An Optimized, Straight-Dough, Bread-Making Method After 44 Years

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ABSTRACT

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An analytical, optimized, straight-dough, experimental bread-making method was described by Finney and Barmore in 1939 and 1941 for the manifestation of loaf-volume and crumb-grain potentials and other functional properties. Its application to the evaluation of many varieties of wheat harvested from four to five crop years was later published by them. That test is as practical and useful today as it was when first described more than 43 years ago. In recent years, however, several modifications of the bread-making method have increased its versatility, simplified its formula, and increased its potential precision. For example, ascorbic acid, for the most part, effectively replaces potassium bromate; and because ascorbic acid is its own buffer against overoxidation, nonfat dry milk or defatted soy flour, such as Ardex 550, is no longer needed in the bread-making formula. The optimized bread-making method now includes formulas that either contain sugar or do not contain sugar. Optimized breads are made when fermentation times vary from 70 to 180 min, either with or without sugar in the formula. The method includes proofing to time only after the appropriate proof height has been established. Those relatively recent modifications are integrated into the optimized bread-making method.

Bread-making research was initiated in 1938 at the Hard Winter Wheat Quality Laboratory. By then, numerous workers had demonstrated that hard winter wheat flours require bromate, but there was a decided lack of information as to the requirements of individual varieties. Similarly, the need for malt syrup or malted wheat flour had been demonstrated, but the response to either ingredient, to nonfat dry milk, and to potassium bromate, singly and in various combinations with the other generally accepted basic ingredients, had not been studied. It was desirable to determine their role in displaying flour potentialities, one or more of which often remained hidden in the routine testing of experimentally milled flours of different wheat varieties. Accordingly, one of the first tasks undertaken at the Hard Winter Wheat Laboratory was to study the response of nonfat dry milk (NFDM), diastatic malt, and potassium bromate when added singly and in combination with six basic bread-making ingredients, and to study the responses of several types of wheat varieties to certain ingredients and techniques used in breadmaking. In that way, we determined which formulas and procedures were capable of accurately characterizing and evaluating new varieties for use as bread flours. Those studies and many supporting techniques and related research published since the early 1940s are integrated at this time with recent modifications of the optimized bread-making method to give increased versatility, a simplified formula, and increased precision.

EARLY STUDY OF BAKING METHODS AND RELATED FACTORS

Six Basic Formula Ingredients

Flour and water were necessary to form a dough, although the water requirement varied with the flour protein content and the variety. Yeast was necessary to ferment sugars into carbon dioxide and ethyl alcohol. Added sugar, in the absence of α-amylase, was required to maintain adequate fermentation. Sodium chloride, the fifth ingredient, was needed for flavor and for increased gas retention. The loaf volume response, optimized at 1.5–1.75% salt (Fig. 1), was 113 cc for an average flour composite that contained 12.7% protein. Shortening, the sixth basic ingredient, was added to increase gas retention and thereby improve crumb grain and loaf volume. The loaf volume response to 3% shortening (Fig. 2), which was optimal, was 129 cc for an average flour composite that contained 12.8% protein. Loaf volume remained constant for 3–7.5% shortening. The responses to both 1.5% salt and 3% shortening generally increase as the quality or quantity of protein increases.

Effects of NFDM, Diastatic Malt, and Potassium Bromate

An analytical, optimized, straight-dough bread-making method for 100 g of flour was described by Finney and Barmore at the AACC Annual Meetings in 1939 and 1941 for the manifestation of loaf-volume and crumb-grain potentials and other functional properties. Its application to the evaluation of many varieties of wheat harvested from five crop years was later published by them (1945a, 1945b). As an example of their studies (Fig. 3), 0.25 g of malt, 4 g of NFDM, and 1 mg of $KBrO_3$ each generally produced a volume response relative to the six basic formula ingredients (with optimum absorption and mixing). Malt and NFDM together increased loaf volume more than the sum of the individual responses. The responses of malt and potassium bromate were usually additive. Those of NFDM and potassium bromate usually were not additive, however, because NFDM buffered the oxidative effects of bromate.

When baked with the basic (B) formula, loaf volume of the soft red winter wheat (SRW, extrapolate to B) with only 8.2% protein probably was equal to or greater than those of all other varieties, except for the hard red spring wheat Thatcher (Tc), even though flour protein content was 4–7.5 percentage points greater than that

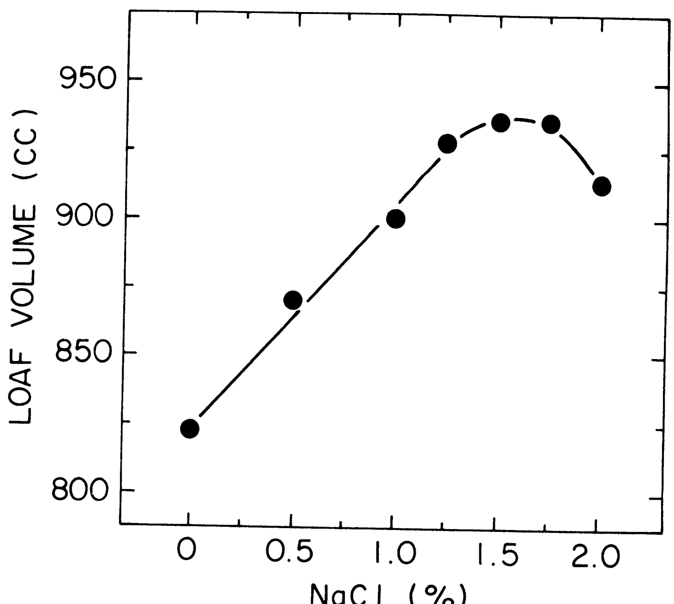

Fig. 1. Bread-volume response to varying amounts of sodium chloride in the formula containing 100 g of flour (14% mb), optimum water, 2 g of compressed yeast, 6 g of sucrose, 3 g of shortening, 4 g of NFDM, 0.25 g of diastatic malt, and optimum $KBrO_3$.

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of the SRW. With the formula containing NFDM, malt, and optimum bromate, loaf volume differentiation was increased from about 100 to about 650 cc. Similarly, with formula B, 4, ¼, 1, the high- and medium-protein Chiefkan flours and the SRW flour produced equal volumes, although they contained 15.2, 12.2, and 8.2% protein, respectively. With optimum potassium bromate, those large protein differences were logically and accurately expressed. The data offer striking examples of how insufficient amounts of potassium bromate can result in an erroneous and completely illogical evaluation of varieties that have equal loaf volume potentialities. For example, the varieties Nebred and Pawnee appeared inferior to Thatcher in volume potential when only 10 ppm of bromate was used in the formula. With bromate levels suitable for each, Nebred was superior to and Pawnee equal to Thatcher. Bromate requirements varied from 0 to 10 ppm for the SRW to 50–60 ppm for the high-protein Chiefkan flour. The data demonstrate why the relationship for loaf volume and flour protein content of hard winter wheats was not linear before the late 1930s.

