SOY FLOUR AS A WHITE BREAD INGREDIENT

I. Preparation of Raw and Heat-Treated Soy Flours, and Their Effects on Dough and Bread[1]

J. M. POLLOCK[2] AND W. F. GEDDES[3]

ABSTRACT

An experimental soy flour, obtained by hammer-milling decorticated soybeans and defatting with cool petroleum ether, proved similar in nitrogen dispersibility and other analytical characteristics to a commercial defatted flour prepared under mild conditions. Controlled heat-treatments (1 hour, 7.9% moisture) at 75°C. or below had no appreciable effect on nitrogen dispersibility; treatment at 100°C. or above substantially reduced nitrogen dispersibility and materially darkened soy flour color.

Inclusion of raw soy flour in farinograph doughs at levels of 1–5% imparted to normal and rest-period curves the characteristics of a stronger flour, the effect increasing with the soy flour level. Soy flour heated 1 hour at 100°C. showed this property to a lesser degree. In baking tests employing 1 mg. potassium bromate per 100 g. of flour, 1% raw soy flour somewhat improved the bread, but higher levels decreased loaf volume; heated soy flours were still more injurious, in proportion to their degree of heat-treatment. Heat-treatment raised the water absorption of the soy flours in doughs.

Although the nutritional advantages of soy flour have been appreciated by many, its acceptance as a bread ingredient has been rather limited mainly because of functional disadvantages and nonuniformity of soy flours in early stages of their development. The functional problems generally associated in the past with the use of soy flours in bread dough include (a) alteration of absorption, mixing, and machining properties, (b) adverse effects on color and flavor, (c) changes in fermentation rates and (d) effects on the gluten complex, including oxidation requirements (4,5,6). Although improvement in processing methods has steadily reduced these disadvantages, lack of uniformity among commercial soy flours has rendered adaptation to this new ingredient difficult (15,16).

One object of the present work was to assess the baking quality of a specially prepared, unheated soy flour and to determine its effects on dough characteristics. Since soy flours receive widely varying degrees of heat-treatment during processing and in view of the well-known effects of heat on the baking quality of milk (8,9) and on

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[2] Present address: The Procter and Gamble Co., Cincinnati, Ohio.

[3] Professor of Agricultural Biochemistry, University of Minnesota, St. Paul.

wheat flour itself (7), the effect of heat on the baking quality of extracted raw soy flour was also examined.

Materials and Methods

Soy Flour Samples. A sample of unheated, decorticated soy beans, ground in a hammer mill to pass 95.9% through a No. 100 U.S. standard screen,[4] was defatted in 3-kg. batches by exhaustive cold extraction with petroleum ether in a Lloyd percolator. The extraction rate was controlled to hold the temperature between 22° and 29°C. This specially extracted flour was air-dried and pulverized during drying. It was then bolted through a 9 XX grits gauze on a mechanical shaker and blended in a MacLellan mixer.

Commercial soy flours representative of the chief types available on the market were obtained for comparison with the experimental soy flour.[5]

Heat-Treatment of Extracted Raw Soy Flour. To minimize moisture losses during heat-treatments, a modified form of the equipment described by Geddes (7) was used. This consisted of a closed stainless-steel cylinder (11.7 by 39 cm. inside dimensions), arranged to rotate in an oil bath to provide a combined tumbling and end-to-end motion.

The laboratory-defatted raw soy flour (7.9% moisture) was heated in 250-g. quantities at 50°, 75°, 100°, and 125°C. for 1 hour.

Analysis of Commercial and Experimental Soy Flours. The ground, decorticated soybeans, the defatted flour, and the commercial soy flours were analyzed, chiefly by routine methods. Moisture and volatile matter were determined by the method of the National Soybean Processors' Association (14). Total nitrogen was determined as prescribed in section 2.26 of AOAC *Methods* (3), except that, in the distillation, the ammonia was absorbed in 4% boric acid solution and titrated directly with standard acid. Ash content was obtained by the NSPA method (14). To determine fat content, the samples were first dried and the moisture loss determined after heating at 95°–100°C. under less than 100 mm. pressure for 5 hours (2). Fat was then determined on the dried material by the NSPA method (14).

