Production of Whole Wheat Bread with Good Loaf Volume[1]

C. S. LAI,[2,3] A. B. DAVIS,[2,4] and R. C. HOSENEY[2]

Cereal Chem. 66(3):224-227

ABSTRACT

A reconstituted whole wheat bread (containing 16.3% bran plus 12.7% shorts) with a loaf volume equal to the control was obtained by allowing indigenous lipoxygenase (soaking the nonflour milling fractions) or added lipoxygenase (enzyme-active soy flour) to oxidize the glutathione from the germ and using optimum absorption. Because lipoxygenase requires oxygen to function and yeast consumes oxygen, a no-yeast sponge stage was included in the baking process. Addition of a high level of enzyme-active soy flour eliminated the need for the no-yeast sponge stage. Certain salts and surfactants were found to improve loaf volume. In this system, compressed yeast was superior to instant dry yeast for maintaining constant bread quality.

Demand for whole wheat bread has increased considerably in the last few years because of its better nutritional image and an increasing preference for its organoleptic characteristics (Pomeranz 1977, Rogers and Hoseney 1982). The loaf volume of whole wheat bread is substantially smaller than that expected solely from the dilution of gluten by nonflour material (Pomeranz 1977, Rogers and Hoseney 1982). This problem makes the production of whole wheat bread with the same loaf volume as white bread more expensive because of the extra flour required (Rogers and Hoseney 1982).

Lai et al (1989a,b) studied the effect of nonflour milling fractions on breadmaking. They proposed that bran binds a relatively large amount of water and changes the appearance and the handling properties of the dough. Therefore, the gluten was not properly hydrated and developed at normal absorption levels. The use of an inappropriate absorption level results in a reduction in loaf volume (Lai et al 1989a). Lai et al (1989b) attributed the negative effects of shorts in breadmaking to glutathione from germ and methoxylhydroquinone (MHQ) types of compounds from the other shorts fractions. They also reported methods to overcome the detrimental effects of bran, shorts, and germ on bread loaf volume. The goal of this study was to develop an optimum formula and procedure to produce whole wheat bread of good quality and volume.

MATERIALS AND METHODS

Flour

Flour used was provided by Ross Milling Company, Wichita, KS. It contained 11.6% protein (N × 5.7) and 0.45% ash (14% moisture basis). Whole wheat flour was milled from a hard red spring wheat (17.6% protein, 14% mb). The flour was stored in a freezer at −14°C until one day before use. Vital wheat gluten was provided by Midwest Grain Products, Atchison, KS.

Surfactants, Salts, and Other Chemicals

Surfactants were provided by Grindsted Product Company, Industrial Airport, KS. They included sodium stearoyl lactylate (SSL), polysorbate, ethoxylated monoglyceride, succinylated monoglyceride, diacetyl tartaric acid esters of monoglycerides (DATEM), lecithin, and monoglyceride. The salts and other chemicals were reagent grade chemicals.

Pup Loaf Baking

The pup loaf baking formula and process was described by Finney (1984).

Response Surface Study

A central composite rotatable design of the Box-Wilson type was used (Cochran and Cox 1957).

No-Yeast Sponge Breadmaking Process

Part of the formula water (which may contain a variable amount of salts) was added to the whole wheat flour or meal (containing 4% nonfat dry milk, 1% enzyme-active soy flour, 6% shortening, and 0.5% SSL; all percentages based on total amount of flour) and mixed to make a no-yeast sponge. This sponge was placed in a covered fermentation bowl and allowed to rest for 2 hr (unless specified otherwise). Yeast and the remaining ingredients (remainder of water, 6% sugar, and 1.5% salt (NaCl unless specified otherwise) were added, and the dough was mixed to optimum. The dough was fermented, punched, and baked as described by Finney (1984) except that doughs containing combinations of salts were proofed to a height equal to that of doughs containing 1.5% NaCl.

Scoring Dough-Handling Properties

Dough-handling properties were scored using a five-point scale. The scoring criteria were as follows: 5, good dough-handling properties (as good as white flour dough); 4, dough can be handled without difficulty when hands are lightly greased; 3, dough can be handled with slight difficulty when hands are greased; 2, dough can be handled with slight difficulty when hands are greased and slight amount of dusting flour is applied; and 1, dough is difficult to handle even when hands are greased and dusting flour is applied.

