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 12¼" x 15¼", 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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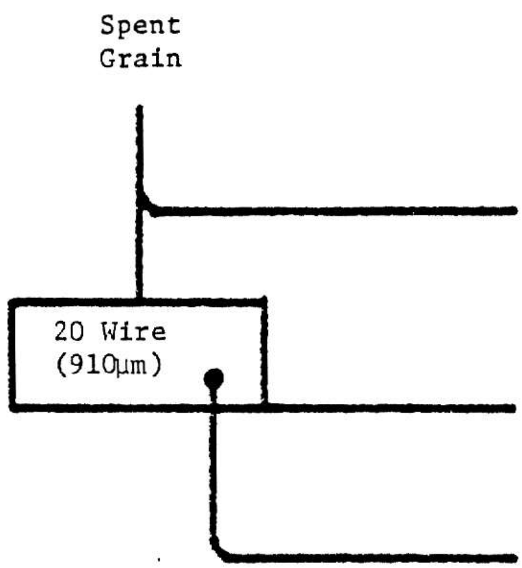
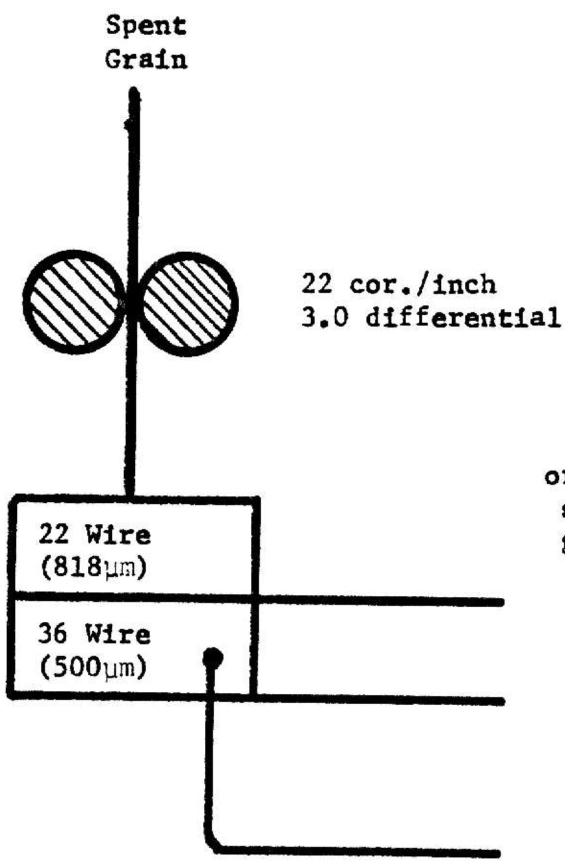


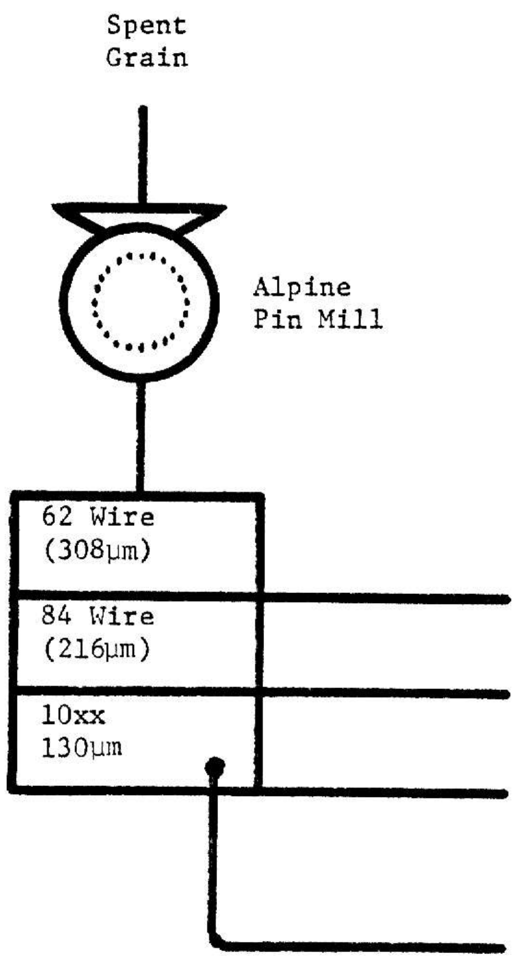
% of original spent grain	Protein %
100	25.6
51	21.9
49	30.7

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



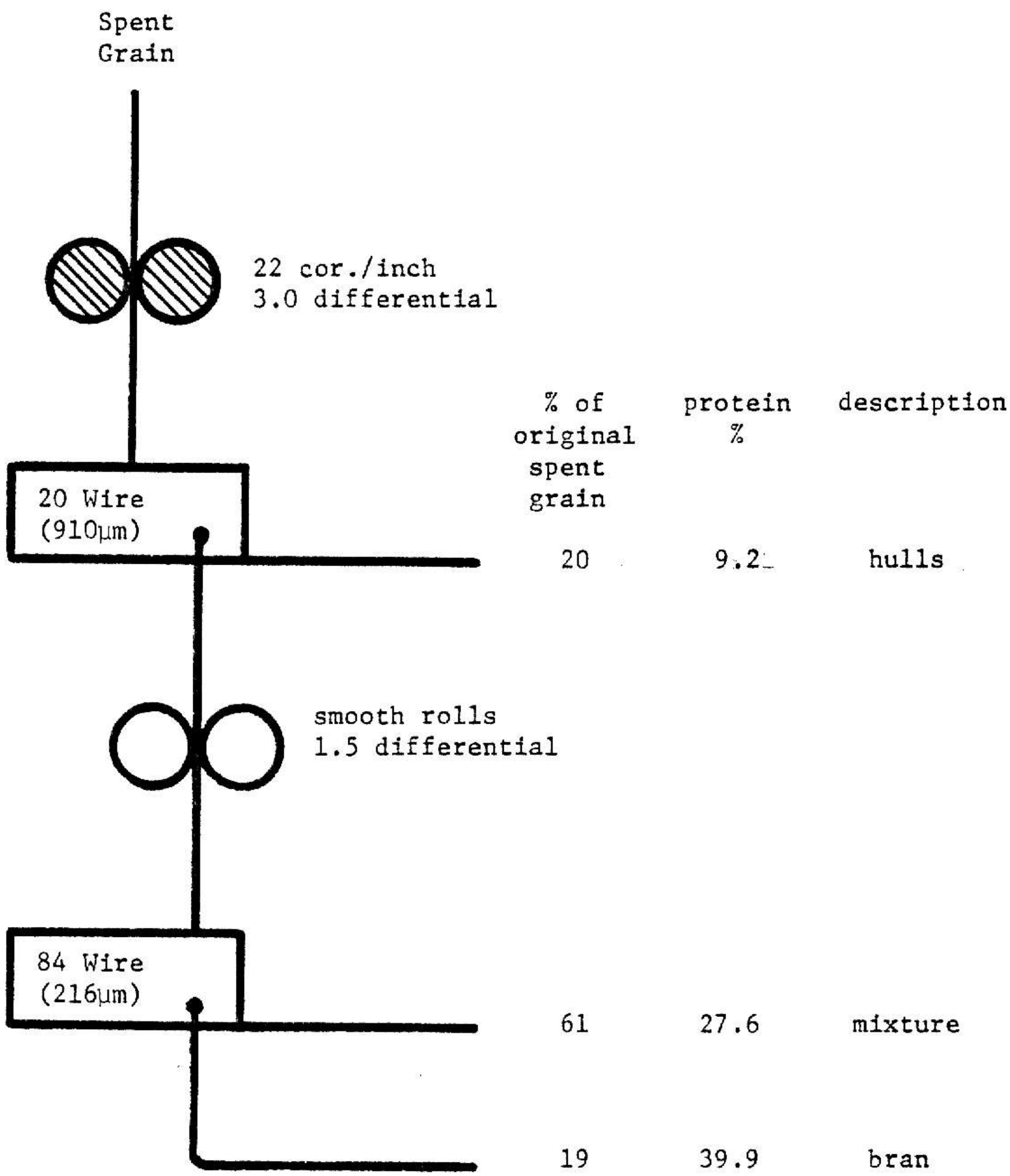
% of original spent grain	Protein %	Description
27	9.7	hulls
22	24.2	mixture
51	34.7	bran

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
3.0 differential
% of original spent grain
protein %
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.

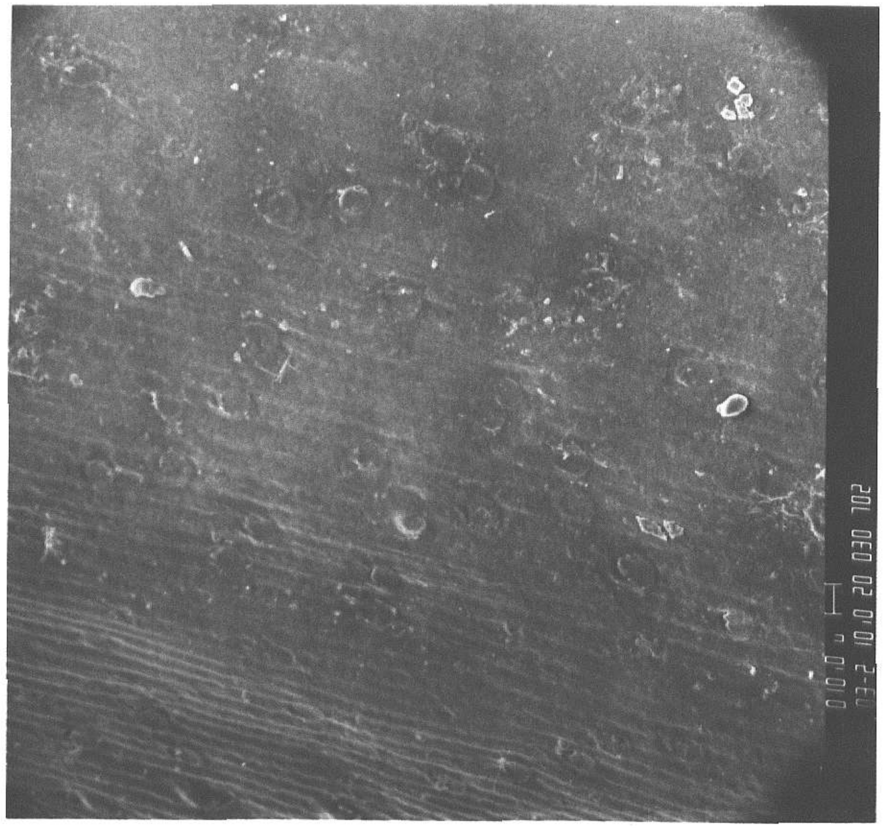
The spent grains apparently do not absorb this water immediately. At these high absorptions, doughs out of the mixer felt sticky and wet. However, by first punch, the BSGB doughs felt optimum in water but were weaker than the control doughs.

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.



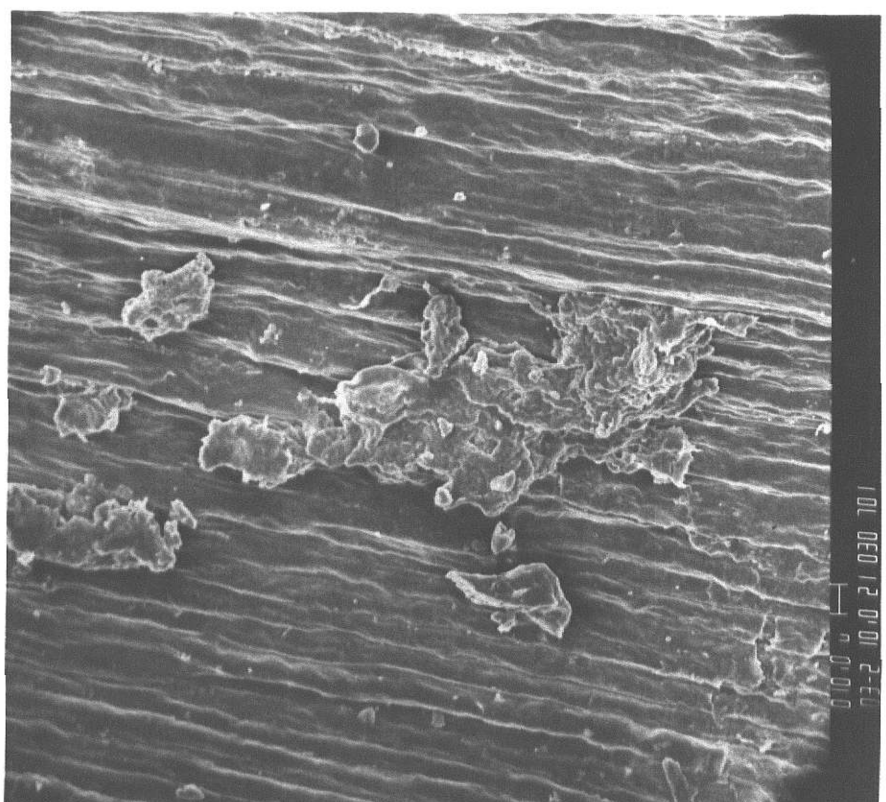
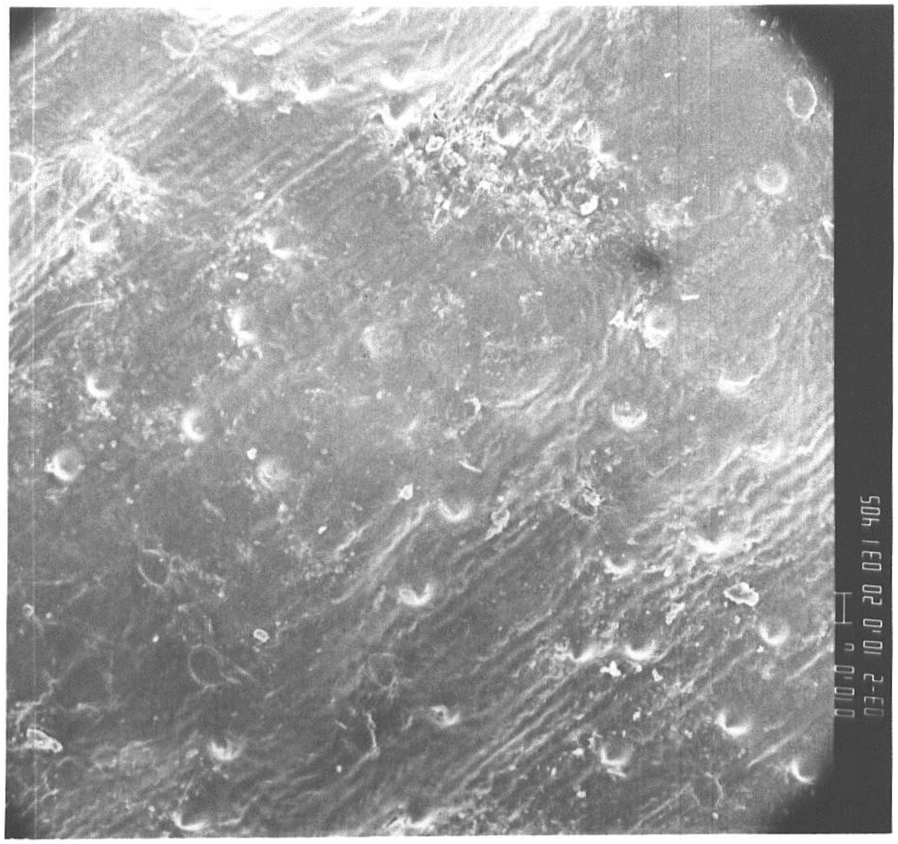


Fig. 7 Cut Barley, outside surface of hull.

