High-Protein Bread from Wheat Flour Fortified with Full-Fat Soy Flour[1]

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ABSTRACT

Fortifying wheat flour with full-fat soy flour in making bread can raise protein content, balance essential amino acids, and increase bread's caloric value. Such fortification, however, can adversely affect both rheological properties and baking quality of wheat flour. Sodium stearoyl-2 lactylate (SSL) could increase the stability of dough containing 12 to 28% soy flour. The effect was enhanced with increased additions of SSL (0.25 to 2.0%). All breads with 12 to 28% soy flour exhibited a small loaf volume and poor grain score. When 0.5% SSL was added, acceptable bread resulted from wheat flour fortified with soy flour up to 24%. Ethoxylated monoglycerides also gave a larger loaf volume but a lower grain score than SSL. Baking quality of defatted soy flour was inferior to that of full-fat soy flour, even compared on an equivalent protein basis. SSL also helped stored breads (soy and control) retain softness.

Protein malnutrition, a serious problem of people whose diets consist mainly of cereal or starchy foods, has aroused keen interest in fortifying breads or other products with protein-rich additives. Of the protein-rich additives now available, soy flour is most attractive in price, quality, and quantity. Defatted soy flour has been extensively studied and generally recommended for such fortifying use. In many poverty areas where diets are deficient in both protein and calories, full-fat soy flour can become an ideal supplement because of its high protein and fat content. Furthermore, to produce full-fat soy flour, simple, hand-operated equipment like that described by Mustakas et al. (1) can be set up and run in primitive villages.

Many workers, notably Ofelt et al. (2,3), Finney et al. (4,5), Pomeranz et al. (6,7), and Tsen et al. (8,9,10)[3], have shown that a) raising absorption, b) decreasing mixing time, c) increasing oxidant (bromate) treatment, d) reducing fermentation period, and e) adding glycolipids, sucroesters, and dough conditioners improve baking performance of flours fortified with soy products, mostly defatted soy flour.

Recent studies, using full-fat soy flour in high-protein bread, were undertaken by Matthews et al. (11). They developed a soft dough method that increased the volume of bread containing 25% full-fat soy flour but loaf volumes were still below acceptable standards.

Bookwalter et al. (12) used extrusion-cooked, full-fat soy flour in high-protein bread. They found that loaf volume decreased less with extruded products than with nonextruded, full-fat soy flour. As soy flour was increased from 5 to 10%, loaf volume reduced gradually; then at 15 and 20%, it decreased sharply.

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[3]Tsen, C. C., and Hoover, W. J. Announcement made at KSU high-protein bread news conference at Kansas City, Mo., Oct. 6, 1970.

Our study, part of a research project on improving the nutritive value of cereal-based foods, was undertaken to examine dough and baking properties of wheat flour fortified with full-fat soy flour and their changes with the added sodium stearoyl-2 lactylate (SSL) or ethoxylated monoglycerides (EM), and to explore any improvements in preparing acceptable bread containing a high level of full-fat soy flour.

MATERIALS AND METHODS

Materials

Wheat flour I was a blend of hard red spring and winter wheat flours milled by a commercial mill. Both defatted and full-fat soy flours were typical commercial products with their protein dispersible indexes, 35 to 45% and 15 to 25%. Their characteristics were:

	Moisture %	*Protein*[a] %	*Ash* %	*Crude Lipid* %
Wheat flour I	13.7	12.7	0.48	...
Defatted soy flour	6.4	52.6	6.80	0.5
Full-fat soy flour	5.2	40.0	4.60	22.2

[a]Protein content is % N × 6.25, except × 5.7 for wheat flour.

Farinograms

Farinograms were obtained by the constant-dough weight method, using 50 g. of sample (13).

Baking Test

The K-State Process for making high-protein bread was used (10). Loaf weight and volume were measured within 10 min. after bread was removed from the oven and averaged from duplicates. Specific loaf volume (cc. per g.) was then calculated from the average loaf weight and volume. Specific loaf volume is an important parameter of bread's marketability. Generally, specific volume of marketable bread (1-lb. loaf) should be at least 6.00 (2,722 cc.) with acceptable appearance, crumb texture, and grain. Breads were scored 18 hr. after baking. Finished bread that scored below 5 was regarded as unsatisfactory. Most of the baking tests were repeated at least once on a different day to substantiate results.

