A Simple Spread Test to Measure the Rheological Properties of Fermenting Dough[1]

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ABSTRACT

A simple spread test was developed to measure the rheological properties of fermenting dough. The spread ratio is independent of the volume of the dough piece. With no fermentation time, sugar increased the spread ratio apparently by increasing the level of free water in the dough. With normal fermentation times, both yeast and potassium bromate decreased the spread ratio. The effect of yeast was independent of the products produced during fermentation. Thus, yeast appears to affect dough directly. Reducing agents increase and oxidants decrease the spread ratio.

Dough undergoes rheological changes between the mixing and oven stages of baking. Yet few have studied those changes, apparently because of the difficulties in measuring the rheology of a fermenting dough. A number of tests have been used successfully to study the rheology of nonfermenting doughs. Hibberd and Parker (1975), Muller (1975), and Rasper (1975) reviewed tests such as the cone and plate, parallel plate, and extensigraph methods. None of these work satisfactorily for fermenting doughs because of changes in dough geometry during fermentation and the heterogeneous nature of fermented doughs. Furthermore, some of the tests involve applying high external forces to create deformation and thus have limited value in bread making.

Matsumoto et al (1973, 1974, 1975) reasoned that fermenting dough rheology should be studied with different methods than those used for unfermenting doughs. They devised a system to study the internal pressure of dough during fermentation. Justifications were made to correlate the internal pressure with the tension of the gas cell membrane.

We devised a relatively simple spread test to study fermenting doughs and the effects of various baking ingredients on the rheology of fermenting doughs.

MATERIALS AND METHODS

The flour used was a composite of many hard winter wheat varieties grown at many locations. The flour had a 12.3% protein content and 0.42% ash content on a 14% mb. The straight dough formula used was: 100 g of flour (14% mb), with 2 g of yeast, 6 g of sugar, 1.5 g of salt, 1 g of malt (60° L), 4 g of nonfat dry milk, 3 g of shortening, $KBrO_3$ (20 ppm based on flour), and optimum water.

Doughs were mixed to optimum development in a National pin mixer and were allowed 180 min of fermentation, with punching at 105 and 155 min. When shorter fermentation time was used, the punching schedule was not changed (ie, if 155 min of fermentation, punching was at 105 min; if less than 105 min of fermentation, there were no punches).

Spread Test

A mixed dough, after fermentation, was mechanically rounded and the entire dough placed on a smooth plate in a fermentation cabinet (30° C, 90% RH). The width and height of the dough were measured with Mitutoyo dial calipers (VWR Scientific) at 15-min intervals for 60 min (Fig. 1). The spread ratio was calculated as width over height with higher values indicating more spread. At least duplicate samples were run for each treatment. Standard deviations were calculated to be 0.112 for 0 min of fermentation and 0.0433 for 180 min of fermentation.

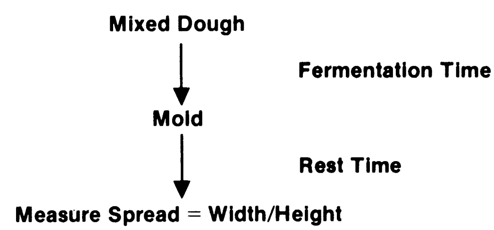

Fig. 1. Experimental scheme.

RESULTS AND DISCUSSION

Three major forces act on the fermenting dough piece: gravity, pressure, and cohesion. The weight of the dough exerts a force vertically downward, and gravity is the major force component responsible for flow. Pressure resulting from gas expansion is exerted at every part of a dough; as a result, the dough expands equally in all directions to increase its volume. The cohesive forces within the dough resist expansion and limit flow. These three forces act separately but simultaneously during fermentation.

Figure 2 shows the spread vs. rest time of a full formula dough system with fermentation time as a parameter. Without fermentation, the spread ratio increased tremendously with the rest time. As the fermentation period was lengthened, the degree of spread was reduced, and the increase in spread ratio with the rest time became less apparent. After 180-min fermentation, the spread ratio remains almost constant throughout the 60-min rest period. Fermentation transforms the dough from a highly mobile system to one of no spread.