For the determination of reducing sugars, the AACC method (1) was modified as follows: extraction of sugars was begun by adding the prescribed amounts of alcohol and acid buffer solution, then shaking briefly but sharply to suspend the sample. After the immediate addition of sodium tungstate solution to inactivate enzymes, the extraction

[4] Courtesy of the Northern Utilization Research and Development Division, Peoria, Illinois.
[5] Courtesy of the Soya Food Research Council, Washington, D. C.

was completed by shaking for exactly 30 seconds. The reducing power of an aliquot against potassium ferricyanide was then determined as directed in the method. Results were expressed empirically in terms of maltose, although substantially none of the reducing power of soy flour is due to maltose.

Urease activity was estimated[6] as the pH increase resulting upon incubation of 0.200 g. of soy flour with 3% urea solution in 0.05*M* phosphate buffer of pH 7.0 at 30°C. for 30 minutes.

Water dispersibility of the nitrogen in the soy flour samples was determined as a criterion of the influence of processing conditions on the protein. Although this property is considered important in the soy flour industry, no standard method has been accepted. In the present work the "nitrogen dispersibility" was obtained by mechanically shaking a 5-g. sample for 2.5 hours with 100 ml. of distilled water at 26°C., centrifuging, and determining the nitrogen in an aliquot of the centrifugate (3).

Physical Dough Tests. The effects of 1, 3, and 5% levels of raw and heated (1 hour at 100°C.) soy flour were evaluated by replacing a portion of wheat flour with the required weight of soy flour and making farinograph tests (small mixing bowl) in the usual manner (1).

"Rest-period" farinograph curves on the same dough compositions were prepared by mixing to maximum consistency, stopping the machine, and leaving the bowl undisturbed for 1 hour with the temperature controlled at 30°C. The machine was then started and the dough remixed for 2 minutes. Three such rests were employed for each mixture.

The farinograph was used in a different manner to standardize absorption or to determine consistency in complete doughs. The proper absorption of the wheat flour was first established at 60% by "feel." The mixing of all the ingredients employed in the baking formula, scaled down to a total weight of 80 g., yielded a farinograph consistency of 400 units. This consistency reading could be reproduced by inserting in the bowl an 80-g. portion of dough premixed in the McDuffee bowl for 3 minutes. Subsequently, this method was used to determine the baking absorption of wheat flour-soy flour mixtures. On the basis of these absorptions, the "water requirement" of each soy flour was calculated as the ratio of water to soy flour (by weight) required to yield the standard consistency (400 units) in a given wheat flour-soy flour dough.

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[6] Courtesy R. E. Anderson, Control Laboratory, Archer-Daniels-Midland Company, Minneapolis, Minnesota.

Experimental Baking Tests. The test formula employed was an average commercial-type formula (Table I) with ingredients in such amounts as to yield 250-g. doughs. The baking procedure (Table I) was of the straight dough type described in *Cereal Laboratory Methods* (1).

TABLE I
BAKING FORMULA AND PROCEDURE FOR 250-GRAM DOUGHS

	Baking Formula	
	Percent of Wheat Flour, 14% Moisture Basis	Weight
		g/mix
Flour [a]	100.0	300.0
Yeast	3.0	9.0
Sugar	5.0	15.0
Salt	2.0	6.0
Dough improver [b]	0.3	0.9
Shortening	2.0	6.0
Water	60.0	180.0
	Procedure	
Mixing time (minutes) [c]	2.5	
Dough weight (g.)	250	
Fermentation at (°C.)	30	
(°F.)	86	
and r.h. (%)	90	
Punched [d] after (minutes)	95	
Molded after (minutes)	25	
Proofing time (minutes)	55	
Oven time at 232°C. (450°F.) (minutes) [e]	25	

[a] Commercial Southwestern flour, 80% baker's patent; ash 0.40%, protein 11.2% (14% moisture basis).
[b] A commercial bread improver containing potassium bromate (0.3%), yeast foods, and an inert ingredient.
[c] Medium speed on Hobart C-10 mixer, equipped with a McDuffee bowl and mixing head.
[d] Punching was done on a National dough sheeter, with rolls set at 9/32-in. For panning, doughs were sheeted twice, at 9/32- and 5/32-in. roll settings. Molding was done by hand.
[e] Baking was carried out in a specially constructed National rotary hearth oven.

Loaf volumes were determined with a National Loaf Volumeter 1 hour after baking, and the loaves were scored the following day for other characteristics.