Staling Test

Staleness was tested by following changes in crumb firmness with a Bloom gelometer with a 1-in. plunger during storage. Three 1-in. slices were taken from each of two loaves which had been wrapped, sealed, and stored at room temperature (about 25°C.) for 1, 3, or 5 days. Three (top, center, and bottom) gelometer (compressimeter) readings (g.) were taken on each slice.

RESULTS AND DISCUSSION

Rheological Properties of Doughs Fortified with Various Percentages of Full-Fat Soy Flour and Treated with and without 0.5% SSL

Figure 1 presents the farinograms of wheat flour fortified with 0 to 28% full-fat

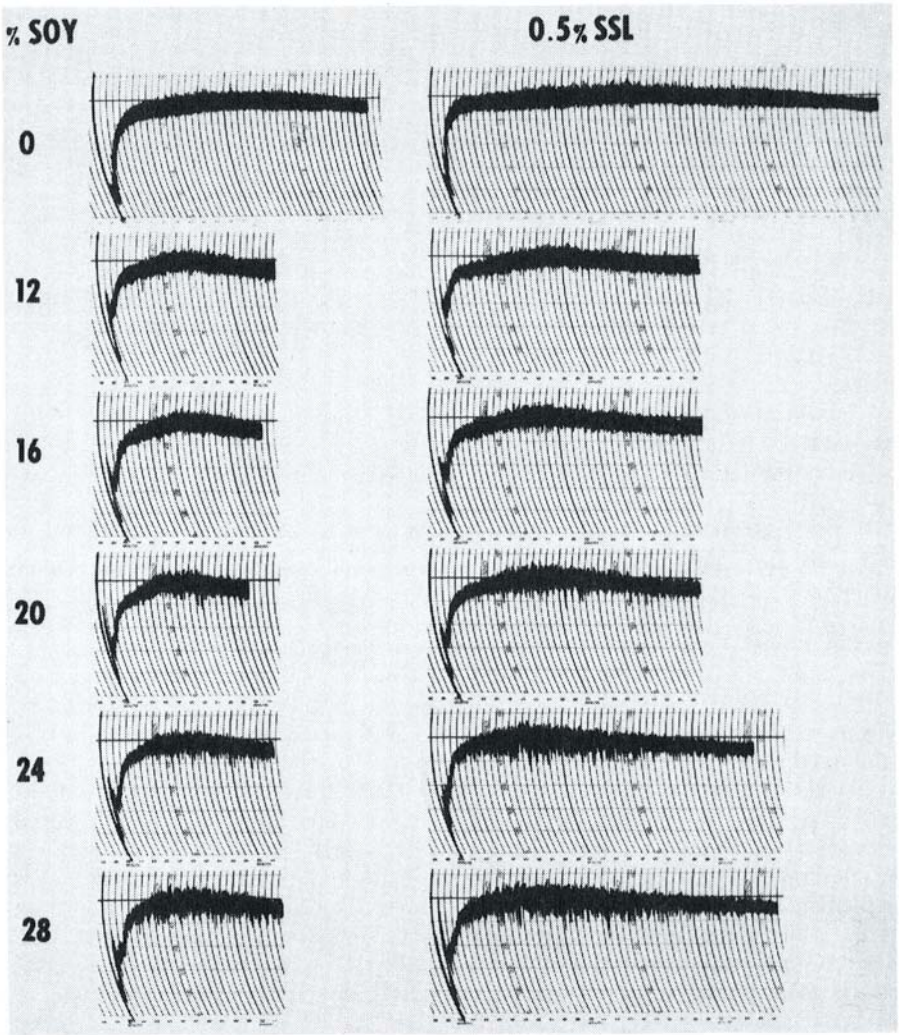

Fig. 1. Farinograms of wheat flour fortified with indicated percentages of full-fat soy flour and SSL.

soy flour; Table I shows changes in absorption, developing time, and stability with and without SSL added.

Absorption of the fortified flour dough increased as full-fat soy flour was increased. Dough developing time was reduced from 10.50 min. for wheat flour dough to 6.40 to 7.00 min. for doughs fortified with 12 to 28% soy flour, a reduction of 33 to 39%. Despite the different percentages of fortified soy flour, changes in developing time among fortified doughs were extremely little. Dough stability was sharply reduced by soy fortification. At 20% soy flour, dough stability was lowest; it increased with further additions of soy flour (24 and 28%).