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



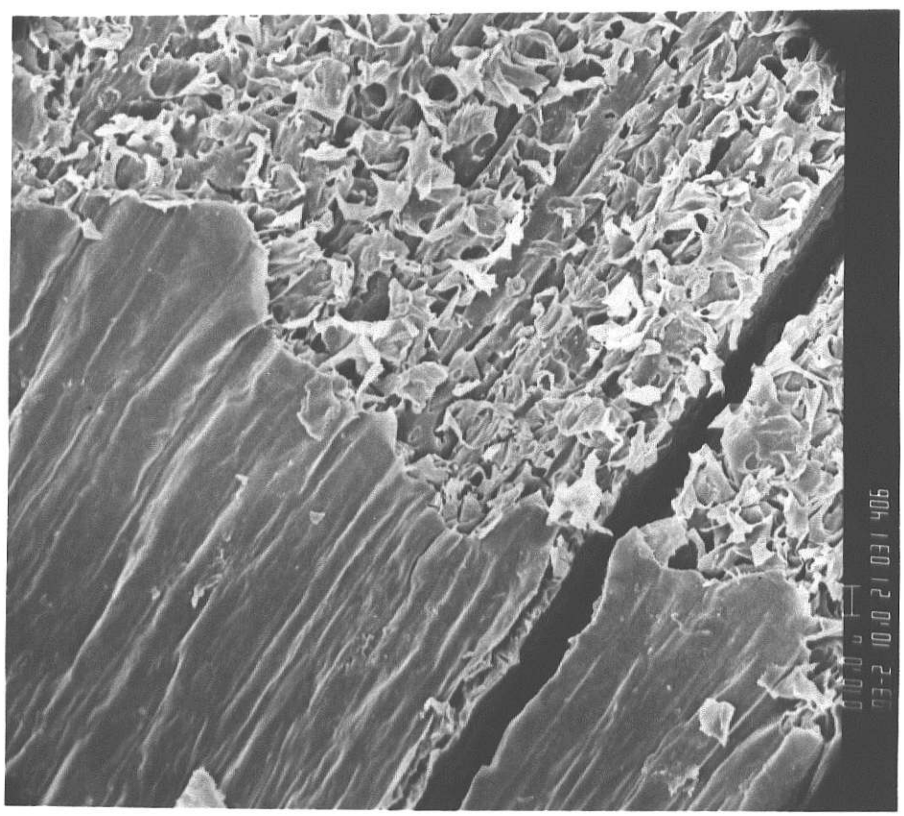
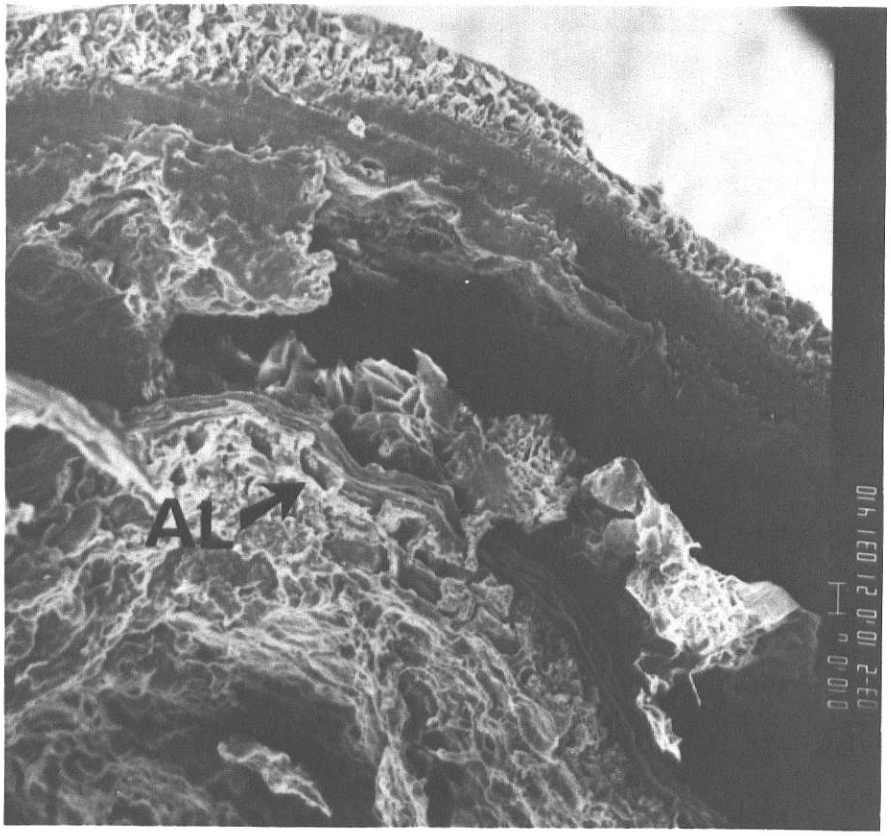


Fig. 9 Spent Grains, cut surface showing aleurone cells (AL).

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


AL

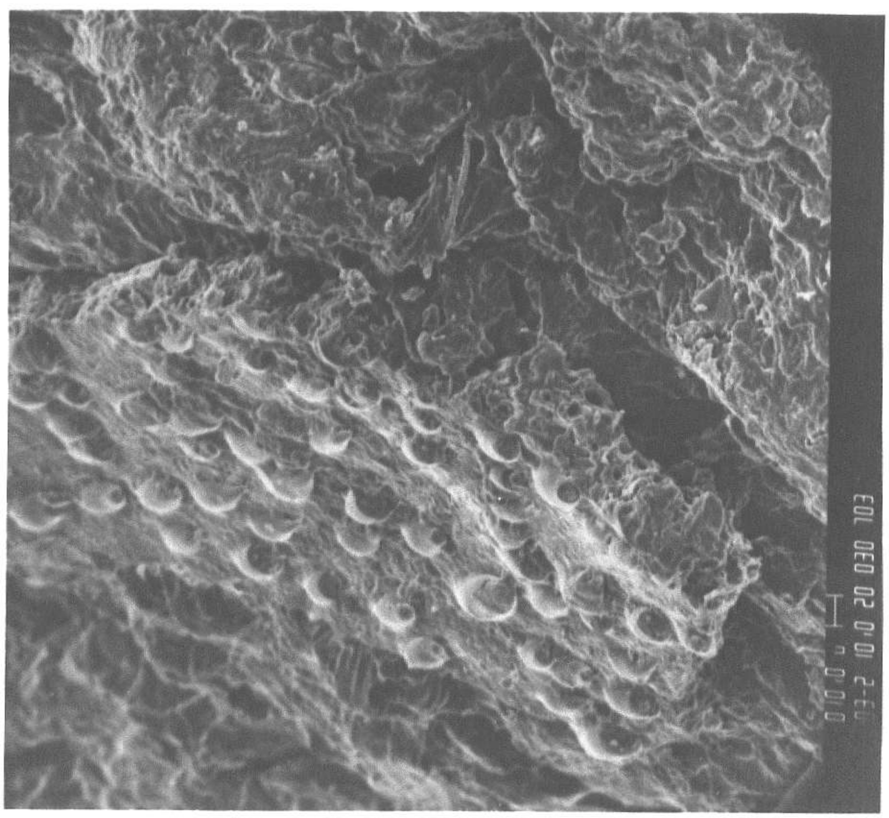
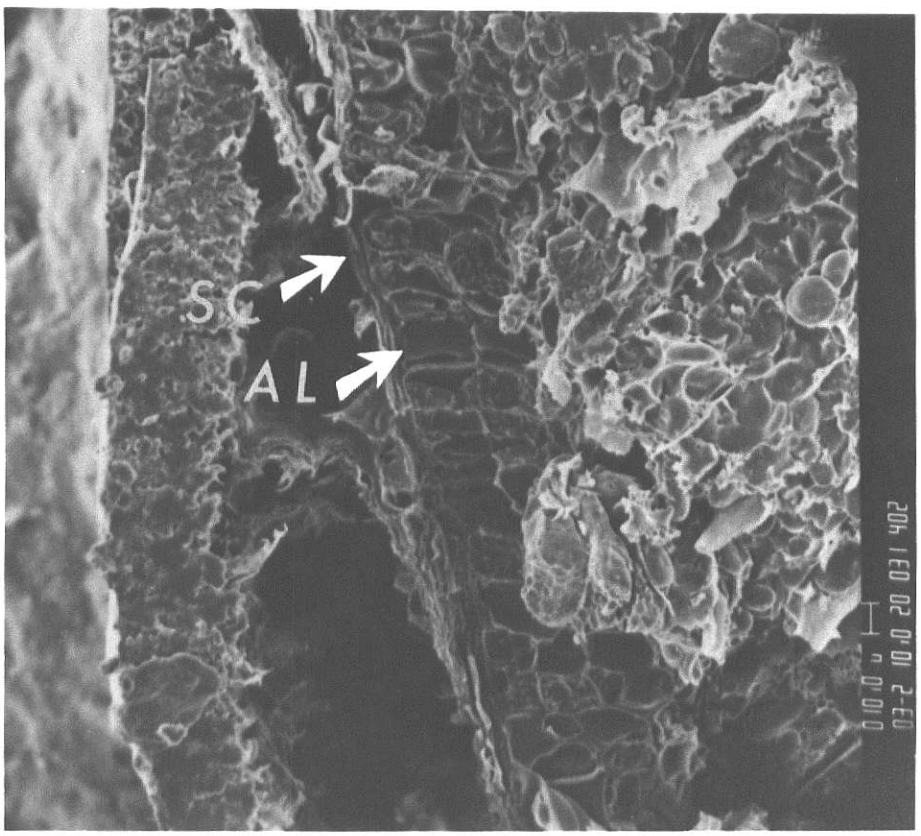


Fig. 11 Spent Grains, fraction that has been ground on rolls and passed through a 30 wire sieve (672µm). Note hull slivers which are longer than sieve opening.

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

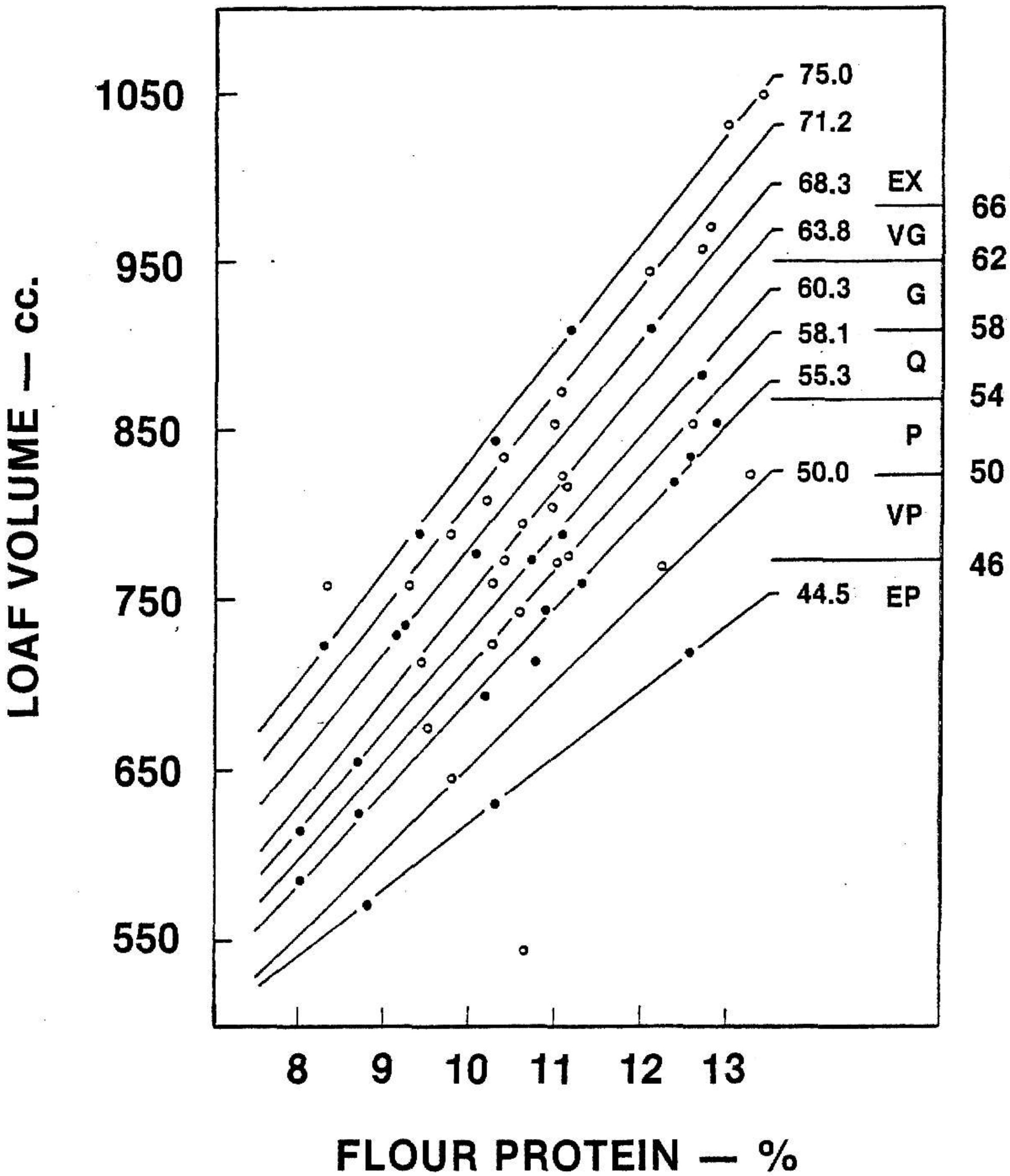

SC
AL

quality) is held constant the relationship between flour protein and loaf volume is approximately linear above 8% flour protein. By use of a graph such as that shown in figure 13, it is possible to predict the loaf volume which would be expected if the spent grains have no loaf volume depressing effect. The BCS 79 flour has 12.2% protein and a control loaf volume of 950 cc. With the graph shown in figure 13, it can be seen that the BCS 79 flour has a loaf volume potential (slope) of 75 cc/g protein in the linear section of the curve. The treatment loaves have 15% less protein than the controls. Therefore, it was possible to calculate that the treatment loaves should have a loaf volume of 0.15 x 12.2 x 75 = 140 cc less than the control loaves. The actual difference (255 cc) as shown in Table IV was larger than this and indicated that the BSGB has a volume depressing effect.

Surfactants (surface active agents) are a class of chemicals which act at interphase surfaces (gas-liquid, water-fat) in food systems. For reasons that are not entirely understood many surfactants improve the grain and loaf volume of bread. The improving effect of surfactants is generally greater for breads containing some form of nongluten protein (such as wheat bran or BSGB) than for white bread which contains relatively small amounts of nongluten protein.