Results

Analysis of Commercial and Experimental Soy Flours. Analytical data for the commercial and laboratory-prepared soy flours are recorded in Table II. The laboratory-extracted raw soy flour (VI) was similar in several respects to the commercial solvent-extracted flours (II, III). However, the data for urease activity and nitrogen dispersibility, which are highly dependent on degree of heat-treatment, mechanical injury, and other processing factors, revealed marked differences between the commercial flours. Judging from decreased nitrogen

TABLE II

ANALYSIS OF COMMERCIAL AND LABORATORY-PREPARED SOY FLOURS[a]

No.	Nature of Sample	Protein	Ash	Fat	Reducing Sugars[b]	Urease	Nitrogen Dispersible in Water
		%	%	%		*pH units*	*% of total*
I	Ground raw decorticated soybeans	44.1	5.06	23.1	132	1.9	65.2
II	Commercial unheated defatted soy flour (solvent extracted)	56.7	6.26	0.3	178	2.0	77.8
III	Commercial defatted soy flour (solvent extracted)	58.5	6.42	0.6	124	1.7	57.0
IV	Commercial low-fat soy flour (expeller process)	55.5	5.90	4.7	116	0.4	21.4
V	Commercial full-fat soy flour	43.5	4.70	24.8	103	0.2	21.8
VI	Laboratory-defatted raw soy flour[c]	57.0	6.37	0.3	128	...	77.6

[a] Analytical values are expressed on a dry-matter basis and are the means of at least duplicate determinations.
[b] Expressed as mg. maltose per 10 g. soy flour.
[c] Represents Sample No. I extracted with petroleum ether, as described in text.

dispersibility in particular, commercial sample No. III appeared to have been processed under more drastic conditions than No. II. Commercial soy flour II was quite similar to the experimental flour, which was carefully prepared to avoid any heat effect.

Other commercial soy flours were decidedly lower in nitrogen dispersibility and urease activity. These effects presumably are traceable to the expeller method of defatting the low-fat soy flour (IV) and the method of grinding the full-fat product (V). The somewhat lower

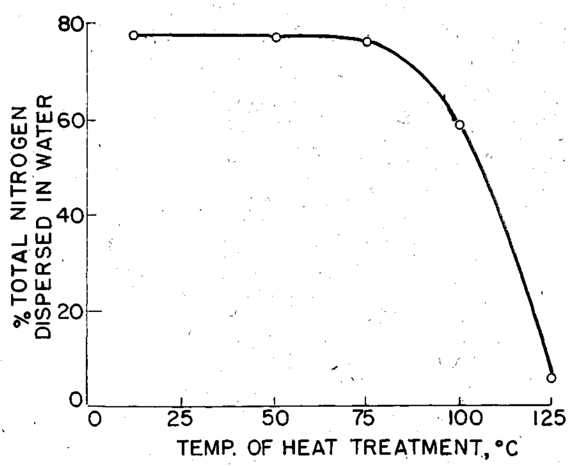

Fig. 1. The effect of controlled heat-treatment on nitrogen dispersibility of experimental, unheated, defatted soy flour. The nitrogen dispersion levels of three commercial soy flours were as follows: unheated, defatted soy flour, 78%; defatted soy flour, 57%; and low-fat soy flour, 21%.

