Baking Properties of the Bran Fraction from Brewer's Spent Grains[1]

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ABSTRACT

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Brewer's spent grain (BSG) was composed of barley hulls and barley pericarp (bran), which were separated after milling. The hulls, which were fibrous and abrasive in texture, were judged to be unusable as human food; all bread-making work was done with BSG bran. When BSG bran was used to replace 15% of the flour in a bread formula, water absorption increased 16%. The BSG decreased loaf volume and had a deleterious effect on crumb grain, giving an appearance similar to that of bread with no shortening. Both conditions were relieved somewhat by adding sodium stearoyl lactylate and/or increasing shortening. Studies with a resistance oven showed that bread containing BSG set at a lower temperature than did the control.

In brewing, a mash is prepared from water, malt, and usually a cooked carbohydrate adjunct like corn grits or rice. The mash is heated to assist the enzymatic hydrolysis of the carbohydrates. When hydrolysis is complete, the liquid (wort) is filtered through the solid residue and used to brew beer. The solid residue that remains after filtration is a by-product of the brewing industry called brewer's spent grain (BSG). For every barrel of beer, 12½ lb (dry basis) of BSG is produced. More than 700,000 tons (dry weight) of BSG is produced annually in the United States.

The spent grain consists mainly of the pericarp and hull portions of barley and of the nonstarchy parts of corn, if corn grits are used as an adjunct. Although "spent" in terms of fermentable carbohydrate, BSG is higher in protein, lipids, and fiber than the original barley-adjunct mixture. Because it is high in both fiber and protein, BSG can be added to human food as a protein and fiber supplement.

Finley and Hanamoto (1980) added milled fractions of BSG to bread at 6 and 12% flour replacement levels. At 12% all bread was judged unsatisfactory. Prentice and D'Appolonia (1977) used BSG in bread at 5, 10, and 15% flour replacement levels. The bread was evaluated by a taste panel and compared with a control containing 30% whole wheat flour and 70% wheat flour. No significant preference was shown between the control and bread containing 5 or 10% BSG. The 30% whole wheat control was significantly preferred over the bread with 15% BSG.

Our objective was to determine why BSG bran (BSGB) decreased loaf volume more than would be expected from a straight dilution of gluten protein. We also wanted to produce good quality bread with 15% of the wheat flour replaced with BSGB.

MATERIALS AND METHODS

BSG

Commercial samples of BSG, dried to a moisture content of about 9% and containing no hop residue, were provided by the Miller Brewing Co., Milwaukee, WI. The BSG was milled, and all baking work was done with BSGB.

Flour

The flour was Kansas State University flour containing 11.4% protein and 0.4% ash and was a straight grade flour milled from hard red winter wheat on the Kansas State University pilot flour mill.

Conventional Oven Baking

The formula for the control bread was 100 g of flour (14% mb), 6 g of sugar, 1.5 g of salt, 4 g of nonfat dry milk, 3 g of shortening, 2 g of yeast, and optimum amounts of $KBrO_3$, water, and malt. In treatment loaves, 15 g of BSGB (14% mb) was substituted for 15 g of flour. A straight-dough, pup-loaf baking procedure was used. Mixing was done in a 100-g National pin mixer, and mixograms were run. Doughs were handled and baked according to the procedure of Finney and Barmore (1943). In this procedure, doughs are punched after 105 and 155 min and panned after 180 min of fermentation. Loaf volume and weight were measured and recorded immediately after loaves came from the oven.

Mixing time was also studied with BSGB bread made by a sponge-and-dough procedure and containing BSGB that had been soaked for 2 hr with 25 ml of water before being mixed.

Resistance Oven Baking

Baker (1939) and Junge and Hoseney (1981) described a method of baking bread in a resistance oven. In our resistance oven, the dough piece was placed between two stainless steel plates (electrodes), which were coated with an alcoholic solution of quinhydrone to decrease electrical resistance at the plate-dough interface. The plates were wired to a variable transformer set to provide 84 V across the plates. When the transformer is on, a current passes through the dough, and the dough is heated by its resistance to the current flow. An advantage of the resistance oven for research is that the dough heats uniformly throughout instead of from the outside to the center.

