Functional Properties of Soy Polysaccharides and Wheat Bran in Soft Wheat Products[1]

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ABSTRACT

The performance of a soy polysaccharide blend in soft wheat products was evaluated; AACC soft white wheat bran was used as a reference fiber source. In Chinese steamed breadmaking, up to 10% soy polysaccharides (wheat flour basis) had less effect than bran on color and surface smoothness but exerted a more detrimental effect on volume and texture. In the cookie-baking test, reduction of cookie diameter and top grain characteristics were more pronounced when up to 15% bran was incorporated. Addition of up to 4% of the two fiber sources to a Japanese sponge cake formulation showed that soy polysaccharides were superior regarding volume, color, and crumb grain. Japanese udon noodles enriched with 8% soy polysaccharides were slightly yellowish and not gritty, whereas 8% bran imparted a brown color and a slightly gritty mouthfeel. The five original soy polysaccharides that constituted the blend were characterized in terms of their analytical and functional properties. They could be ranked according to their color *L* values. The darkest soy polysaccharide sample differed significantly in particle size distribution from the others. Functional differences among the samples were found in steamed breadmaking and the cookie-baking test.

Public concern about the health effects of dietary fiber has prompted a fast-growing market of high-fiber and calorie-reduced products. Most common fiber sources include bran from wheat, barley, corn, and oats; fruit and vegetable fiber (apple or sugarbeet fiber); legume fiber; powdered cellulose; and gums.

A major problem associated with incorporating high levels of these fiber sources in food systems is the detrimental effect they have on physical and sensory properties of foods. Changes in flavor, palatability, appearance, and texture are unacceptable to most marketers and consumers.

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A light-colored and bland-flavored soy fiber has recently been introduced in the baking industry for production of consumer-acceptable and nutritionally improved bread. This soy fiber, which consists of polysaccharides derived from processing dehulled and defatted soybean flakes, is primarily cell wall material of the soybean cotelydon. It is neither soybean hull nor soy bran. Physicochemical properties of polysaccharide components of soybean cotelydon are described in the literature (Aspinall et al 1967, Snyder and Kwon 1987, Thompson et al 1987). According to a review by Kawamura et al (1981), these polysaccharides include mainly cellulose, arabinogalactan, arabinan, and an acidic polysaccharide complex.

Much has been reported on effects of fiber in breadmaking (Pomeranz 1977, Pomeranz et al 1977, Shogren et al 1981, Sosulski and Wu 1988). This study was made to evaluate the performance of soy polysaccharides in soft wheat products. AACC soft white wheat bran was used as a reference fiber source.

MATERIALS AND METHODS

Soft Wheat Flours and Composite Flours

Flour for the steamed bread baking test (13.5% moisture, 0.40% ash, 8.3% protein) was a commercial blend of Pacific Northwest soft wheat varieties obtained from Fisher Co., Seattle, WA. Cookie flour (11.8% moisture, 0.41% ash, 8.9% protein) was a blend of Pacific Northwest varieties milled on an experimental Buhler mill in the USDA Quality Laboratory, Pullman, WA. Flour for the sponge cake baking test (12.3% moisture, 0.39% ash, 8.4% protein) was received from Nisshin Mills, Japan, and flour for Japanese udon noodle preparation (14.6% moisture, 0.44% ash, 8.9% protein) was obtained from Nippon Mills, Japan. Composite flours were prepared by adding the fiber sources, dry matter basis, to the wheat flours (14% mb).

Fiber Sources

The commercial soy polysaccharides were a composite of five batches received from Ralston Purina Co., MO. AACC-certified soft white wheat bran (AACC Check Sample Service, St. Paul, MN) served as standard fiber source. It was used as-is and as fine bran ground with a Udy cyclone sample mill to pass a screen with 1-mm openings.

General Analytical Procedures

Moisture, ash, and protein (N × 5.7) were determined by AACC methods 44-15A, 08-01, and 46-12, respectively (AACC 1983). Dietary fiber was assayed by an enzymatic-gravimetric method (AOAC 1985). The assay, designed to determine total dietary fiber, was modified for separate determination of insoluble dietary fiber and soluble dietary fiber. Total dietary fiber was calculated as the sum of insoluble and soluble dietary fiber.

Water hydration capacities of the fiber sources were determined by suspending the samples in water, centrifuging, and weighing the sediment (method 56-20, AACC 1983).

Color

Color of soy polysaccharide samples was measured with a filter colorimeter (Colorgard 2000 system, Pacific Scientific Co., Silver Spring, MD). Calibration of the instrument was performed with white and black tiles. The soy sample with the highest L value was defined as standard sample S1 ($L = 91.77$, $a = 0.83$, $b = 22.44$). Total color differences ΔE between S1 and the other soy preparations were calculated according to the equation

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}$$

where $+\Delta$ or $-\Delta$ values indicate deviations from the standard S1, $+\Delta L$ = white, $-\Delta L$ = black, $+\Delta a$ = red, $-\Delta a$ = green, $+\Delta b$ = yellow, and $-\Delta b$ = blue.

