indicating superior quality, and lower than 5 inferior quality as compared with the control. In this way comparisons between experimentally prepared bread and the reference sample were secured for flavor, color of crumb, and factors entering into crumb grain and texture—cell distribution, cell wall thinness, overall appearance, springiness, moistness, and tenderness.

The rate and extent of gluten development were determined by means of viscosity measurements of batters and by observations of physical characteristics of batters and doughs. When the amount of mixing necessary for maximum gluten development was in doubt, as for doughs mixed at 40° C., baking trials were carried out. The amount of mixing that gave loaves of maximum volume in these preliminary trials was used thereafter. Viscosity measurements of the batters included dropping rate of a measured volume of batter from a funnel, volume of the drops, and spreading rate of a measured volume of batter. By means of the Recording Dough Mixer curves were made showing gluten characteristics at mixing temperatures of 10°, 25°, and 40° C. of the all-purpose flour used for this study.

Data were collected on bread dough and baked loaves as follows: mixing time required for maximum gluten development; fermentation and proofing periods; interior temperature of fermenting doughs obtained by means of a Recording Potentiometer; cross section areas of bread as an indication of volume; and scores for palatability characteristics.

Results and Discussion

Gluten development

The rate of gluten development varied under different conditions of temperature, speed of mixing, and flour-water ratio. Each of the following conditions brought about more rapid development: higher proportion of flour to water, higher temperatures during mixing, and faster mixing speed. Data for maximum gluten development are reported in Table 1.

TABLE 1. MIXING TIMES FOR MAXIMUM GLUTEN DEVELOPMENT

Batter or dough identification	Speed of mixing machine setting	Temperature during mixing: 10° C. min.	sec.	25° C. min.	sec.	40° C. min.	sec.
Flour-water batter 126.5% water on flour basis	6	27	37	10	33	8	15
	10	16	40	6	0	4	25
Flour-water dough 84% water on flour basis	6	3	0	2	30	2	0
	10	2	0	1	30	1	0
Straight dough 56% water on flour basis	6	5	0	4	0	2	30
	10	4	0	3	0	2	0

Flour-water ratio: Of the variables studied the flour-water ratio had most effect on the rate of gluten development. The higher the proportion of flour to water the more rapidly maximum gluten development was attained. This was doubtless due to the concentration of the reacting substances. As Hildebrand states, "Another means of increasing the number of favorable collisions between molecules is to increase the concentration of the reacting substances" (4).

The tendency toward rapid gluten development when more flour was present was so great that differences due to temperatures and speed of mixing, though real, were so small as to be of negligible importance in the high flour mixtures, i.e. flour-water doughs having 84% water and straight doughs having 56% water. For the flour-water batters, 126.5% water, both temperature and mixing speed had a pronounced effect on the rate of gluten development, which was slower at lower temperatures and at the slower mixing speed.

Temperature during mixing: Temperatures used affected viscosity of the batters and doughs. Temperature effects are illustrated in the mixogram patterns, Figure 1. At 40° C. viscosity of the dough was so low that very little resistance was offered to mixing. The resulting curve was flat and the width of the line narrow. At 25° C. viscosity was greater as shown by a higher curve, which demonstrated that the dough offered more resistance to mixing. At 10° C. high viscosity of the dough brought about great resistance to mixing and