The resistance oven was constructed from ¼-in. plexiglass so that the dough could be watched as it baked (Junge and Hoseney 1981). A centimeter scale was attached to each end of the oven so that, by sighting from one end to the other, one could accurately determine the height of the baking loaf.

Doughs were made with the same formula used in the pup-loaf baking studies except that 2.0 g of salt was used. Shortening and sodium stearoyl lactylate (SSL) were added in various amounts, as experimental variables.

The doughs were baked in the resistance oven for 18 min with height recorded at 30-sec intervals. Loaf heights were plotted against baking time.

RESULTS AND DISCUSSION

Visual examination of BSG shows that it consists of two widely different fractions. One, the hulls, has a relatively large particle size and is fibrous and abrasive in texture. The other, the barley pericarp, is darker brown, has smaller particles, and is much softer and more amorphous in texture.

We assumed that the hulls would not be usable as food because of their abrasive texture, so we milled the BSG. Removing the hulls gave us a 51% yield of BSGB, which was used in baking studies.

Conventional Oven Baking

Water absorption increased dramatically when BSGB was included in the baking formula; optimum absorption increased by 16% when 15 g of flour was replaced by 15 g of BSGB.

Spent grains apparently do not absorb this water immediately.

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At such high absorptions, doughs out of the mixer felt sticky and wet. However, by first punch, the BSGB doughs felt optimum in water although weaker than the control doughs.

The high absorptions were necessary to produce optimum bread. Weights and volumes of BSGB loaves baked at different absorptions are shown in Table I. The loaves with absorptions below optimum not only had lower volumes but also had rounded, pulled-in corners characteristic of bread baked with too little water. The loaf weights listed in Table I show that the extra water was retained through baking.

Bread loaf volume is affected by the quality and quantity of gluten protein in the loaf. If the flour (and therefore the gluten quality) is held constant, the relationship between flour protein and loaf volume is linear above 8% protein. Thus, if the spent grains do not depress loaf volume, prediction of the expected loaf volume is possible. The flour has 11.4% protein with a loaf volume of 880 cc. A linear regression for this flour has a slope of 73 cc/g of protein. The treatment loaves have 15% less gluten protein than the controls. Thus the treated loaves should be 0.15 × 11.4 × 73 or 125 cc less in loaf volume than the control loaves. The actual difference (170 cc) was larger, indicating that the BSGB had a volume-depressing effect.

TABLE I
Baking Data for Bread Baked with Brewer's Spent Grain Bran at Different Water Absorptions

Absorption	Loaf Weight (g)	Volume (cc)
61 (control)	144	880
75	155	690
76	156	705
77	158	710
78	160	710
79	160	705

TABLE II
Effects of Shortening and/or Sodium Stearoyl Lactylate (SSL) on Loaf Volume of Bread Containing Brewer's Spent Grain Bran

Shortening (%)	SSL (%)	Loaf Weight (g)	Volume (cc)
3 (control)[a]	···	144	880
0	0	155	665
	0.5	157	705
	2.0	157	735
3	0	156	710
	0.5	157	745
	2.0	160	785
6	0	160	750
	0.5	159	780
	2.0	161	815

[a] Without brewer's spent grain.

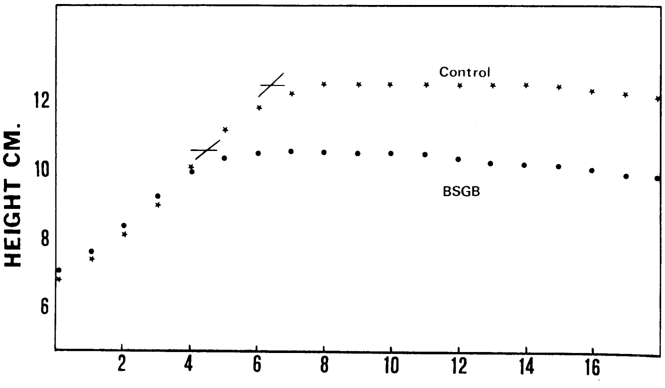

Fig. 1. Loaf height vs baking time for control and bread containing brewer's spent grain bran (BSGB).