TABLE I. FARINOGRAPHIC CHARACTERISTICS OF WHEAT FLOUR FORTIFIED WITH INDICATED PERCENTAGES OF FULL-FAT SOY FLOUR AND SSL

Full-Fat Soy Flour %	No SSL			0.5% SSL		
	Absorption %	Developing time min.	Stability min.	Absorption %	Developing time min.	Stability min.
0	65.0	10.50	15.00	64.0	15.00	28.75
12	68.2	6.75	9.35	68.2	10.10	15.00
16	69.6	6.40	7.50	69.6	8.50	14.40
20	70.8	7.00	6.40	70.8	8.50	13.25
24	72.0	6.75	7.85	72.0	7.85	16.00
28	72.4	6.70	9.55	72.4	8.10	18.00

Adding 0.5% SSL did not affect absorption, but could delay dough development and greatly increase dough stability, so SSL clearly can increase the mixing tolerance of wheat flour fortified with soy flour.

To substantiate that SSL could increase mixing stability of dough containing soy flour, additional tests were made to examine effects of SSL added at 0.25, 0.50, 1.00, or 2.00% on doughs containing 16% full-fat soy flour. That both dough developing time and stability increased as SSL was increased confirmed the dough strengthening effect of SSL for soy fortified dough (Table II).

Effect of Different Percentages of Full-Fat Soy Flour on Baking Quality

To explore how much full-fat soy flour could be used, we fortified wheat flour with 12, 16, 20, 24, and 28% soy flour and evaluated their baking performances. Optimum breadmaking conditions for each soy flour percentage tested were first established in preliminary tests.

Figure 2 and Table III show adverse effects of full-fat soy flour on loaf volume and grain score of finished bread; both loaf volume and grain score reduced progressively with soy flour increments from 12 to 28%.

The improving effect of SSL was obvious. Without 0.5% SSL, all finished breads supplemented with 12 to 28% soy flour had small loaf volumes and poor grain scores. None was acceptable. However, with 0.5% SSL added, breads made from wheat flour fortified with soy flour up to 24% were acceptable. Even at 28%, specific loaf volume still averaged 5.82 cc. per g. and the finished bread had an acceptable grain score (Fig. 2 and Table III).

TABLE II. FARINOGRAPHIC CHARACTERISTICS OF WHEAT FLOUR FORTIFIED WITH 16% FULL-FAT SOY FLOUR AND TREATED WITH INDICATED PERCENTAGES OF SSL

Full-Fat Soy Flour %	SSL %	Absorption %	Developing Time min.	Stability min.
0	0	65.0	10.50	15.00
16	0	69.6	6.40	7.50
16	0.25	69.6	8.40	14.40
16	0.50	69.6	8.50	14.40
16	1.00	69.6	10.00	15.50
16	2.00	69.6	11.25	24.60