RESULTS AND DISCUSSION

Reconstituted Whole Wheat Breads

Results from our previous studies (Lai et al 1989 a,b) suggested that the detrimental effects of bran could be overcome by using an optimum absorption and the detrimental effects of shorts could be overcome by soaking them, thus, allowing the indigenous lipoxygenase to function. A reconstituted whole wheat bread was made by adding 0.5% SSL and 29% soaked bran and shorts mixture (16.3% bran plus 12.7% shorts, based on flour weight) to 100 g of flour. The reconstituted whole wheat bread had a loaf volume equal to that of the control (100% white flour), but the loaf had a flat top and sagging sides, indicating a weak dough (Table I). Addition of a higher level of oxidant did not produce a significant improvement in grain or shape of the loaf. Vital wheat gluten (2%) was added to strengthen the flour. A reconstituted whole wheat bread with good loaf volume was obtained using this fortified flour (Table I). Shape and grain of the baked loaf were improved, but these loaves still showed signs of weakness.

Lai et al (1989b) reported that a MHQ and glutathione mixture mimicked the effects of shorts and that their detrimental effects could be overcome by including enzyme-active soy flour in the baking formula and adding a no-yeast sponge step in the baking process. Reconstituted whole wheat breads were baked with a similar no-yeast sponge method (with 2 hr of resting time). The

[1]Contribution no. 88-113-J, Kansas Agricultural Experiment Station, Manhattan.
[2]Graduate research assistant, associate professor, and professor, respectively, Department of Grain Science and Industry, Kansas State University, Manhattan 66506.
[3]Present address: Hershey Company, Hershey, PA.
[4]Present address: Entenmann's Inc., Bay Shore, NY.

optimum resting time to produce the best loaf volume and grain (Table I) was found to be 1 hr.

Determination of Optimum Absorption for Whole Wheat Bread Quality

Our previous work with wheat bran (Lai et al 1989a) indicated that the best loaf volumes were obtained with the highest water level possible that did not produce an excessively sticky dough. Similar results were obtained with whole wheat flour.

Effect of Neutral Salts on Whole Wheat Bread Quality

Holmes and Hoseney (1987a,b) showed that certain ions affected loaf volume and changed the optimum NaCl level for breadmaking. Bran and shorts contain 14 and 17% ash, respectively, and thus, are likely to alter the optimum NaCl level normally used for white pan bread. Producing whole wheat breads containing various amounts of NaCl and combinations of sodium phosphate (dibasic) and NaCl showed that high levels of salts (2.5% NaCl or 1.5% NaCl + 0.5% Na_2HPO_4) reduced yeast activity but had little effect on loaf volume. However, the added salts did significantly improve strength and handling properties of the dough. The grain and shape of the baked loaves were also substantially improved. This data suggested that, with additional proof time, the inclusion of phosphates or other salts might improve both loaf volume and grain of whole wheat bread. It appears that a whole wheat bread with good loaf volume can be produced by a no-yeast sponge process with the inclusion of an appropriate combination of certain salts.

As shown above with the model whole wheat system, the inclusion of dibasic phosphate improved dough strength and loaf volume if the dough was given sufficient proof time. Replacing the 1.5% NaCl with 1.2% sodium phosphate (dibasic) or 1.4% sodium citrate improved loaf volume by about 80 cm^3 (Table II). These findings suggested that an appropriate combination of salts could improve loaf volumes.

A model describing the effects of sodium citrate and NaCl on loaf volume was obtained from response surface analysis (Fig. 1). The square of the multiple correlation coefficient (R^2) of this model was 0.91. According to the model, the best loaf volume can only be obtained by using an appropriate combination of sodium citrate and NaCl (Fig. 1). For this flour, the optimum combination was 1.5% NaCl and 1.4% sodium citrate. That salt combination and 61 min proof time were used in the following tests, unless otherwise specified.

TABLE I
Effect of Rest Time on Loaf Volume of Model[a] Whole Wheat Bread

Treatments	Loaf Volume[b] (cm^3)	Standard Deviation (cm^3)
Control (fortified control flour)[c]	975	9.1
Whole wheat (soaking method)	965	14.7
Whole wheat (no yeast sponge method)	977	22.5
Whole wheat		
0-min rest	933	2.9
30-min rest	982	14.3
60-min rest	990	7.1
90-min rest	982	18.9
120-min rest	981	12.6

[a] Model whole wheat flour is made up of 100 g of white flour, 16.3% fine bran, and 12.7% shorts.
[b] Averages of four observations.
[c] All doughs contained 2% vital gluten whether made with or without bran-shorts mixture.

