BREWERS SPENT GRAINS
AND THEIR BREADMAKING CHARACTERISTICS

by

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INTRODUCTION

In the first stage of brewing a mash is prepared by adding water to ground malt, which in many cases, also contains a cooked carbohydrate adjunct such as corn grits or rice. The temperature is raised to favor the enzymatic hydrolysis of the carbohydrates in the mash. When hydrolysis is complete the liquid (wort) is filtered through the solid residue. The wort continues through the brewing process and eventually becomes beer. The solid residue which remains after filtration of the wort is called brewers spent grain (BSG) and is a by-product of the brewing industry. Twelve and a half pounds (dry basis) of BSG are produced for every barrel of beer, amounting to over 700,000 tons dry weight annually in the United States.

The spent grain consist mainly of the pericarp and hull portions of the barley and of nonstarchy parts of corn if corn grits are used as an adjunct. Although "spent" in terms of carbohydrate, BSG is higher in protein, lipids, and fiber than was the original barley-adjunct mixture. The large amount of BSG produced has, at times, been a disposal problem. The most common use of BSG has been as a feed for ruminants.

Some evidence indicates that lack of fiber in the human diet may contribute to the occurrence of certain noninfectious diseases such as diverticulosis, colon cancer, hemorrhoids, arteriosclerosis, varicose veins, and appendicitis. BSG, because it is high in both fiber and protein, can be added to human food as a protein and fiber supplement.

There are three objectives which could be fulfilled by putting BSG in human food;

1. The protein and fiber contents of the food containing the BSG would be increased.
2. By direct human consumption, better utilization of the food resource would be made.
3. The brewers who produce the BSG would be paid a higher price for their product.

In order for those three objectives to be fulfilled, appreciable quantities of food containing BSG would have to be consumed.

A survey (Anon 1980) conducted by the USDA to determine consumer awareness and attitudes on food grading showed that consumers are more concerned about the quality of bread than nutrition or any other characteristic. Quality was important to 61%, type of bread to 35.9%, brand to 33.8%, price to 30.9%, ingredients to 16.3%, and nutrition to only 8.7%. Therefore the nutritional value alone will not be sufficient to sell BSG. If the three objectives listed above are to be met by putting BSG in bread, a high quality bread containing BSG must be made.

LITERATURE REVIEW

Finley and Hanamoto (1980) milled BSG on a Quadramat Sr. flour mill into two bran fractions, a shorts fraction, and a flour fraction. Each fraction was added to a bread formula at 6 and 12% flour replacement levels. Loaf weights and volumes were measured and loaf quality characteristics were judged. The two bran fractions depressed loaf volume less and were less detrimental to bread quality than the flour or shorts fractions, but at the 12% replacement level all bread was judged unsatisfactory. No attempt was made to alter the fractionation made by the milling system and no special treatments were used to improve the quality of the bread containing the BSG.

In another bread study 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 to a control that contained 30% whole wheat flour and 70% wheat flour. There was no significant preference shown between the control and bread containing 5 and 10% BSG. The 30% whole wheat control was significantly preferred over the bread having 15% BSG.

Prentice et al. (1978) replaced soft wheat flour with ground BSG in cookie formulas. They found that the addition of soy lecithin to a cookie dough containing BSG improved cookie quality.

MATERIALS AND METHODS

Brewers Spent Grain

Commercial samples of BSG were provided by the Miller Brewing Co., Milwaukee, Wisconsin. The BSG had been dried to a moisture content of about 9% and contained no hop residue.

Flour

Two different wheat flours were used during the course of the baking studies. One was BCS 79 which is a research flour milled from a composite of hard red winter wheats grown throughout the great plains. The other flour used was KSU flour which is a hard red winter wheat flour milled on the KSU pilot mill. Analytical and baking characteristics of BCS 79 and KSU flour are given in Table I.

Milling

Three different grinding machines were studied; the Mikro-Bud grinder, which is a pin mill with a built-in air classifier; the Alpine pin mill, which is a one pass, high-speed pin mill; and a roller mill.

The air being drawn through the classifier of the Mikro-Bud grinder can be adjusted by changing a slide valve in the suction line. The classifier speed can be varied from 500 to 1500 rpm. The speed of the Alpine pin mill can be varied but, was used only at 14000 rpm in this study.

The roller mill used was from Ross Machine and Mill Supply,

TABLE I

Analytical and Baking Data for BCS 79 and KSU Flour Used in Baking Studies.

	BCS 79	KSU
% Protein (N x 5.7)	12.2	11.4
% Ash	0.4	0.4
% Moisture	12.4	13.5
Optimum: Absorption (%)	61.2	60.3
$KBrO_3$ (ppm)	20.0	5.0
Mix time (min)	4.25	6.5
Control loaf volume (cc)	950.0	880.0

Oklahoma City, OK, and has a roll size of 6" x 6" (diameter x length). The rolls were corrugated with 22 corrugations/inch. The fast roll speed is set at 435 rpm. The slow roll speed can be varied from 100 to 336 rpm, thus giving a variable differential from 4.35 to 1.3.