BSGB bread was baked with six different surfactants included at different concentrations in the formula. In all cases the surfactants were simply added with the dry ingredients. It is possible that a different method of addition, such as melting

Fig. 13 Loaf volume vs. flour protein for several wheat varieties. Source: Finney (1972)



LOAF VOLUME — cc.
1050
950
850
750
650
550
8
9
10
11
12
13
FLOUR PROTEIN — %
75.0
71.2
68.3
63.8
60.3
58.1
55.3
50.0
44.5
EX
VG
G
Q
P
VP
EP
66
62
58
54
50
46

Table IV
Baking Data for BSGB Bread Baked
at Different Water Absorptions.

Absorption	Loaf Weight g	Loaf Volume cc
63 (control)	147	950
68	156	590
70	156	600
72	157	645
74	157	685
76	160	690
78	160	695

with the shortening or grinding with the BSGB in a Stein mill, would have improved the performance of some of the surfactants. The data showing the baking performance of the six surfactants are presented in Table V. Sodium stearoyl lactylate (SSL) at levels of 1.5 and 2.0%, flour basis, improved the loaf volume of the BSGB loaves to where it was essentially equal to the theoretical maximum of 810 cc. At 0.5% concentration four other surfactants, Tween 60, triglycerol monoglycerides, Pluronic F-108, and ethoxylated monoglycerides, performed as well, or very nearly as well as did SSL, but no surfactant performed better than SSL.

Because SSL is one of the most commonly used surfactants and because it performed as well as any other at the 0.5% level, we decided to use SSL for the remainder of our baking studies. The results from baking with SSL at 1.5 and 2.0% flour basis showed that loaves containing 15 g BSGB/85 g flour can be made with loaf volumes at the theoretical maximum and with good grain and texture. But, legally SSL can not be used at levels higher than 0.5% flour basis. Therefore we wanted to develop a treatment which would produce BSGB loaves with good volume, grain and texture and would not require a high level of SSL.

Loaves containing BSGB and no surfactants had a grain similar to bread baked with no shortening. Adding 0.5% SSL improves the grain but a hint of the "no shortening" look remains. We postulated that there might be a lipophyllic fraction in the BSGB that was taking a lipid component away from the rest

Table V
Baking Data for Certain Surfactants
Added to the Dough Containing BSGB.

Surfactant	%	Loaf Weight g	Loaf Volume cc
Control 1 (no BSGB, no surfactant)	-	148	950
Control 2 (BSGB but no surfactant)	-	165	670
SSL	0.5	163	755
SSL	1.0	162	755
SSL	1.5	164	805
SSL	2.0	163	805
Pluronic F-108	0.5	164	740
Pluronic F-108	1.0	164	695
Pluronic F-108	1.5	165	660
Pluronic F-108	2.0	170	635
Ethoxylated Monoglycerides	0.5	164	735
Monoglycerides	0.5	162	710
Tween-60	0.5	162	760
Triglycerol Monoglycerides	0.5	163	750

of the dough. In an attempt to saturate the lipophilic fraction of the BSGB, corn oil was added to the formula. The corn oil and SSL each were added in two different ways; A) to the dry ingredients and B) mixed separately with the BSGB in a Stein mill. The results of adding oil and SSL are shown in Table VI and Table VII. Adding the oil and SSL in a Stein mill improved both loaf volume and crumb grain. Additional bakes to determine the optimum amount of oil and the effect of defatting BSGB are summarized in Table VIII. The optimum level of oil was 0.7% based on the weight of the composite flour. With 0.5% oil and 0.5% SSL reducing the shortening to 2.0% had no noticable effect, but when the shortening was reduced to 1.0% the grain became inferior and the volume dropped slightly.

The volume produced by the defatted BSGB and regular BSGB were essentially equal, but the grain with the regular BSGB was judged slightly better. When treated with oil and SSL the defatted BSGB loaves showed less increase in volume than did the regular BSGB loaves. In addition the regular BSGB loaves had better crumb grain than the corresponding defatted BSGB loaves.

Adding 0.7 g corn oil and 0.5 g SSL to the BSGB in the Stein mill produced bread with close to the theoretical maximum volume and with good grain and texture (the "no shortening" look has disappeared).

We used a resistance oven to investigate the improving effect of oil and SSL on bread containing BSGB. Loaf height versus baking time curves for a control dough (no BSGB) and a dough

Table VI
Effect of Oil and SSL on Quality
of Bread Containing BSGB

Oil[a]	SSL[b]		Loaf Weight g	Loaf Volume cc
		Control:	146	950
-	-		162	685
-	0.5		163	735
0.5	-		163	700
0.5	0.5		163	785

[a]added in a Stein mill.

[b]added directly to the dough and not in a Stein mill.

Table VII

Baking Data for Corn Oil and SSL Added to the Dough Containing BSGB

Treatments		Loaf	
Oil %	SSL %	Weight g	Volume cc
-	-(control no BSGB)	145	950
-	-	160	705
-	0.5	162	740
-	0.5[a]	161	760
0.5	0.5	162	760
0.5	0.5[a]	162	770
0.5[a]	0.5	161	795
0.5[a]	0.5[a]	161	790

[a]added to the BSGB in a Stein mill.

NOTE: The grain of the bread to which both the SSL and oil were added in the Stein mill was judged slightly superior to that in which the oil was added in the Stein mill and the SSL added normally.

TABLE VIII

Baking Data for Various Levels of Shortening, Corn Oil, and SSL in Loaves Containing 15 grams of BSGB

Treatments			Loaf	
Fat %	Oil[a] %	SSL[a] %	Weight g	Volume cc
Control				
3.0	-	-	146	950
Regular BSGB				
3.0	-	-	158	700
3.0	0.4	0.5	161	770
3.0	0.5	0.5	161	790
3.0	0.6	0.5	162	790
3.0	0.7	0.5	162	815
3.0	0.8	0.5	163	800
3.0	0.9	0.5	162	805
3.0	1.0	0.5	162	805
2.0	0.5	0.5	161	805
1.0	0.5	0.5	161	775
Defatted BSGB				
3.0	-	-	162	700
3.0	0.5	0.5	162	760

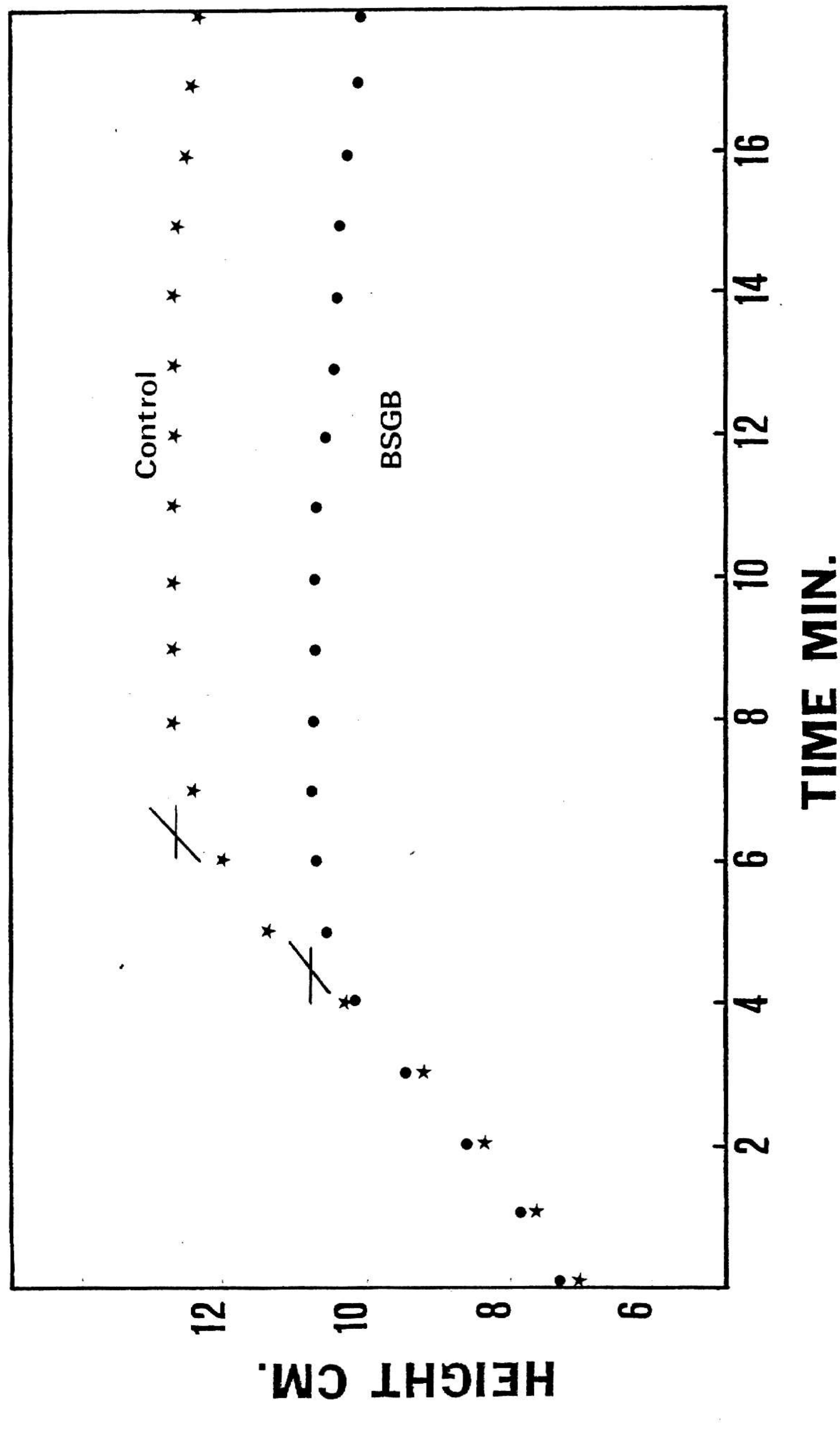
[a]added in a Stein mill

containing BSGB but no special treatment are shown in Figure 14. It can be seen that the BSGB loaf has a slightly higher proof height than the control and that the two loaves expand at approximately the same rate during the initial stage of baking. The reason for the greater final height of the control is that it did not stop expanding until about two minutes after the BSGB loaf had stopped expanding. Junge (1980) showed that the time a loaf in a resistance oven stops expanding is the time starch gelatinization takes place. The fact that the BSGB loaf stops expanding earlier than the control loaf is therefore an indication that the starch in the BSGB loaf gelatinized earlier (at a lower temperature) than the starch in the control loaf.

Doughs containing 0% or 3% shortening, 0% or 0.5% SSL, and 0% or 0.7% oil were baked in the resistance oven. All possible combinations of the three ingredients at the two levels of each gave eight different treatments. The graphs produced by these eight treatments are shown in Figures 15, 16, 17 and 18.

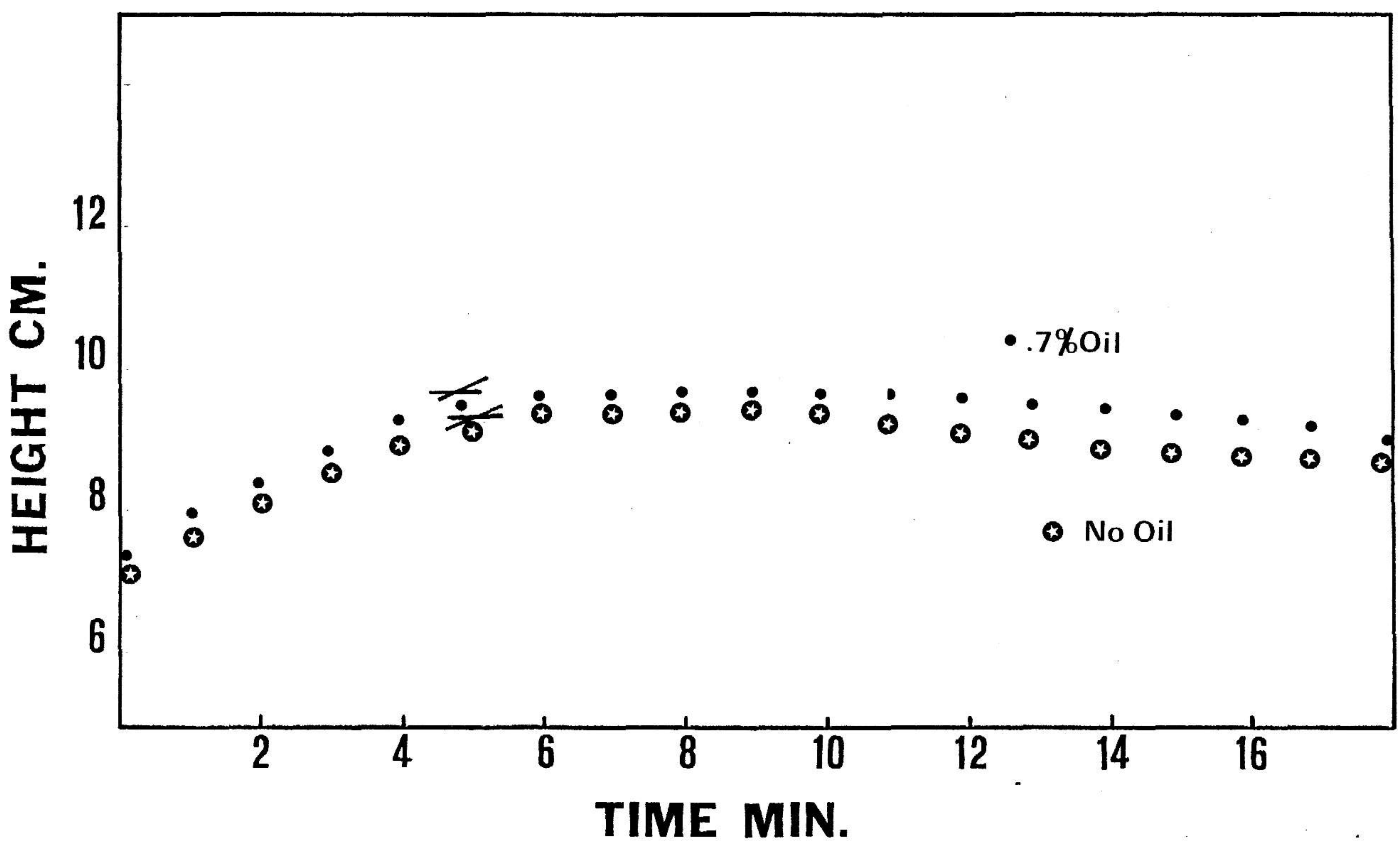
When 3% shortening and 0.5% SSL are present the addition of 0.7% oil made virtually no difference in the doughs performance in the resistance oven, which indicated that the oil does not have much of a volume improving effect on a dough that contains shortening and SSL. The dough containing both shortening and oil gave a slightly higher height vs. time curve than did the dough containing shortening and no oil. The height for the dough containing oil plus SSL was much higher than the height for the dough containing SSL and no oil. The effect appears to be

Fig. 14 Loaf height vs. baking time for Control and BSGB bread.