Supporting Techniques and Studies

The merits of the comparatively rich formula containing milk, malt, and varying amounts of bromate were largely dependent on other studies reported by Finney (1945, 1946), Finney and Barmore (1939, 1943, 1944, 1945a, 1945b, 1948), Finney et al (1949, 1950), and Finney and Fryer (1958). Those studies attested to the accuracy and usefulness of the formula in obtaining an accurate expression of inherent properties and potentialities. The studies concerning optimum vs fixed mixing time (Finney and Barmore 1945b) explained the conflicting results previously reported by others for overmixed dough. Our data clearly demonstrated that overmixing is deleterious. If the dough is not sufficiently oxidized, however, the effects may be obscured by the beneficial effects of the much-needed additional oxidation provided by the overmixing. Regardless of oxidation level, undermixing produced lower loaf volume and poorer bread than a flour was capable of producing. In a study on the effects of under- and overmixing of optimally oxidized doughs of eight hard winter wheat varieties that varied in mixing requirement from 2 to 5 min, a fixed 2 min (Fig. 4) was optimum for the three flours that required 2 min, but the flour that required 5 min was undermixed 3 min. When a fixed 5 min was employed, all flours were overmixed to varying degrees, except for the one requiring 5 min. Thus, loaf volume decreased with increasing amounts of under- or overmixing.

Studies concerning yeast variability (Finney and Barmore 1943) and methods of determining and factors affecting dough absorption (Finney 1945, and Finney and Shogren 1972) have contributed materially to obtaining accurate and consistent data within and between varieties of wheat harvested at different locations and in different crop years.

Flour-blending studies (Finney and Barmore 1944) explained the complementary effects previously reported for blends of high-protein winters or springs with low-protein flours. Data indicated that when the properties and potentialities of a variety are sufficiently expressed, the baking properties of a blend of flours are dependent on the properties, potentialities, and quantities of each flour included in the blend.

Until the late 1940s, it was not understood why wheats harvested at certain locations in the Great Plains often had impaired functional properties. The inconsistent quality of wheat from year to year at some locations was interpreted by some as a reflection on baking methods. Studies by Finney and Fryer (1958) showed that

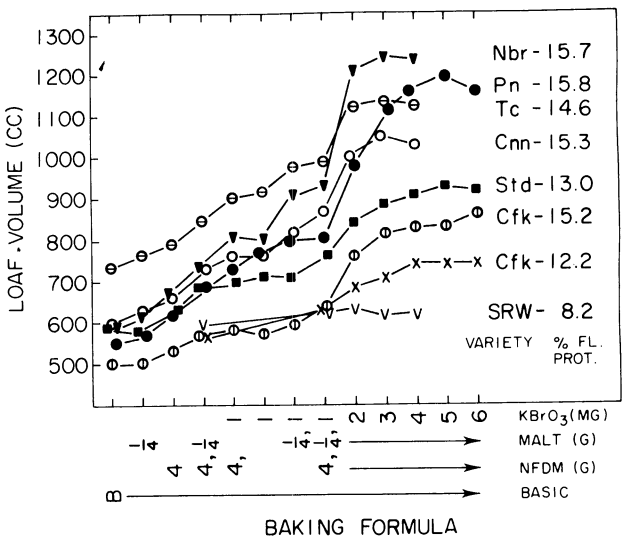

Fig. 3. Bread-volume response of six wheat variety flour composites and two wheat flour blends to nonfat dry milk, diastatic malt, and potassium bromate when added singly and in combination with six basic (B) ingredients: flour (100 g), water, yeast, sugar, salt, and shortening. Each dough had optimum absorption and mixing. Nbr = Nebred, Pn = Pawnee, Tc = Thatcher, Cnn = Cheyenne, Std = Standard Composite, Cfk = Chiefkan, and SRW = soft red winter.

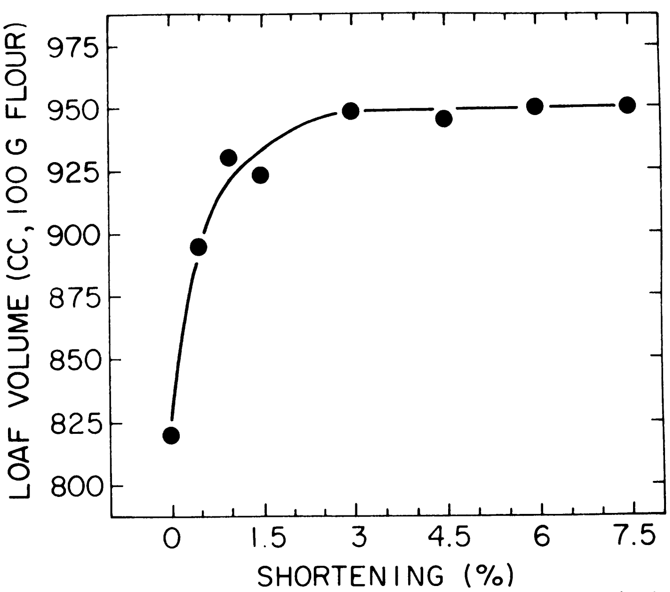

Fig. 2. Bread-volume response to varying amounts of shortening in the formula containing 100 g of flour (14% mb), optimum water, 2 g of compressed yeast, 6 g of sucrose, 1.5 g of sodium chloride, 4 g of NFDM, 0.25 g of diastatic malt, and optium $KBrO_3$.

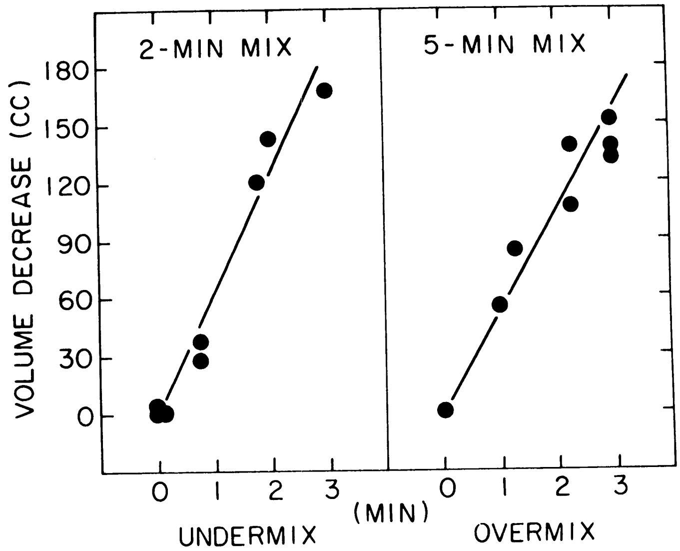

Fig. 4. Bread-volume (100 g of flour) decreases by undermixing and overmixing of optimum-oxidized doughs of eight hard winter wheat varieties that varied in mixing requirement (optimum mixing time) from 2 to 5 min. On the left, all varieties were mixed for 2 min, and on the right, for 5 min. Minutes undermixed (x axis) plus 2 equals the optimum; 5 min minus the minutes overmixed equals the optimum.

subnormal loaf volumes were consistently associated with high temperatures (above 90° F) the last 15 days before harvest. The physical and chemical condition of the soil and relative humidity also were important factors in regulating the extent of injury from a given amount of high temperature during the last 15 days of the fruiting period. Varieties with medium to long mixing requirements were more tolerant or resistant to the detrimental effects of high temperature during fruiting than those with short mixing times. Protein content accounted for 95% of the variations in loaf volume if temperature during the fruiting period was not a limiting factor, thereby further attesting to the merits of the baking method that is as useful today as it was when described 44 years ago.