All sifting was done on a Richmond lab sifter with a seive size of $12\frac{1}{4}$" x $15\frac{1}{4}$", a throw of 2", and a speed of 290 rpm. For all data reported the sifter was run for four minutes with a sample size of 500 g.

Scanning Electron Microscope

BSG and milled fractions of BSG were viewed and photographed with a scanning electron microscope (SEM). For comparison, barley hulls and barley which had been hand dissected with a razor blade were also viewed. Fine material (smaller than farina sized particles) were stuck to the microscope stubs using double stick scotch tape. Coarse material (farina sized particles or larger) were glued to the stub with silver paste. All samples were coated, under vacuum, with a layer of carbon and then with a layer of gold-palladium of approximately 60 Å and 100 Å thickness, respectively. Photographs were taken with Polaroid Type 55 film on an ETEC U-1 Autoscan SEM operated at an accelerating voltage of 5 kv.

Baking

The bread formula used is shown in Table II. It was a straight dough pup loaf baking procedure. Doughs were handled and baked according to the procedure of Finney and Barmore (1943). In this procedure doughs are punched after 105 and 155 minutes and panned after 180 minutes fermentation. Loaf volume and weight were measured and recorded immediately after coming out of the oven.

Resistance Oven

Baker (1939) and Junge (1980) have each described a method in which bread was baked in a resistance oven. In our resistance oven the dough piece was placed between two stainless steel plates (electrodes). The plates were coated with an alcoholic solution of quinhydrone to decrease electrical resistance at the plate and dough interface. The plates were wired to a variable transformer which was set to provide 84 volts across the plates. When the transformer is on, a current passes through the dough. 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 of the dough to the center.

The resistance oven was constructed from ¼" plexiglass so the dough could be watched as it baked (Junge 1980). A centimeter scale was attached to each end of the oven and by sighting from one end to the other, the height of the baking loaf could be accurately determined.

Doughs were made with the same formula as used in the pup loaf baking studies except that 2.0 g salt was used instead of 1.5 g. Shortening, oil, SSL, and sugar were all added in varying amounts, as experimental variables.

TABLE II

Control and Treatment Bread Formulas
Used in Baking Studies.

Control	Treatment
100 g (14% MB) flour	85 g (14% MB) flour
6 g sugar	15 g (14% MB) BSG bran
1.5 g salt	6 g sugar
4 g NFDM	1.5 g salt
3 g shortening	4 g NFDM
2 g yeast	3 g shortening
$KBrO_3$ optimum	2 g yeast
Water optimum	$KBrO_3$ optimum
Malt optimum	Water optimum
	Malt optimum
	Treatment additives

The doughs were baked in the resistance oven for 18 minutes and the height was recorded at 30 second intervals. The loaf heights were plotted against baking time.

Lyophilizing and Lipid Extraction of BSG Doughs

Bread doughs of the same formula used in the baking studies, except that yeast was left out, were mixed to optimum development in a National pin mixer. Immediately after mixing the dough was placed in a Waring blender with 250 ml distilled water and blended for 10 seconds at low and 15 seconds at high speed. This totally dispersed the dough. The suspension was centrifuged for 20 minutes at 1600x g.

After centrifugation, the solids in the centrifuge tube were in layers. The layers were separated with a spatula, frozen, and lyophilized. Each fraction was ground in a Stein mill and analyzed for moisture, protein, ash, and lipid. The lipid analysis was done by a soxlet extraction with petroleum ether.

RESULTS AND DISCUSSION

Milling

A visual examination of brewers spent grains (BSG) shows that it consists of two very different fractions. One fraction, the hulls, is relatively large in particle size and fibrous and abrasive in texture. The other fraction, the barley pericarp, is darker brown in color, smaller in particle size, and much softer and more amorphous in texture.

Because of their abrasive texture, we assumed that the hulls would not be usable as food. Therefore, the first work we undertook was milling the brewers spent grain. The objective of the milling studies was to find a method for separating the pericarp residue (bran) from the hulls.

BSG was ground with the Mikro-Bud grinder, the Alpine pin mill, and the roller mill. The product from each mill was sifted and the resulting fractions were weighed and subjectively judged for purity of bran or hulls. The milling data is shown in Table III.

During milling the BSG hulls had a tendency to break into long narrow slivers. The slivers, by standing on end, would pass thru sieves that had openings much smaller than the length of the sliver. This made separation difficult. The roller mill had less of a tendency to break the hulls into slivers than did either of the two impact mills.

The rolls, therefore, appeared best suited for a bran-hull

TABLE III

Sifting Date for Brewers Spent Grains Ground on Different Milling Machines.