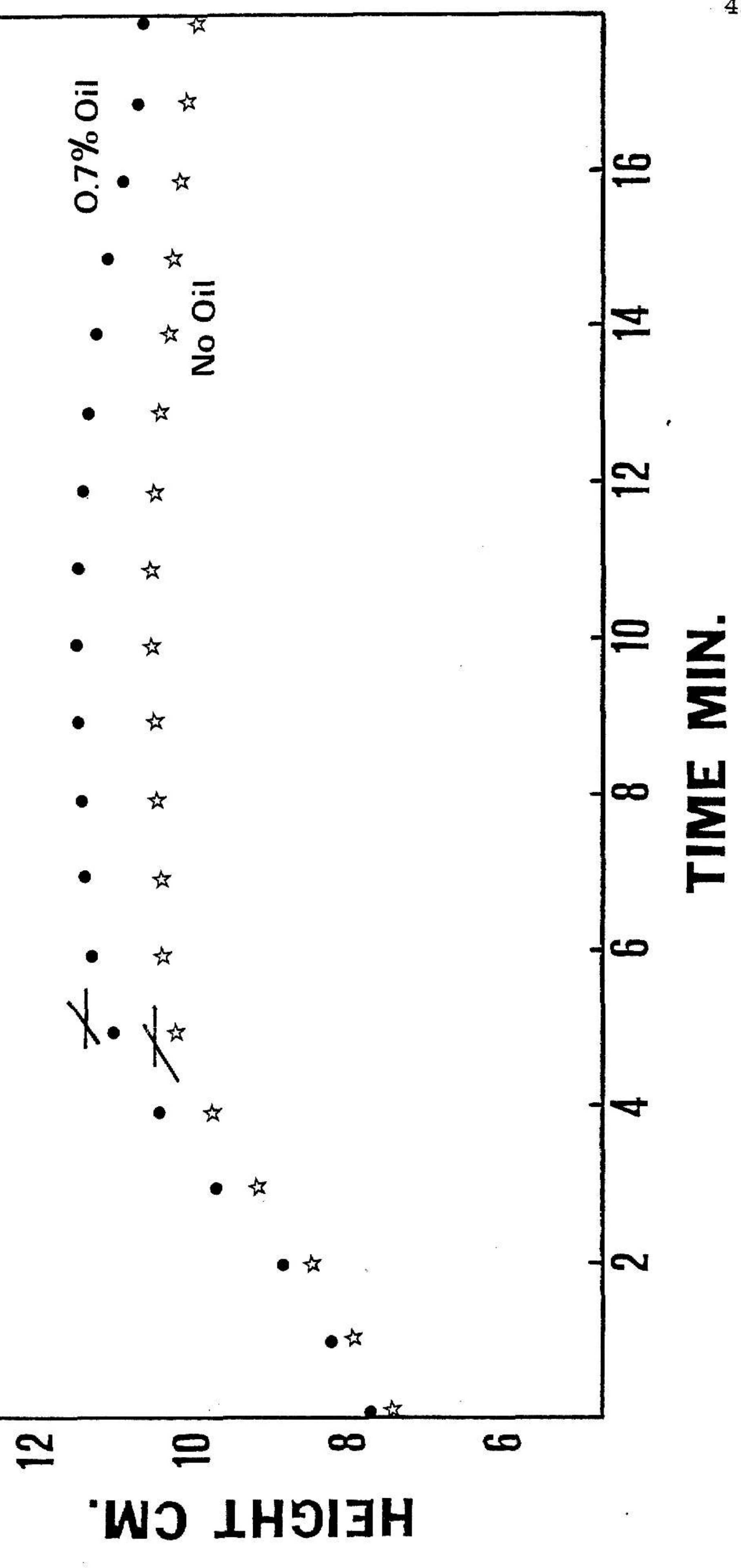
CONTROL AND BSGB

Fig. 15 Loaf height vs. baking time for BSGB bread with no shortening and no SSL, with and without 0.7% oil.



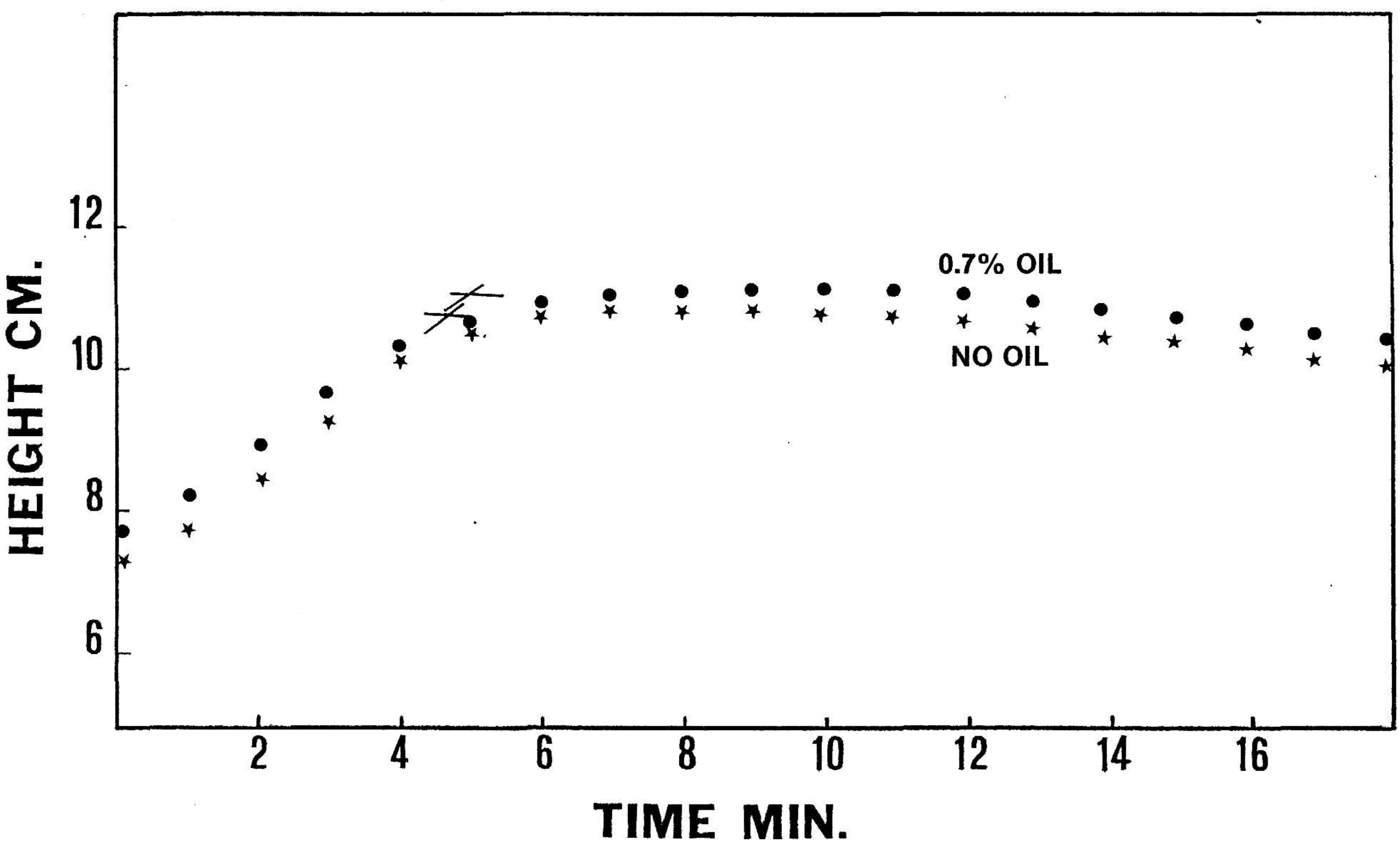
NO SHORTENING NO SSL

Fig. 16 Loaf height vs. baking time for BSGB bread with no shortening and 0.5% SSL with and without 0.7% oil.



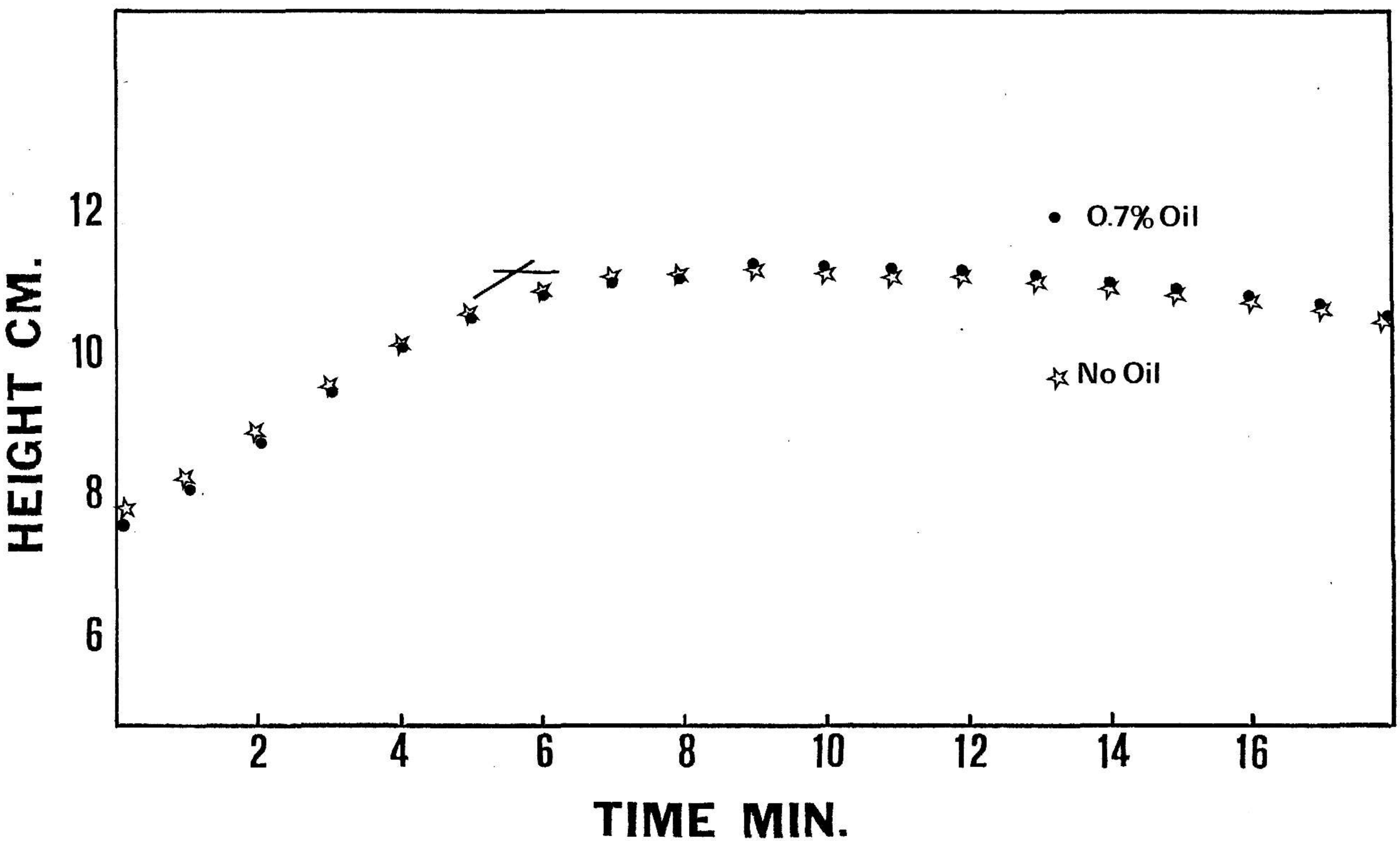
NO SHORTENING 0.5% SSL

Fig. 17 Loaf height vs. baking time for BSGB bread with 3% shortening and no SSL with and without 0.7% oil.



3% SHORTENING NO SSL

Fig. 18 Loaf height vs. baking time for BSGB bread with 3% shortening and 0.5% SSL with and without 0.7% oil.



3 % SHORTENING 0.5 % SSL

primarily because the dough containing the oil plus SSL had a better oven spring than did the dough containing SSL alone. The height for the dough with oil alone added is slightly higher than the height for the dough with no added lipid. The greatest height of dough baked with the resistance oven was for the dough containing oil plus SSL with no shortening. It is slightly higher than the dough containing shortening plus oil plus SSL or shortening plus SSL. The difference is slight and may not be real. The data tend to indicate that the volume potential for BSGB bread which has had SSL and additional lipid added is the same regardless of the type of additional lipid.

In some instances data from resistance oven baking and from conventional oven baking do not agree. The resistance oven baking data shown in Figure 18 indicate that a BSGB loaf containing 3% shortening and 0.5% SSL should have the same volume, regardless of whether or not 0.7% oil is also present. The conventional oven baking data shown in Table VII shows that a BSGB loaf having 3% shortening, 0.5% SSL and 0.5% oil has a higher loaf volume than a BSGB loaf having 3% shortening, 0.5% SSL, and no oil.

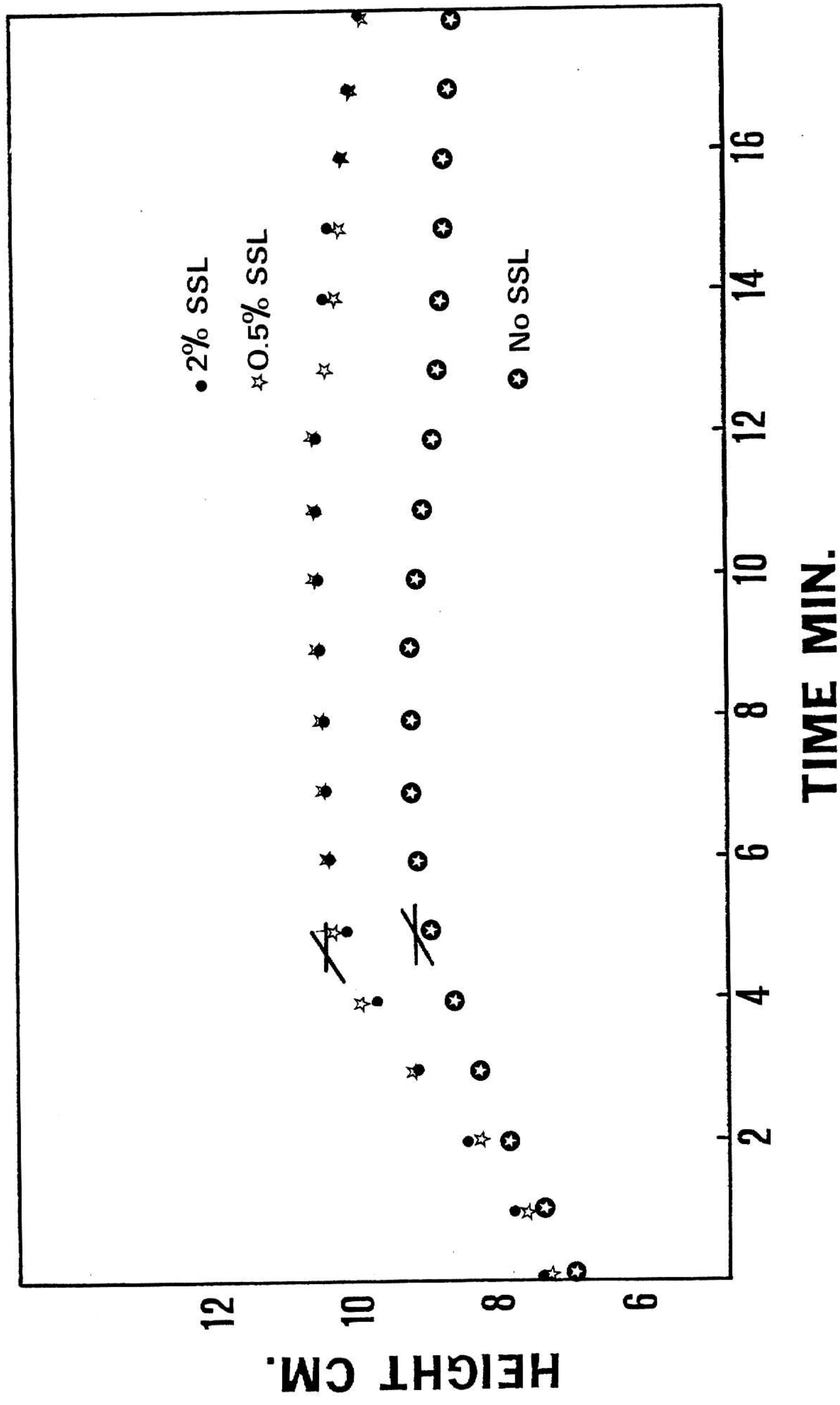
The general trend that adding shortening and/or SSL to bread containing BSGB causes an increase in loaf volume is true for both conventional and resistance oven baking. We used the resistance oven to bake doughs with 0, 3, and 6% shortening and 0, 0.5, and 2.0% SSL. Loaf height versus baking time plots for those doughs are shown in Figures 19-24. The expected increase in loaf height when the level of shortening or SSL was increased is apparent. Those increases in height come from increases is proof height and in oven spring and from delaying the time at which the loaf stopped expanding.

