SHORT-TIME BAKING SYSTEMS. I. INTERDEPENDENCE OF YEAST CONCENTRATION, FERMENTATION TIME, PROOF TIME, AND OXIDATION REQUIREMENT[1]

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ABSTRACT

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Balancing formulas for short-time baking systems led to the conclusion that yeast concentration, fermentation time, proof time, and oxidation requirement are interdependent. Breads produced with fermentation times of 120, 70, or 45 min were comparable to those made with a standard 180 min of fermentation. The only required formula changes included increases in yeast concentration and oxidant ($KBrO_3$) and decreases in proof time. Changes in other ingredients gave inferior (nonoptimum) results. When fermentation time was decreased from 180 to 70 min, required yeast concentration increased by a factor of 3.6 from 2 to 7.2%, $KBrO_3$ requirement increased by a factor of 3, and proof time (about 30% of fermentation time) decreased from 55 to 21.5 min. Optimum breads produced with fermentation times of 70, 120, or 180 min were equal in loaf volume, internal and external appearances, and flavor. Gas production was a function of fermentation time and yeast concentration, and remained constant for any balanced, optimized system.

In some commercial bread processes that allow little or no fermentation time, yeast concentration generally is increased to about 3%. Most workers agree that the yeast level and fermentation time are inversely related in achieving proper dough development and that yeast concentrations above 4% do not produce quality bread because gluten does not develop properly and an undesirable yeast flavor remains in the bread (1, 2).

In most short-time processes, relatively more oxidant (generally KIO_3:$KBrO_3$ or azodicarbonamide:$KBrO_3$ mixtures) is used than in regular processes. Breads produced by short-time procedures are not conventional, and some regard them as inferior. The high-speed mixing used in most short-time processes is generally accepted to replace part or all of the fermentation requirement, but no firm evidence supports that contention (3).

Reported here are factors necessary to produce optimum bread within a relatively short fermentation time.

MATERIALS AND METHODS

Flour Samples

An experimentally milled hard winter wheat flour composite (RBS-73A), a hard spring wheat flour composite (SWS-72), and a commercially milled hard winter wheat flour were used as standards. In addition, three hard winter wheats ('Gage,' 'Winoka,' and 'Shawnee') and two hard spring wheats ('Chris' and 'Red

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River 68') grown in 1971 at Garden City and Presho, S. Dak., were selected for ranges in protein contents, mixing times and other physical dough properties, and oxidation requirements.

Baking Test

Formula water, mixing time, and potassium bromate were optimized in the straight-dough bread-baking procedure (4). The formula included 100 g flour (14% mb), 1.5 g NaCl, 6 g sucrose, 3 g shortening, 4 g nonfat milk solids, 0.75 g malted wheat flour with 120 SKB α-amylase units per g (30° C), and 2 g yeast (5). Doughs were punched after 105 and 155 min and panned after 180 min of fermentation. Proof time was 55 min and loaves were baked 24 min at 218°C. Loaves were weighed as they came from the oven, and volumes were determined by dwarf rapeseed displacement.

Gassing Power

Gassing powers on 10 g flour were determined at 30°C with a gauge-type pressure meter (National Mfg., Lincoln, Nebr.). All baking ingredients, except yeast, were combined and brought to temperature in a water bath. Then yeast was dispensed at 2-min intervals and the doughs mixed by hand for about 1 min. Doughs had normal consistencies and contained amounts of formula water used in breadmaking.

Other Tests

Flour protein, moisture, and ash contents were determined by standard AACC methods (6). Mixograms were made on the 10-g mixograph as described by Finney and Shogren (7). Breadmaking absorptions (normal consistencies) were used.