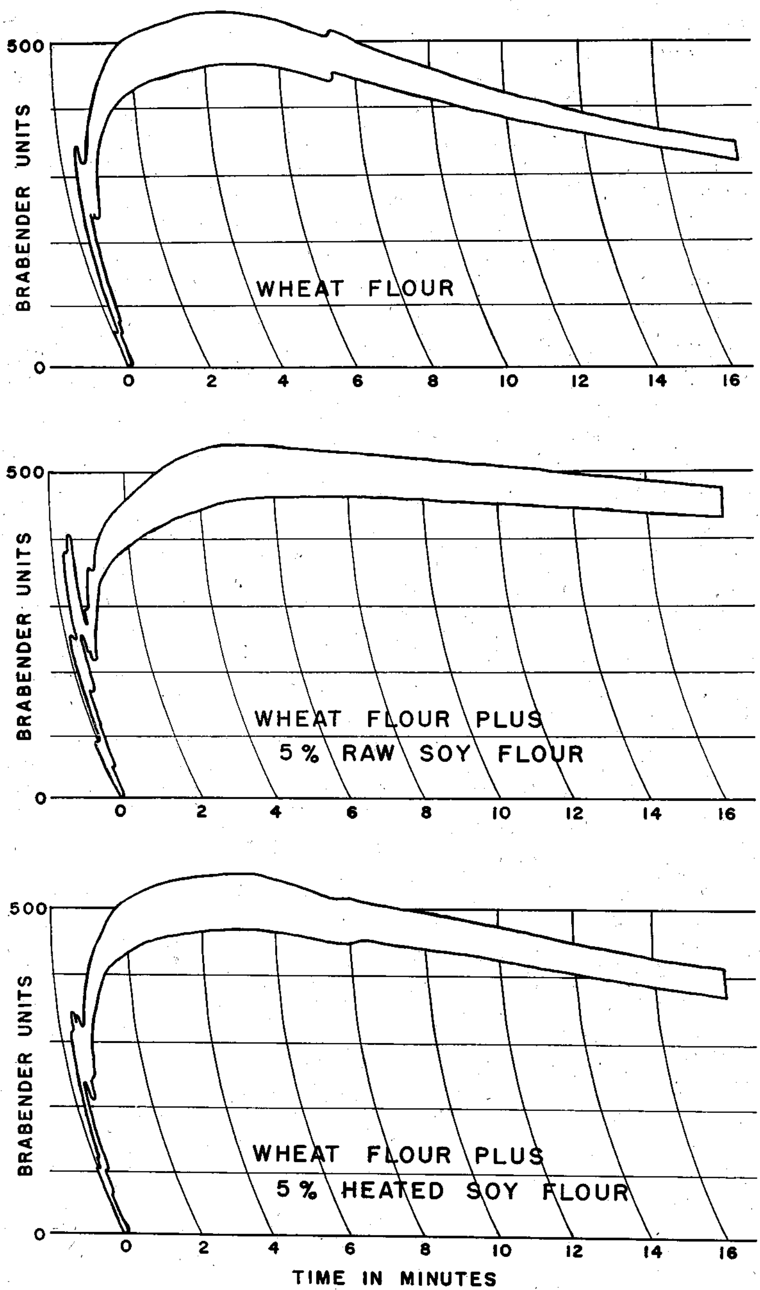

Fig. 2. The effect of raw and heat-treated soy flours on characteristics of the normal farinograph curve.