The mechanism through which shortening and SSL improve the loaf volume and crumb structure of BSGB bread is probably quite complex. Though numerous reports have been published the nature of the actions and interactions of wheat flour lipids, shortening, and surfactants in the breadmaking process is not clear. Native wheat flour lipids and added shortening each affect loaf volume and crumb grain, but probably by different mechanisms. Interactions between shortening and wheat flour lipids occur, but depend on the quality of the flour lipids (Pomeranz and Chung, 1978).

In petroleum ether-defatted flours the addition of non-polar lipids has a detrimental effect, and the addition of glycolipids has an improving effect on breadmaking quality (Chung and Pomeranz, 1977). Addition of free fatty acids was shown to have harmful effects on the breadmaking properties of both petroleum ether defatted flour and untreated flour (DeStefanis and Ponte, 1976).

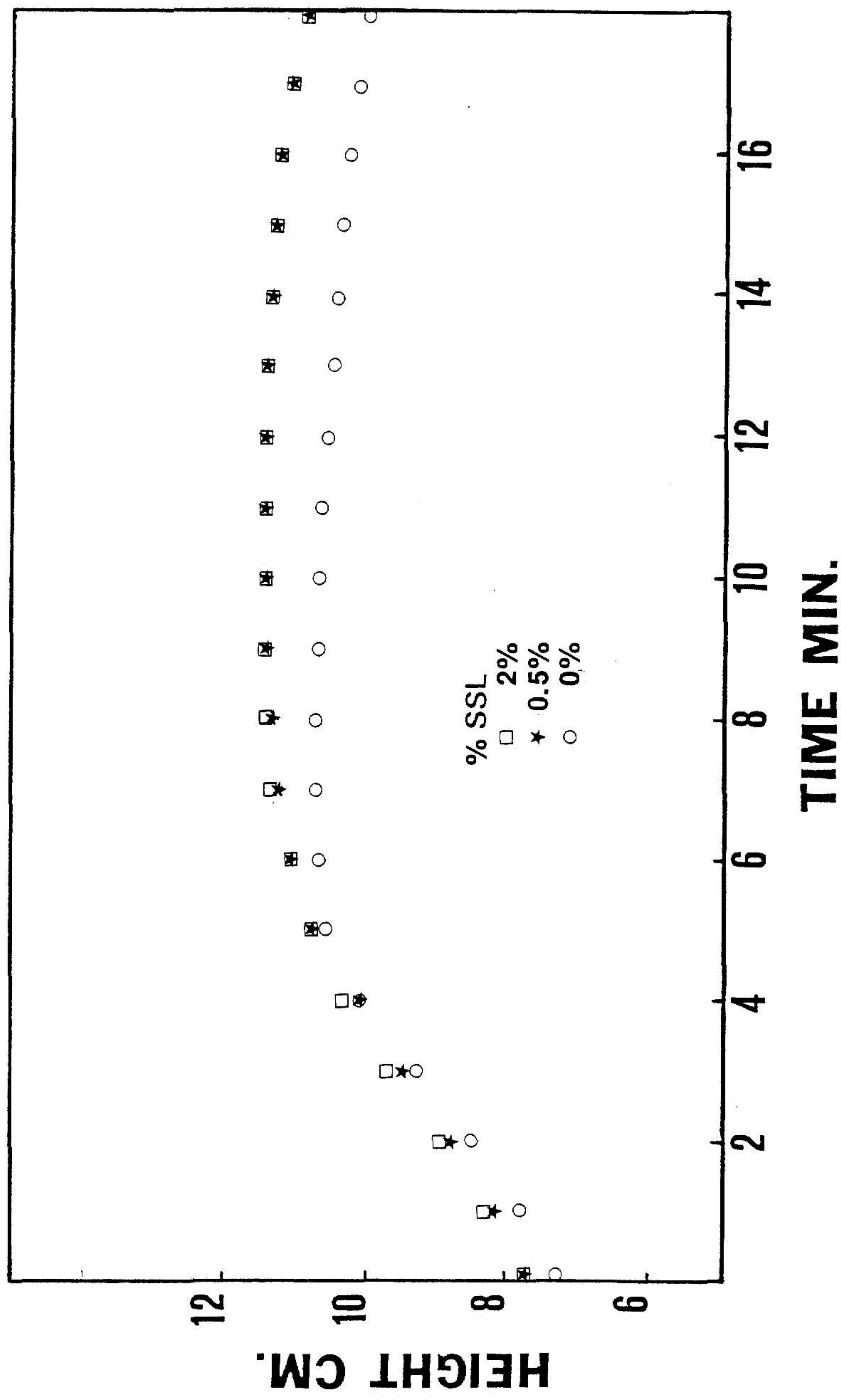
Polar lipids are generally recognized as being beneficial to breadmaking, however, their beneficial effect depends upon their quantity and quality. When 0.3% free polar lipids (rich in glycolipids) were added to petroleum ether defatted flour (containing 0.6% bound polar lipids) and bread was made the

Fig. 19 Loaf height vs. baking time for BSGB bread with no shortening, at 3 levels of SSL.



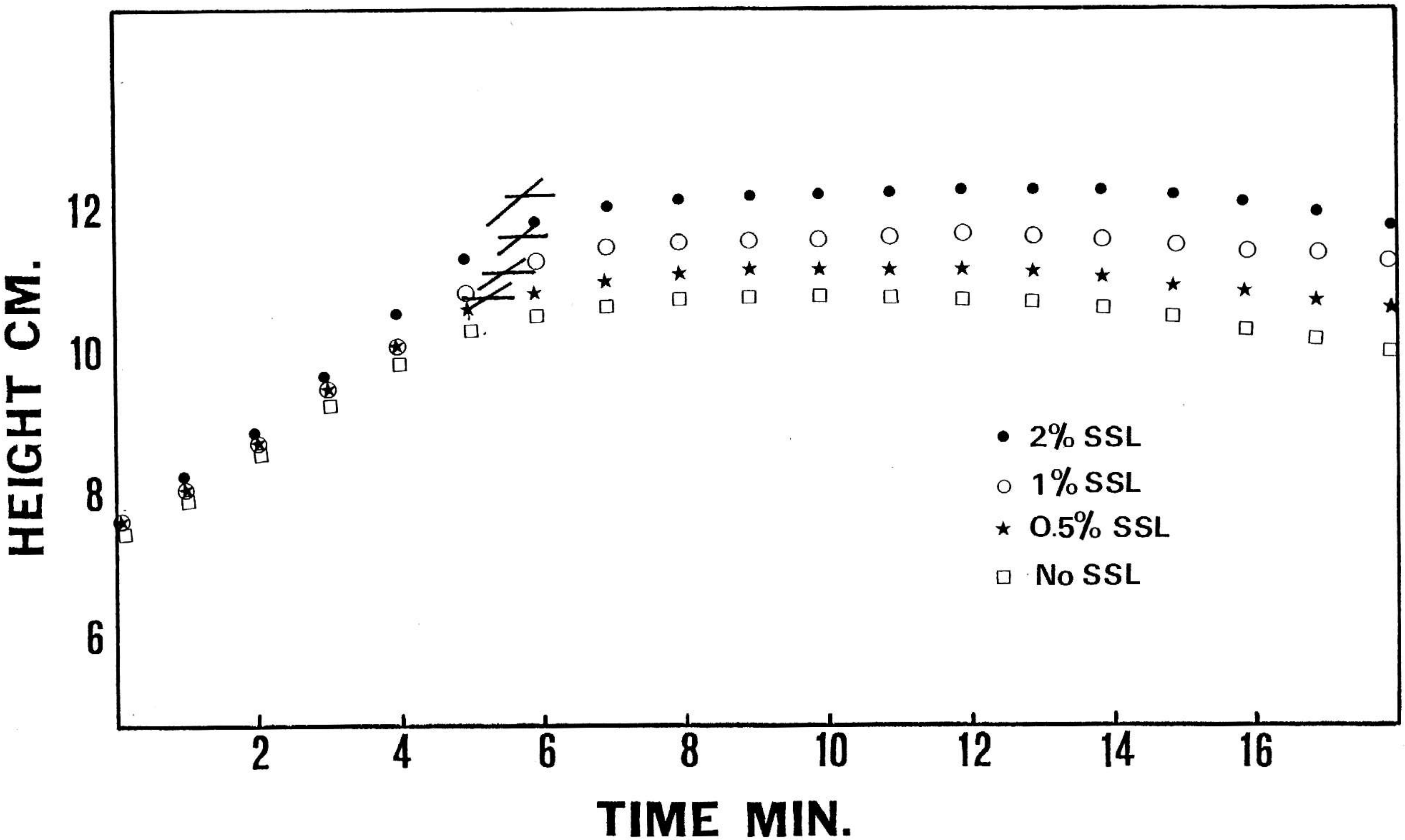
NO SHORTENING

Fig. 20 Loaf height vs. baking time for BSGB bread with 3% shortening at 3 levels of SSL.



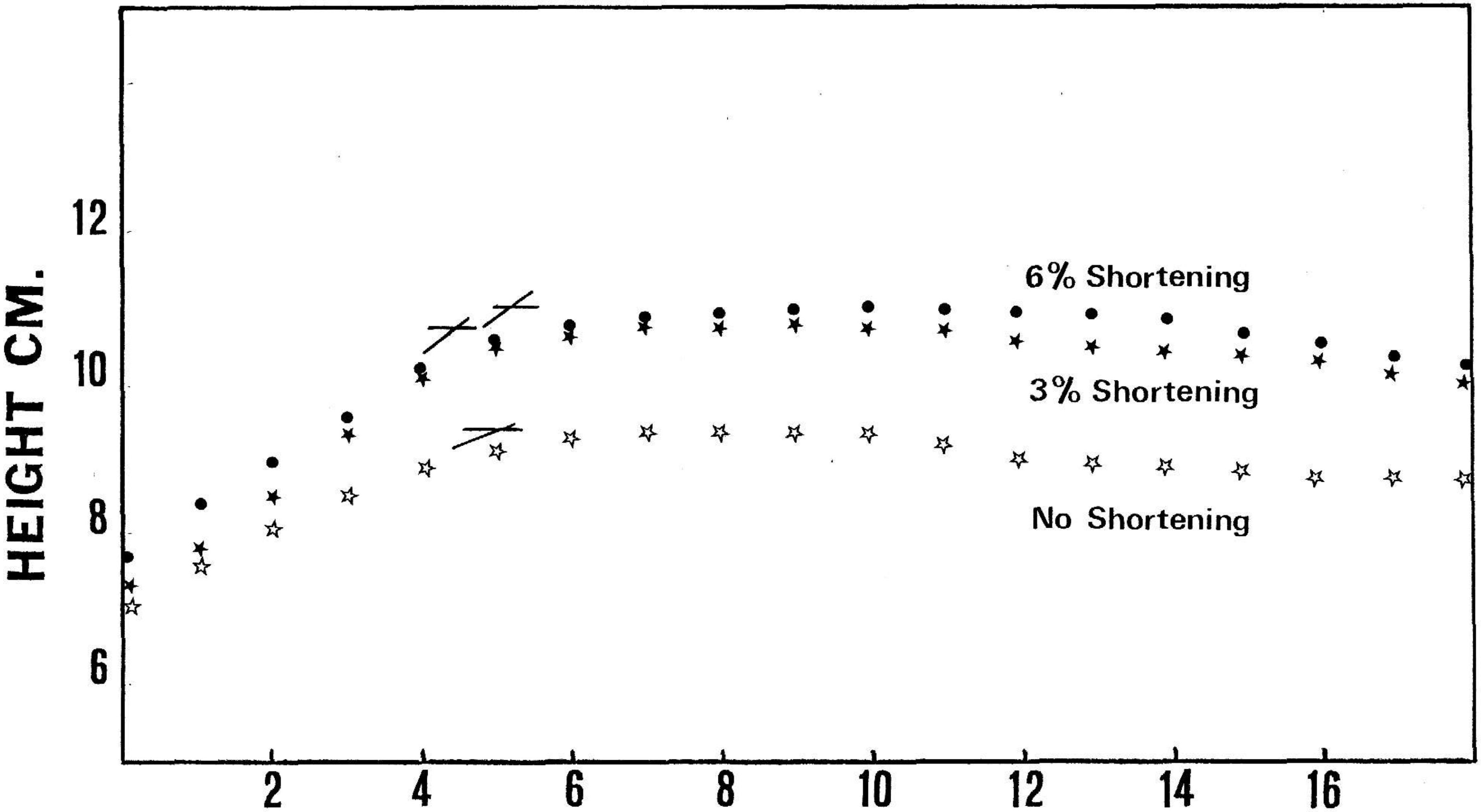
3% SHORTENING

Fig. 21 Loaf height vs. baking time for BSGB bread with 6% shortening at 4 levels of SSL.



6 % SHORTENING

Fig. 22 Loaf height vs. baking time for BSGB bread with no SSL at 3 levels of shortening.



TIME MIN.

NO SSL

Fig. 23 Loaf height vs. baking time for BSGB bread with 0.5% SSL at 3 levels of shortening.