RESULTS AND DISCUSSION

Preliminary studies suggested that balancing formulas for fermentation times

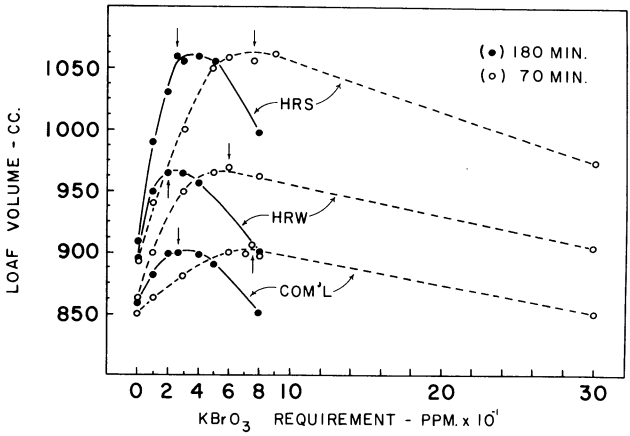

Fig. 1. Loaf volumes and $KBrO_3$ requirements for the three standard flours with 180 (•) and 70 (o) min of fermentation. Arrows denote $KBrO_3$ required for optimum internal and external loaf characteristics.

below 70 min would be difficult. Thus, in early stages of this study, we decided to start with 70 min of fermentation.

Formulation for 70-min Fermentation

With fermentation time at 70 min, yeast levels varied from 2 to 10%; 2% was optimum for 180 min of fermentation. As yeast concentration was increased above 7.2%, doughs became progressively stiff and bucky, and the breads appeared overdeveloped. As yeast concentration was decreased below 7.2%, doughs and breads became progressively underdeveloped. Concentrations of sugar, salt, and malted wheat flour were varied with the 70-min fermentation time (7.2% yeast). However, no changes in amounts of those ingredients were required to produce breads comparable to those obtained by the standard procedure.

Punchings after 105 and 155 min of fermentation (180 min total) were decreased to 40 and 60 min, respectively; proof time also required a proportionate decrease from 55 to 21.5 min. Deviating from those times altered the internal or external appearance of the loaves. When yeast was increased from

TABLE I
Chemical, Physical, and Baking (180 *vs.* 70 min Fermentation) Data for Flours of Hard Winter and Hard Spring Wheat Varieties Harvested at Garden City and Presho, S. Dak. in 1971[a]

Location and Sample	Protein %	H_2O abs %	Mix Time min	$KBrO_3$ 180 min ppm	$KBrO_3$ 70 min ppm	Loaf Volume 180 min cc	Loaf Volume 70 min cc
Garden City, S. Dak.							
Gage, W[b]	11.8	62.6	2-1/2	25	75	917	912
Winoka, W	10.8	61.7	4-3/4	20	60	915	912
Shawnee, W	11.6	67.1	3-3/4	20	60	987	995
Chris, S	12.4	69.2	4	30	90	960	972
Red River 68, S	11.6	63.2	7	0[c]	10	903	925
Red River 68[d]	11.6	63.2	3-3/4	10	30	997	999
Presho, S. Dak.							
Gage	15.1	68.0	4	25	75	1117	1118
Winoka	14.4	67.9	5-3/8	25	75	1109	1130
Shawnee	14.7	70.6	5	15	45	1126	1132
Chris	16.8	69.6	3-5/8	25	75	1219	1195
Red River 68	15.6	70.0	14	0[e]	...	1010	...
Red River 68[f]	15.6	70.0	5	10	30	1175	1200
Standard composites							
Commercial, W	11.8	66.0	3-3/4	25	75	900	910
RBS-73A, W	12.7	66.8	4	20	60	968	973
SWS-72, S	13.9	67.1	3-1/2	25	75	1060	1055

[a]Data expressed on a 14% mb.
[b]W and S, abbreviations for hard winter and hard spring wheats, respectively.
[c]Bread appeared overoxidized the equivalent of at least 10 ppm of potassium bromate.
[d]60 ppm cysteine · HCl added before mixing.
[e]Bread appeared overoxidized the equivalent of at least 20 ppm of potassium bromate.
[f]120 ppm cysteine · HCl added before mixing.

2 to 7.2%, baking absorption for normal dough consistency remained constant and mixing time increased only 1/8 min.

When fermentation times of 180 min (2% yeast) and 70 min (7.2% yeast) were applied to the three standard flours, and potassium bromate was varied (Fig. 1), 70 min of fermentation required three times as much $KBrO_3$ as 180 min. Loaves for the two fermentation times were indistinguishable by volume, internal or external appearance, and flavor.