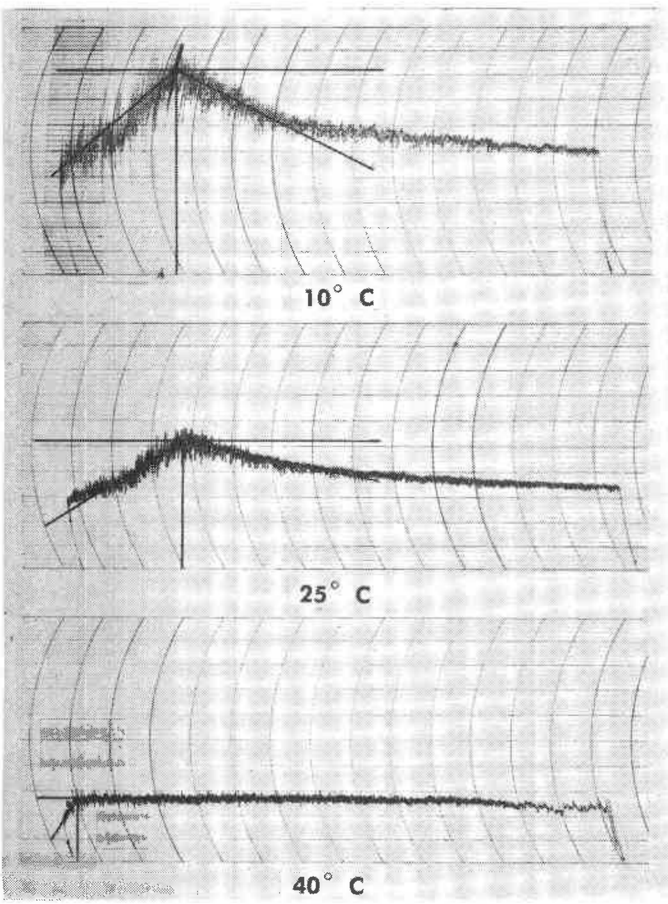

Figure 1. Mixograms made at different temperatures.

the curve was much higher than when mixed at 25° or 40° C. Heights of the mixogram curves were 27, 52, and 80 chart units for 40°, 25°, and 10° C. respectively.

Effect of temperature on gluten development was especially evident for flour-water batters. The rate at which drops of batter flowed through a funnel, used as an indication of viscosity and of gluten development, was expressed as dropping rate in milliliters per 3 minutes. After the initial wetting of the flour, the fewer the number of drops flowing through the funnel in a 3-minute period the greater the viscosity. For example, after 2 minutes of mixing with speed 6 at 25° C., 17 drops of batter totaling 2.3 ml. flowed through the funnel in a 3-minute period. The drop volume was therefore, .13 ml. per drop. After 7 minutes of mixing, the number of drops decreased to 6 totaling 1.3 ml. The drop volume was .21 ml. The larger volume of the drops as well as the slower dropping rate with continued mixing indicated greater viscosity and greater gluten development. At 10° C. a slow gluten development, at 25° C. an

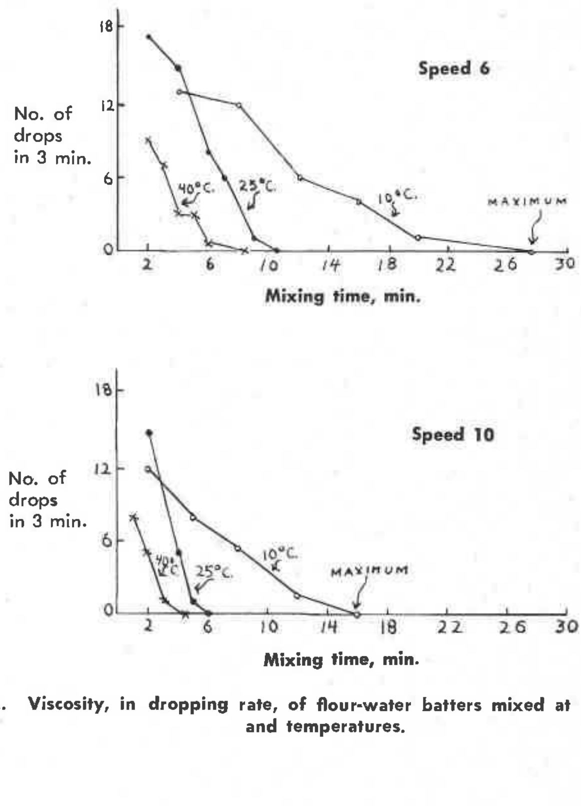

Figure 2. Viscosity, in dropping rate, of flour-water batters mixed at different speeds and temperatures.

intermediate rate of development, and at 40° C. a rapid development were shown by differences in the slope of the dropping rate curve, Figure 2.

Spreading rate, also used as a criterion of gluten development of the batters, showed the same trends as already noted for dropping rate and volume of drops. After an initial increase in spreading rate during which the water was distributed throughout the flour particles, there was a continous decrease in spreading rate with continued mixing of the batters until the point of zero spread was reached. This indicated maximum gluten development. Spreading rate measurements showed that a "breakdown" of the gluten structure occurred with excessive mixing. A decrease in viscosity was shown by a sudden increase in spreading rate with continued mixing after maximum gluten was reached. These effects are shown in Figure 3.