TABLE II
Effects of Salts on Loaf Volume of Whole Wheat Bread

Treatment	Loaf Volume[a] (cm^3)	Standard Deviation (cm^3)
Control (1.5% NaCl)	840	5
1.2% Na_2PO_4	921	21.7
1.4% Sodium citrate	918	20.2

[a] Numbers are averages of six observations.

Relation of Optimum Resting Time and Soy Flour

Surface response analysis was also used to determine the effect of soy flour (source of lipoxygenase) level and rest time on loaf

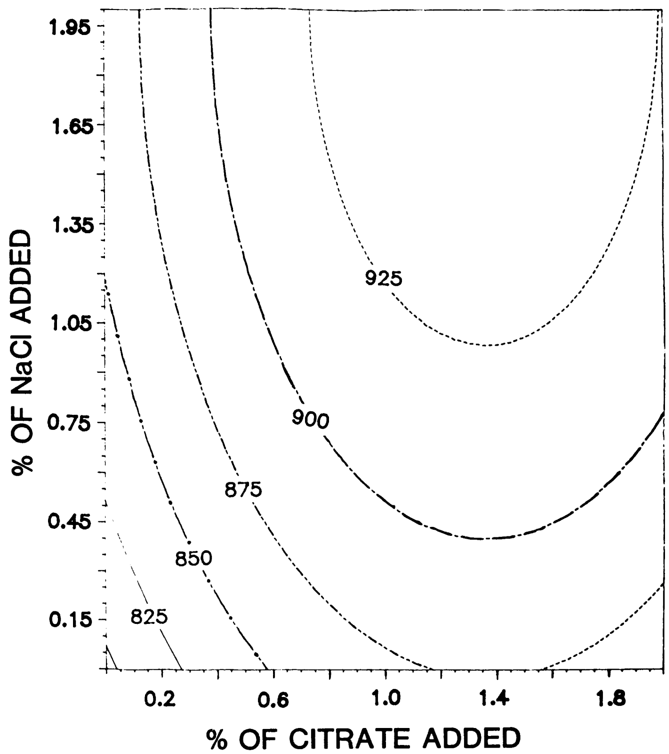

Fig. 1. Loaf volume contours as a function of NaCl and sodium citrate concentration. Volume = $812 + 100.9C + 52.2S - 45.7C^2 + 15CS - 31.3S^2$, where C = % of citrate and S = % of NaCl.

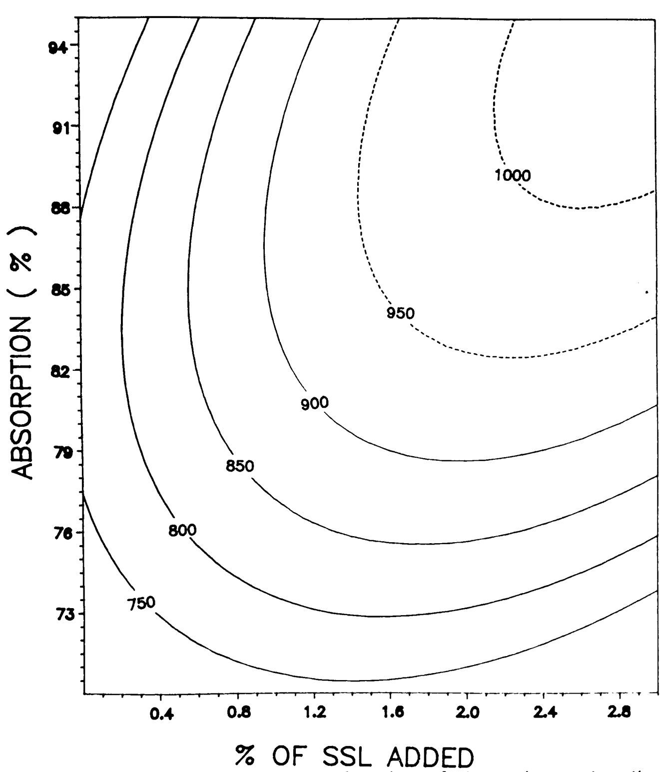

Fig. 2. Loaf volume contours as a function of absorption and sodium stearoyl lactylate (SSL) concentration. Shortening level 6%. Volume = $-3{,}386 + 100.65A - 219.4S - 0.61A^2 + 5.1AS - 7.21FS - 37S^2$, where A = absorption, F = shortening (%), and S = SSL (%).

volume. According to the regression model, increasing soy flour level reduced the resting time (Fig. 2). Furthermore, increasing the rest time reduced the required soy flour level (Fig. 2). Subsequent baking experiments showed that the required resting time could be reduced to zero by adding 3% enzyme-active soy flour.