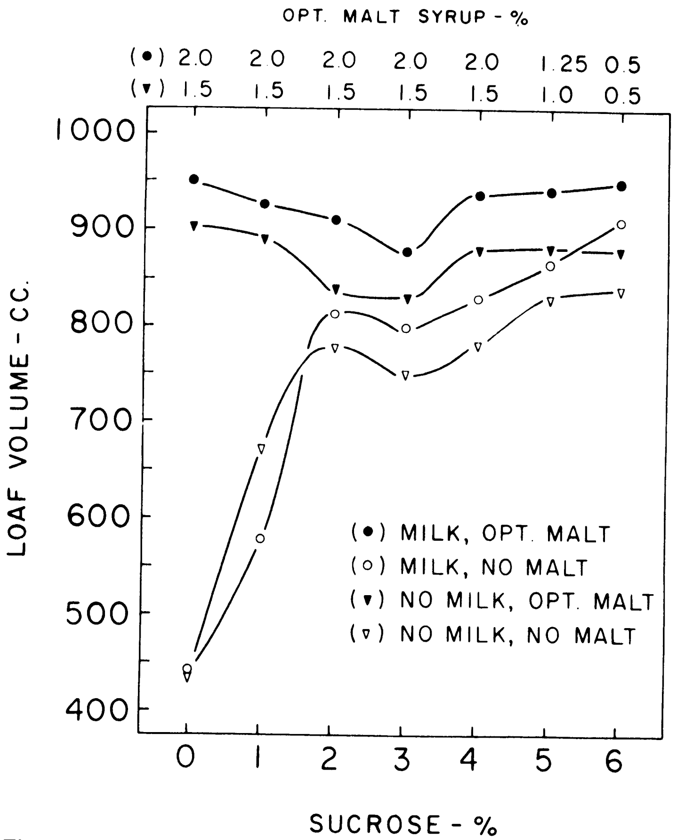

Fig. 5. Bread-volume response to 0–6 g of sucrose, singly and in combination with 4 g of nonfat dry milk and/or optimum malt (12 DU/g, 20° C). Formula also included 100 g of flour, optimum water, 2 g of yeast, 1.5 g of salt, 3 g of shortening, and optimum potassium bromate (30 ppm with nonfat dry milk and 10 ppm with no milk).

MODIFICATIONS OF THE BREAD-MAKING METHOD

No Added Sucrose

Research on cereal malts in breadmaking (Finney et al 1972) was the key to producing bread with no added sugar in the formula. For example, in straight-dough, 180-min fermentation time experiments without malt (Fig. 5), loaf volume increased sharply as sucrose levels were increased from 0 to 2%, decreased somewhat at 3%, and increased significantly with further increases in sucrose, for both the milk and no-milk formulas. In the formulations with optimum levels of malt and various levels of sucrose (Fig. 5), the malt requirement decreased as the sucrose level was increased above 4%, for both the milk and the no-milk formulas. Increasing sucrose levels from 0 to 6% in the presence of optimum malt did not increase loaf volume relative to that for 0% sucrose. Loaves baked without added sucrose but with optimum malt were equal in loaf volume to those baked with 6% sucrose and optimum malt, and higher than those baked with 6% sucrose but no malt. Thus, suitable amounts of cereal malt, in place of sugar, hydrolyzed enough starch into fermentable sugars to support fermentation during breadmaking.

Ascorbic Acid Replaces $KBrO_3$ and NFDM

Shogren and Finney (1974) demonstrated that ascorbic acid effectively replaced most, if not all, of the $KBrO_3$ required for optimum oxidation of typical hard winter and hard spring wheat-flour doughs. Generally, flours that had medium to short mixing requirements and/or high protein contents needed about 10 ppm of $KBrO_3$ in addition to an excess of 80 ppm of ascorbic acid. They showed that optimum loaf volume and other loaf chracteristics were maintained even when ascorbic acid levels were more than 600 ppm. Thus, since ascorbic acid was its own buffer against overoxidation, NFDM was no longer needed in the bread-making formula.

No-Added Sucrose and High-Protein Breads

The no-added-sugar formula for breads (Finney 1975) is given in Table I. As soy flour increased (Table II), with shortening in the formula, loaf volume decreased from 946 (no soy flour) to 833 cc (12% soy flour). With the formulation containing optimum sucrose palmitate, loaf volume was essentially constant through 10% soy flour (937 cc), and decreased only 28 cc at the 12% level. Similarly, loaf crumb grain score (Table II) for the formulation containing shortening decreased from satisfactory (S) to unsatisfactory (U) at the 12% level. For the sucrose palmitate formulation, crumb grains did not become poorer than satisfactory (Q) until the soy flour level

TABLE I
Sugar (Regular) and No-Added-Sugar (High-Protein), Straight-Dough Bread Formulas When Using 180-Min Fermentation

Bread Ingredients	Formula[a] Regular (%)	High-Protein (%)
Wheat flour	100.0	88.0–96
Soy flour	···	12.0–4
Sugar	6.0	···
Lipid[b]	Sh 3.0	SP 0.15–0.65
NFDM[c]	4.0	···
Malt (60° L)[d]	0.5	2.0
$KBrO_3$ (ppm)	10.0[e]	···
Ascorbic acid (ppm)	50.0	50.0

[a]Optimum water, 1.5% salt, and 2% yeast were common to both formulas.
[b]Sh and SP are abbreviations for shortening and sucrose palmitate, respectively.
[c]Nonfat dry milk processed with high heat to give a whey protein nitrogen of not more than 1.5 mg/g.
[d]12 DU (20° C) = 24 SKB (30° C) = about 60° L.
[e]No $KBrO_3$ if NFDM is omitted.

TABLE II
Effect of Soy Flour on Loaf Volume and Crumb Grain of Bread When Using Either Shortening or Sucrose Palmitate, No-Added-Sugar Formula, and 180-Min Fermentation

Wheat Flour/ Soy Flour	Loaf Volume: 3% Shortening (cc)	Loaf Volume: Optimum Sucrose Palmitate (cc)	Crumb Grain[a]: 3% Shortening	Crumb Grain[a]: Optimum Sucrose Palmitate	Optimum Sucrose Palmitate (%)
100/0	946	941	S	VS	0.15
96/4	928	945	S	S+	0.25
95/5	915	958	S	S+	0.30
94/6	910	945	Q-S	S	0.35
93/7	915	953	Q-S	S	0.40
92/8	915	950	Q	S	0.45
91/9	888	945	Q	Q-S	0.50
90/10	898	937	Q-U	S	0.55
89/11	860	920	Q-U	S	0.60
88/12	833	913	U	Q	0.65

[a]VS, S, Q, and U are abbreviations for very satisfactory, satisfactory, questionable, and unsatisfactory, respectively.

was 12%. Typical high-protein breads (Fig. 6) baked with 6% sugar and 10% soy flour (top left) and with 6% sugar, 10% soy flour, and 4% soy grits (bottom left), have undesirably brown and thick crusts compared to the thin and golden crusts of the corresponding loaves (top and bottom right) baked with no added sugar in the formula. High-protein formulations containing added sugar give loaf crusts that appear burned because of excessive browning. Presently, satisfactory high-protein bread can be made with the no-added-sugar formulation by using 3% shortening plus sodium stearoyl-2-lactylate instead of only optimum sucrose palmitate.