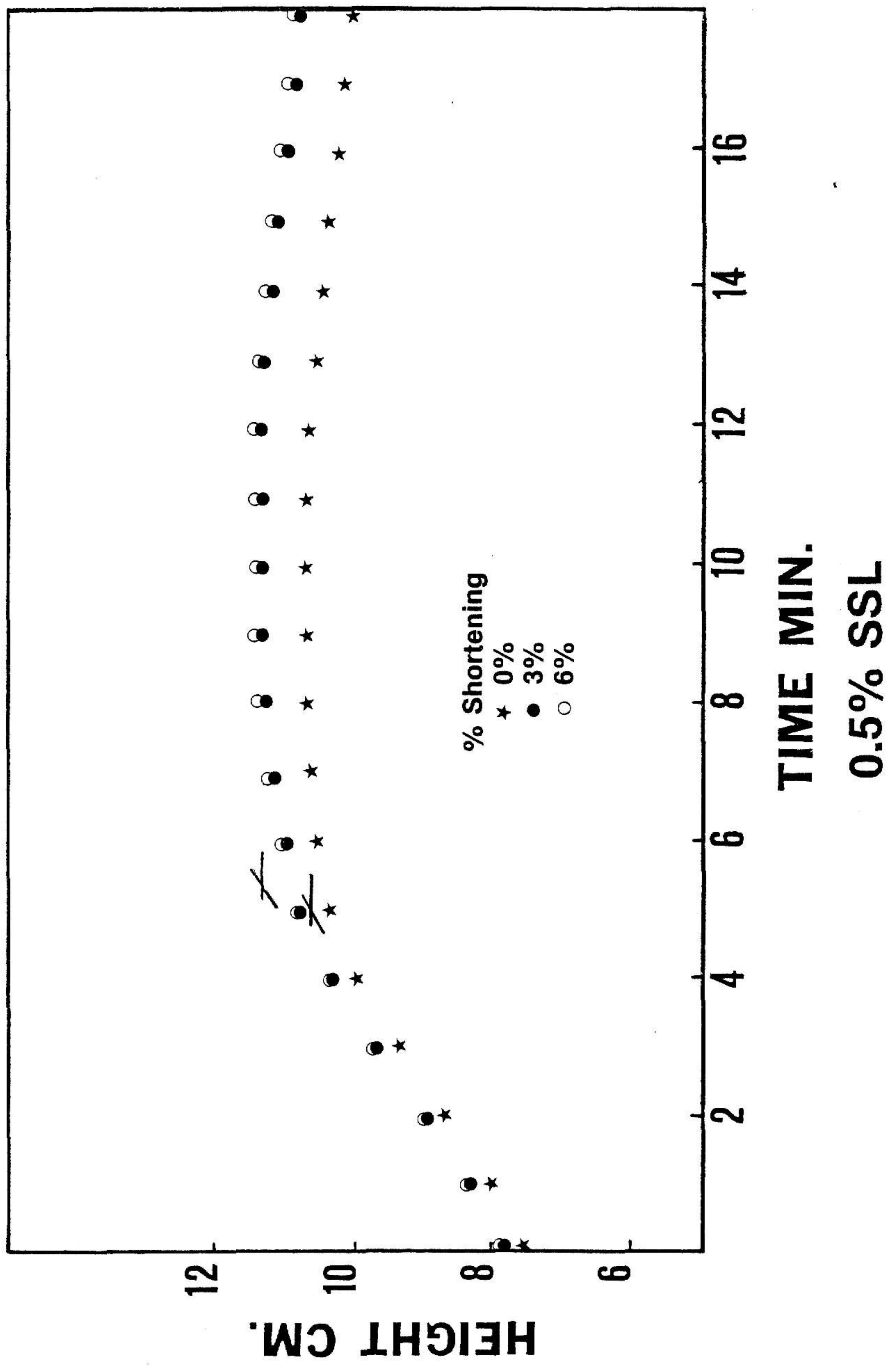
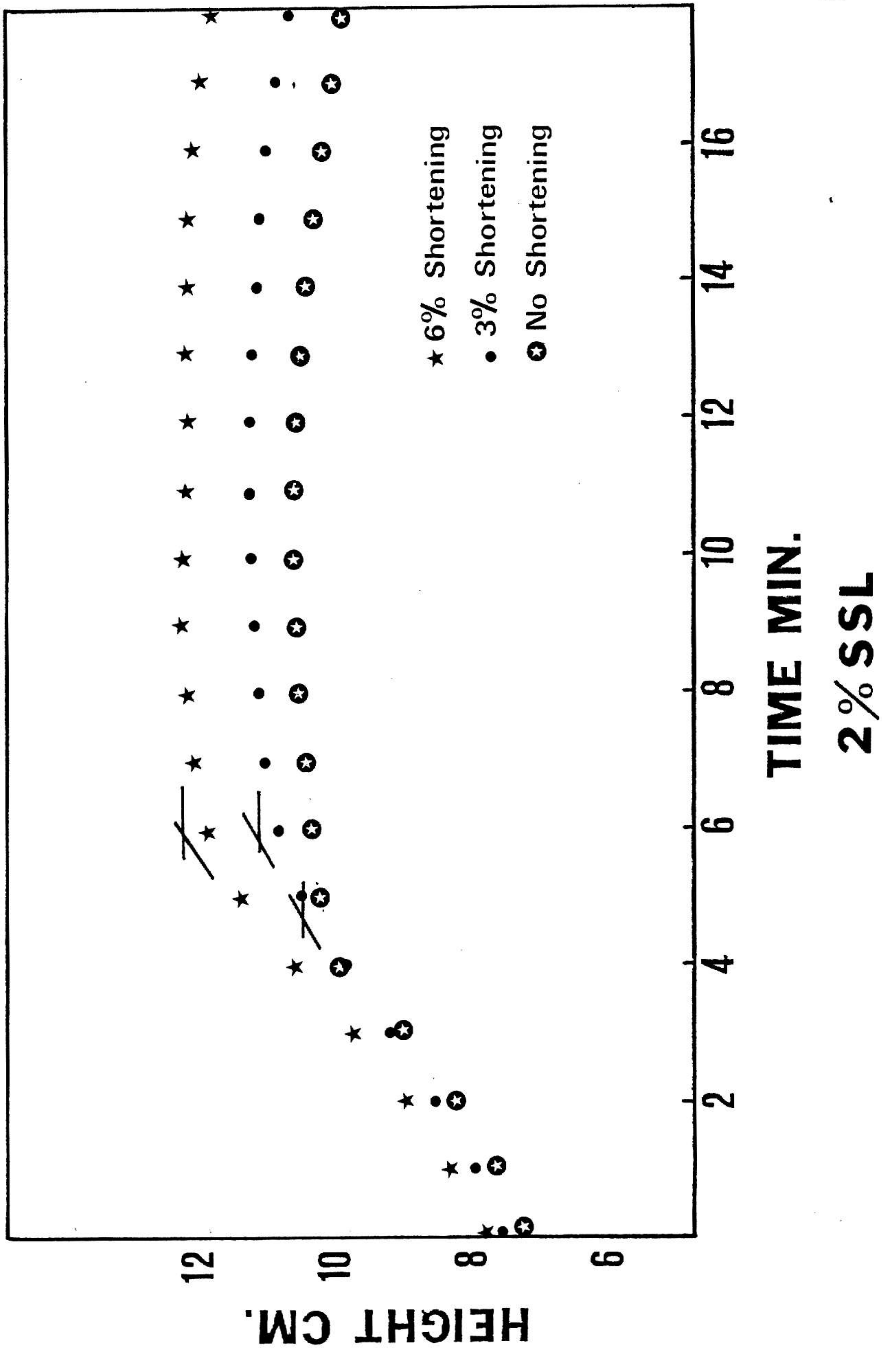

HEIGHT CM.
12
10
8
6
2
4
6
8
10
12
14
16
% Shortening
0%
3%
6%
TIME MIN.
0.5% SSL

Fig. 24 Loaf height vs. baking time for BSGB bread with 2% SSL at 3 levels of shortening.


HEIGHT CM.
6
8
10
12
2
4
6
8
10
12
14
16
TIME MIN.
2% SSL
★ 6% Shortening
• 3% Shortening
✪ No Shortening

resulting loaf volume was comparable to the loaf volume given by the original flour when baked with 3% shortening (Hoseney, et al,; 1969). Adding 0.2% bound polar lipids (about equal in phospholipids and glycolipids) to the petroleum ether defatted flour caused no improvement in loaf volume over that given by the extracted flour (Hoseney et al. 1969). Small amounts of polar lipids have been shown to be detrimental and larger amounts of the same polar lipids have been shown to be beneficial when added to an almost completely defatted flour and baked with 3% shortening (Hoseney et al. 1969).

When shortening is added to bread, crumb grain is improved and loaf volume is increased. Bell, et al. (1977) reviewed several hypothetical physical mechanisms for the shortening effect. Among the hypothesis examined were lubrication, lipoprotein structures in gluten, pore-sealing, and structural support. No one of the individual mechanisms was thought to explain all aspects of the shortening effect but physical mechanisms were thought to be more probable than the chemical mechanism of lipid oxidation. Bell, et al. (1977) stated that for nonpolar lipids to exert a full improving effect a certain minimal amount of the shortening must remain solid at the temperatures of mixing and proofing. Castor oil improves loaf volume in the chorleywood bread process and is an exception to the general requirement for a solid shortening (Bell et al. 1977).

Daniels and Fisher (1976) showed that, with the English system of high speed mechanical development and short fermentation time, carbon dioxide was released more rapidly from a dough baked without shortening than from dough baked with shortening.

Junge (1980) used a straight dough system with a three hour fermentation and showed that shortening had no effect on carbon dioxide release. He (Junge, 1980) further showed that shortening delays starch gelatinization during baking. Since starch gelatinization causes the loaf to become rigid a loaf containing shortening (in which starch gelatinization is delayed) is allowed to expand in the oven for a longer period of time.

Lipid related surfactants act as antistaling agents and dough modifiers in bread and can replace all or part of the shortening needed to produce good bread (Chung and Pomeranz, 1977). In doughs containing high protein additives, such as soy flour, surfactants cause an even larger improvement than in white bread (Pomeranz et al. 1969).

As noted earlier, we observed that loaves containing BSGB stopped expanding at an earlier time (starch gelatinized earlier) than control loaves. We reasoned that this was because of the extra water added to the BSGB doughs. That additional water would be expected to make the starch granules gelatinize at a lower temperature.

Sugars are known to delay starch gelatinization and disaccharides are known to have a greater delaying effect than monosaccharides. The gelatinization delaying effect of sugars has been shown by viscosity measurements (Bean and Osman, 1959) and with photomicrographs (Savage and Osman, 1978, Bean and Yamazaki, 1978). Spies (1981) used a differential scanning calorimeter to show the gelatinization delaying effect of sugar and to show definitively that the mechanism for the effect was not the decrease in water activity caused by sugar.

BSGB doughs were made with 12% sugar. The high sugar content caused the doughs to be sticky and more slack than normal, indicating that the dough contained an excess of water. To alleviate this condition the dough water was dropped from 77% to 75%.

To determine the effect of the lowered water a control (15% BSGB, 6% sugar, 75% water) was baked and the lower water caused a delay in the setting of the loaf. This might be expected because there was less free water in the system. However, oven spring was much slower in the dry dough and the loaf height was lower than that for dough with 77% water. For doughs containing 75% water, increasing the sugar from 6% to 12% and from 12 to 15% caused a progressive delay in the setting of the loaves. The oven spring was essentially the same for the three sugar concentrations so the loaf height increased with increasing sugar. This increase in height was in spite of the fact that there was diminished yeast activity in the high sugar doughs (lower dough heights at first punch).

The data with the resistance oven was checked by baking in a conventional oven (Table IX). There was a steady improvement in both loaf volume and crumb grain as the level of shortening or SSL was increased. Adding oil to the BSGB dough containing 3% shortening and 0.5% SSL again caused a slight improvement in grain and a slight increase in loaf volume (Table X).

Baking data indicated that yeast activity was depressed when sugar concentration was increased from 6 to 12%. Gas production data indicated that a yeast concentration of 2 3/8% in a dough with 12% sugar and 75% water gave about the same yeast activity as a dough with yeast, sugar, and water levels of 2.0, 6.0 and 77% respectively.

As mentioned earlier, increasing sugar concentration caused an increase in slackness and stickiness of dough. This indicated that the optimum water level for dough having 12% sugar would be less than the 77% used with 6% sugar.

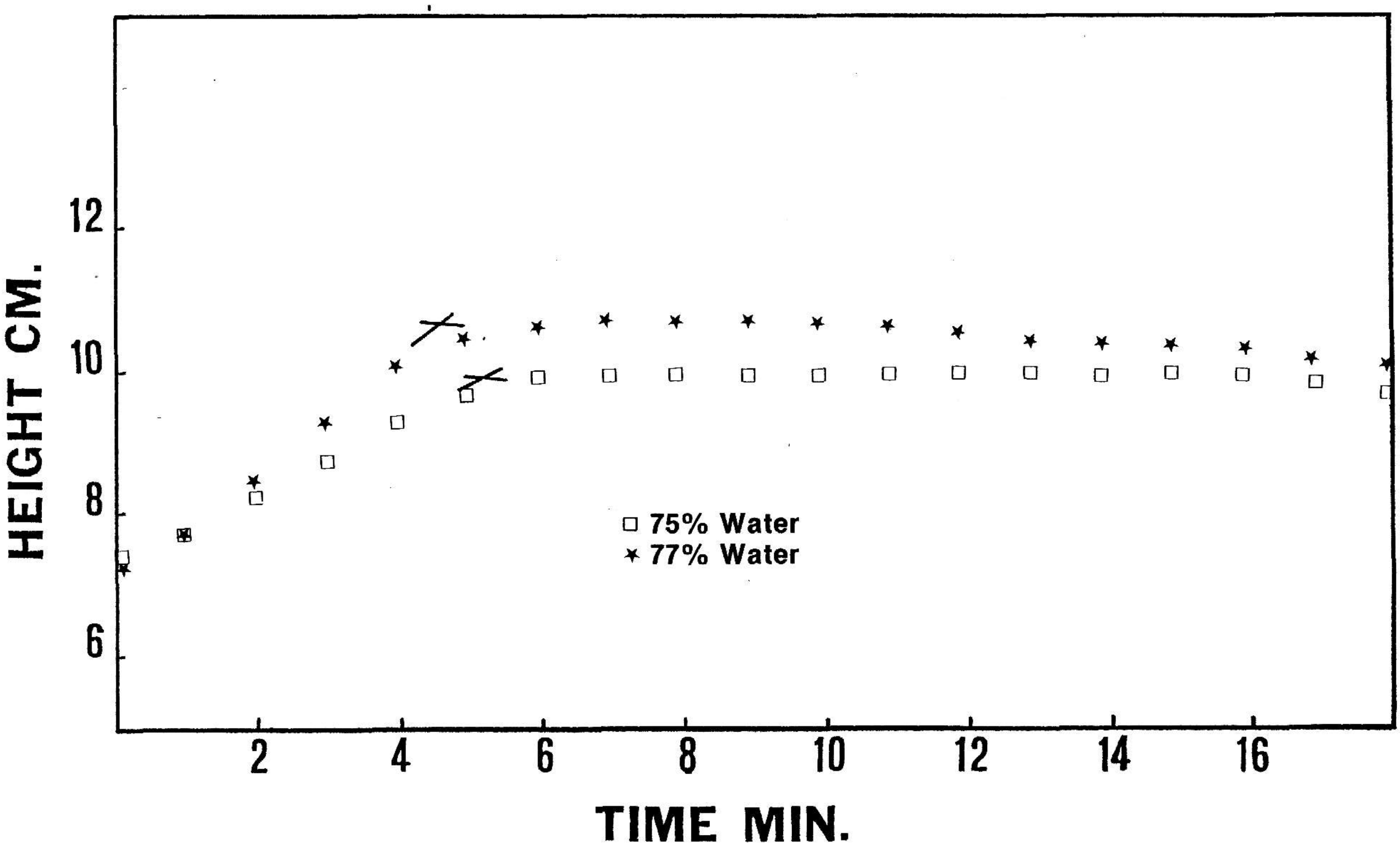
To optimize the yeast and water levels for 12% sugar, BSGB doughs were baked with various water levels (Table XI). The optimum absorption was found to be 75%. At the 75% water level, the three yeast concentrations performed about equally well.

