SHORT-TIME BAKING SYSTEMS. II. A 70-MIN SUGAR-FREE FORMULA FOR CONVENTIONAL AND HIGH-PROTEIN BREADS[1]

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ABSTRACT

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Bread of high volume and lacy, well-structured crumb grain was made with a sugar-free formula (no added sugar), a 70-min fermentation time, and a straight-dough-batch procedure. With no sugar in the formula, a lag phase occurred in gas production. Lag time varied with source and potency (batch) of yeast. Lag-time differences within and between yeasts were equalized in terms of end-product by proofing to height. When fermentation time was decreased from 180 to 70 min, the requirement for malt decreased 50%, and for $KBrO_3$ it increased 200%. When nonfat dry milk was omitted from the formula, $KBrO_3$ requirement was reduced 50%. Adding 50 to 100 ppm ascorbic acid decreased $KBrO_3$ requirement by two-thirds. A low level of $KBrO_3$ in combination with a relatively high level (excess) of ascorbic acid effectively optimized loaf volume and crumb grain of bread. In the 70-min sugar-free formula, 84 g of wheat flour carried 16 g of high-protein supplements of high biological value and produced bread that had good volume and crumb grain and about 50% more protein than that made with wheat flour alone. Sucrose palmitate, shortening, sodium stearoyl-2-lactylate (SSL), and a combination of shortening and SSL were compared in the bread formula.

The use of cereal malts in breadmaking to increase gas production and improve bread characteristics is commonly accepted (1). For conventional straight-dough methods (180-min fermentation time), optimum amounts of cereal malts were used to replace added sucrose and to hydrolyze starch into fermentable sugars (2). Recently, that sugar-free formula (no added sugar) was used to make superior high-protein breads by substituting a high level of soy flour for wheat flour (3). Finney *et al.* (4) have demonstrated that optimum bread can be produced by use of a short fermentation time and a high level (7–8%) of yeast in a sugar formula. The next step was to use a short fermentation time and a sugar-free formula to produce conventional and protein-fortified breads in about 50% of the usual straight-dough processing time.

Reported here are experimental data that contribute to the science of making optimum bread with no added sugar (sugar-free formula), a short (70-min) fermentation time, and a straight-dough-batch procedure.

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MATERIALS AND METHODS

Wheat Flour

Wheat flour (CS-73A) was a composite of hard winter flours experimentally milled from many wheat varieties grown throughout the Great Plains in 1973. CS-73A had a protein content of 12.4% (14% mb), excellent loaf volume potential, and a medium mixing time of 4 min. The flour was supplemented with about 0.15% of malted barley flour (about 50 DU/g, 20°C) during milling.

Soy Flour

A defatted soy flour (Ardex 550, furnished by Archer-Daniels-Midland Co.) had a protein content of 48.7% (N × 6.25, 14% mb).

Baking Test

Mixing time, water absorption, and oxidation ($KBrO_3$) or a combination of $KBrO_3$:ascorbic acid) were optimum. Values greater or less than optimum are reflected in lower loaf volume and at least somewhat poorer crumb grain and external loaf characteristics than those for optimum values. Additional ingredients were 1.5 g salt, 3 g shortening, 4 g nonfat dry milk (NFDM), 7.2 g compressed yeast, and 0.75 g malted barley flour (about 50 DU/g, 20°C), except for formula variations indicated in the tables; 0.75 g malt contains about 0.075 g sugar. In high-protein breads, soy flour and NFDM replaced equal portions of

TABLE I
Effect of $KBrO_3$ Alone and in Combination with Ascorbic Acid on Loaf Volume and Crumb Grain of Bread Made by the 70-min Sugar-Free Method (100% CS-73A Wheat Flour + 4% NFDM)

$KBrO_3$ ppm	Ascorbic Acid ppm	Loaf Vol[a] cc	Crumb Grain[b]
0	0	773	Uu
30	0	925	Su
60	0	1010	S
0	100	871	Su
10	100	955	Su
20	100	1011	VS
30	100	1015	VSo
20	50	1011	VS
20	100	1011	VS
20	150	1010	VS
0	0	773	Uu
0	100	871	Su
0	200	885	Su
0	400	875	Su

[a]Average proof height, 7.75 cm.