With the sugar-free formula containing 10% of soy flour and 4% soy grits, bread contains about 13.5% protein of high biological value compared to only 9% protein in conventional bread, and crusts are golden brown and thin (Finney 1975). Adding high levels of protein supplements, such as soy flour, improves the nutritive value of wheat flour by increasing both protein content and the amount of lysine. Lysine, the limiting amino acid in cereal proteins, is almost tripled. A small amount of dry malt is blended with most bread-making flours at the mill, but the amount, when sugar is omitted in the formula, is only a part of that desired to convert (hydrolyze) some of the starch of wheat flour to fermentable sugars.

The no-added-sugar formula is applicable to the production of regular bread as well as high-protein bread (Table I). For regular bread, protein supplements, such as soy flour and grits, would be eliminated or replaced with only 4% of NFDM, milk substitute solids, or soy flour. Soy flour (4%) has properties similar to those of NFDM (Finney 1946). Also, the formula could include 2–3% shortening and/or 0.25% SSL, together with 50 ppm ascorbic acid and about 2% of the specified barley or wheat malt. If 52 DU malt is used, concentrations of only 0.13% and 0.5% would be required in the regular and high-protein formulas, respectively.

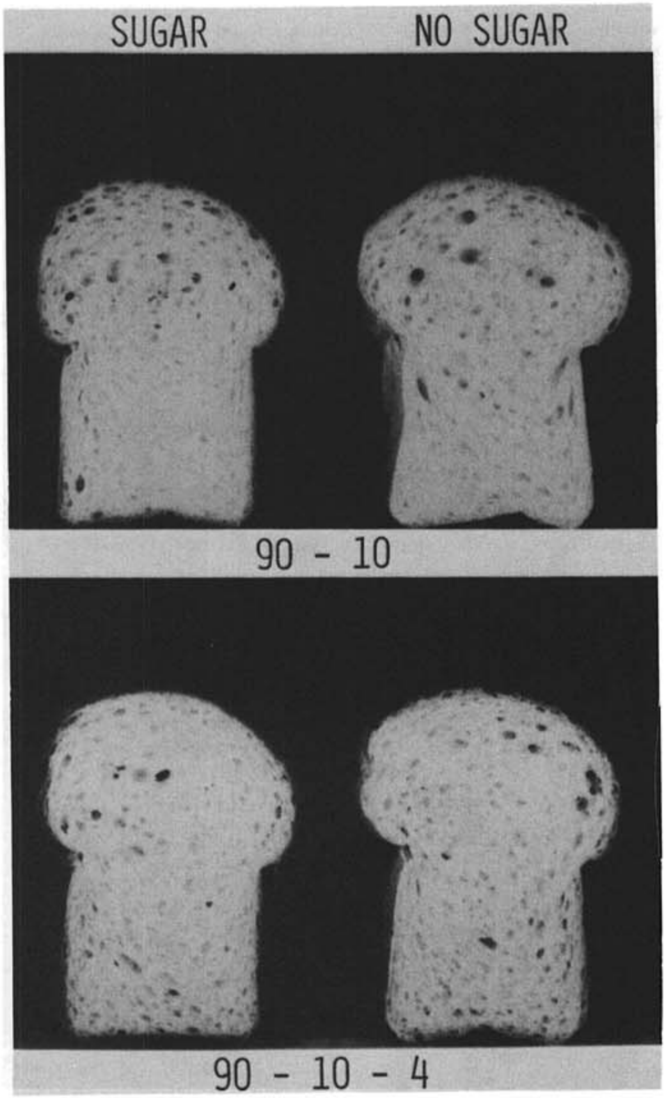

Fig. 6. Typical high-protein breads made with 6% and no added sugar in the formula and that contained blends of 90% wheat flour and 10% soy flour, with and without 4% added soy grits. (See high-protein formula in Table I.)

70-Min Fermentation and Added Sucrose

At the same time the sugar-free formula was being applied to the 180-min, straight-dough method, P. L. Finney et al (1976) materially reduced production costs by making optimum bread with a fermentation time of only 70 min, instead of 180 min, by increasing the yeast level from 2.0 to 7.2% in a straight-dough formula containing sugar (Fig. 7). The key to producing optimum bread with a 70-min fermentation time was in optimizing the yeast and bromate levels and proof time. For example, as fermentation time decreased, yeast concentration increased.

Plotting $KBrO_3$ requirements and corresponding fermentation times for 13 flours (Fig. 8) established the general relation between those two factors. Specifically, each flour's $KBrO_3$ requirement (relative to 180 min of fermentation) 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, when the corresponding yeast concentrations shown in Fig. 7 were used.

Optimal proof times (Fig. 9) for 180-, 120-, 70-, and 45-min fermentation times were 55, 36.5, 21.5, and 12 min, respectively, when the corresonding yeast concentrations in Fig. 7 and bromate requirements in Fig. 8 were employed.

70-Min Fermentation, No-Added Sucrose, High-Protein Breads

Magoffin et al (1975,1977) cut the no-added-sugar bread-making time in half by combining the 70-min fermentation time and the no-added-sugar formula in which 16% of wheat flour was replaced with 12% soy flour and 4% NFDM. In addition, increasing the yeast from 2.0 to 7.2% increased about fourfold the amount of highly nutritious yeast proteins in bread (Table III).