Effect of pH on the Required Rest Time

Because enzyme activity is affected by pH, adjustment of pH would be expected to also affect rest time. Response surface methodology was used to study the interaction between pH and rest time.

Increasing the pH increased the dough strength as indicated by the feel of the dough. However, pH affects the charge on gluten proteins, thus, altering the dough handling properties. Therefore, the effect of pH on loaf volume might not be attributed solely to its effect on lipoxygenase activity.

The regression model indicated that the optimum pH was between 6.4 and 8.3 (Fig. 3). Longer rest times were required at both higher and lower pH. The pH of the whole wheat flour used was 6.57.

TABLE III
Effects of Surfactants on Whole Wheat Bread Loaf Volume

Surfactants[a]	Loaf Volume[b] (cm^3)	Standard Deviation (cm^3)
None	760	...
SSL	862	17.7
Polysorbate	775	28.3
Ethoxy monoglyceride	813	24.7
DATEM	853	20.2
Monoglycerides	763	15.3
Succinated monoglycerides	838	5.8
Lecithin	837	15.3

[a] Addition levels were 0.5% (based on flour weight). SSL = sodium stearoyl lactylate, DATEM = diacetyl tartaric acid esters of monoglycerides.
[b] Numbers are averages of three observations. Loaves were baked using 61 min proof time.

Effects of Surfactants on Quality of Whole Wheat Bread

SSL, polysorbate, ethoxylated monoglyceride, succinylated monoglyceride, DATEM, lecithin, and monoglyceride all at 0.5% were added with 6% shortening to the breadmaking formula. Except for monoglyceride and polysorbate, all the tested surfactants improved loaf volume (Table III). SSL and DATEM were the most effective.

Effect of Storage on the Baking Quality of Whole Wheat Flour

Whole wheat flour was stored at 40°C for four weeks to determine its shelf life. The baking quality of the whole wheat flour did not change during the four weeks of storage except that the mixing time increased (Table IV).

Effects of Water, SSL, and Shortening on Whole Wheat Breadmaking

A three-factor, five-level central composite design was used to study the effects of water, SSL, and shortening on whole wheat breadmaking. The R^2 of the regression model describing the effect of SSL, shortening, and water on loaf volume was 0.91. The regression model indicated that the best loaf volume cannot be obtained without a high level of absorption plus high levels of SSL, greater than 2% (Fig. 4). The regression model also suggested that shortening was slightly detrimental to loaf volume. This appears to

TABLE IV
Effect of Storage on Baking Quality of Whole Wheat Flour

Storage Time	Loaf Volume[a] (cm^3)	Standard Deviation (cm^3)	Mixing Time[b]
Control (0 days)	931	13.9	5 min 30 sec
2 days	932	17.6	5 min 30 sec
6 days	928	2.9	6 min 45 sec
14 days	905	13	6 min 30 sec
21 days	930	23.1	6 min 25 sec
28 days	932	2.9	7 min 10 sec

[a] Averages of six observations.
[b] Mixing time does not include the 1 min time used in preparing the no-yeast sponge.