Wheat Variety Testing with 70-min Fermentation

Because the three standard flours gave comparable breads with both 180- and 70-min fermentation times, we studied applicability of the 70-min fermentation time for wheat quality research and variety testing.

When the 70-min fermentation time was applied to three hard winter and two hard spring wheat varieties, grown at two locations, bread loaf volumes and other loaf characteristics were fully equal to those for 180 min (Table I). Subjective tests indicated that keeping quality of the 70-min bread was equal to that fermented for 180 min. Flour protein contents of samples from Presho were 3.1 to 4.4% greater than those from Garden City. Mixograms (Fig. 2) illustrate the wide variation in mixing and other physical dough properties of the varieties studied. The potassium bromate requirement increased by a factor of 3.0, and yeast concentration by a factor of 3.6 when fermentation time was decreased from 180 to 70 min.

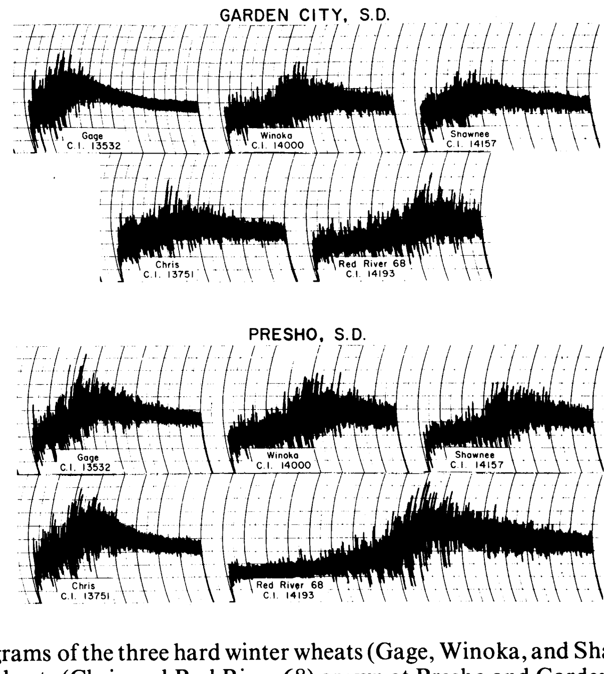

Fig. 2. Mixograms of the three hard winter wheats (Gage, Winoka, and Shawnee) and two hard spring wheats (Chris and Red River 68) grown at Presho and Garden City, S. Dak., in 1971.

Yeast Concentration *vs.* Fermentation Time

After yeast concentrations were established for fermentation times of 180 and 70 min, times of 120 and 45 min were studied. Breads comparable to those produced with the standard 180-min fermentation time were obtained for 3.5% yeast and 120 min and for 12% yeast and 45 min. The 12% yeast and 45-min fermentation time produced optimum loaf volume and other external properties, but the crumb grain was slightly brownish, the crumb was noticeably wet, and the flavor was bitter or yeast-like. The general relationship of yeast concentration and fermentation time for optimum bread is summarized by Fig. 3. Fermentation times appreciably less than 70 min require undesirably large amounts of yeast. The baking formulas remained the same for all fermentation times given in Fig. 3, except for $KBrO_3$ requirement.

Fermentation Time *vs.* $KBrO_3$ Requirement

Plotting (Fig. 4) $KBrO_3$ requirements and corresponding fermentation times for all flours (Table I) established the general relation between those two factors. The $KBrO_3$ requirements of the commercial flour for 180, 120, 70, and 45 min fermentation times were 20, 30, 60, and 120 ppm, respectively (Fig. 4, bold curve). As fermentation time decreased, $KBrO_3$ requirement increased. Specifically, each flour's $KBrO_3$ requirement increased by a factor of 1.5 for 120 min of fermentation, 3.0 for 70 min, and 6.0 for 45 min of fermentation. That flours vary in $KBrO_3$ requirement when using 180 min of fermentation is well established (4). Each 5 ppm of bromate at 180 min of fermentation was equivalent to 7.5 ppm at 120 min, 15 ppm at 70 min, and 30 ppm at 45 min (after extrapolation). Related hyperbolic curves for different flours indicated that as $KBrO_3$ requirement approached zero for 180 min of fermentation, it also approached zero for any fermentation time between 180 and 45 min.