Using the formula containing 90 g of wheat flour, 10 g of soy

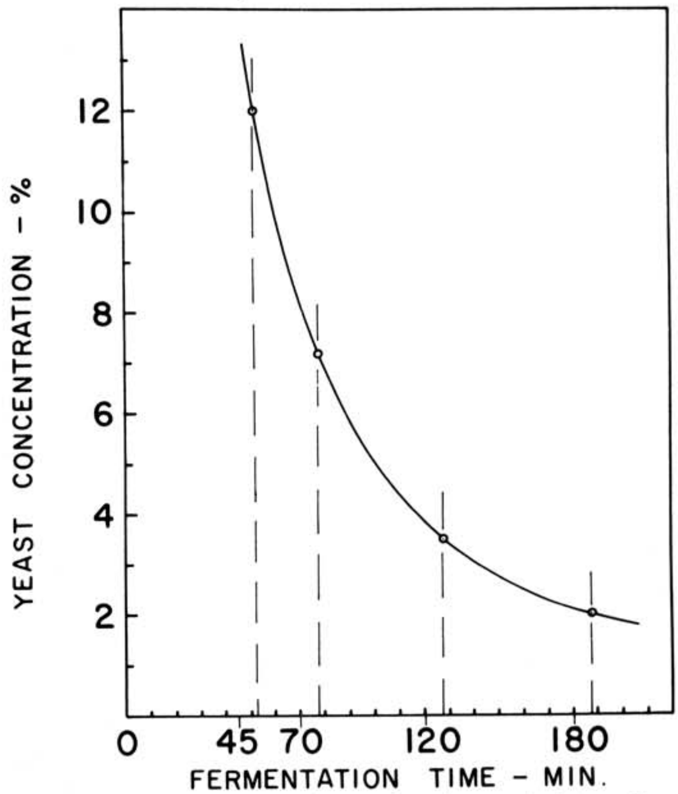

Fig. 7. Yeast concentrations and fermentation times required to produce optimum bread. Formula also included 100 g of flour (14% mb), optimum water, 6 g of sugar, 1.5 g of NaCl, 3 g of shortening, 4 g of nonfat dry milk, 0.25 g of wheat malt (120 SKB/g, 30 C), and optimum $KBrO_3$. (See corresponding bromate requirements in Fig. 8.)

flour, and no NFDM (Table IV, 90/10/0), bread had highly satisfactory loaf volume and crumb grain. Those superior loaf characteristics were essentialy 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 10–12% 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 crumb grain and loaf volume (900 cc, Table IV). Thus, 84 g of wheat flour carried 16 g of foreign protein of high biological value, and the bread contained 50% more protein than that made from 100 g of wheat flour.

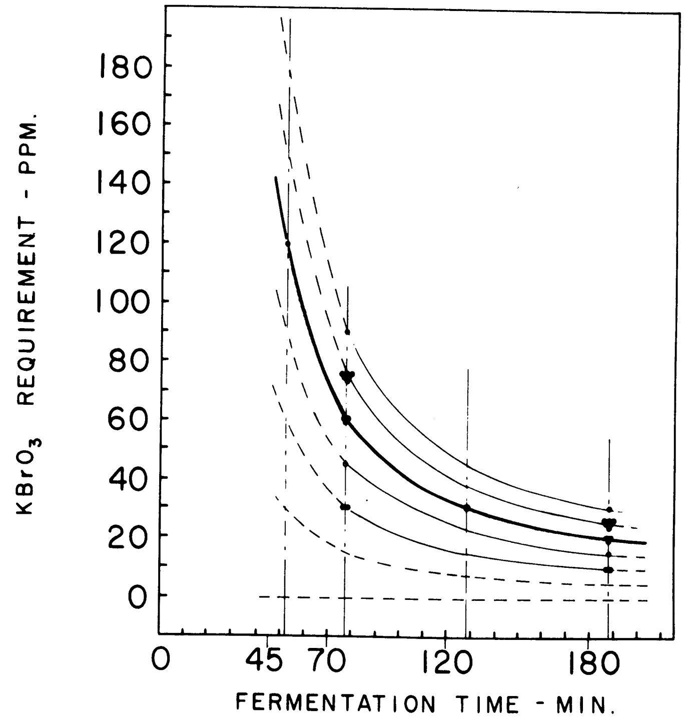

Fig. 8. Potassium bromate requirements and fermentation times required to produce optimum breads from 13 flours that varied in oxidation requirement from 10 to 30 ppm for 180 min of fermentation. (See corresponding yeast concentrations in Fig. 7.)

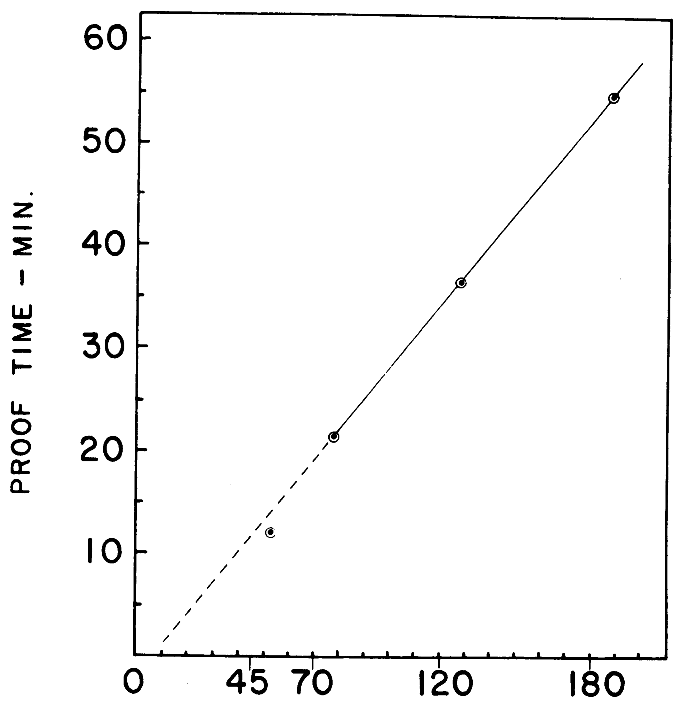

Fig. 9. Proof and fermentation times for optimum bread. (See corresponding yeast concentrations in Fig. 7 and corresponding bromate requirements in Fig. 8.)

Typical breads fermented for 70 min and containing 100% wheat flour (Fig. 10) and a blend of 86% wheat flour, 10% soy flour, and 4% NFDM (bottom right) have volumes and crumb grains that are somewhat superior to those for corresponding loaves fermented for 180 min (top and bottom left). The water absorption of wheat flour was about 60%, NFDM was 75%, and soy flour (Ardex 550) was about 125%. Both NFDM and soy flour, depending on the concentration, increase mixing requirement.

Ingredient Response, 70-Min Fermentation, No-Added Sucrose

Figures 11 and 12 illustrate the effects and importance of dough ingredients on loaf volume and crumb and on differentation between good- and poor-quality samples. RBS-76 good-quality flour (100 g, 14% mb) and water (as needed) formed a dough, but its

TABLE III
No-Added Sugar, High-Protein, Straight-Dough Bread Formulas Using 180 and 70 Min of Fermentation[a]

Ingredients	Fermentation Time (min) 180[b] (%)	70[c] (%)
Flour[d]	82.0–100	82.0–100
Soy flour[e]	14.0–0	14.0–0
NFDM[f]	4.0	4.0
Shortening	3.0	3.0
Sodium stearoyl-2-lactylate	0.5	0.5
Yeast	2.0	7.2
Malt[g]		
Flour (52 (DU/g, 20°C)	1.5	0.75
Syrup (250°L)	2.0	1.0
Bromate (ppm)[h]	10.0	20.0
Ascorbic acid (ppm)	50.0	50.0

[a] Water (optimum) and 1.5% salt were common to both formulas. Amounts of malt, oxidizers, and yeast may vary depending on flour properties and treatment, shop conditions, and yeast potency.
[b] If ascorbic acid is omitted, increase bromate 5–10 ppm. If bromate is omitted, increase ascorbic acid 30–50 ppm. Ascorbic acid usually improves crumb grain.
[c] Bromate should not be omitted when NFDM is in the formula.
[d] A bakers' flour containing 12.0–12.5% protein.
[e] For example, Ardex 550.
[f] Nonfat dry milk processed with high heat to give a whey protein nitrogen of not more than 1.5 mg/g.
[g] The malted barley flour (Amylomalt) was from Ross Industries, Wichita, KS. The malt syrup was from Standard Brands Canada Limited, Montreal, Quebec, Canada.
[h] When NFDM is omitted, omit bromate, except that some flours may need 5–10 ppm of bromate when fermentation is 70 min.