[b]S = Satisfactory, VS = very satisfactory, U = unsatisfactory, o = overoxidized, u = underoxidized. Over or underoxidized appearance of crumb grain does not nullify the relative lightness and uniformity of a VS crumb grain.

wheat flour to give a total of 100 g (14% mb). Doughs were punched after 40 and 60 min, and panned after 70 min of fermentation. Loaves were proofed to heights indicated in the tables and baked 24 min at 218°C. Loaves were weighed as they came from the oven, and volumes were determined by dwarf rapeseed displacement. Baking data are averages of at least two determinations. Loaf volume differences of 20 cc are significant at P = 0.05.

Gassing Power

Gassing powers on 10 g of flour were determined with gauge-type pressure meters (National Mfg. Co., Lincoln, Nebr.). All baking ingredients, except yeast,

TABLE II
Effect of $KBrO_3$ Alone and in Combination with Ascorbic Acid on Loaf Volume and Crumb Grain of Bread Made by the 70-min Sugar-Free Method (100% CS-73A Wheat Flour, NFDM Omitted)

$KBrO_3$ ppm	Ascorbic Acid ppm	Loaf Vol[a] cc	Crumb Grain[b]
20	0	958	VSu
25	0	997	VS
30	0	1006	VS
40	0	985	VSo
0	100	961	VSu
5	100	983	VS
10	100	1000	VS
20	100	989	VSo

[a]Average proof height, 7.75 cm.
[b]VS = Very satisfactory, o = overoxidized, u = underoxidized. Over- or underoxidized appearance of crumb grain does not nullify the relative lightness and uniformity of a VS crumb grain.

TABLE III
Effect of Yeast Variation on Proof Time and Loaf Volume of Bread Made by the 70-min Sugar-Free Method (100% CS-73A Wheat Flour + 4 g NFDM)

Yeast Brand	Date Received	Proof Time[a] min	Loaf Vol cc
Anheuser-Busch	12-11-74	42	1020
AB-Composite	4-10-75 4- 3-75 3-27-75	50	1001
Red Star	12-11-74	33	1015
RS-Composite	4- 2-75 3-26-75 3-19-75	37	1015

[a]Average proof height, 7.75 cm.

were combined and brought to 30° C in a water bath. Then yeast was dispensed at 2-min intervals; each dough was mixed by hand for about 1 min. Doughs had normal consistencies and contained amounts of formula water used in breadmaking. Gassing values are averages of duplicate determinations.

Other Tests

Flour protein, moisture, and ash contents were determined by AACC Approved Methods (5).

RESULTS AND DISCUSSION

Sugar-Free Formulation

When malt was varied from 0 to 2.5% in the 100% wheat-flour (100% WF) formula, 1.5 and 0.75% malt, respectively, were required for 180- and 70-min fermentation times, to obtain optimum volume and crumb grain. When wheat flour was replaced with 10% soy flour (no milk added), 2.0 and 1.0% malt, respectively, were required for 180- and 70-min fermentation times. Bromate requirement increased from 20 ppm for 180 min fermentation time to 60 ppm for 70 min.

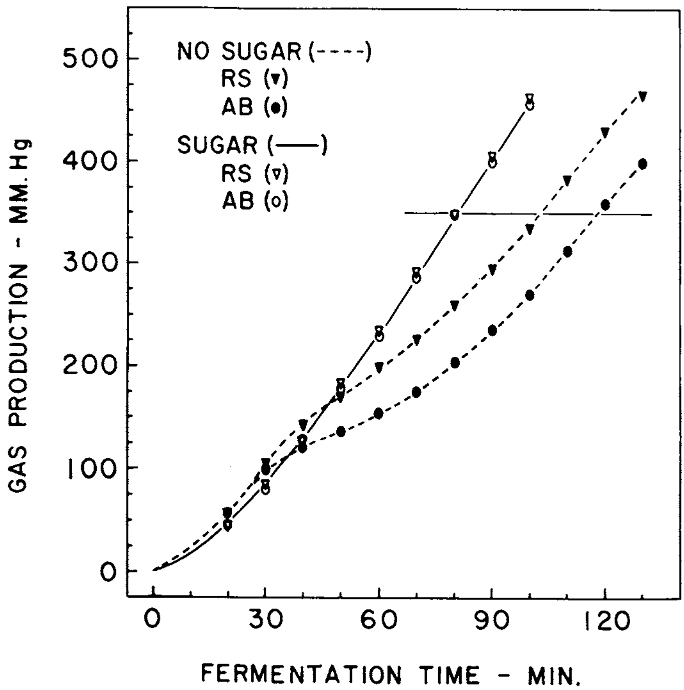

Fig. 1. Gas production for the 70-min sugar and sugar-free formulations after 20 to 130 min of fermentation with two composite brands of yeast, Red Star (RS) and Anheuser-Busch (AB).