Both Red River 68 flours appeared "gluten-bound" (a critical lack of extensibility) to various degrees. Neither flour exhibited a bromate requirement with 180-min fermentation time. However, once the "gluten-bound" character was eliminated by 60 and 120 ppm of cysteine hydrochloride (Table I), the bromate requirements for the 180- and 70-min systems were 10 and 30 ppm, respectively.

Gassing Power

Observations of the dough size suggested that the total gas retained at punchings during fermentation was constant, even though total fermentation time varied (see Fig. 3 for corresponding variations in yeast). Those observations, together with the equality of bread properties, including crust color, suggested that total gas production remained constant as fermentation time varied.

Gassing power data were obtained for 2, 7.2, and 12% yeast concentrations (Fig. 5). During the baking procedure, 8 min of fermentation takes place between the times when ingredients are added and dough mixing ends. A line drawn vertically to the x-axis at 188 (180 + 8) min fermentation intersects the 2% yeast curve at 350 gassing units. Nearly identical gassing power values were produced at 53 (45 + 8) and 78 (70 + 8) min fermentations. Thus, the fermentation activity of the three yeast systems was essentially constant.

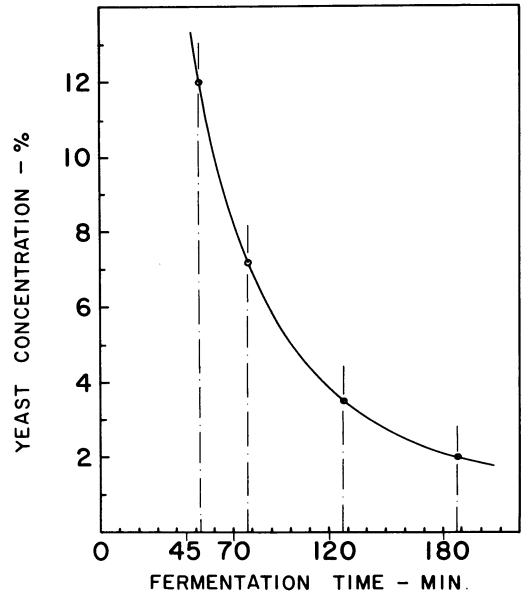

Fig. 3. Yeast concentrations and fermentation times required to produce optimum breads with the standard commercial flour.

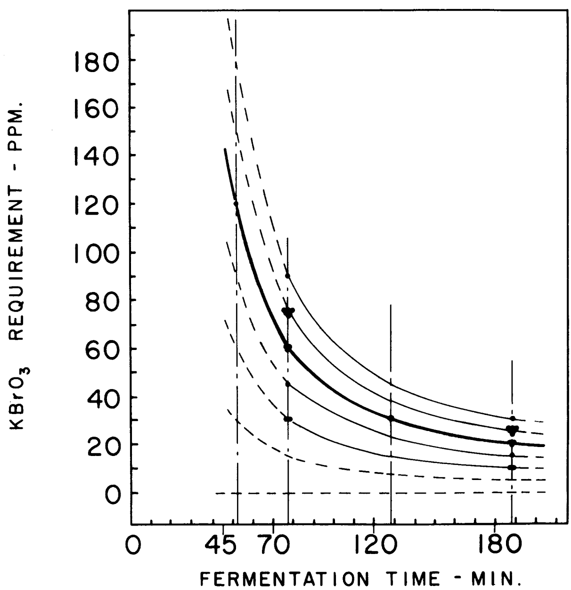

Fig. 4. $KBrO_3$ requirements and fermentation times required to produce optimum breads for all flours in Table I. See corresponding yeast concentrations in Fig. 3.

Proof Time *vs*. Fermentation Time

Proof time for the 70-min fermentation time was 21.5 min. As proof times were increased beyond 21.5 min, loaves appeared overproofed, and had shell tops or double breaks. Proofing for less than 21.5 min gave low volume and an underdeveloped appearance. Optimum proof times for 120- and 45-min fermentation times were 36.5 and 12 min, respectively. See corresponding yeast concentrations in Fig. 3 and corresponding bromate requirements in Fig. 4.