The effects of ingredients on the spread ratio of a fermenting dough were studied by eliminating the ingredients, one at a time, from the original formula, and measuring the spread ratio at the end of the 60-min rest period after both 0 and 180 min of fermentation (Table 1). At zero fermentation, sugar was the only ingredient that had a major effect on the spread ratio of the dough. The spread ratio was reduced when sugar was not present in the dough because sugar competes with gluten for the available water. With the sugar removed, more water is bound to gluten and a less mobile system is created. With 180 min of fermentation, the data showed that yeast and bromate are the two ingredients responsible for the rheological changes. The effect of yeast was particularly

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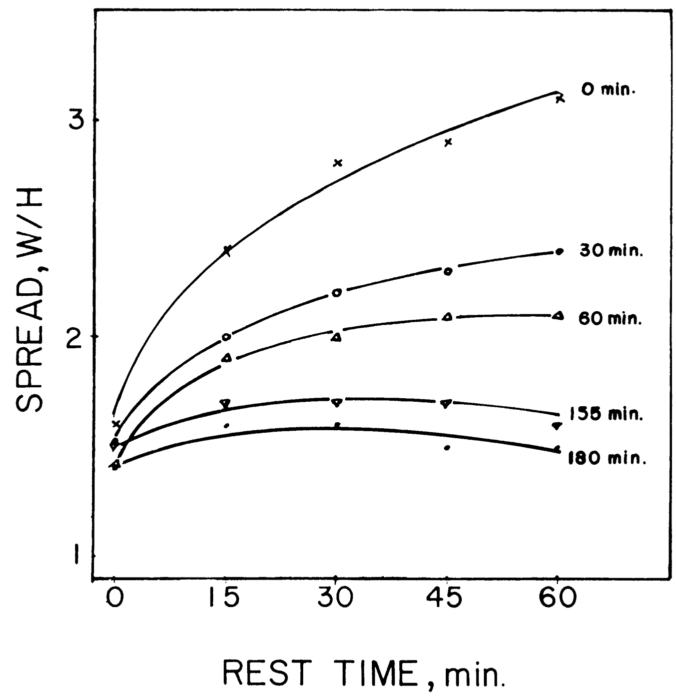

Fig. 2. Spread ratio vs. rest time with fermentation time as the parameter.

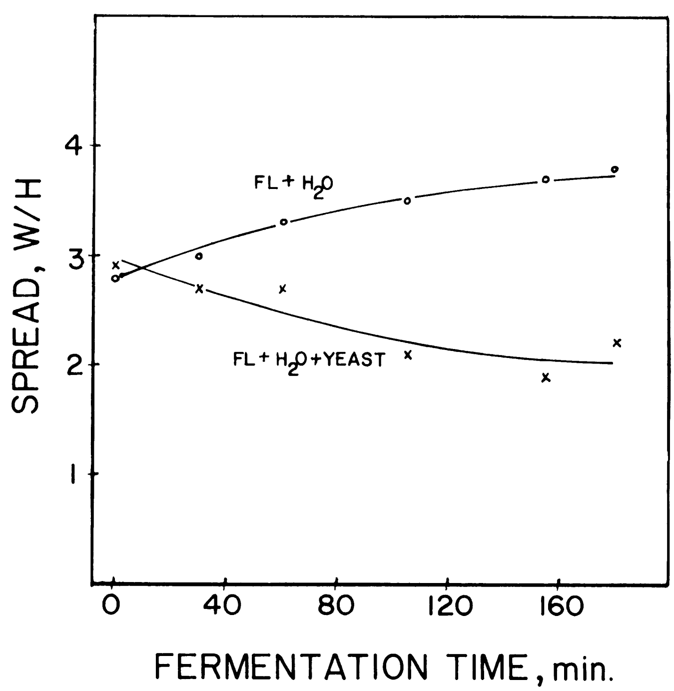

Fig. 3. Effect of yeast on the spread ratio of a fermenting dough.