Change in viscosity of the batters was slowest at 10° C. and fastest at 40° C. At the high temperature, rapid increase in vicosity as shown by decrease in dropping rate, increase in size of drops, and de-

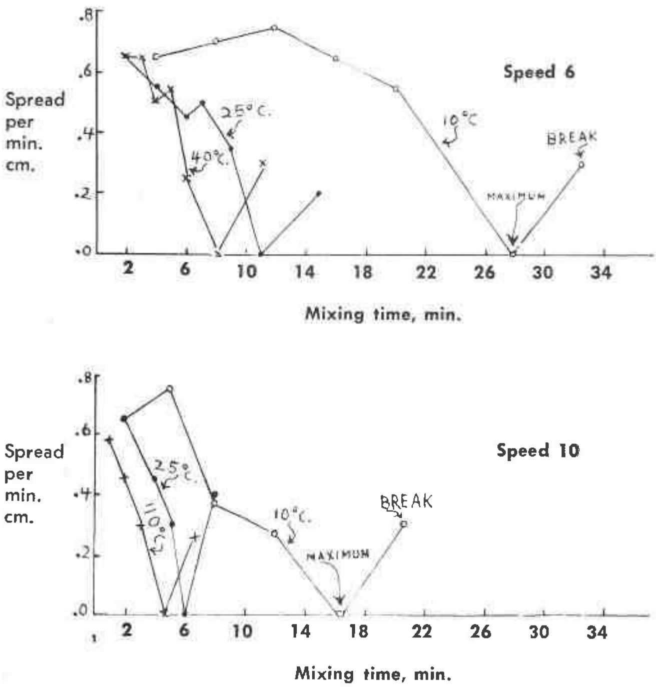

Figure 3. Spreading rate, in cm. per minute, of flour-water batters mixed at different speeds and temperatures.

crease in spreading rate indicated that hydration and bonding of the protein particles proceeded rapidly. This contrasts with slow changes in batters mixed at 10° C.

Temperature effects on mixing time were much more pronounced for batters than for doughs. For example, at speed 6, mixing times required for maximum development at different temperatures fell within 2 minutes of each other for straight doughs, 1 minute of each other for flour-water doughs, and 20 minutes of each other for flour-water batters.

Speed of mixing: Faster mixing speed brought about more rapid gluten development as shown by more rapid decrease in fluidity of flour-water batters and a slightly faster development of the doughs. This took place at each temperature. Hence, in spite of the effect of a high proportion of water in the flour-water batters which inhibited gluten development or the effect of low temperature which increased viscosity, the higher speed of mixing, through increasing the rate of contact between gluten particles, resulted in faster gluten development, Figure 4.

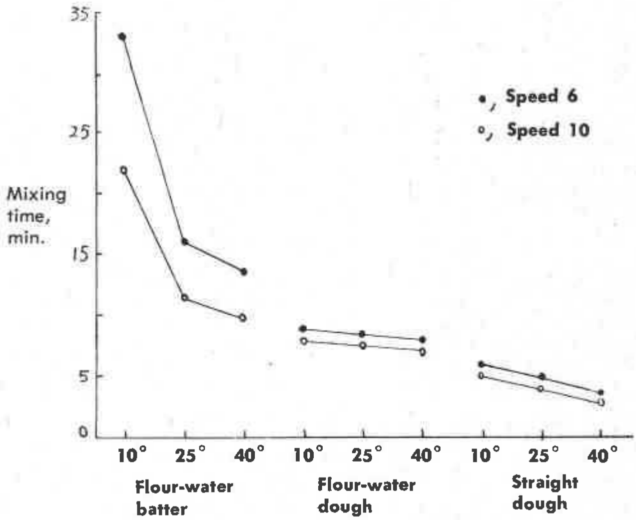

Figure 4. Total mixing time required for gluten development. Times given include preliminary mixing at different speeds and temperatures and final mixing to develop bread dough.

Dough fermentation and proofing

The statement has been made that the time required for a dough to attain correct ripeness will depend upon the quantity of yeast employed and the temperature of the dough (5). Dissolving yeast in cold water will check fermentation while too warm water will have a tendency to decrease the strength of the yeast; 80° F. (26.5° C.) is recommended for dissolving yeast (3).

Temperatures of bread doughs at the beginning of the fermentation periods are given in Table 2. An analysis of variance was computed to determine whether dough temperature at the beginning of fermentation, or the type of dough, i.e. based on flour-water batter, flour-water dough, or straight dough affected the time required for fermentation. Regression of time on temperature was calculated for each type of bread dough. Analysis of variance showed that the regression of time on temperature was highly significant. Thus, time required for each bread dough to ferment was dependent primarily upon temperature of the dough at the start of fermentation. Individual minus overall regression was not significant. This would indicate that regression lines for the different types of dough were parallel. Therefore, speed of rising was not significantly affected by the doughmaking process, i.e. flour-water ratio at the beginning of mixing, Table 3 and Figure 5.