The grain of loaves containing BSGB was similar to that of bread baked with no shortening. We postulated that a lipophylic fraction in the BSGB was taking a lipid component away from the rest of the dough.

BSGB bread baked with various levels of shortening and SSL (Table II) showed steady improvement in both loaf volume and crumb grain as shortening or SSL was increased. A combination of shortening and SSL was even more effective; 3% shortening and 2% SSL or 6% shortening and either 0.5 or 2.0% SSL gave volumes larger than the calculated volume (755 cc) that should result from adding BSGB to controls (880−125).

Resistance Oven Baking

We used a resistance oven to investigate the effect of BSGB on bread during the baking process. Loaf height versus baking time curves for a control dough (with no BSGB) and for a dough containing BSGB but no special treatment are shown in Fig. 1. The BSGB loaf has a slightly higher proof height than the control, and the two loaves expand at approximately the same rate during the initial stage of baking. The final height of the control is higher because it continued to expand for about 2 min after the BSGB loaf had stopped expanding. Junge and Hoseney (1981) showed that a loaf in a resistance oven stops expanding when starch gelatinization takes place. The fact that the BSGB loaf stopped expanding earlier than the control loaf therefore indicates that the starch in the BSGB loaf gelatinized earlier than the starch in the control loaf.

The general trend of increased loaf volumes with the addition of shortening and/or SSL to BSGB doughs was true for both conventional and resistance oven baking. We used the resistance oven to bake doughs with 0, 3, and 6% shortening and 0, 0.5, and 2.0% SSL. The expected increase in loaf height as shortening or SSL increased was apparent. The increases in height come from increases in proof height and oven spring and from delayed loaf setting.

Effect on Mixing Time

The formula modifications that improved the quality of bread containing BSGB also increased mixing time (Table III).

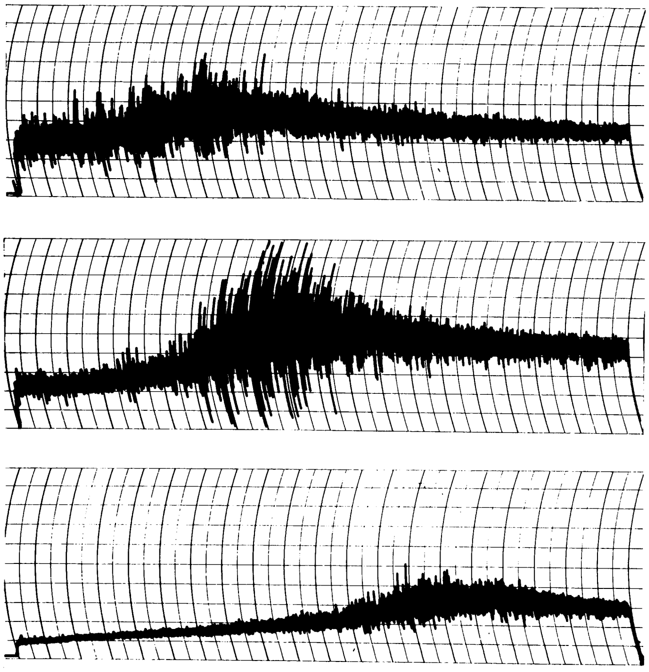

Fig. 2. Mixograms. **Top**, 100% Kansas State University (KSU) flour and 61% water (control); **middle**, 100% KSU flour, 6% sugar, 1.5% salt, 3% shortening, and 61% water; **bottom**, 85% KSU flour, 15% brewer's spent grain bran, and 77% water.