Seive		Grinding Machine			
		None	Alpine	Mikro-Bud[a]	Rolls[b]
Thru	Over	% of Original BSG			
-	20 wire (910μm)	51.3	0	2.3	13.6
20 wire (910μm)	62 wire (308μm)	43.3	12.2	25.7	54.1
62 wire (308μm)	84 wire (216μm)	3.3	15.1	17.8	17.1
84 wire (216μm)	10 xx (130μm)	1.4	34.5	24.0	9.9
10 xx (130μm)	Pan	0.5	35.8	29.8	4.6
Total Recovery		99.8	98.6	99.6	99.3

[a]At 500 rpm with air setting at 2.5

[b]Differential set at 3.0

separation process. The rolls were studied at differentials of 2.5, 3.0, 3.5, and 4.0 and with various roll settings (distance between rolls). A visual subjective evaluation was made of the stock produced by each differential-roll setting combination. The best combination was 3.0 differential and a "tight" setting. The rolls would just touch if there was no stock running between them. With this differential and setting one-pass thru the rolls was sufficient to free the bran from the hulls so that the remaining separation problem was one of sifting and not of grinding.

When the BSG that had been ground once on the rolls was sifted, there was a natural break between a 22 wire (818µm) and 36 wire (500µm) sieve. The overs of the 22 wire fraction was 27% of the total BSG and was virtually all hulls. The fraction passing thru the 22 wire and staying over the 36 wire was 22% of the total BSG and was a mixture of hulls and bran. The thrus of the 36 wire was bran and was pure enough that no further separation was deemed necessary.

The protein of the unmilled BSG was 25.6%, the protein of the bran fraction was 34.7% and that of the hulls was 9.7%. The highest and lowest protein contents obtained on any of the milling fractions were 39.9% and 6.6%, respectively.

If the bran is assumed to be totally homogeneous and to have a protein content of 39.9%, and if the hulls are assumed to be totally homogeneous and to have a protein content of 6.6%, then the protein content of any BSG fraction can be used to calculate the composition (in terms of bran and hulls) of that BSG fraction.

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We found evidence (to be discussed later) with the scanning electron microscope that the bran fraction contains some aleurone cells and is therefore not totally homogeneous. Inaccuracy of the homogeneity assumption will cause error in theoretical composition calculations, but it is apparent that, in general, the protein content and percentage composition of bran tend to be directly related for fractions of BSG.

The proteins of some BSG milling fractions along with diagrams of the process developed for separating the bran and hulls, and of the processes which led to the highest and lowest protein fractions are shown in figures 1, 2, 3, and 4. The BSG bran was used in all baking studies. No further work was done with the hulls.

Scanning Electron Microscope

We examined the BSG milling fractions with a scanning electron microscope. For comparison, barley and barley hulls dissected by hand with a razor blade were also examined. The BSG hulls (Figs. 5 and 6) appeared to be unaffected by the brewing process and were virtually indistinguishable from hulls removed with a razor (Figs. 7 and 8). The outside of the hulls can be distinguished from the inside by the many bumps (probably hair cells) on the outside surface. The inside surface of the hulls tends to attract debris (probably electrostatically) when the BSG is milled. The cell structure of the barley pericarp (called bran in the milling description) is modified in the brewing process (Figs. 9

Fig. 1 Protein of unmilled brewers spent grains and of sifted fractions thereof.

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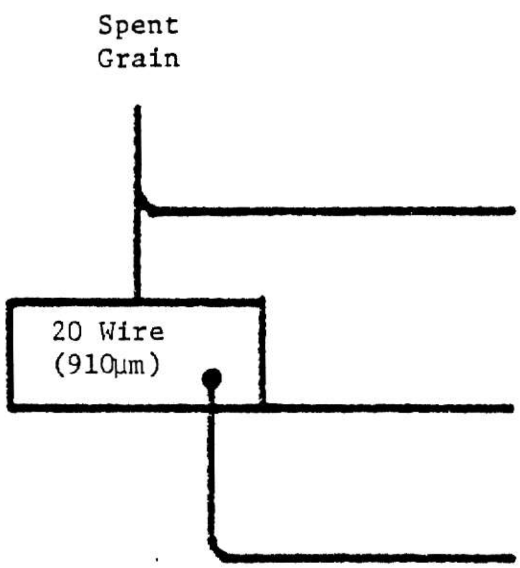
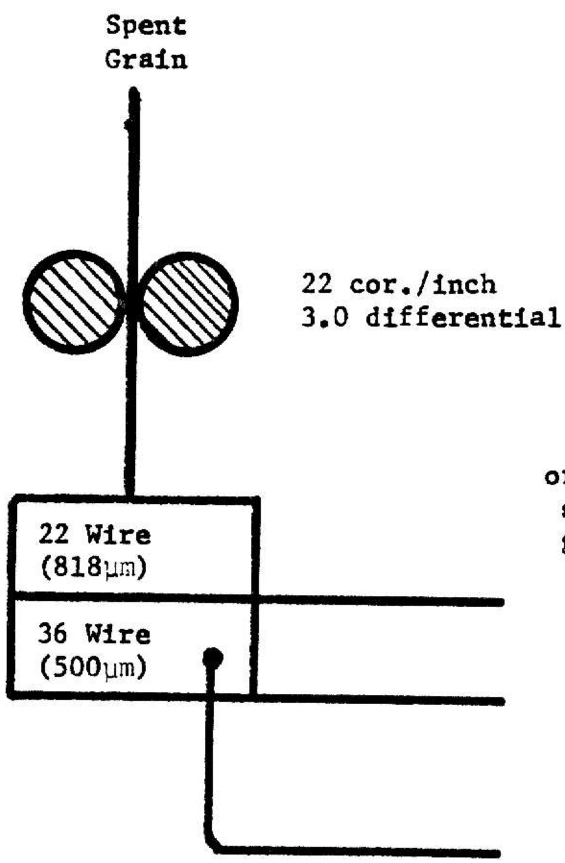