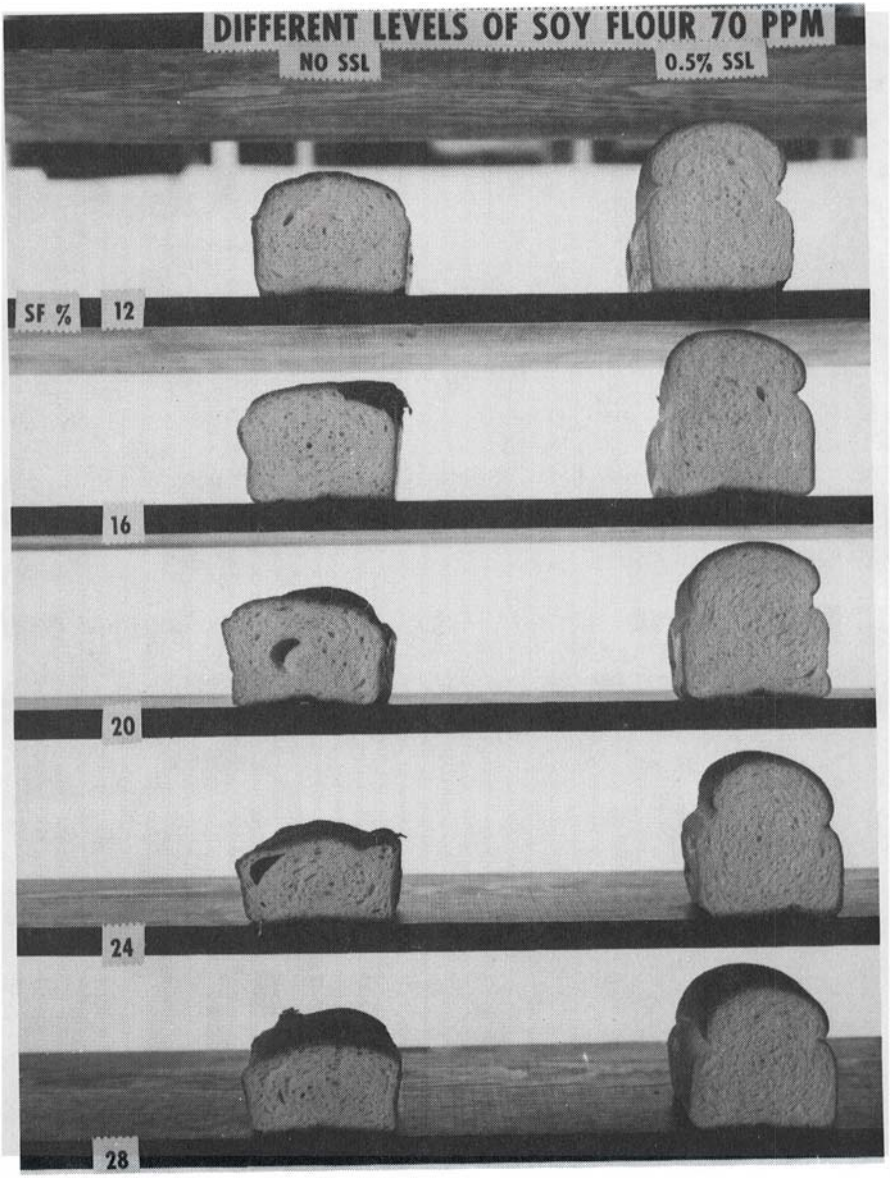

Fig. 2. Breads made from wheat flour fortified with indicated percentages of full-fat soy flour and treated with 70 p.p.m. potassium bromate and with or without 0.5% SSL.

Improving Effect of Ethoxylated Monoglycerides

In previous screening evaluations of various additives in high-protein breads here (8, 9, 10)[3], SSL and EM exerted improving actions. To add to that finding, we conducted baking tests on flour fortified with 24% full-fat soy flour and treated with 0.5 and 1.0% SSL or EM under the testing conditions described in Table III.

TABLE III. EFFECTS ON BAKING QUALITY OF FORTIFYING WHEAT FLOUR WITH INDICATED PERCENTAGES OF FULL-FAT SOY FLOUR

Soy Flour %	SSL %	Absorption %	Bromate p.p.m.	Mix min.	Avg. Loaf Volume cc.	Avg. Specific Loaf Volume cc./g.	Grain Score
12	0	76	70	5.0	2,223	4.90	4
16	0	80	70	4.0	2,077	4.58	4
20	0	84	70	3.5	1,923	4.24	3
24	0	88	70	3.5	1,733	3.82	2
28	0	92	70	3.0	1,461	3.22	2
12	0.5	76	70	5.0	3,003	6.62	9
16	0.5	80	70	4.0	2,876	6.34	8
20	0.5	84	70	3.5	2,830	6.24	8
24	0.5	88	70	3.5	2,735	6.03	7
28	0.5	92	70	3.0	2,640	5.82	7

Figure 3 shows the loaf-pictures of such treated breads. The specific volume of all breads, as indicated in the legend, was around 6.00 when 0.5 or 1.0% SSL or EM was added, indicating that EM, like SSL, can improve the baking performance of flour containing 24% full-fat soy flour. However, grain and texture of EM-treated breads were slightly inferior to those of SSL-treated bread. Volume of the former was larger than that of the latter.