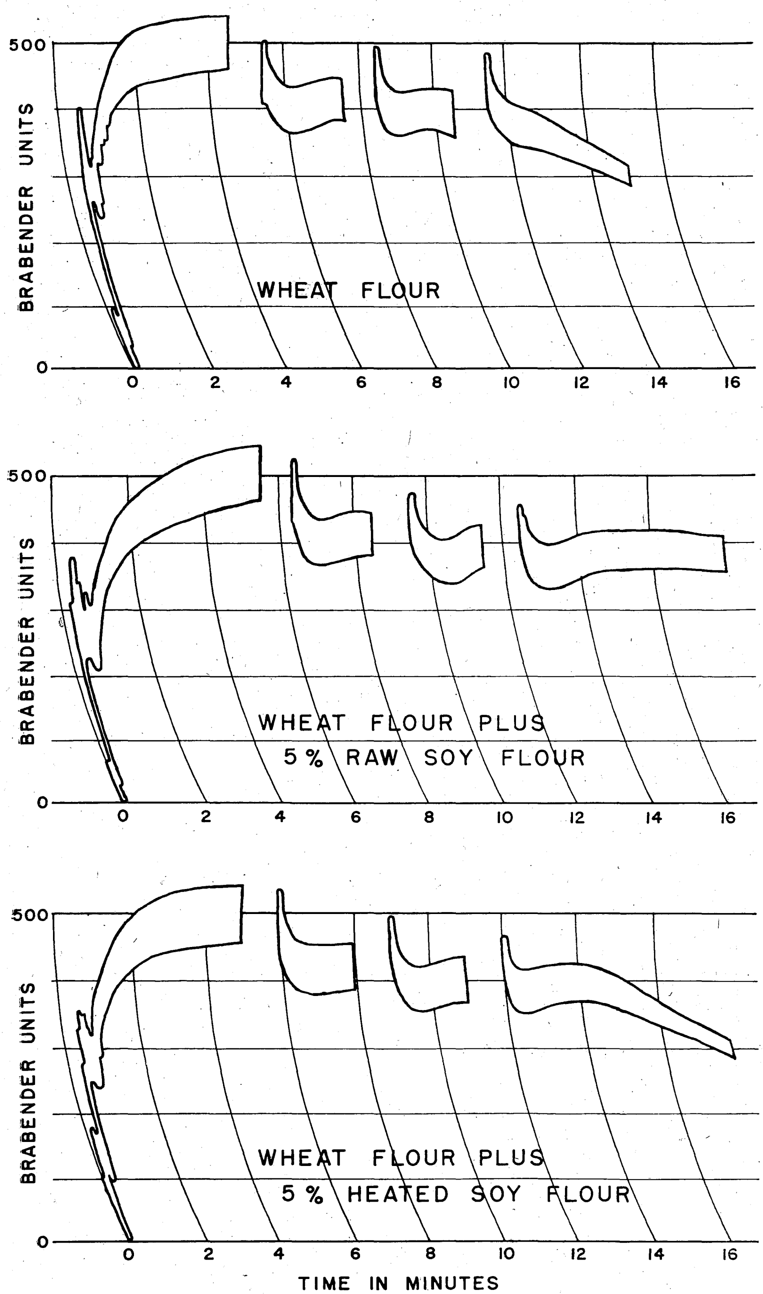

Fig. 3. The effect of raw and heat-treated soy flours on farinograph "rest period" curves.

nitrogen dispersibility of the ground, raw, decorticated beans (I) than of the defatted flour prepared from it (VI) is probably due to interference of the fat with protein dispersion.

Effect of Controlled Heat-Treatment on Nitrogen Dispersibility of Experimental Soy Flour. The influence of heat-treatment on nitrogen dispersibility is shown in Fig. 1. At the prevailing moisture content (7.9%), 1-hour heat-treatments at 75°C. or below had no effect on nitrogen dispersibility; however, treatment at 100°C. had a marked effect, whereas treatment at 125°C. largely destroyed nitrogen dispersibility.

Physical Dough Tests. Normal farinograms for doughs made with and without the addition of raw (5%) and of heat-treated (1 hour at 100°C.) soy flours, respectively, are shown in Fig. 2. As little as 1% of unheated soy flour (VI) imparted to the dough the farinogram characteristics considered typical of a stronger flour. The increased dough stability, curve width, and dough development time were augmented with increased percentages of raw soy flour. Heated soy flour had a smaller effect; the 5% level altered the control curve less than the 1% level of raw soy flour.

Rest-period farinograms, to reveal any delayed effect of these soy flours on the physical properties of the doughs, were made (Fig. 3). The apparent strengthening effect of raw and heated soy flours prevailed throughout three 1-hour rest periods; again, the raw soy flour gave the more pronounced effect.

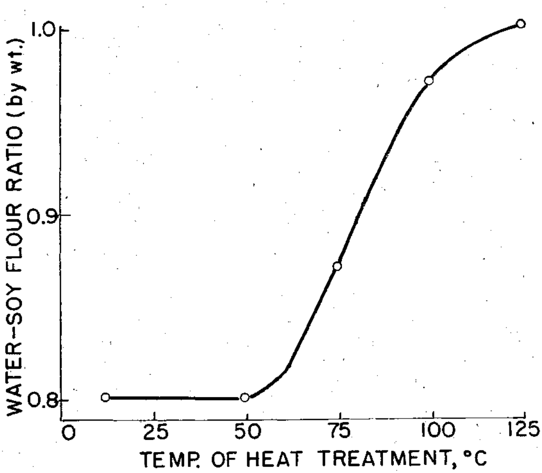

Fig. 4. Effect of heat-treatment of soy flour on the ratio of the weight of additional water to the dry weight of soy flour which is required to yield a dough of standard consistency (400 B.u.) in the farinograph.

The inclusion of soy flour in dough necessitated the use of additional water to obtain a standard farinograph dough consistency. Figure 4 shows the water requirements of raw and heated soy flours, in terms of the ratio of the weight of additional water to the dry weight of soy flour which is required to yield a dough with a consistency of 400 B.u. The water-soy flour ratios probably reflect the influence of heat on water-binding capacity of the protein. Comparison with the nitrogen dispersibility data (Fig. 1) indicates an inverse relationship between nitrogen dispersibility and the water-binding capacity as approximated by the farinograph method.