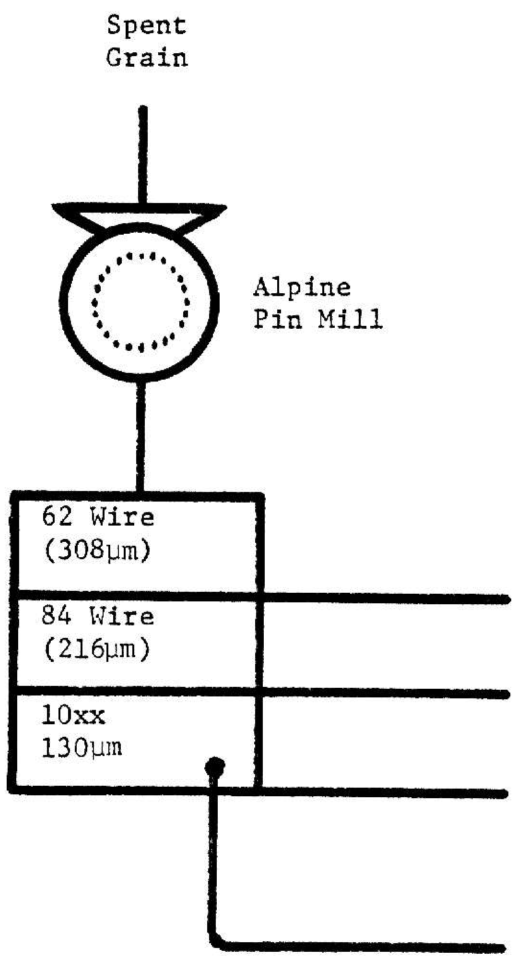
% of original spent grain	Protein %
100	25.6
51	21.9
49	30.7

Figure 2. Schematic diagram of brewers spent grain milling procedure.



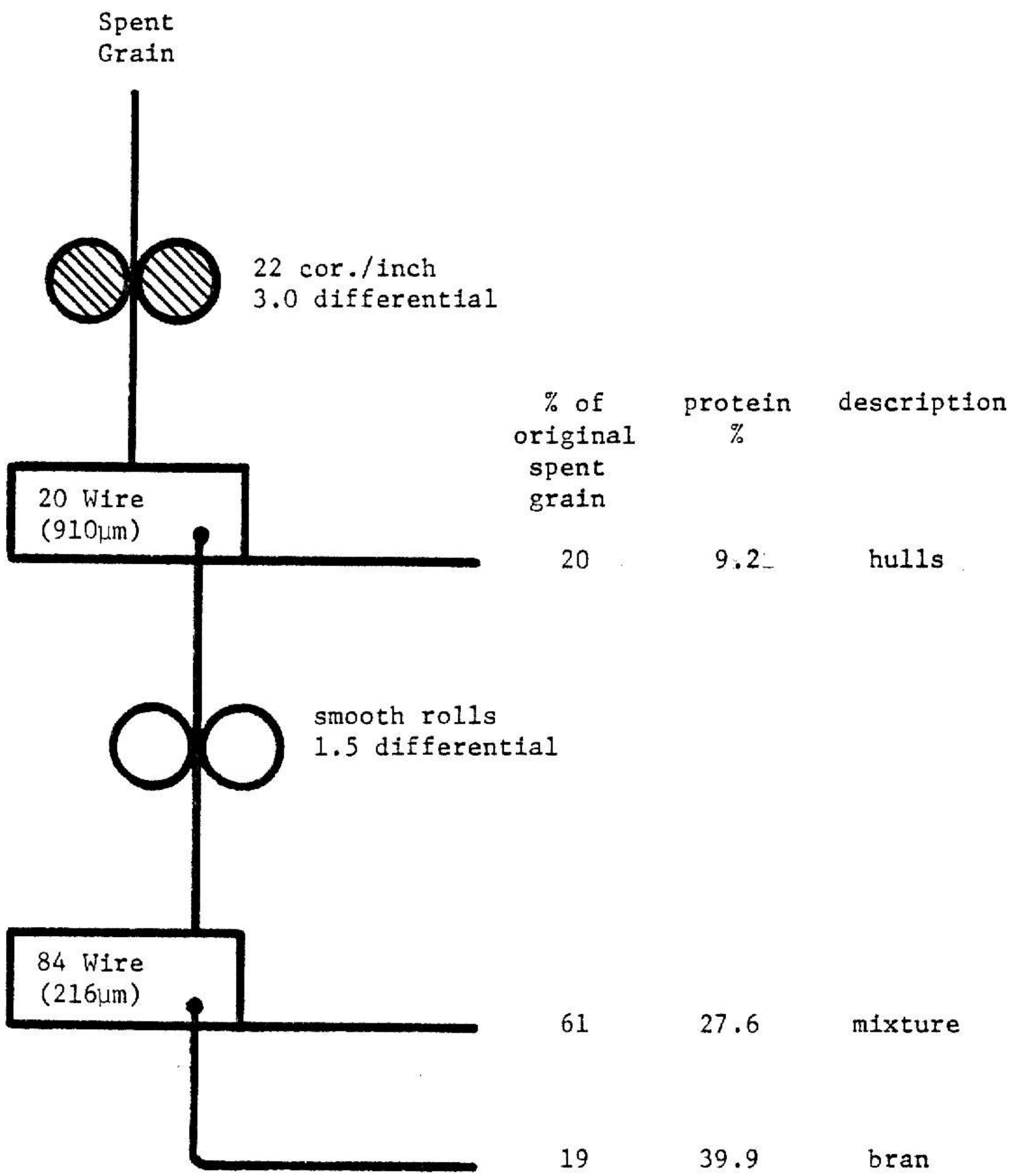
% of original spent grain	Protein %	Description
27	9.7	hulls
22	24.2	mixture
51	34.7	bran