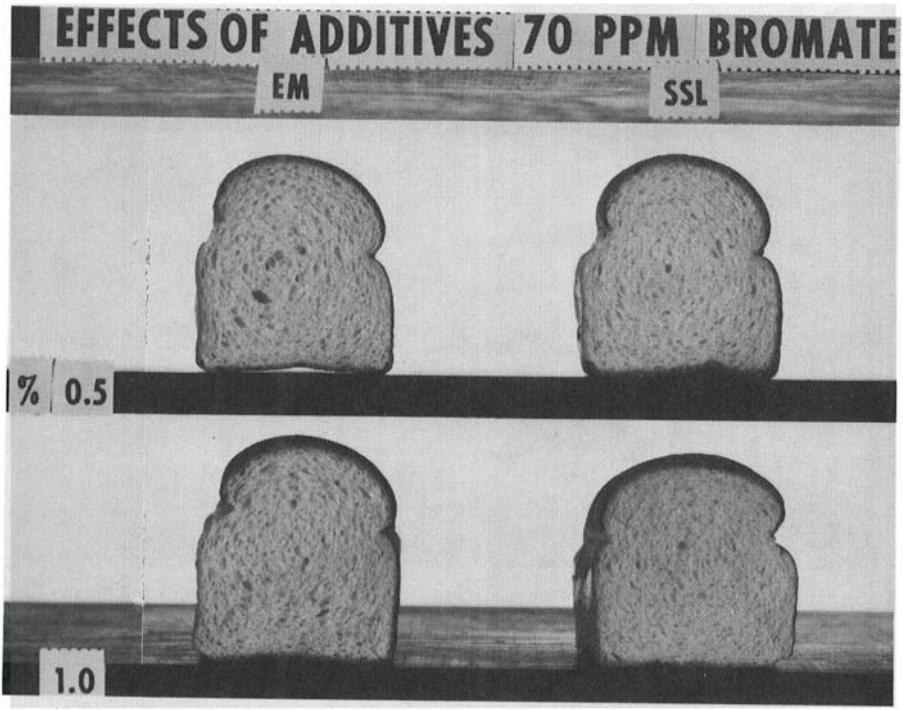

Fig. 3. Breads made from wheat flour fortified with 24% full-fat soy flour and treated with 0.5 and 1.0% SSL or EM and 70 p.p.m. potassium bromate. Specific volumes (cc. per g.) are 6.03 and 5.91 for the breads containing 0.5 and 1.0% SSL, and 6.04 and 6.14 for those containing 0.5 and 1.0% EM.

Comparison of Full-Fat and Defatted Soy Flours

In view of the excellent baking performance of flour fortified with full-fat soy flour and SSL or EM, a comparative baking test was made with defatted soy flour under the same experimental conditions. Results, given in Table IV, show that both loaf volume and grain score reduce progressively with the addition of defatted soy flour from 12 to 28%. Comparison of data in Tables III and IV reveals that the baking quality of defatted soy flour is inferior to that of full-fat soy flour. It is, of course, not fair to compare baking qualities of full-fat soy flour and defatted soy flour both fortified at the same level for making high-protein bread. Defatted soy flour contains 12.6% more protein than full-fat soy flour. The extra protein could damage the gluten network in dough and thus reduce both loaf-volume and grain score, as reflected by the lower loaf-volume and grain score of breads fortified with defatted soy flour when compared to those of breads with full-fat soy flour (Tables III and IV and Fig. 4).

SSL improves the baking performance of fortified flour. Its improving effect is greater for full-fat soy flour than for defatted soy flour, so more full-fat than defatted soy flour can be used to prepare acceptable bread, as shown in Fig. 4. Under our experimental conditions, data show that acceptable bread can be made from flour fortified with 24% full-fat soy flour but not with 16% defatted soy flour. That indicates that with the addition of 0.5% SSL, full-fat soy flour is far superior to defatted soy flour, even when compared on an equivalent protein basis. Whether protein quality, fat and natural emulsifiers such as glycolipids and lecithin (14,15), or other substances in full-fat soy flour are responsible for this superiority remains unknown.

Staleness Evaluation

For staleness evaluations, breads were made from wheat flour fortified with 20% full-fat soy flour with or without 0.5% SSL. Control breads with no soy fortification also were prepared with the same wheat flour under the same processing conditions (Table V).

Table VI shows average compressimeter readings (g.) for loaves stored 1, 3, or 5

TABLE IV. EFFECTS ON BAKING QUALITY OF FORTIFYING WHEAT FLOUR WITH INDICATED PERCENTAGES OF DEFATTED SOY FLOUR[a]

Defatted Soy Flour %	SSL %	Avg. Loaf Volume cc.	Avg. Specific Loaf-Volume cc./g.	Grain Score
12	0	2,059	4.54	4
16	0	1,878	4.14	3
20	0	1,542	3.40	2
24	0	1,438	3.17	2
28	0	1,334	2.94	2
12	0.5	2,821	6.22	8
16	0.5	2,613	5.76	7
20	0.5	2,291	5.05	6
24	0.5	1,928	4.25	5
28	0.5	1,533	3.38	3

[a]Breadmaking conditions the same as in Table III.

days. Soy bread without SSL firmed rapidly; its crumb became so firm that all compressimeter readings registered more than 500 g. SSL effectively helped stored breads (soy and control) retain softness. Soy bread with 0.5% SSL compared favorably with the control bread with 0.5% SSL and exceeded the control bread without SSL in softness retention. No soy bread showed any sign of off-flavor after 5 days of storage.