TABLE 2. TEMPERATURE OF BREAD DOUGH AT BEGINNING OF THE FERMENTATION PERIOD

	Speed 6			Speed 10		
Dough process	10° C.	25° C.	40° C.	10° C.	25° C.	40° C.
Flour-water batter	22.5	25.0	26.5	22.5	24.0	25.0
Flour-water dough	20.0	26.0	30.0	19.0	26.0	25.0
Straight dough	17.0	27.0	32.5	16.0	28.5	33.5

Time required for pan proof was controlled by height of dough. In contrast to the effect on fermentation time, time required for proofing was influenced only slightly by the temperature used during the doughmaking process. Since differences in proofing times were small, variations in total time required for fermentation and proofing were largely accounted for by length of the fermentation period. For each type of dough total time required for fermentation and proofing was longest when part or all of the dough had been mixed at 10° C. and shortest when a temperature of 40° C. was employed.

TABLE 3. ANALYSIS OF VARIANCE OF TIME OF FERMENTATION

Source of variance	Degrees of freedom	Mean squares	F.
Regression on temperature, within preparations	3	3707	
Overall regression on temperature	1	3696	175.2**
Individual regressions minus overall regression	2	6.5	
Error	14	21.1	
Total	17		

** Significant at the 1% level.

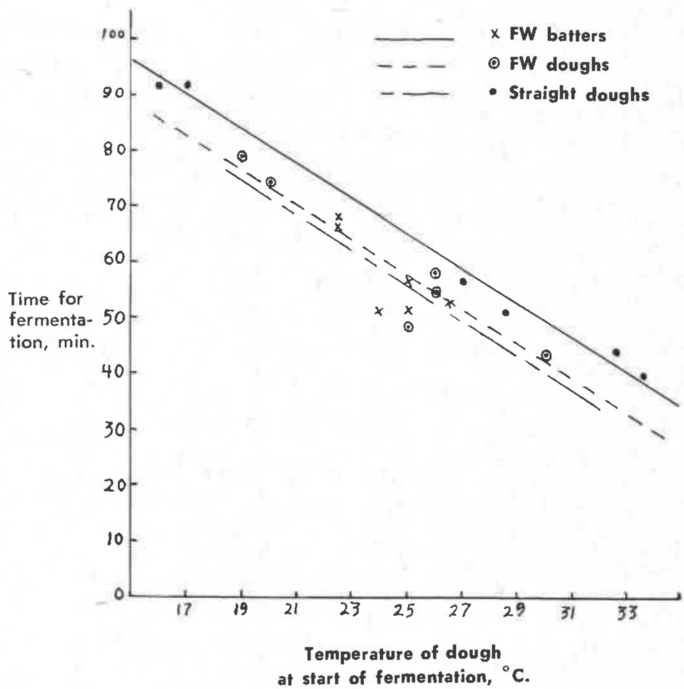

Figure 5. Regression of time on temperature.

Bread quality

Significant differences were found in the finished bread only when there were variations in flour-water ratio during the early stages of mixing, as shown by the analysis of variance for cross-section areas and scores, Table 4. Breads based on flour-water batters had the largest volumes, and these loaves as well as those based on flour-water doughs had better grain than those made by the straight dough method, Figure 6.

TABLE 4. CHARACTERISTICS OF BREAD MADE BY DIFFERENT DOUGHMAKING PROCESSES

	Doughmaking process, means				
	Significance of difference	Flour-water dough	Flour-water batter	Straight dough	Least significant difference ($P = .05$)
Palatability scores					
Color of crumb	*	28.83	29.22[a]	28.00	.94
Overall grain	*	28.72[a]	28.50[a]	25.89	2.29
Cell distribution	*	30.61[a]	28.89	27.61	2.21
Cell wall thinness	**	28.33[b]	29.89[a]	26.17	1.42
Springiness	**	28.39[b]	29.89[a]	27.06	1.31
Moistness	*	29.50[a]	29.72[a]	28.22	1.06
Tenderness	*	29.83	30.67[a]	29.17	1.09
Volumes					
Cross section areas	**	9.20	9.59[a]	9.17	.22

[a] Best.
[b] Intermediate.
* Significant at the 5% level.
** Significant at the 1% level.