Figure 3. Schematic diagram of milling process leading to lowest protein fraction.



% of original spent grain	Protein %	Description
12	6.6	hulls
16	15.8	mostly hulls some bran
34	23.8	mixture
36	35.4	bran

Figure 4. Schematic diagram of milling process leading to highest protein fraction.


Spent
Grain
22 cor./inch
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% of
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grain
protein
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description
20 Wire
(910µm)
20
9.2
hulls
smooth rolls
1.5 differential
84 Wire
(216µm)
61
27.6
mixture
19
39.9
bran

and 10). In many cases, it was difficult to tell what part of the pericarp we were looking at. There were only a few aleurone cells present in the BSG. Most of the aleurone cells (Fig. 12) were apparently lost in the brewing process. Figure 11 is a picture of stock which has passed through a 30 wire sieve (672µm) and shows several hull slivers which are longer than the size of the seive opening.

Conventional and Resistance Oven Baking

Water absorption increased dramatically when brewers spent grain bran (BSGB) was included in the baking formula. When 15 g of flour was replaced by 15 g of BSGB the optimum absorption increased by 15% and 16% for the BCS 79 and KSU flour, respectively.

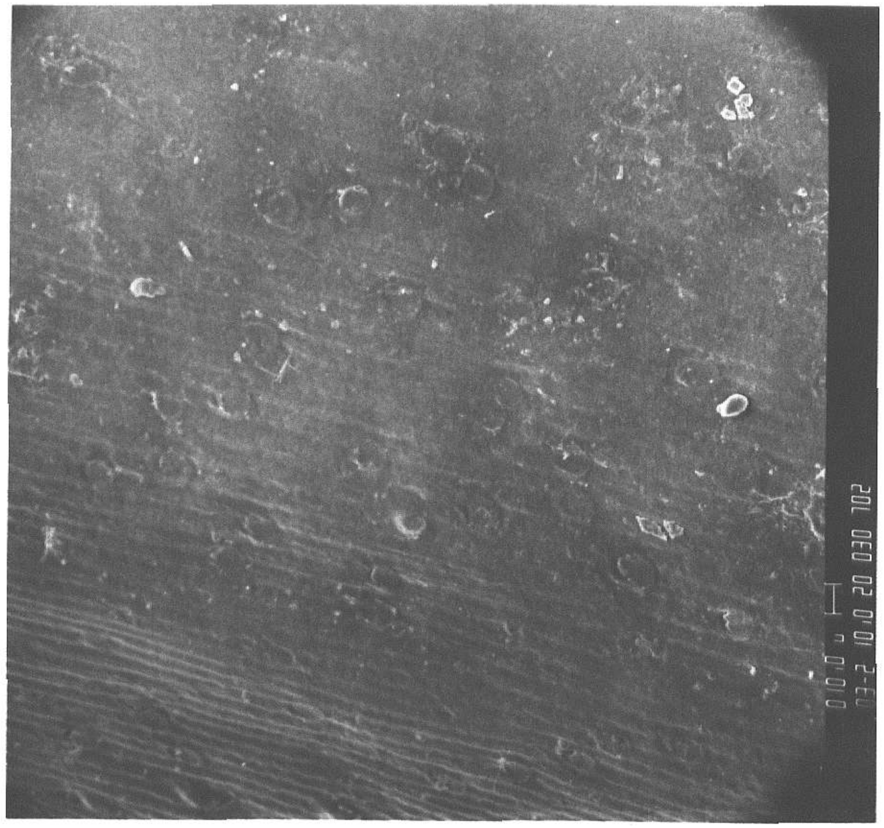
The spent grains apparently do not absorb this water immediately. At these high absorptions, doughs out of the mixer felt sticky and wet. However, by first punch, the BSGB doughs felt optimum in water but were weaker than the control doughs.

The high absorptions were necessary to produce optimum bread. The weights and volumes of BSGB loaves baked at different absorptions are shown in Table IV. The loaves with absorptions lower than the optimum absorption 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 IV 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 wheat variety (gluten

Fig. 5 Spent Grains, outside surface of hull.