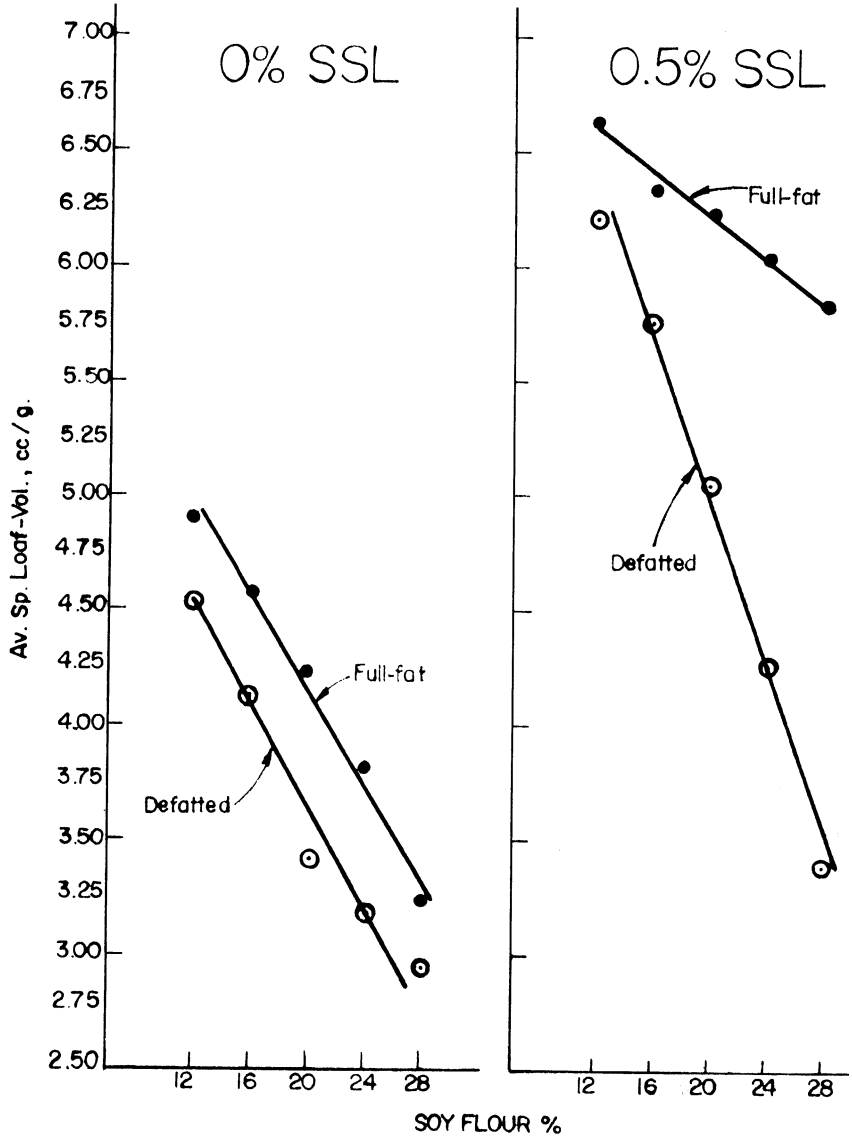

Fig. 4. Effect of soy flour increments on specific loaf volumes.

TABLE VI. AVERAGE COMPRESSIMETER READINGS (g.) OF STORED CONTROL BREADS AND BREADS CONTAINING 20% FULL-FAT SOY FLOUR

Bread	Days Stored		
	1	3	5
Control	101.2	140.1	181.3
Control + 0.5% SSL	68.1	93.8	115.8
Soy	346.6	437.6	>500.0
Soy + 0.5% SSL	76.7	85.1	134.0

TABLE V. PROCESSING CONDITIONS AND BAKING RESULTS FOR BREADS (FULL-FAT SOY FLOUR AND CONTROL) PREPARED FOR STALENESS EVALUATION

Soy Flour %	SSL %	Bromate p.p.m.	Absorption %	Mix min.	Avg. Loaf Volume cc.	Avg. Specific Loaf Volume cc./g.	Grain Score
0	0	50	64	6.0	2,908	6.41	8
0	0.5	50	64	6.0	3,316	7.31	9
20	0	90	84	3.5	1,969	4.34	3
20	0.5	90	84	3.5	2,803	6.18	8

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