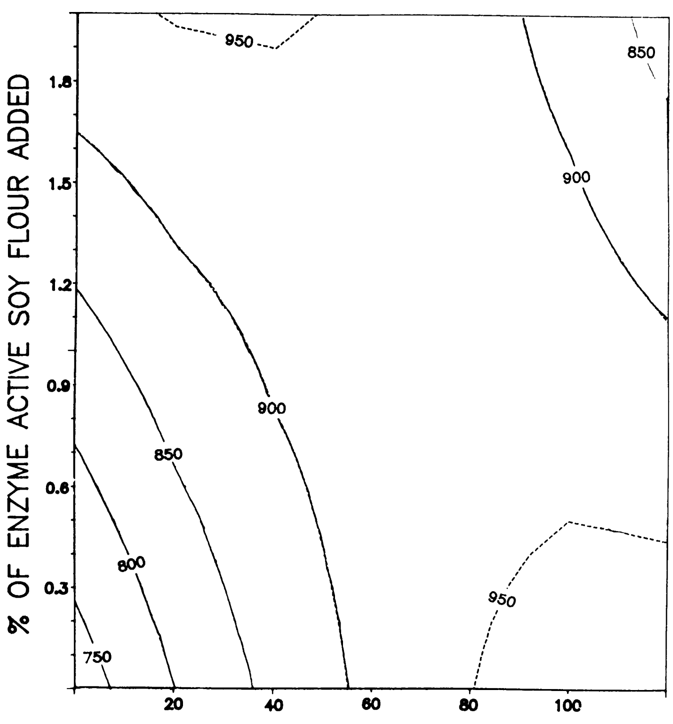

Fig. 3. Loaf volume contours as a function of rest time and enzyme-active soy flour level. Volume = 722 + 108.1S + 4.15T − 2.4S² − 1.54ST − 0.016T², where S = % of soy flour level, and T = rest time in minutes.

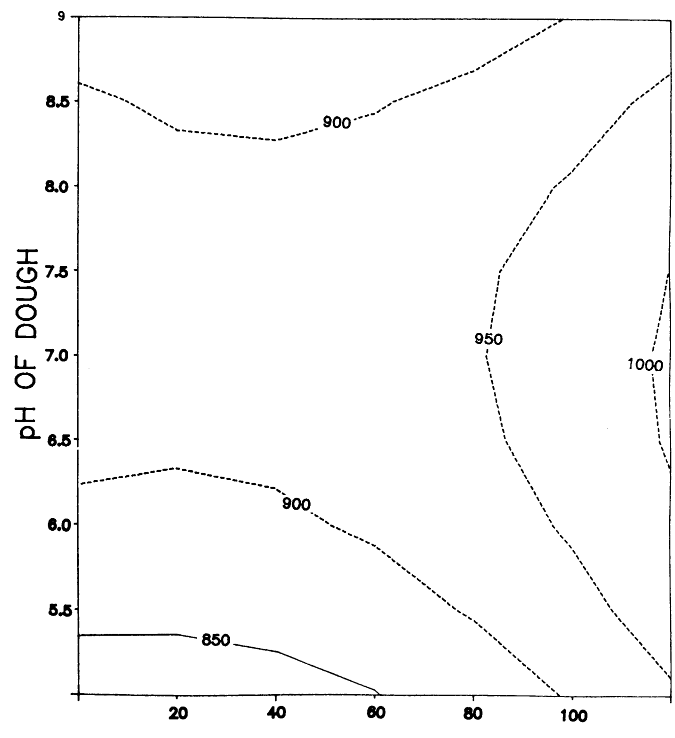

Fig. 4. Loaf volume contours as a function of rest time and dough pH. Volume = −30.9 + 258P + 0.55T − 17.4P² − 0.15PT + 0.01T², where P = pH of the dough, and T = rest time in minutes.

TABLE V
Effect of Yeast Level on Whole Wheat Bread Loaf Volume

Types of Yeast	Yeast (%)	Loaf Volume[a] (cm^3)
Compressed	1.8	829
Compressed	2.0	884
Compressed	2.2	968
Compressed	2.4	960
Fermipan	0.75	910
Fermipan	0.82	932
Fermipan	0.89	949

[a]Averages of four observations.

contradict our earlier findings with bran (Lai et al 1989a), possibly because the baking absorptions used in this test were much higher than those used in the previous studies.

After fermentation, the doughs had a wet surface that lowered their handling scores. The regression model produced to describe the effect of water, SSL, and shortening on dough handling properties had an R^2 of 0.85. According to the models, water was detrimental to dough handling properties. Inclusion of SSL increased the tolerance for high absorption and improved dough handling (Fig. 5).