For the 100% WF, sugar-free formula, bromate required was 60 ppm (Table I), malt was optimum (0.75%), and proof height was 7.7–7.8 cm; bromate was the same as for a 100% WF, sugar formula (4). When NFDM was omitted from the formula, $KBrO_3$ requirement was reduced 50% (Table II). Adding 50 to 100 ppm ascorbic acid to the formula, with or without NFDM, reduced $KBrO_3$ requirement by two-thirds (Tables I and II). Optimum combinations of bromate and ascorbic acid for the milk and no-milk formulas included a low level of bromate and a relatively high level (excess) of ascorbic acid (6). Loaves of bread were indistinguishable in volume, internal or external appearance, and flavor from those baked after a 180-min fermentation time (100% WF, sugar-free formula).

Yeast Variability

Red Star (RS) and Anheuser-Busch (AB) yeasts received each week were tested in a sugar-free formula. Lag time (associated with yeast adaptation from originally present fermentable sugars of flour to maltose produced enzymatically from starch) varied, depending on yeast potency within and between brands. As a result of the variations in yeast, the proof times varied from 33 to 50 min (Table III). Variability within either RS or AB yeast was associated with the manufacture of the yeast. Doughs with RS consistently proofed 9 to 13 min shorter than those with AB yeast. To minimize the effect of variability within a brand of yeast during baking, two or three batches were composited.

Gassing Power

Observation of dough size for the 70-min sugar-free method indicated that gas retained at second punch and pan was not equal to that for the 70-min sugar method (4). Gassing-power determinations (Fig. 1) for the 70-min sugar and sugar-free formulations were made on two composite samples of yeast, RS and AB. After 30 min of fermentation for the sugar-free formulation, fermentation rate of AB decreased for about 10 min, then gradually increased for the next 60 min (100 min total fermentation), and thereafter remained about constant through 130 min. Fermentation rate of RS, however, did not decrease until after

TABLE IV
Effect of Varying Fermentation Time of Red Star and Anheuser-Busch Yeasts on Proof Time, Loaf Volume, and Bread Crumb Grain (Sugar-Free Formula and 100% CS-73A Wheat Flour + 4 g NFDM)

Yeast Brand	Fermentation Time min	Proof Time[a] min	Loaf Vol cc	Crumb Grain[b]
Anheuser-Busch	70(40-20-10)[c]	50	1000	S
	85(49-24-12)	44	1004	S
Red Star	70(40-20-10)	39	1008	S
	55(32-15-8)	45	982	S

[a]Average proof height, 7.75 cm.
[b]S = Satisfactory.
[c]40-20-10 refers to proportioned time (min) to first punch, second punch, and pan.

about 40 min of fermentation; then, after about 50 min, the rate gradually increased for the next 50 min, thereafter remaining constant. The decrease in fermentation rate for about 10 min after 30 to 40 min of fermentation created a significant lag in total fermentation not characteristic of the sugar formula. A line drawn perpendicular to the y-axis at 350 gassing units (Fig. 1) intersects the RS and AB sugar curve at about 80 min, the RS sugar-free curve at 103 min (lag time = 103 − 80 = 23 min), and the AB sugar-free curve at 118 min (lag time = 118 − 80 = 38 min). Lag time of AB yeast composite was 15 min greater than that of RS (118 − 103). When those yeast composites were compared by the sugar-free 70-min baking method, the 15-min greater lag time increased proof time by 11 min (Table IV). However, when 15 min of fermentation time was proportionately added to doughs containing AB yeast and subtracted from doughs containing

TABLE V
Loaf Volumes and Bread Crumb Grains when Fermentation Times of 70 and 180 min Were Used with the Sugar-Free Formula Containing 100% CS-73A Wheat Flour, NFDM Omitted, and Indicated Levels of Sucrose Palmitate or Shortening

		70 min		180 min	
Sucrose Palmitate %	Shortening %	Loaf Vol[a] cc	Crumb grain[b]	Loaf Vol cc	Crumb Grain
0	3	1000	S	1000	S
0	0	830	Q	813	Q
0.3	0	966	S	974	S
0.4	0	987	VS	982	VS
0.5	0	1007	VS	1008	VS
0.6	0	988	VS	988	VS

[a]Average proof height, 7.75 cm.
[b]S = Satisfactory, VS = very satisfactory, Q = questionable.