TABLE IV
Effect of Soy Flour and NFDM on Loaf Volume and Crumb Grain of Bread When Using the No-Added-Sugar Formula and 70-Min Fermentation[a]

Wheat Flour (%)	Soy Flour (%)	NFDM (%)	Loaf Volume[b] (cc)	Crumb Grain[c]
100[d]	0	0	1,010	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] With 3% shortening and 0.50% sodium stearoyl-2-lactylate.
[b] Average proof height was increased from 7.75 to 8.15 cm for doughs containing soy flour.
[c] VS, S, and Q-S are abbreviations for very satisfactory, satisfactory, and questionable to satisfactory, respectively.
[d] With 0.25% sodium stearoyl-2-lactylate instead of 0.50%.

loaf volume was only 228 cc, equal to that of the dough volume after mixing. Leavening with 7.2% yeast increased loaf volume to 530 cc. Adding 0.5% malt (52 DU/g) and then both malt and 1.5% salt to flour, water, and yeast further increased loaf volume to 706 and 778 cc, respectively, but all crumb grains were unsatisfactory to varying degrees. When 3% shortening and 50 ppm ascorbic acid were added to the five basic ingredients, a loaf of excellent volume (1,044 cc) and crumb grain was produced (Fig. 11).

Volumes of loaves 1, 2, and 3 of the poor-quality 76-412 flour (Fig. 12) were significantly less than those of the corresponding loaves of RBS-76. Loaf 4 of 76-412 containing NaCl was 134 cc less than loaf 4 of RBS-76; and loaf 5 of 76-412 containing NaCl, shortening, and ascorbic acid (724 cc) was 320 cc less than that (1044 cc) of RBS-76. Thus, the poor responses of poor-quality gluten proteins to bread-making ingredients and the good responses of good-quality gluten proteins define a criterion of quality.

RECOMMENDED BREAD-MAKING METHOD

Formula and Techniques

For most purposes, the bread-making method includes mixing to minimum mobility (optimum) at about 100 rpm or more, optimum water (depending on quantity and quality of protein), and 50 ppm of ascorbic acid, an excess in the absence of NFDM. Ascorbic acid is its own buffer against overoxidation. Additional formula ingredients are 100 g of flour (14% mb), 3.5 or 5.3 g of compressed yeast for 120 or 90 min of fermentation, respectively, 6 g of sugar, 1.5 g of salt, 3 g of shortening or equivalent surfactant, and 0.25 g of barley malt (about 50 DU/g, 20° C). Fermentation times for first punch, second punch, and pan depend on total time (Table V). For 120 min of fermentation, proof 47 ± 1 min at 30° C; for 90 min, proof 32 ± 1 min (the time required to proof the controls containing about 12.5% protein to 7.8 cm). Of course, the proof height will vary with the flour protein content of the controls (add 4 mm to proof heights Fig. 13). Bake for 24 min at 215° C. Weigh loaves immediately as they are removed from the oven. Immediately thereafter, determine volumes by rapeseed displacement. Additional related details are given by Finney (1945), Finney and Barmore (1943, 1945a, 1945b), Finney et al (1976), and Bruinsma and Finney (1981).

Flours that have short to medium-short mixing times also may

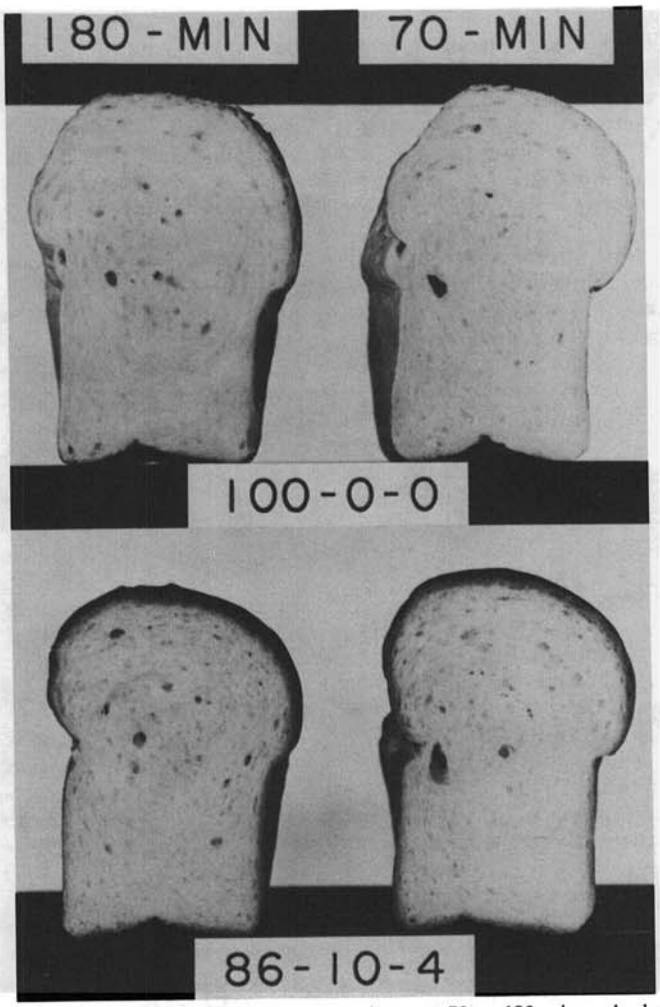

Fig. 10. Typical bread when fermentation was 70 or 180 min and when doughs contained 100% wheat flour or a blend of 86% wheat flour, 10% soy flour, and 4% nonfat dry milk. (See formulas in Table III.)

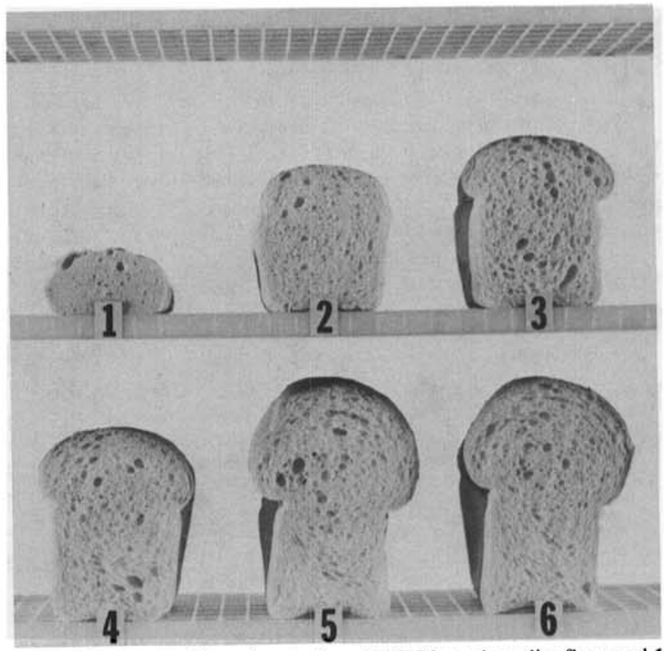

Fig. 11. Cut loaves of bread made from RBS-76 good-quality flour and **1,** water (228 cc) plus: **2,** yeast (530 cc); **3,** yeast and malt (706 cc); **4,** yeast, malt, and salt (778 cc); **5,** yeast, malt, salt, shortening, and ascorbic acid (1,044 cc); and **6,** yeast, malt, salt, shortening, ascorbic acid, and 4% of soy flour (1,033 cc). (See Table III, 70 min of fermentation.)