The formula modifications which improved the quality of bread containing BSGB also had another effect. Increasing water, increasing shortening, increasing sugar, and adding SSL all increased mix time. The mix times, in the 100g national pin mixer, for several BSGB doughs are shown in Table XII. Mixographs (Figs. 23, 24, 25, and 26) were run to document the mix time lengthening effect and gain insight into its nature. The mixographs show that the BSGB dough offered virtually no resistance to the mixer for a considerable time after mixing was begun. The doughs developed very slowly until a certain critical development was reached, after which development was much more rapid.

The peaks of the BSGB dough mixographs are difficult to determine precisely. For all BSGB doughs the viscosity was at or very nearly at its maximum within four minutes after the curve first crossed the third horizontal line from the bottom of the mixograph. The control dough crossed this third line quickly but then took another 6 1/2 or 9 minutes to reach peak development for the flour water and fully formulated doughs respectively. The increase in mix time of the BSGB doughs over the control, and of some BSGB doughs over others, was due to the long lag time from when the mixer was started till enough consistancy is achieved to cross the third line. It was hypothesized that this lag time was due to the time taken by the BSGB in soaking up the large amount of water in the dough.

Doughs were made for which the 15 g of BSGB were soaked for two hours with 25 ml of water before being mixed. Mix time was reduced somewhat. BSGB bread was made by a sponge and dough procedure and the BSGB was added to both the sponge and the dough. Mix time was greatly reduced in each case and was only slightly longer than the control. Mix times for the straight dough with the soaked BSGB and for the sponge and dough procedure are shown in Table XII.

Fig. 25 Loaf height vs. baking time for BSGB bread with 75% and 77% water.



6% SUGAR

Fig. 26 Loaf height vs. baking time for BSGB bread with 75% water at 3 levels of sugar.

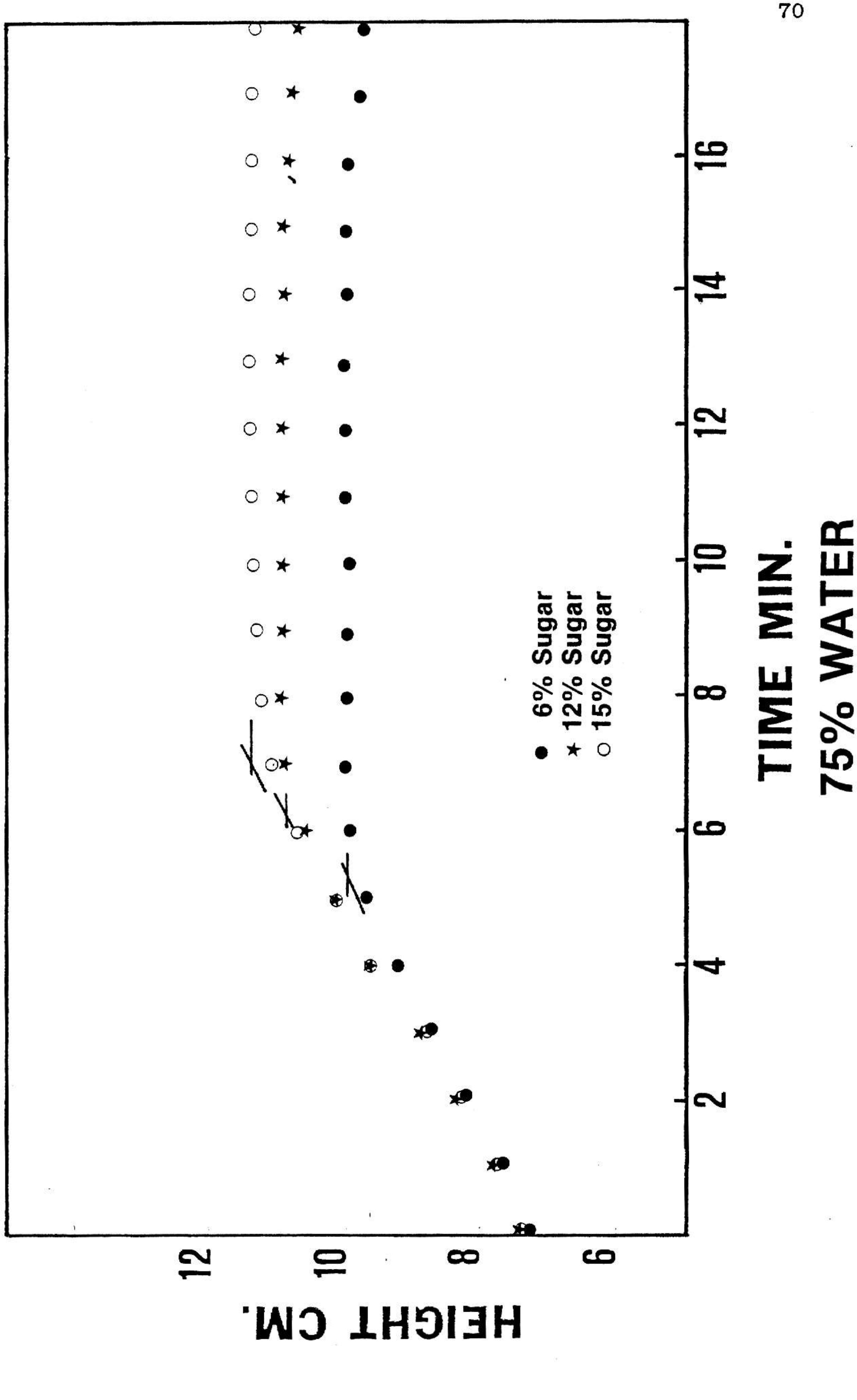

HEIGHT CM.
12
10
8
6
2
4
6
8
10
12
14
16
TIME MIN.
75% WATER
● 6% Sugar
★ 12% Sugar
○ 15% Sugar

Table IX

Effect of Shortening and SSL on Loaf Volume of Bread Containing Brewers Spent Grain Bran.

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

Data in Table IX and X are from the same bake.
Flour is KSU flour.

Table X

Effect of Oil on Loaf Volume of Bread Containing Brewers Spent Grain Bran.

	Shortening (%)	SSL (%)	Oil[a] (%)	Loaf Weight (g)	Loaf Volume (cc)
no BSGB	3	-	-	144	880
BSGB	3	0.5	-	157	745
BSGB	3	0.5	0.7	157	765

[a]Added to the BSGB in a Stein mill.

Data in Table IX and Table X are from the same bake.

Flour is KSU flour.

Table XI

Effect of Water and Yeast Levels on Loaf Volumes of Bread With 15% BSGB and 12% Sugar.

	Yeast (%)	Water (%)	Loaf Weight (g)	Loaf Volume (cc)
Control				
	2	61	144	880
BSGB Bread With 12% Sugar				
	2 1/4	69	161	685
	2 1/4	71	162	720
	2 1/4	73	165	740
	2 1/4	75	166	770
	2 3/8	69	161	710
	2 3/8	71	160	735
	2 3/8	73	163	765
	2 3/8	75	164	770
	2 1/2	69	161	735
	2 1/2	71	163	755
	2 1/2	73	164	760
	2 1/2	75	163	775

Flour is KSU flour.

Table XII

Mixing Times of BSGB Doughs With Various Treatments.

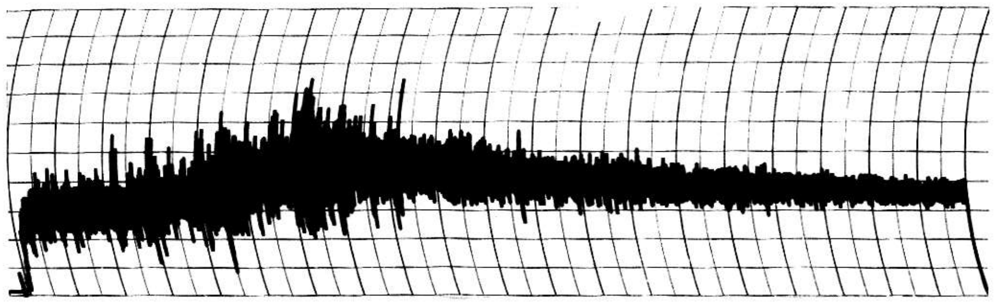
Absorption %	Sugar %	Shortening %	Oil %	SSL %	Mix Time (minutes)
Control(noBSGB)	6	3	-	-	6.5
77	6	3	-	-	10.7
77	6	3	-	0.5	13.0
77	6	3	0.7	-	11.0
77	6	3	0.7	0.5	13.3
77	6	3	-	2.0	15.5
77	6	6	-	-	11.5
77	6	6	-	0.5	13.8
77	6	6	-	2.0	16.0
77	12	3	-	-	13.0
76	12	3	-	-	12.2
75	12	3	-	-	11.7
Soaked BSGB					
77	6	3	-	-	9.6
<u>Sponge and Dough Procedure</u>					
Control(no BSGB)					4.0
BSGB added to sponge					
77	6	3	-	-	5.5
BSGB added to dough					
77	6	3	-	-	4.8

Fig. 27 Mixographs

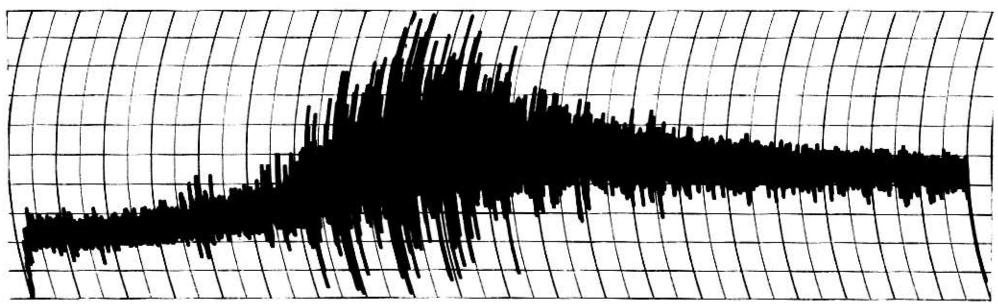
Top Mixograph: 100% KSU flour and 61% water.

Middle Mixograph: 100% KSU flour, 6% sugar, 1.5% salt, 3% shortening, and 61% water.

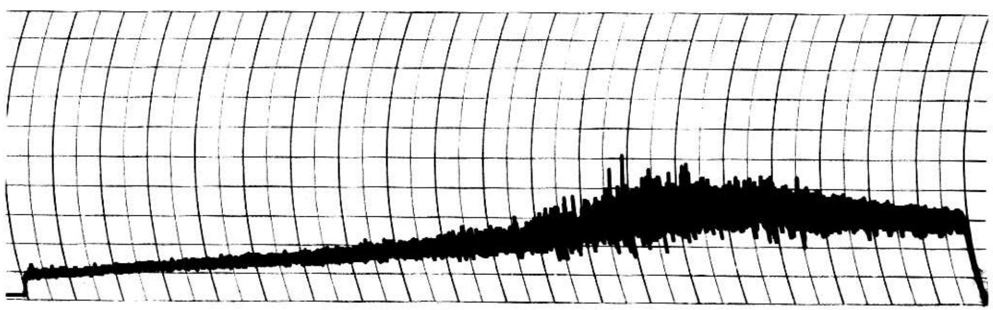
Bottom Mixograph: 85% KSU flour, 15% BSGB, and 77% water.



Flour and Water



Flour, Sugar, Salt
Shortening,
and Water



Flour, BSG, and
Water

Figure 28. *Mixographs of BSGB Doughs.*

In addition to the amount of SSL noted, all doughs contain the following: 85% KSU flour, 15% BSGB, 6% sugar, 1.5% salt, 3% shortening, and 77% water.

Top Mixograph: No SSL

Middle Mixograph: 0.5% SSL

Bottom Mixograph: 2% SSL

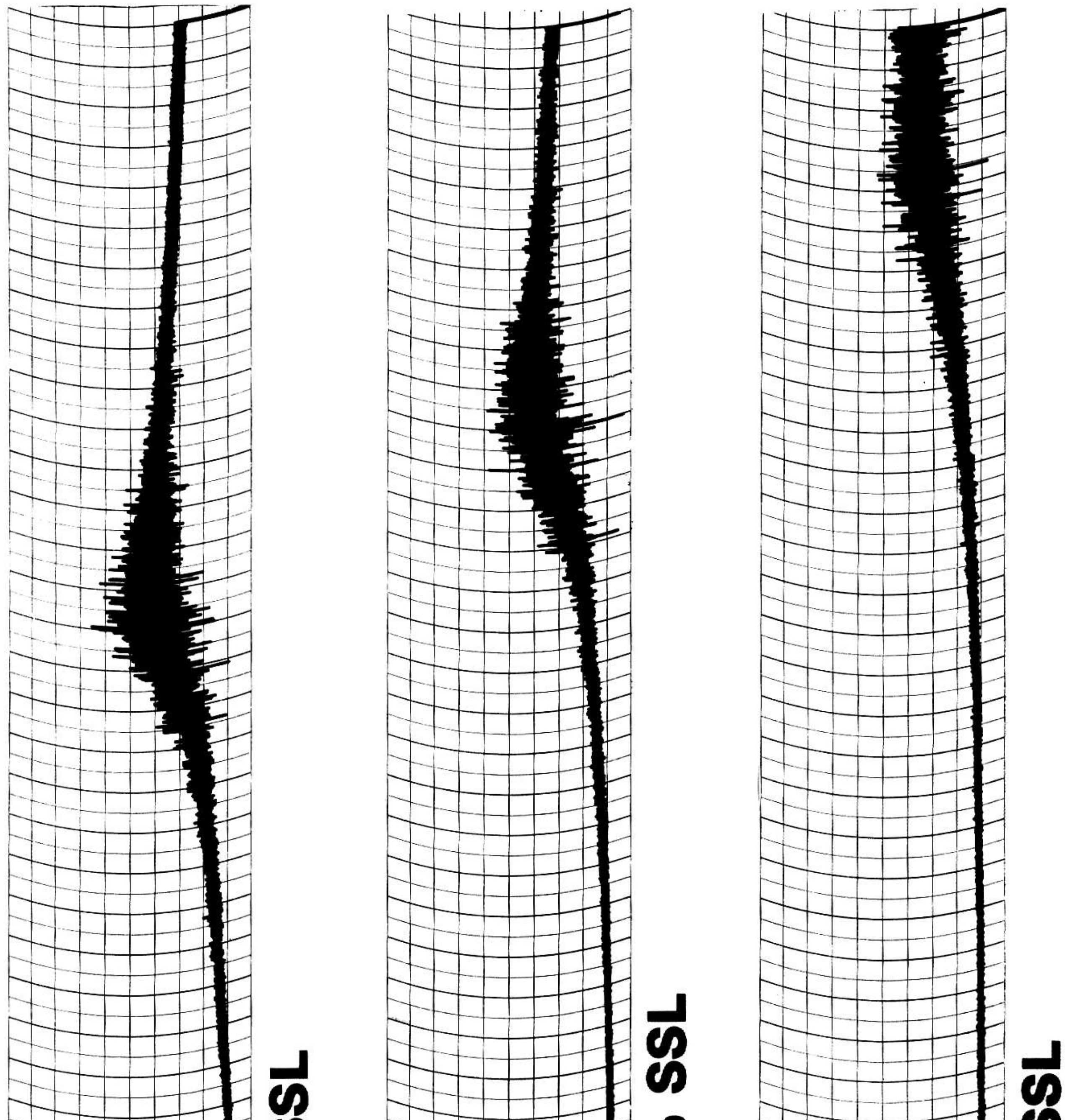

No SSL
0.5% SSL
2% SSL

Fig. 29. Mixographs of BSGB Doughs.