TABLE VI
Loaf Volumes and Bread-Crumb Grains when Fermentation Times of 70 and 180 min Were Used with the Sugar-Free Formula Containing CS-73A Wheat-Flour (90%) and Soy-Flour (10%) Blends and Indicated Levels of Sucrose Palmitate or Shortening (NFDM Omitted)

		70 min		180 min	
Sucrose Palmitate %	Shortening %	Loaf Vol[a] cc	Crumb Grain[b]	Loaf Vol cc	Crumb Grain
0	3	917	Q	898	Q
0	0	755	U	730	U
0.3	0	953	Q–S	965	Q–S
0.4	0	967	S	970	S
0.5	0	979	S	984	S
0.6	0	977	S	965	S

[a]Average proof height, 7.75 cm.
[b]S = Satisfactory, Q = questionable. U = unsatisfactory, Q–S = questionable to satisfactory.

RS yeast, proof times of the two yeasts were essentially equal. Increasing fermentation time of AB yeast by 15 min decreased proof time 6 min; and decreasing fermentation time of RS yeast by 15 min increased proof time 6 min. Although internal and external characteristics of the loaves were indistinguishable and volumes essentially equal, the RS yeast fermented for 55 min and proofed 45 min gave a somewhat lower loaf volume (982 cc) than when fermented for 70 min and proofed 39 min. Thus, variations in lag time were effectively compensated for by adjusting proof time for a predetermined proof height.

Deliveries of yeast used in this study do not necessarily represent a normal

TABLE VII
Effect of Shortening and/or Sodium Stearoyl-2-Lactylate (SSL) on Loaf Volume and Crumb Grain of Bread Made from 100% Wheat Flour and from Wheat- and Soy-Flour Blends by a 70-min Sugar-Free Method (NFDM Omitted)

Wheat Flour/Soy Flour %	SSL %	Shortening %	Loaf Vol cc	Crumb Grain[a]
100/0	0	0	830	Q
100/0	0	3	1000	S
100/0	0.25	0	971	VS
100/0	0.25	3	1010	VS
90/10	0	0	755	U
90/10	0	3	917	Q
90/10	0.50	0	940[b]	VS
90/10	0.50	3	980[b]	VS

[a]S = Satisfactory, VS = very satisfactory, Q = questionable, U = unsatisfactory.
[b]Average proof height of doughs containing soy flour increased from 7.75 to 8.15 cm.

TABLE VIII
Effect of 10 to 14% Soy Flour, with and without NFDM, on Loaf Volume and Crumb Grain of Bread Made by the 70-min Sugar-Free Method [3% Shortening + 0.50% Sodium Stearoyl-2-Lactylate (SSL)]

Wheat Flour %	Soy Flour %	NFDM %	Loaf Vol[a] cc	Crumb Grain[b]
100	0	0	1010[c]	VS
90	10	0	980	VS
86	10	4	961	VS
88	12	0	938	S
84	12	4	900	S
86	14	0	875	Q–S
82	14	4	830	Q–S

[a]Average proof height of doughs containing soy flour increased from 7.75 to 8.15 cm.
[b]S = Satisfactory, VS = very satisfactory, Q–S = questionable to satisfactory.
[c]0.25% SSL instead of 0.50%.

statistical sampling; hence, variations in lag time or proof time within and between the two good brands of yeast (AB and RS) do not imply that one is superior to the other.

High-Protein Formulations

When 3% shortening was replaced with 0.5% sucrose palmitate (180 min fermentation), optimum loaf volume and crumb grain of bread made with wheat flour (Table V) were maintained and loaf volume and crumb grain of bread made with wheat- and soy-flour blends (Table VI) were materially improved. Decreasing fermentation time from 180 to 70 min (Tables V and VI) did not change the optimum level of sucrose palmitate (0.5%), which thus remained unchanged for two formulations and two fermentation times. Optimum proof height (7.7–7.8 cm) also remained unchanged for the 70-min method.