Fig. 6 Spent Grains, inside surface of hull with small debris attached.



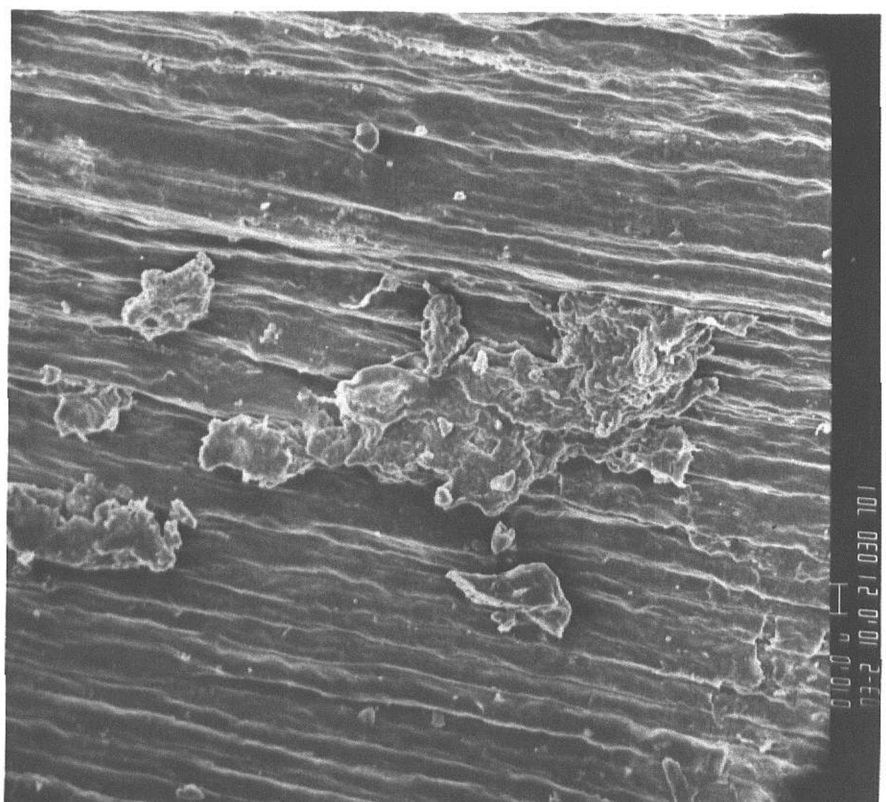
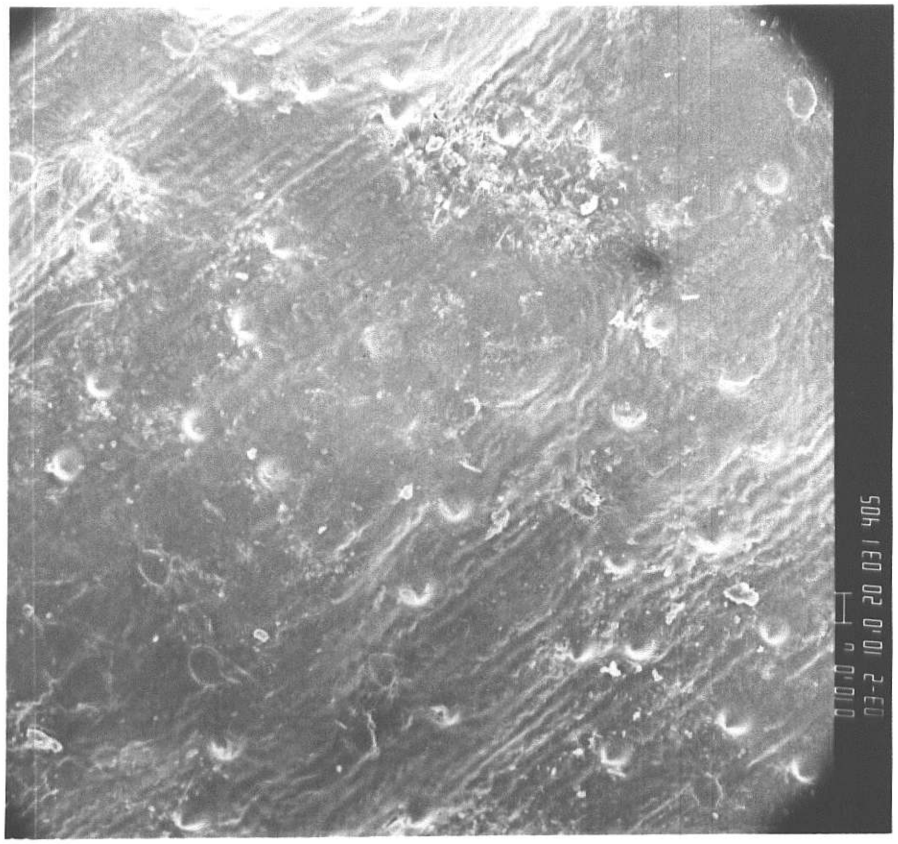


Fig. 7 Cut Barley, outside surface of hull.

Fig. 8 Cut Barley, inside surface and interior of hull.