In addition to the amount of SSL noted all doughs contain the following: 85% KSU flour, 15% BSG, 6% sugar, 1.5% salt, 6% shortening, and 77% water.

Top Mixograph: No SSL

Middle Mixograph: 0.5% SSL

Bottom Mixograph: 2% SSL

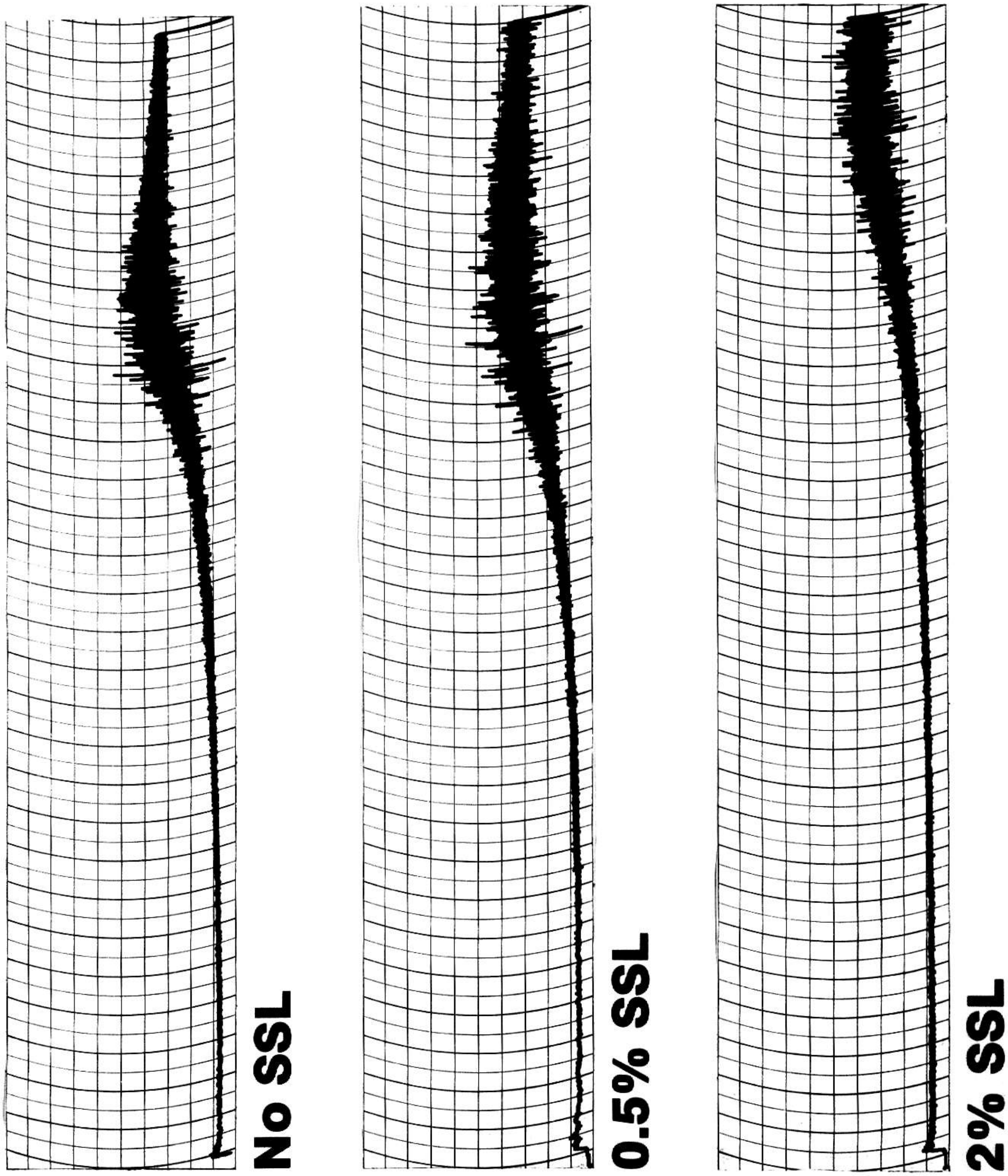

No SSL
0.5% SSL
2% SSL

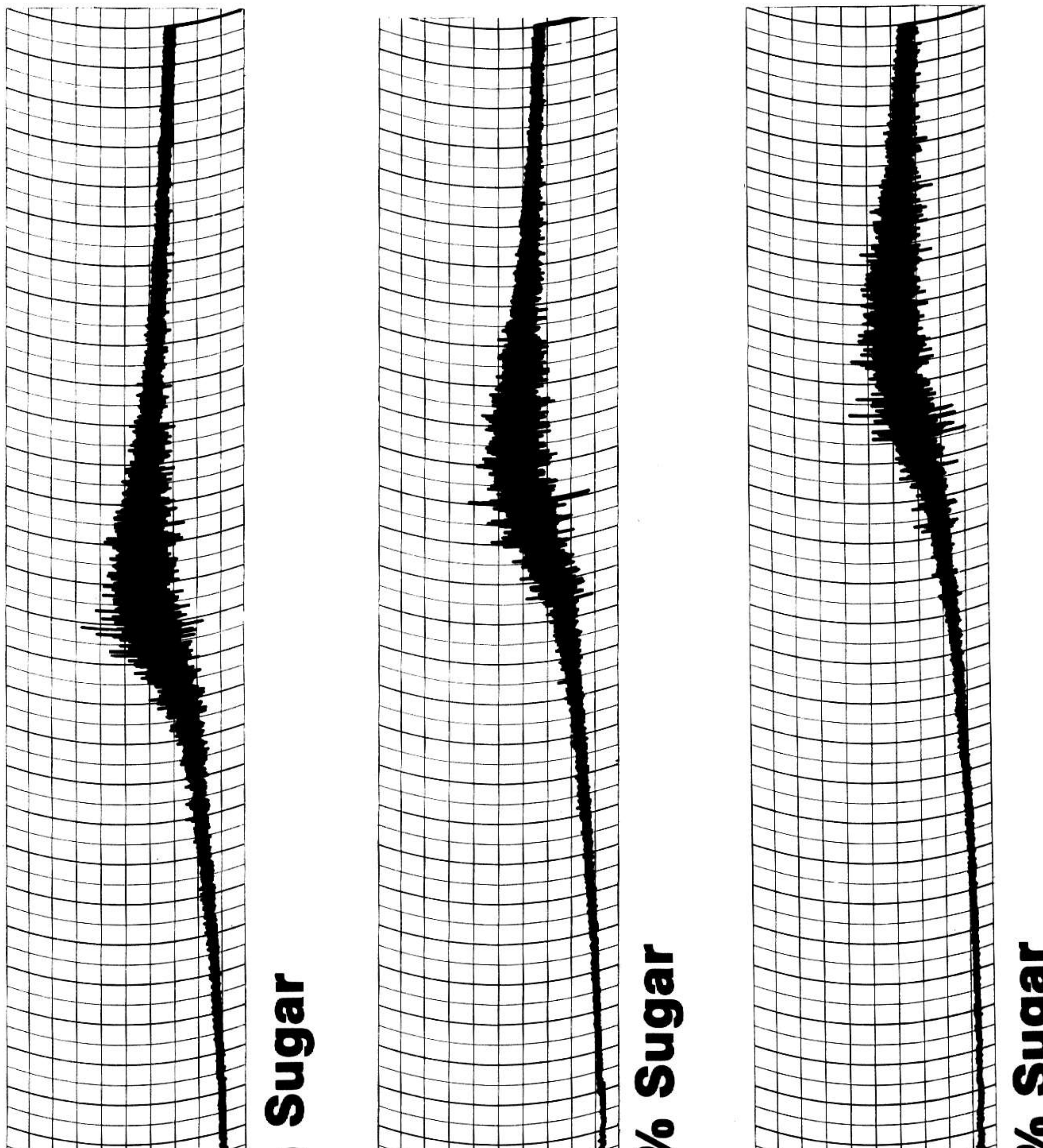
Figure 30. Mixographs of BSGB Doughs.

In addition to the amount of sugar noted all doughs contain the following: 85% KSU flour, 15% BSGB, 1.5% salt, 3% shortening, and 77% water.

Top Mixograph: 6% sugar

Middle Mixograph: 12% sugar

Bottom Mixograph: 15% sugar


6% Sugar
12% Sugar
15% Sugar

Lyophilizing and Lipid Extraction of BSGB Doughs

When developed bread doughs were dispersed in water and centrifuged the solid dough components settled in layers in the centrifuge tube. The top layer contained the gluten and the bottom layer the starch. If spent grain bran was present in the formula, it was found as a layer between the gluten and starch fractions. The border between the gluten and BSGB layers was indistinct. The gluten-starch boundary with control doughs and BSGB-starch boundary in the BSGB dough were clear and distinct.

The proximate analysis of fractions from control and BSGB doughs are shown in Table XIII and XIV. The masses and concentration of extractable lipids, and mass balance of extractable lipids are also shown.

The yield of the dough fractions are somewhat surprising. The weight of gluten is approximately the same for the control and BSGB doughs even though there was 15% less flour used in the BSGB doughs. There was only 12.9 g BSGB (dry basis) added to each BSGB dough but the weight of the BSGB layer recovered after centrifuging was over twice that amount. The extra weight apparently came from the starch. The weight of the starch fraction in the BSGB doughs was only slightly over half of the starch weight from the control doughs.

Subtracting the lipid extracted from a no shortening dough from that extracted from the corresponding dough with 3% shortening gave the following results: control - 1.85 g, BSGB, no treatment - 2.61 g, BSGB with 0.7 g oil and 0.5 g SSL - 2.9 g.

The values for the two BSGB doughs are approximately equal but the value for the control is significantly lower. The fact that only 1.85 g of 3 g shortening added is recovered from the control dough shows that the flour is binding the shortening. The BSGB is apparently filling the sites that normally bind the shortening and thereby causing less to be bound. When 0.7 g oil and 0.5 g SSL are added more binding sites are filled and more of the added shortening is recovered.

This explanation agrees with the observations of Olcott and Mecham (1947). They showed that when flour is wetted the fraction of total lipids extractable with ether decreases from 70% to 30% and when the flour is mixed into a dough the ether extractable lipids are only 6% of the total. But, they also showed, when lipids are added to the dough the flours capacity to bind lipids is apparently saturated at somewhere between 3 and 7% added lipids. When lipids are added in excess of this amount the fraction of the total dough lipids extractable by ether increases rapidly.

Table XIII
Proximate Analysis and Mass Balance of Extractable Lipids From Doughs With 3% Shortening.

Dough	Fraction	Yield(g)	% Protein	% Ash	Lipid	
					%	Grams
Control	gluten	24.7	44.1	1.9	7.98	1.81
	starch	61.1	1.0	0.45	0.32	0.19
		85.8				2.00
BSGB, no treatment	gluten	24.2	39.4	2.1	9.61	2.43
	BSGB	31.1	15.3	1.3	3.06	0.95
	starch	31.1	15.3	0.48	0.37	0.12
		86.4				3.50
BSGB, 0.7 oil, 0.5 SSL	gluten	27.3	35.4	1.7	13.05	3.46
	BSGB	24.7	15.3	1.3	2.97	0.74
	starch	34.2	1.4	0.47	0.49	0.17
		86.2				4.37

Protein = N x 6.25 for BSGB.

Protein = N x 5.7 for gluten and starch.

All data are dry basis.

Table XIV

Proximate Analysis and Mass Balance of Extractable Lipids From no Shortening Doughs.

Dough	Fraction	Yield(g)	% Protein	% Ash	Lipid %	Lipid Grams
Control	gluten	24.7	41.6	1.8	0.27	0.067
	starch	60.1	0.9	0.42	0.14	0.084
		84.8				0.151
BSGB, no treatment	gluten	22.9	39.5		1.51	0.364
	BSGB	30.2	15.5	1.4	1.69	0.510
	starch	31.1	1.5	0.47	0.11	0.034
		84.2				0.908
BSGB, 0.7 oil, 0.5 SSL	gluten	24.1	36.9	2.5	3.52	0.848
	BSGB	25.3	15.6	1.5	2.24	0.567
	starch	32.9	1.3	0.51	0.17	0.056
		82.3				1.471

Protein = N x 6.25 for BSGB.

Protein = N x 5.7 for gluten and starch.

All data are dry basis.

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BREWERS SPENT GRAINS
AND THEIR BREADMAKING CHARACTERISTICS

by

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ABSTRACT

Brewers spent grains (BSG) were found to be composed of the residues from the barley hulls and the barley pericarp (bran). The spent grains were milled and separated into three fractions. The coarse fraction was essentially all hulls, the medium fraction was a mixture of bran and hulls, and the fine fraction was essentially all bran. The hull, mixture, and bran fractions comprised 27, 22, and 51% respectively of the original BSG.

The hulls were fibrous and abrasive in texture and were judged to be unusable as human food. All breadmaking work was done with brewers spent grain bran (BSGB).

When BSGB was used to replace 15% of the flour from a bread formula water absorption was increased by 15% and 16% in the two flours tested. The BSGB decreased loaf volume and had a deleterious effect on crumb grain (caused it to have an appearance similar to bread with no shortening). Both of these conditions were relieved somewhat by adding sodium stearoyl lactylate and/or increasing shortening levels. Adding corn oil to the BSGB in a Stein mill improved crumb grain and loaf volume when used with SSL.

Studies with a resistance oven showed that starch in BSGB bread gelatinized at a lower temperature than in controls.