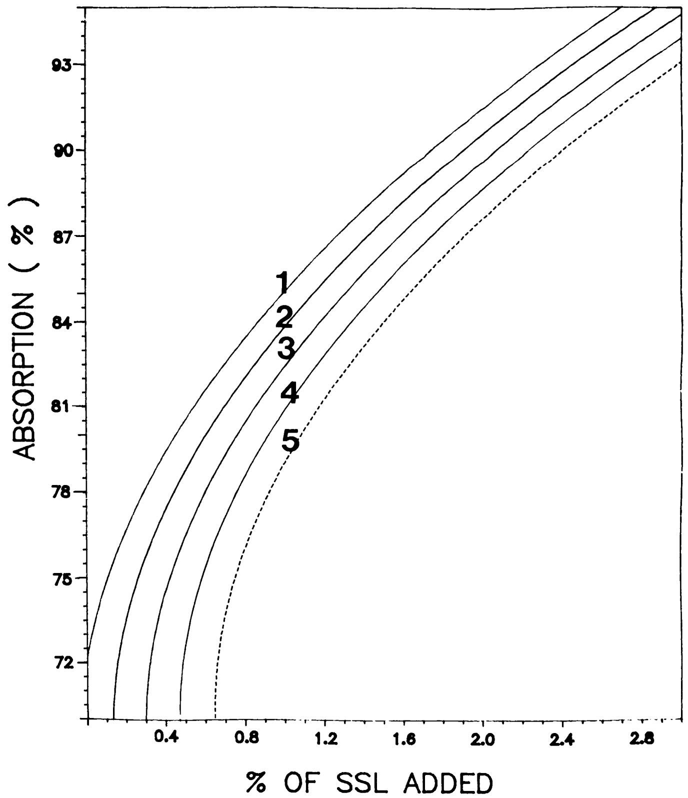

Fig. 5. Dough handling property (after fermentation) score contours as a function of absorption and sodium stearoyl lactylate (SSL) level. Shortening level 6%. Score = $-143.7 + 4.2A - 5.5S - 0.03A^2 + 0.09AS - 0.45S^2$, where A = absorption, and S = SSL.

Comparison of Fermipan and Compressed Yeast

A preliminary test showed that a slight change in yeast activity did not affect loaf volume of white pan bread much but significantly affected the loaf volume of whole wheat bread (data not shown). Increasing the level of instant dry yeast to 0.89% improved loaf volume (Table V) but the grain of the loaf deteriorated. The bread crumb developed large holes when instant dry yeast level exceeded 0.82 g/100 g of flour; however, the loaves did not appear overoxidized. Fermented doughs containing high levels of instant dry yeast were stickier than those containing the level normally used (0.75 g).

Dough containing 2% compressed yeast produced loaves with a volume almost equal to that of loaves containing 0.75 g of instant dry yeast. A slight increase (0.2%) of compressed yeast level increased loaf volume up to about 970 cm^3. Further increases in yeast level did not improve loaf volume but caused large holes in the crumb (Table V). Unlike instant dry yeast, high levels of compressed yeast did not significantly affect the dough handling properties.

The data suggest that in order to ensure constant bread loaf volume, a yeast level higher than the minimum level that normally gives the best loaf volume should be used. Compressed yeast was superior to instant dry yeast for maintaining constant bread quality in this system, because it can be used at high levels without causing any negative effects.

CONCLUSIONS

Good quality whole wheat bread can be produced using a no-yeast sponge baking process. The required rest time was a function of enzyme soy flour level and pH. The best loaf volume was obtained using an appropriate combination of certain salts and the highest absorption possible while maintaining a manageable dough.

Inclusion of high levels of SSL increased the tolerance for high absorption and also improved bread loaf volume and dough handling properties. A level of compressed yeast higher than the minimum level required for the best loaf volume was needed to ensure consistent bread quality.

LITERATURE CITED

COCHRAN, W. G., and COX, G. M. 1957. Experimental designs, 2nd ed. Wiley: New York.

FINNEY, K. F. 1984. An optimized straight-dough breadmaking method after 44 years. Cereal Chem. 61:20.

HOLMES, J. T., and HOSENEY, R. C. 1987a. Chemical leavening: Effect of pH and certain ions on breadmaking properties. Cereal Chem. 64:343.

HOLMES, J. T., and HOSENEY, R. C. 1987b. Frozen dough: Freezing and thawing rate and the potential of using a combination of yeast and chemical leavening. Cereal Chem. 64:348.

LAI, C. S., DAVIS, A. B., and HOSENEY, R. C. 1989a. Functional effect of bran in breadmaking. Cereal Chem. 66:217.

LAI, C. S., HOSENEY, R. C., and DAVIS, A. B. 1989b. Functional effect of shorts in breadmaking. Cereal Chem. 66:220.

POMERANZ, Y. 1977. Fiber in breadmaking: A review of recent studies. Baker's Dig. 51(5):94.

ROGERS, D., and HOSENEY, R. C. 1982. Problems associated with producing whole wheat bread. Cereal Foods World 27:451.

[Received March 11, 1988. Accepted January 9, 1989.]