Combinations of sodium stearoyl-2-lactylate (SSL, optimum) and shortening (3%) produced both optimum loaf volume and crumb grain of bread made with either wheat flour alone or wheat- and soy-flour blends (Table VII). In the

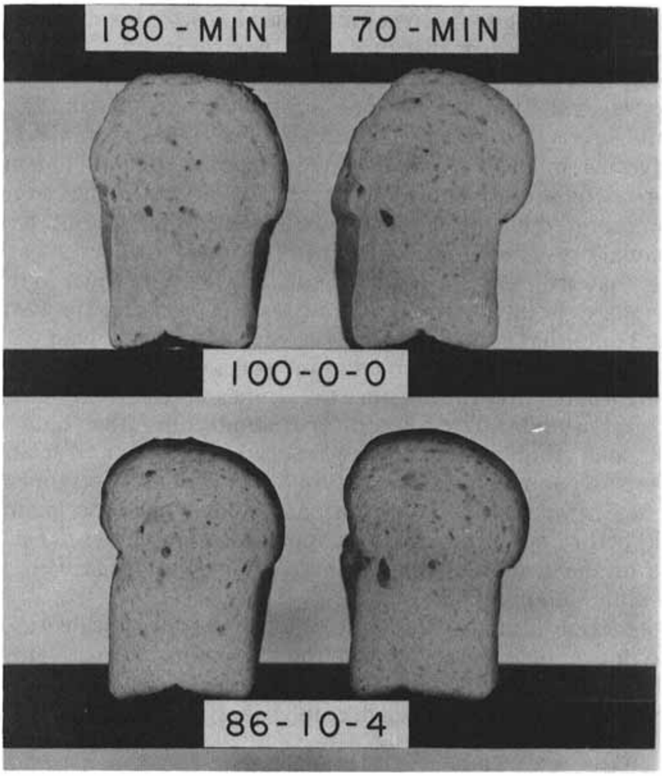

Fig. 2. Typical breads made from doughs (sugar omitted) fermented for 70 and 180 min and containing 100% wheat flour alone and a blend of 86% wheat flour, 10% soy flour, and 4% nonfat dry milk.

formula containing 3% shortening, 0.5% SSL, and wheat- and soy-flour blends, proof height was increased to 8.15 cm to maintain the volume level for 0.5 g sucrose palmitate (Table VI).

With the formula containing 90 g of wheat flour, 10 g of soy flour, and no NFDM (Table VIII, 90:10:0), bread had very satisfactory loaf volume and crumb grain. Those superior loaf characteristics were essentially maintained even when 4 g of NFDM was included (86:10:4). However, when the 4 g of NFDM was replaced with 4 g of soy flour (86:14:0), loaf volume and crumb grain were distinctly inferior to those for 86:10:4. Thus, 10 to 12% soy flour is the practical maximum amount that can be carried by the wheat flour. Replacing 16 g of wheat flour with 12 g of soy flour and 4 g of NFDM (84:12:4) gave a satisfactory (S) crumb grain and loaf volume (900 cc, Table VIII). Thus, 84 g of wheat flour carried 16 g of high-protein supplements of high biological value, and the bread contained 50% more protein than that made from 100 g of wheat flour. Typical breads (Fig. 2) were made from doughs fermented for 70 and 180 min and containing 100% wheat flour alone and a blend of 86% wheat flour, 10% soy flour, and 4% NFDM.

Special Considerations

It is well known that European countries need little or no added sugar in their conventional bread formulas, because often their flours have exceptionally high diastatic activities. High rainfall or high humidity during and after ripening of wheat encourages the initial phases of germination, so that the flours contain relatively high levels of starch hydrolyzing enzymes (amylases). Generally, bread wheats harvested in the U.S. and Canada require added sugar in the bread formula for adequate fermentation. Those facts do not reveal any of the new information reported in this or previously related studies on how to make good or conventional breads with sugar-free formulations (no added sugar) from U.S. wheat flours that ordinarily (by popular concepts) require sugar in the formula.

As previously pointed out, the purpose of our study was to report experimental data that contribute to the science of making bread with no added sugar and a short (70-min) fermentation time when using a conventional, straight-dough-batch procedure. Since the studies were carried out under highly replicable and standardized laboratory conditions, the data speak for themselves, and should require no special claims or disclaimers. Past improvements in commercial baking technology probably were made first on a laboratory scale. Small-scale laboratory and pilot-plant experiments generally are the rule before new technology is applied on a commercial scale. It is the prerogative of the reader to think either positively or negatively about new, laboratory-scale baking data.

Because a straight-dough-batch process on a laboratory scale was used in our studies, we make no inferences that the data apply directly to the highly automated, continuous-dough process. In the U.S., about 60% of bread is made by the batch process. With the present emphasis on more nutritious and specialty breads, that percentage is likely to increase.

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