TABLE I
Effects of Baking Ingredients on the Spread Property of Dough

	Spread–W/H, Fermentation	
Ingredient	**0 min**	**180 min**
Control	3.0	1.5
Sugar	2.4	1.5
Salt	2.8	1.6
Nonfat dry milk	3.1	1.5
$KBrO_3$	2.9	1.7
Yeast	3.0	2.5
Shortening	2.8	1.5
Malt	2.8	1.5

noticeable, for without yeast, the system remained highly mobile. That the effect is a function of yeast and not fermentation is shown by the dough without sugar. Even though fermentation was much less, the spread ratio was equal to the control. This also shows that the spread ratio does not depend on the volume of the dough piece. The action of yeast also can be shown in a simple flour and water system (Fig. 3).

If yeast and bromate were the only ingredients responsible for the rheological changes during fermentation, the same changes should occur in any system containing these two ingredients and in the full formula system. This was proved in a system containing only flour, water, yeast, and bromate (Fig. 4). After 180-min fermentation, the spread ratio of the simplified system was reduced to a level equal to that of the full formula system. The rheological changes, however, took place more rapidly in a full formula system than in the simplified system.

The effects of other additives were studied using the spread test. Table II shows the action of cysteine, glutathione, and azodicarbonamide (ADA) in dough systems with and without yeast. Cysteine and glutathione are known reducing agents that make dough more slack and extensible. In our spread test, those additives gave spread ratios higher than those for the controls. ADA, on the other hand, is a fast-acting oxidant that strengthens the dough. In our spread test, this was shown by a reduced spread ratio.

TABLE II
Effects of Certain Additives on the Spread Ratio of Dough

	Spread–W/H, Fermentation	
Additive	**0 min**	**180 min**
Nonyeasted dough control		
(flour-H_2O)	2.8	3.8
Cysteine (15 ppm)	3.1	4.0
Glutathione (30 ppm)	3.2	4.0
Azodicarbonamide (20 ppm)	2.0	1.9
Yeasted dough control	2.9	2.2
Cysteine (15 ppm)	3.2	2.4
Glutathione (30 ppm)	3.3	2.6
Azodicarbonamide (20 ppm)	2.0	1.5

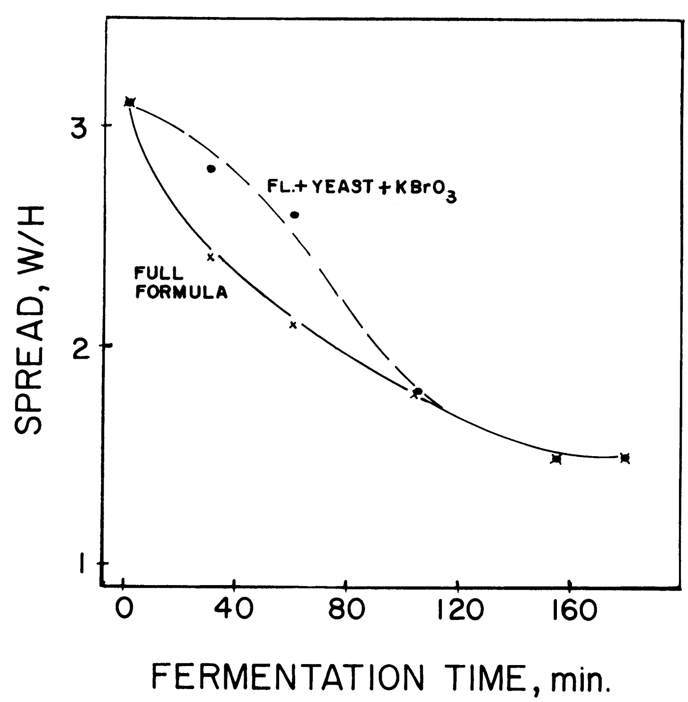

Fig. 4. Rheology change of a flour-yeast-bromate dough vs. the full formula dough.