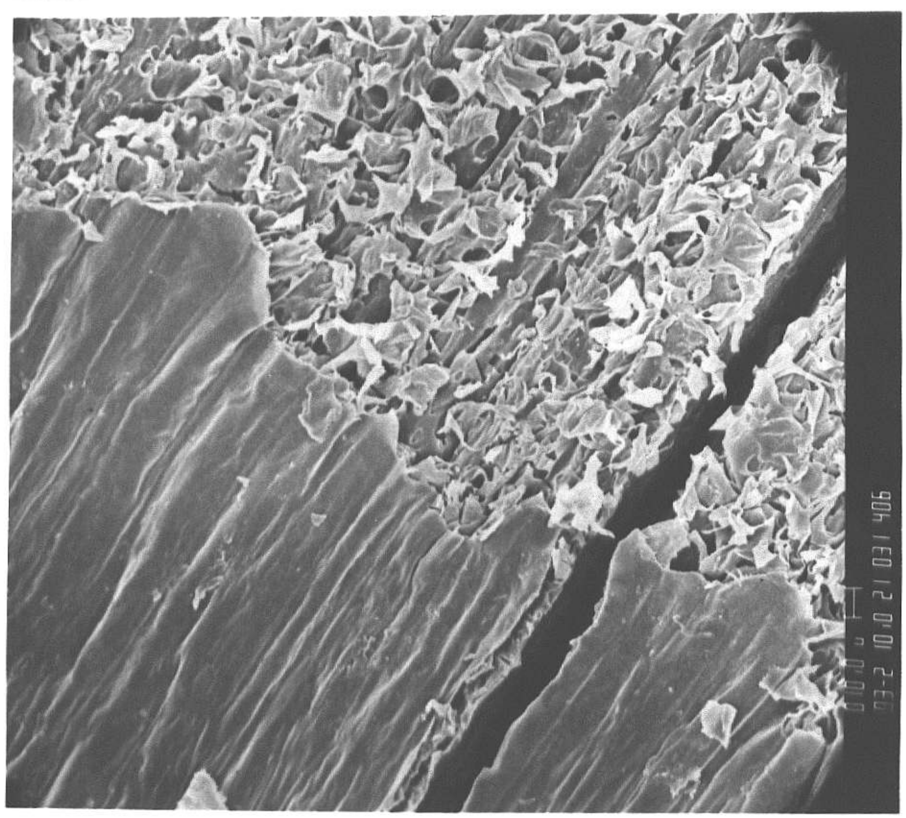
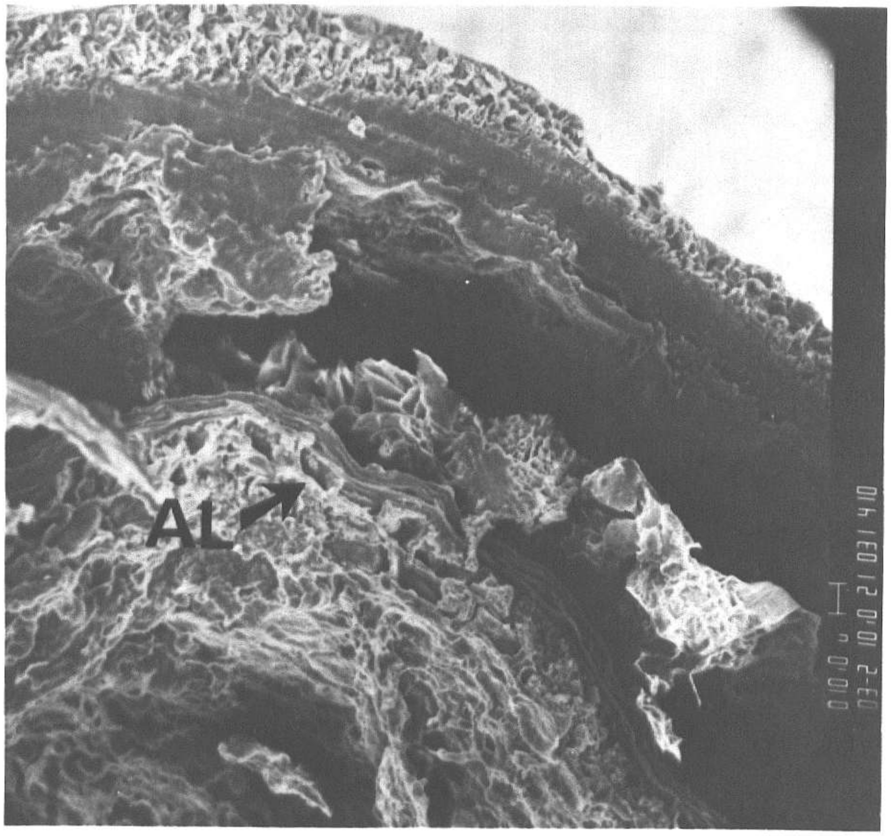


Fig. 9 Spent Grains, cut surface showing aleurone cells (AL).

Fig. 10 Spent Grains, pericarp cell structure not discernable.