TABLE III
ABSORPTION AND MEAN LOAF VOLUMES OF LOAVES CONTAINING HEAT-TREATED SOY FLOURS

Sample No.	Temp. of Heat Treatment[a]	Soy Flour Level[b]	Absorption	Loaf Volume[c]
	°C	%	%	cc
Control		0	60.0	1225
VI	nil	1	60.8	1285**
		3	62.4	1250
		5	64.0	1200
VI–a	50	1	60.8	1220
		3	62.4	1220
		5	64.0	1175**
VI–b	75	1	60.9	1230
		3	62.6	1235
		5	64.3	1170**
VI–c	100	1	61.0	1215
		3	62.9	1185*
		5	64.9	1110**
VI–d	125	1	61.0	1200
		3	63.0	1175**
		5	65.0	1135**

[a] Heat treatments were for 1 hour at 7.9% moisture.
[b] Based on wheat flour at 14% moisture.
[c] Means of duplicates. The standard error (single determination) computed from all sets of duplicate values was 16.1 cc. A minimum difference of 32.2 cc. is required between any two means for them to be considered significantly different; to be regarded as highly significant the differences must equal or exceed 48.3 cc. The loaf volumes which are significantly different from the control at the 5% and 1% points are designated by * and ** respectively.

Baking Tests. The loaf volumes obtained from doughs containing 1, 3, and 5% levels of raw and heated soy flour samples are shown in Table III. Unheated soy flour (VI) at the 1% level gave a significant loaf-volume increase. The higher levels had no appreciable effect; this may be due to the use of a constant level of oxidizing improver in all samples. In general, heated soy flours were deleterious, the effect increasing with severity of heat-treatment. The dough formula could "carry" 3% of soy flour heated at 50° or 75°C. without a significant decrease in loaf volume; only 1% additions of samples heated at 100° or 125°C. could be tolerated. Although these experimentally heated samples are not comparable with most commercial soy flours, the poor performance in bread of some commercial products, many of which are subjected to considerable heat-treatment, is easily understood.

Crumb color of bread containing any appreciable amount of soy flour has long been a problem. While a 5% level of any soy flour sample in this series was sufficient to cause significant crumb discoloration, samples heated at 100° and 125°C. gave progressively more undesirable colors. Thus, the most marked color development paralleled the most severe loss in nitrogen dispersibility, as shown in Fig. 1.

A slightly different picture was presented by the flavor scores; samples containing the soy flour heated at 100°C. were rated highest. Apparently this treatment was sufficient to dispel the raw "beany" flavor, but not enough to impart the marked toasted flavor characteristic of more severely heated samples.

Discussion

These results are based on dough formulas containing a single level of bromate-containing dough improver, and the relative performance of the soy flours would probably have been altered by employing different amounts of bromate. The work of Finney (6), Bayfield and Swanson (4), and, more recently, of Ofelt *et al.* (15,16) has indicated that with the use of proper amounts of bromate, the effects of good-quality soy flours are without practical significance when used at levels of about 5%.

The beneficial effect of raw soy flours on the stability of the doughs, as measured by the "normal" and "rest-period" farinograms, is quite striking. It is well known that soy beans and many other leguminous seeds contain a trypsin inhibitor (12). Learmonth (10) has shown that aqueous extracts of raw soybeans will inhibit the action of papain on a gelatin substrate and that heating the extract will decrease the inhibition. With the use of the rest-period farinograph technique with fermenting doughs, he showed that aqueous extracts of raw soybeans would decrease the weakening of control doughs (and more particularly of doughs containing added papain) which normally occurs upon extended fermentation (11). Melnick (13) has obtained a patent on the use of an aqueous extract of soy flour which inhibits the degradation of gluten and improves the baking quality of bread doughs containing "immature" flour, wheat germ, or other components that contain proteases or protease activators.

In the present studies, the beneficial effects of 5% raw soy flour on the farinogram were not reflected in improved baking quality. The observation that increasing levels of raw soy flour above 1.0% decreased baking quality suggests that inhibition of proteases was not the principal or sole factor responsible for its effects in doughs.

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