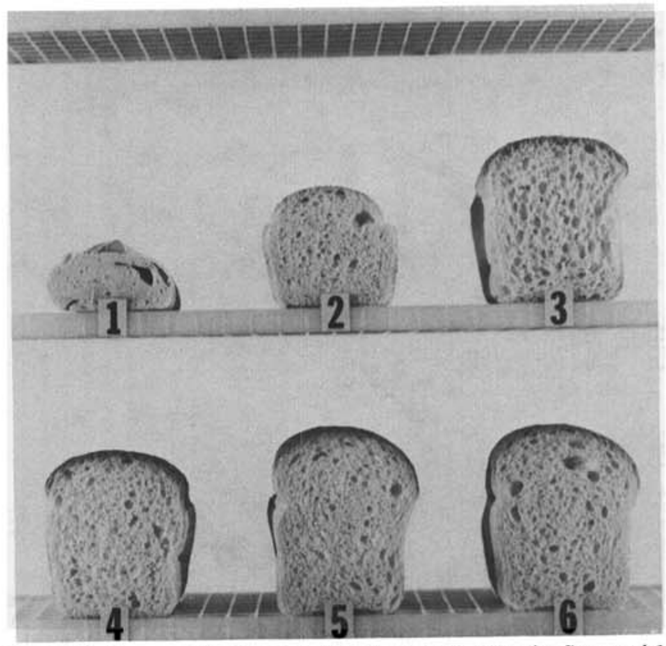

Fig. 12. Cut loaves of bread made from 76-412 poor-quality flour and **1,** water (205 cc) plus: **2,** yeast (460 cc); **3,** yeast and malt (669 cc); **4,** yeast, malt, and salt (644 cc); **5,** yeast, malt, salt, shortening, and ascorbic acid (724 cc); and **6,** yeast, malt, salt, shortening, ascorbic acid, and 4% of soy flour (721 cc). (See Table III, 70 min of fermentation.)

need 10 ppm of bromate in addition to 50 ppm of ascorbic acid. Flours that have medium-long to long mixing times and other strong physical-dough properties likely will need only 10–20 ppm of ascorbic acid. However, their loaf volumes are not apt to be penalized by 50 ppm of ascorbic acid, but their crumb grains probably will be somewhat overdeveloped.

Flours that also require 10 ppm of bromate generally require the highest amounts of bromate when ascorbic acid is omitted. The recommended method can be used to predict bromate requirement when ascorbic acid is omitted, but it would be desirable to add 4% of NFDM as a buffer against overbromating. If NFDM is not added in the recommended method, then flours that have medium-long to long mixing requirements will require no or little bromate that should be added in 0.25–0.5-mg increments per 100 g of flour. When mixing times are short, 1-mg increments can be added. When NFDM and an average of 30 ppm of bromate were used in the first replicate of all wheat varieties baked in the Hard Winter Wheat Quality Laboratory, bromate requirement for subsequent bakes was predicted from optimum mixing time. Flours that have short mixing requirements generally have high bromate requirements, and those with long mixing requirements have low requirements (Finney and Yamazaki 1967).

In formulas that contain relatively high levels of 8–12% of soy flour in place of wheat flour, sugar should be omitted and the barley malt doubled or trebled. High levels of soy flour produce excessive browning in the presence of sucrose. Also, both 3% of shortening and 0.5% of a surfactant such as sodium stearyl-2-lactylate should be in the formula.

TABLE V
Time Intervals (During Breadmaking) Between Dough Mixing, First Punching, Second Punching, and Panning for Various Fermentation Times and the Corresponding Yeast Concentrations

Fermentation Time (min)	Yeast (%)	Punching[a] First (min)	Punching[a] Second (min)	Panning[a] (min)
180	2.0	105	50	25
150	2.5	87	42	21
120	3.5	69	34	17
90	5.3	52	25	13
70	7.2	40	20	10
60	8.6	35	17	8

[a] Times to first and second punchings and panning of straight doughs are about 58, 28, and 14% of each fermentation time, respectively.

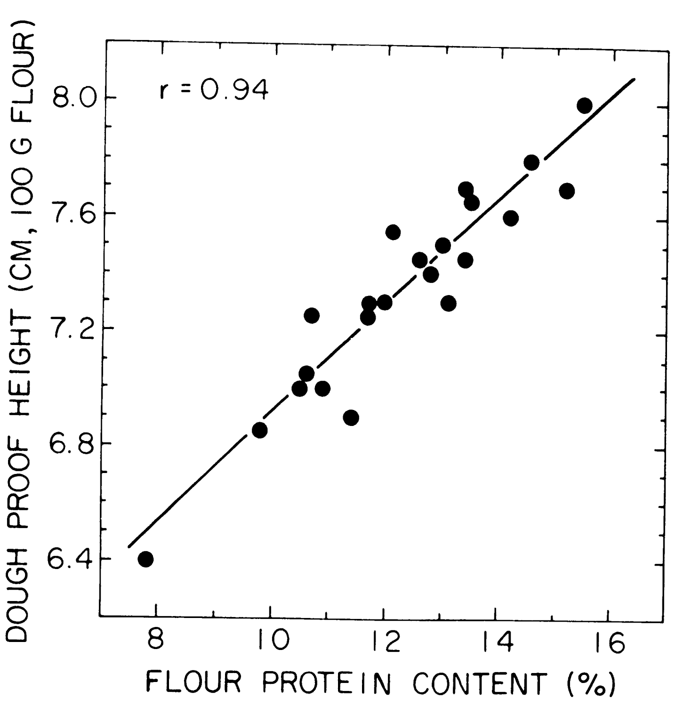

Fig. 13. Dough proof height and flour protein content of 22 location composites. Each contained equal quantities of 25 varieties of hard winter wheat, each grown at the 22 locations in the Southern Great Plains in 1973.

Subjective Determination of Optimum Mixing Time

During the first 30 sec of mixing, water is absorbed by the flour, and all dough ingredients are incorporated into a rough, lumpy, wet-appearing dough. As mixing continues, the gluten protein is gradually developed and the dough gradually loses the rough, lumpy, and wet appearance until optimum mixing (point of minimum mobility) is attained, at which point the dough has a smooth and satiny appearance, is not sticky from overmixing, and has optimum handling properties. Replicate subjective determinations of mixing requirements usually agree within ⅛ min and are corroborated by mixogram mixing time to the peak (Finney and Barmore 1945b).