TABLE III
Effects of Preferment and Chelating Agents on the Spread Ratio of Dough

Treatment	Spread–W/H, Fermentation	
	0 min	180 min
Flour-$KBrO_3$-H_2O	2.5	2.5
+ Preferment	2.5	1.8
+ Citric Buffer	2.4	1.9
+ EDTA (5,000 ppm)	2.9	1.8

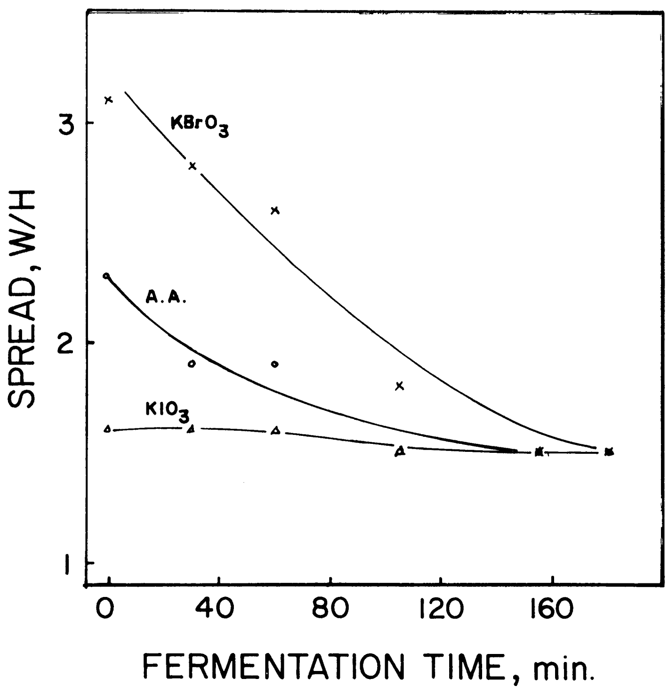

Fig. 5. Actions of different oxidants as measured by the spread test.

A simple flour-water-yeast-oxidant system was used to study other oxidant systems (Fig. 5). The action of potassium bromate is believed to be pH dependent. Thus, the effectiveness of potassium bromate should increase as the fermentation time increases. A gradual decrease in spread ratio with fermentation time was observed for samples containing potassium bromate. Potassium iodate was a fast-acting oxidant; therefore, its effect was evident at the beginning of fermentation. The effect of ascorbic acid was between those of potassium bromate and potassium iodate. These studies with oxidizing and reducing agents proved to us that the spread test is a sensitive tool to study the rheological changes during fermentation.

Yeast was the major ingredient contributing to rheological changes in a fermenting dough. It was not clear, however, whether the yeast was acting directly on the dough or indirectly by its fermentation products to produce the rheological changes. A liquid ferment system (Ling and Hoseney 1977) was used to differentiate those possibilities. Yeast, with nutrients in a buffered solution, was fermented for 3 hr at 30°C. After fermentation, the yeast was separated from the fermentation broth by centrifugation. The fermentation broth (preferment), which contains the fermentation products, was used in the spread test studies (Table III). If fermentation products changed the rheological properties, the spread ratio should have been decreased at zero fermentation time. The data did not show such an immediate drop; therefore, the rheological changes in fermenting dough apparently were caused by other enzyme systems in yeast. The enzymes were from yeast because no decrease in the spread ratio was found for the flour-water-bromate system.

With 180-min fermentation, the spread ratio was reduced for samples containing the preferment (Table III). However, essentially the same result was obtained by adding the citric buffer to a flour-water-bromate dough. Citric acid is a known chelating agent, and EDTA had a similar effect. These results agree with Hlynka's observation (1957) that chelating agents enhance the action of potassium bromate in dough.

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