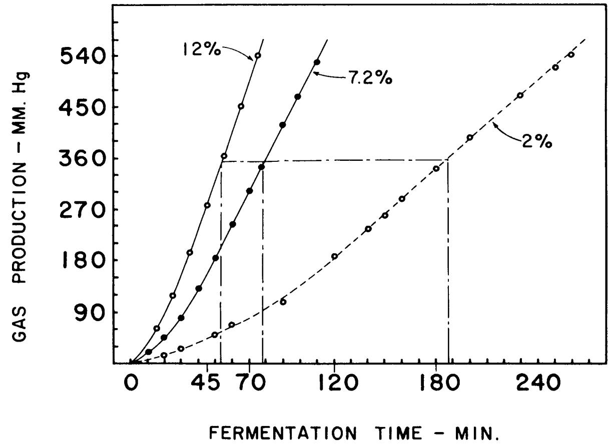

Fig. 5. Gas production for 2, 7.2, and 12% yeast concentrations related to fermentation times.

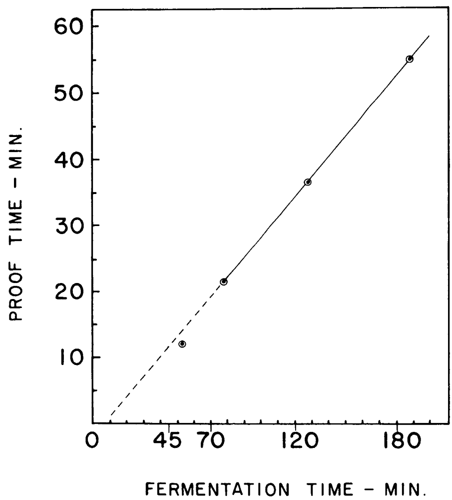

Fig. 6. Proof and fermentation times for optimum bread. See corresponding yeast concentrations in Fig. 3 and corresponding bromate requirements in Fig. 4.

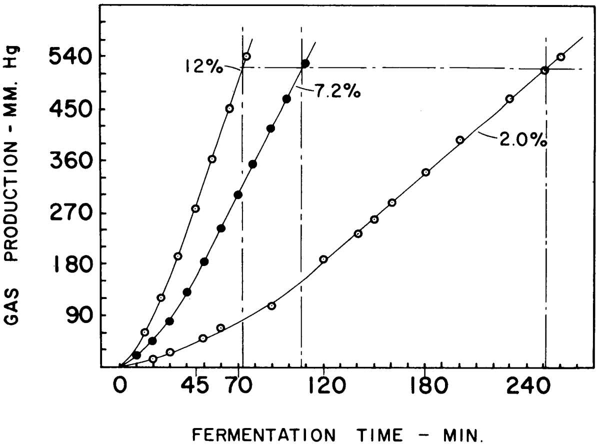

Fig. 7. Gas production for 2, 7.2, and 12% yeast related to total fermentation times (measured 8 min before mixing ends until 8 min after baking begins).

Those proof times established a general relationship of fermentation time to optimum proof time (Fig. 6). Proof time decreased in proportion to the decrease in fermentation time from 180 to 70 min. At 45-min fermentation, a proof time of 12 min (rather than 13.75 min as the broken part of the regression line suggests) was optimum for 12% yeast.

Fermentation activity begins when the yeast and sugar solutions come into contact 8 min before mixing is completed and ends a few min after the dough is placed in the oven, or as soon as the oven temperature inactivates the yeast. We estimate the time for inactivation to be about 8 min for the pup doughs baked at 218°C. When 16 min was added to each of the fermentation times studied, and those sums were added to the respective proof times used, the total fermentation times of the systems studied were 251, 107.5 and 73 min instead of 180, 70, and 45 min. Taking the gassing power data (Fig. 5) and drawing (Fig. 7) a line parallel to the x-axis to intersect the 2% yeast curve at 251 min of fermentation, we note that the line intersects the 7.2 and 12% yeast curves at about 107.5 and 73 min, respectively, the identical total fermentation times used in baking.

Acknowledgment

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