Bread-Making Equipment

Each 100 g of flour (14% mb) is placed in a plastic container with a metal screw cap prior to mixing. The container has a capacity of about 265 ml, an inside top diameter of about 6.35 cm (2½ in.), and an inside height of about 8.73 cm (3 7/16 in.).

When feasible, ingredients are dispensed as standard solutions from automatic pipettes mounted on a dispensing stand. Yeast is kept in suspension with a magnetic stirrer. After being heated to 55–60° C, shortening (Crisco) is dispensed in a circle on top of the flour with a 5-ml pipette modified and calibrated to dispense 3 g. Nearly all of a 5-ml pipette below the bulb is cut off.

The dough mixer used is specifically for 100 g of flour. Two pairs of planetary pins revolve at 100 rpm around two pins in the bowl. The Swanson-Working-type mixer was designed for 100 g of flour by K. F. Finney and is manufactured by the National Mfg. Co. Dough containing 100 g of flour cannot be mixed properly in National's 100–200-g mixer, which is satisfactory, however, for 200 g of flour. Mixing a dough containing 200 g of flour and dividing it into two equal parts does not give legitimate duplicates. Averaging the two dough parts probably minimizes the variability in punching, molding, etc, but it also averages out the variability between the two dough parts that are a reflection of the heterogeneity of the undivided dough.

After mixing to optimum and recording the dough temperature, each dough is placed in a stainless steel fermentation bowl that has a capacity of about 780 ml and a top inside diameter of about 14.76 cm (5 13/16 in.). Each pan with dough is covered with a loose-fitting can lid during fermentation. Doughs mixed to optimum come from the mixer at about the same temperature for given ambient conditions (Finney and Barmore 1945b).

The dough sheeter, fermentation cabinet, reel oven, and volumeter are from the National Mfg. Co.

Our dough molder is a "Heart Thomson of the Bakery," that is no longer manufactured by the Thomson Machine Co. An inexpensive, simple, and reliable molder is described by Shogren and Finney (1977).

Several AACC members expressed their desire to use the same type of baking pan that we have used since the early 1940s. That led to the National Mfg. Co. taking over our last order of pans from the manufacturer and stocking them for the convenience of others. The pan has the proportions of a commercial pan for 1-lb loaves. Its top inside dimensions are about 14.29 × 7.94 cm (5⅝ × 3⅛ in.); bottom outside dimensions are about 12.86 × 6.35 cm (5 1/16 × 2½ in.); inside depth is 5.72 cm (2¼ in.). Asbestos (1.6 mm thick) covers each revolving metal tray of the oven to decrease the penetration of heat through the bottom of the pan and thereby give a desirable bottom-crust color.

A device for measuring proof height of dough was designed by K. F. Finney and is manufactured by the National Mfg. Co. The device also is used on dough containing 10 g of flour by inserting a block 3 cm high (aluminum or other suitable material).

Our bread-making laboratory is kept at 25 ± 0.5° C.

Dispensing of Ingredients

Yeast suspension. For 2,000 ml of yeast suspension that contains

5.25 g of yeast/20 ml (25° C), for example, there will be 100 dispensings (2,000 ÷ 20); and 5.25 × 100 = 525 g of yeast are required. Because 1 g of compressed yeast (about 70% moisture) displaces about 0.9 ml of water, 525 g displaces about 472 ml; with 1,528 (2,000 − 472) ml of distilled water (at 25° C and then heated to 32° C), make a thin paste of the yeast and then dilute to 2,000 ml. Diluting with the approximate required water will serve as a check.

Sugar and salt solution. Dissolve 1090.0 g of sucrose and 272.7 g of NaCl in about 1,211 ml of distilled water in a 2,000-ml volumetric flask. Dilute with about 90% of the water and stir with magnetic stirrer until sugar and salt are solubilized and all trapped air has escaped. Then allow for the volume of the magnet, and dilute to 2,000 ml. Dispense 11 ml. Sugar and salt in 10 ml of solution is too viscous. In volumes greater than 11 ml, the keeping quality progressively decreases.

Salt solution. Dissolve 300 g of NaCl in about 887 ml of distilled water in a 1,000-ml volumetric flask. Five milliliters of solution contains 1.5 g of salt and about 4.44 ml of water.

Shortening. When dispensing 3 g of melted shortening with the modified pipette described, allow two or three drainage drops in the calibration to facilitate ease and accuracy of dispensing. A solid glass piston within glass tubing also can be calibrated to deliver 3 g of semisolid shortening.

Malt solution. Fifty grams of barley malt (50–60 DU/g, 20° C) is extracted with 250 ml of 0.5% NaCl solution by stirring for 30 min. After centrifuging for 20 min at 1,800 rpm, 62.5 ml of the supernatant is diluted with distilled water to 250 ml. Five ml contains the extract of 0.25 g of malt. If preferred, 0.25 g of malt flour can be added to each flour sample. The concentrated malt extract (supernatant), when refrigerated, can be used for several days.

Ascorbic acid solution. Dissolve 250 mg of ascorbic acid in distilled water and dilute to 250 ml; 5 ml contains 5 mg (50 ppm) of ascorbic acid. Ascorbic acid solution is prepared each day of breadmaking.

Potassium bromate solutions. Dissolve 20 g of $KBrO_3$ in distilled water and dilute to 500 ml as a stock solution. Dilute each 5, 10, and 20 ml of the stock solution to 2,000 ml, 5 ml of which contains 0.5 mg (5 ppm), 1.0 mg (10 ppm), and 2.0 mg (20 ppm) of bromate, respectively.

Important Considerations

It is desirable to determine the gas production of each weekly shipment of compressed yeast and, when necessary, adjust the concentration to produce a predetermined amount of gas, depending on whether a dough or slurry is employed in the gas production test (Rubenthaler et al 1980, Bruinsma and Finney 1981, Finney et al 1982) and depending on the fermentation time and yeast concentration in the bake (Finney et al 1976). Variations in yeast potency from week to week, as well as any decrease in potency during the week of baking, were effectively compensated for by adjusting proof time for a predetermined proof height. When fermentation was 180 min and proof time was 55 min for the southern regional performance nursery station composites (just prior to completing the studies on short-time baking systems), proof height (Fig. 13) increased about 2 mm for each 1% increase in flour protein content. Since employing short-time doughs, we have used proof heights that are about 4 mm higher than the values in Fig. 13.

Although I prefer a 70-min fermentation when feasible, a 90- or 120-min fermentation is more practical when the number of samples in the bake is 30 to 35 on a 3-min schedule. For example (Table V), for a 90-min fermentation and 30 samples, 17 mixings would be made before first punching begins (52/3) and 25 mixings would be made before second punching begins (77/3). Applications of the 70-, 90-, and 120-min fermentations are by Magoffin et al (1977), Bruinsma and Finney (1981), and Finney et al (1982). Data for different fermentation times are comparable, providing yeast concentration, oxidation level, and proof time are appropriate (Finney et al 1976, Magoffin et al 1977).

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