TABLE III
Mixing Times of Brewer's Spent Grain Bran (BSGB) Doughs with Indicated Treatments

Dough Treatment	Shortening (%)	SSL[a] (%)	Mixing Time (min)
Straight-dough procedure			
Control (no BSGB)	3	···	6.5
BSGB added[b]	3	···	10.7
	3	0.5	13.0
	3	2.0	15.5
	6	···	11.5
	6	0.5	13.8
	6	2.0	16.0
Soaked BSGB added[b]	3	···	9.6
Sponge-and-dough procedure			
Control (no BSGB)	3	···	4.0
BSGB added			
To sponge[b]	3	···	5.5
To dough[b]	3	···	4.8

[a] Sodium stearoyl lactylate.

[b] 77% absorption.

Mixograms (Figs. 2 and 3) were run to document the effect of lengthened mixing time and to gain insights into its nature. The mixograms show that for a considerable time after mixing began, BSGB dough offered virtually no resistance to the mixer. The doughs developed extremely slowly until a certain critical development was reached, after which development was much more rapid.

Peaks of the BSGB dough mixograms are difficult to determine precisely. For all BSGB doughs, the viscosity was at or very nearly at its maximum within 4 min after the curve first crossed the third horizontal line from the bottom of the mixogram. The control dough (Fig. 2) crossed this third line quickly but then took another 6½ and 9 min to reach peak development for flour-water and fully formulated doughs, respectively. The increase in mixing time of the BSGB doughs over the control, and of some BSGB doughs over others (Fig. 3), resulted from the long lag between the time the mixer started and the time enough consistency was achieved to cross the third line. We hypothesized that the lag time resulted from the time that BSGB took to soak up the large amount of water in the dough.

Mixing time was reduced somewhat when the 15 g of BSGB was soaked in water before being mixed (Table III). BSGB bread was made by a sponge-and-dough procedure with the BSGB added to both the sponge and the dough. Mixing time was greatly reduced in each case, to only slightly longer than that of the control.

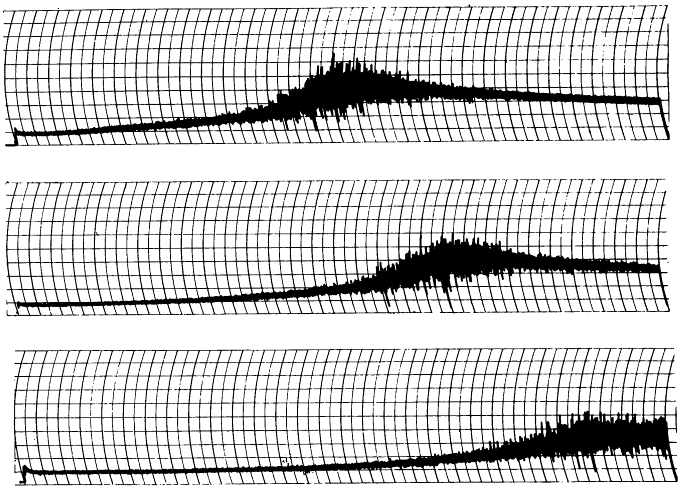

Fig. 3. Mixograms of brewer's spent grain bran (BSGB) doughs. All doughs contained: 85% Kansas State University flour, 15% BSGB, 6% sugar, 1.5% salt, 3% shortening, and 77% water. Sodium stearoyl lactylate content: **top**, none; **middle**, 0.5%; **bottom**, 2%.

CONCLUSIONS

When BSGB is included in a bread formula, water absorption and mixing time are increased and loaf volume is decreased. The decrease in loaf volume results from the BSGB loaf setting earlier in the baking process than the control. Increasing shortening and/or SSL delays loaf setting and increases volume of BSGB bread. The increase in mixing time caused by the BSGB can be decreased slightly by soaking the BSGB in water before mixing, and mixing time is much shorter with the sponge-and-dough process than with the straight-dough process.

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