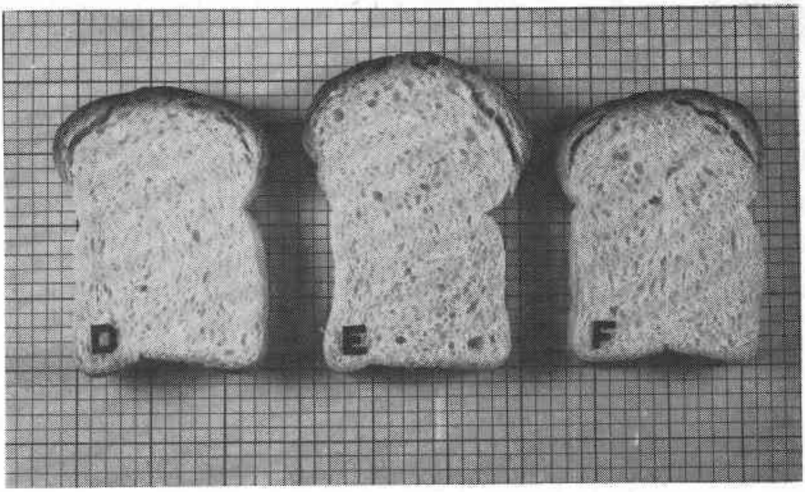

Figure 6. Center slices from loaves based on (D) flour-water dough; (E) flour-water batter; and (F) straight dough.

Any variation in gluten development which may have arisen from speed or temperature differences during mixing must have disappeared during the final stages of breadmaking. It also appears that neither yeast action nor dough quality was impaired by low temperature during preparation of doughs and during part of the fermentation period. For example, straight doughs in spite of the retarded fermentation after mixing at 10° C. gave loaves equal or better in volume and grain than doughs mixed at 25° or 40° C. This was true also for bread prepared from the flour-water doughs mixed at 10° C. Fermentation time was longer, but oven spring and volume of these loaves was equal to or better than others in the same series mixed at higher temperatures.

It is difficult to evaluate separately the effects on mixing time of temperature and flour-water ratio in the first stages of dough preparation. Flour-water batters required longer mixing times because of their dilution. Cold flour-water batters, 10° C., required a longer time than warmer batters to reach maximum gluten development. Hence, temperature and dilution were interrelated in their effect on mixing time.

The high proportion of water together with the prolonged mixing of the flour-water batters might have brought about a change in the per cent of bound water. If so, the finished doughs should have differed from each other in consistency or in fermentation rate. Doughs having a higher per cent of bound water should be somewhat firmer and should ferment more slowly, since, according to reports in the literature, slack doughs rise faster. The fermentation period was found to be but little related to the per cent of water at the beginning of mixing, as demonstrated by the same rate of rising of doughs prepared at the same temperature but with different processes. Further, no differences in consistency due to doughmaking processes were observed in the finished bread doughs. It appears, therefore, that the per cent of bound water in the doughs was the same regardless of flour-water ratio at the start of mixing.

A second possibility to account for larger loaf volumes might be that the longer mixing periods associated with the flour-water batters might have increased the opportunity for development of reducing sugars which would have stimulated yeast action. Skovholt and Bailey (7) have stated that most of the reducing sugars develop in the first few minutes of mixing. Since fermentation time was not appreciably affected, differences in reducing sugar development were probably not important.

The most likely explanation of larger loaf volumes produced by the flour-water batter process, and the better grain of these and the flour-water dough loaves, is an improvement of bread structure due to oxidation during the longer mixing times. It is interesting to note that during mixing of the bread doughs, the flour-water batters blended with the added flour and other ingredients with great ease; the flour-water doughs in turn blended with the dry-flour addition more readily than was the case for the straight-dough process in which the flour and water combined with most difficulty. The water held by the flour-water batter or dough was evidently readily accessible to the protein of the new flour addition. Swanson (9) has stated that less than one fourth of the water in a dough is bound and that approximately 56 ml. of water are needed for 100 grams of flour to form a dough; of this approximately 17 ml. of water would be held in the bound state. Therefore in a flour-water batter containing 200 ml. water and 158 g. flour there would be a high proportion of free water—about 175 ml. When an excess of water is present, the water films on the gluten particles are thick, contacts are loose, and the dough is slack. Because of thick water films and loose contacts, the previously developed gluten network could easily disperse, at the same time releasing excess water to the granules of the added portion of flour used to form a bread dough.

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