AL

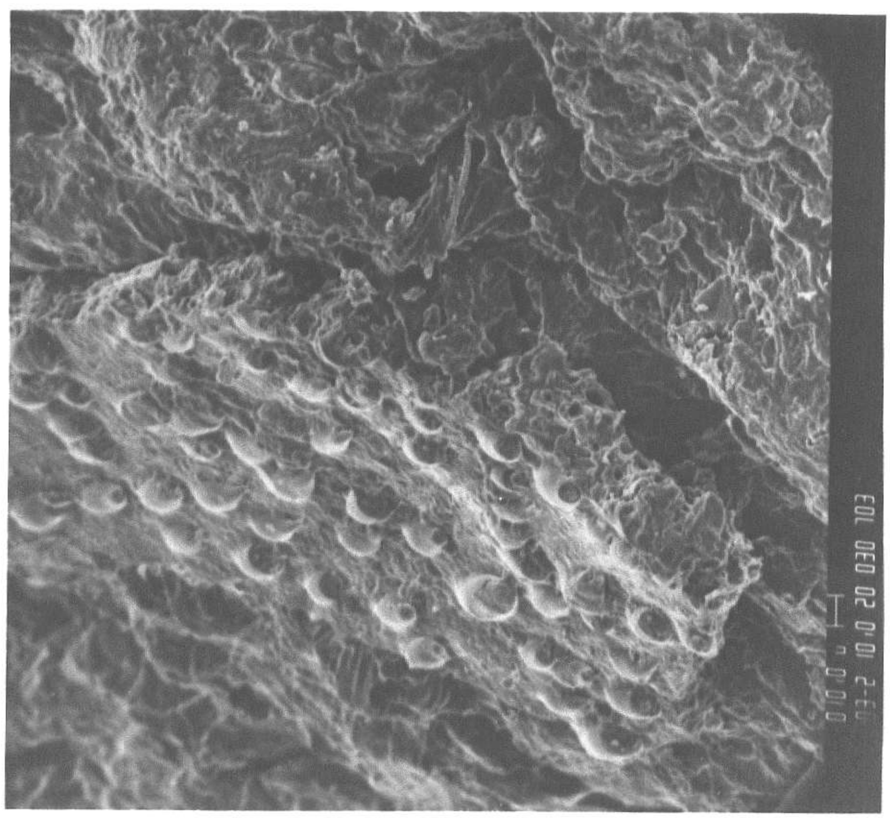
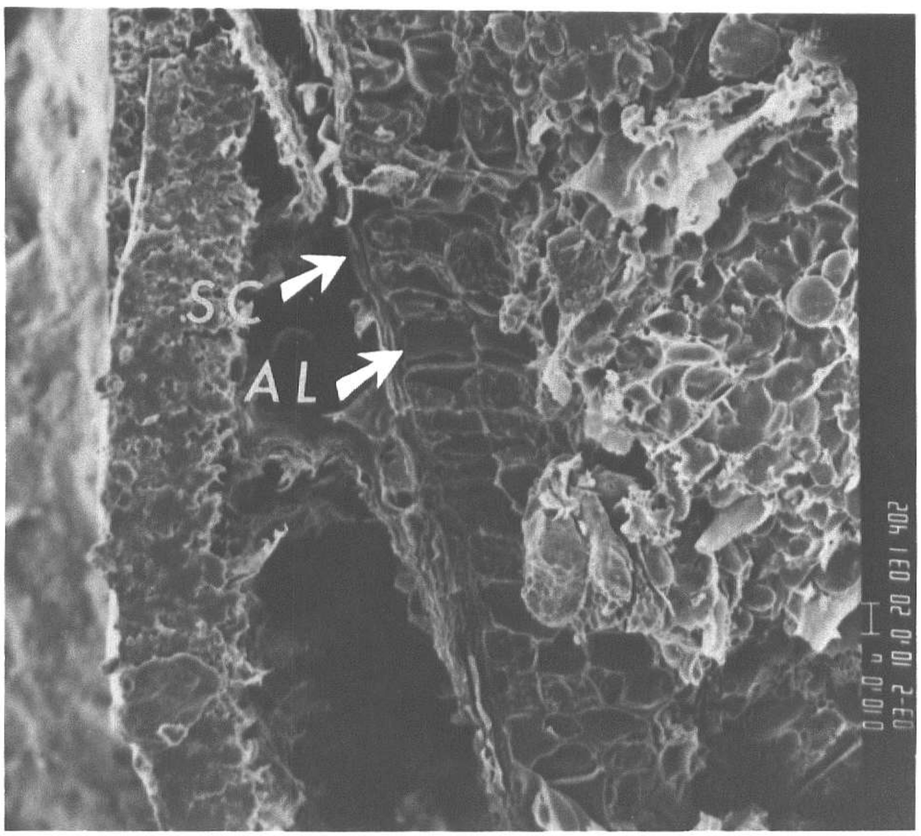


Fig. 11 Spent Grains, fraction that has been ground on rolls and passed through a 30 wire sieve (672μm). Note hull slivers which are longer than sieve opening.

Fig. 12 Cut Barley, showing aleurone cells (AL) and seed coat (S.C.).


SC
AL