Soft Wheat Products

Chinese steamed bread. A method for experimental production of Chinese steamed bread, based on a straight dough procedure, was developed in the USDA Quality Laboratory, Pullman, WA. Standard flour (160 g, 14% mb), 79.2 ml of water, 12.8 g of granulated sugar, 3.2 g of shortening, and 1.6 g of dried yeast were mixed in a National dough mixer for 1 min 21 sec (dough temperature 27.0–29.0°C). Water absorption and mixing time of control flour and composite flours were derived from mixogram curves. The dough was fermented at 30°C and >95% rh for 3.5 hr, then molded and divided into eight equal pieces. After proofing at 30°C and >95% rh for 58 min, the dough pieces were steamed for 10 min in an Ultra Steam Convection Steamer (Market Forge, Everett, MA). Volume (cm^3) of every batch was determined by rapeseed displacement 5 min after breads were removed from the steamer. Texture value (g/cm^2) as an indicator for crumb softness was measured using a Rheometer (Fudoh Kogyo Co., Ltd., Japan) fitted with a probe with a 1 cm^2 surface disk and an automatic stop accessory adjusted to penetrate 1 cm into sliced steamed bread. The lower the value, the softer the bread.

Cookies. Cookies were baked by AACC method 10-52 (AACC 1983). Water addition to composite flours was adjusted by evaluating dough mixing and handling properties. Overall scoring was done with special consideration to cookie diameter and cracking condition (top grain) of the surface. No numerical score was assigned. Cookie diameters (cm) were averaged from the diameters of two cookies.

Japanese sponge cake. Methods of production and evaluation of Japanese sponge cake were described by Nagao et al (1976). Evaluation of the cakes considered three quality characteristics: external factors (shape, crust color, and appearance), crumb grain (cell uniformity, size, and cell wall thickness), and texture (softness, moistness, and tenderness). The characteristic external factors were given 32 points and the characteristic crumb grain and texture 24 points if their quality equaled that of the control cake. A higher score was assigned when the finished product was superior to the control, a lower score was given to products that were inferior to the control. The three numerical scores for each cake characteristic were added to give an overall score. The control cake had an overall score of 80.

Noodles. Japanese udon noodles were made and tested according to the methods of Nagao et al (1976) modified by Jeffers et al (1979). Four noodle characteristics (color of the raw and cooked noodles, texture, and yield) were evaluated. Typical and acceptable color of raw and cooked noodles and yield were assigned 16 points each, and characteristic texture 32 points, when they equaled the quality of the control noodle. More or fewer points indicated a better (superior) or poorer (inferior) quality, respectively. The overall score was calculated as the sum of individual scores. The control noodle had an overall score of 80.

RESULTS AND DISCUSSION

Chemical Composition

Protein, ash, and dietary fiber of the soy polysaccharide blend and of wheat bran are listed in Table I. Soy polysaccharides contained less protein but more insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) than wheat bran. IDF predominated in both fiber sources.

Soft Wheat Products

Preliminary investigations showed that quality of Japanese sponge cake was affected even by minute amounts of fiber additives. On the other hand, cookies tolerate substantially larger amounts. Consequently, the amount of fiber materials added varied with the product. The addition of soy polysaccharides or bran did not affect fermentation rates, as determined by an instrument that measures gas production in doughs (data not reported here).

Chinese steamed bread. Addition of 5 and 10% soy polysaccharides and bran to the steamed bread formula increased water absorption and (with the exception of 5% wheat bran) mixing time; the increase was larger for soy polysaccharides than for bran (Table II). Loaf volume decreased and texture values increased with increasing levels of fiber. Effects varied both with the amount of fiber and its source. Reduction of volume and increase in texture parameters were less pronounced when bran was incorporated; no significant differences could be detected between coarse and fine bran. Presoaking of the additives before

TABLE I
Protein, Ash, and Dietary Fiber Composition of Soy Polysaccharides and Wheat Bran (%, dry basis)[a]

Fiber Source	Protein (N × 5.7)	Ash	Dietary Fiber		
			IDF[b]	SDF[c]	TDF[d]
Soy polysaccharides	10.0	4.2	68.7	8.9	77.6
Wheat bran	17.1	6.7	43.6	2.5	46.1
LSD (0.05)	0.3	0.2	1.2	0.9	1.2

[a] Each value is the mean of three replications.
[b] IDF = insoluble dietary fiber.
[c] SDF = soluble dietary fiber.
[d] TDF = total dietary fiber.

blending with the flour is reported to counteract the deleterious effect of fiber on bread volume (Sosulski and Wu 1988). In steamed breadmaking, this procedure provided no significant improvement in volume and texture values over fiber that had not been presoaked.

The decrease in loaf volume with increasing levels of fiber was accompanied by flattening of the shape, darkening of the color, and a more open internal grain structure. Soy polysaccharides affected color and surface smoothness less than bran. Whereas fine bran imparted a uniform yellowish color to the steamed bread, bread containing coarse bran showed specks due to individual bran particles.

Cookies. As the percentage of fiber added increased, cookie diameter decreased (Table III). Influence on cookie spread varied with the source of fiber. Coarse bran had the least effect and soy polysaccharides and fine bran had the greatest effect. Fine bran produced a more deleterious effect than coarse bran only when added at higher levels (>10%). With respect to visual scores, adding soy polysaccharides produced lighter colored cookies and had a more pronounced effect on top grain characteristics than adding bran. As amounts of soy polysaccharides were increased, a desirable coarse top grain was replaced by fine hairline cracks. A similar, less pronounced, tendency was observed with increasing levels of fine bran. Coarse bran affected top grain appearance the least. Adding 15% bran affected top grain characteristics rather than cookie spread.

Japanese sponge cake. When up to 4% of the fiber materials were added to the sponge cake formulation, soy polysaccharides performed better than bran at all levels of addition (Table IV). Overall scores for cakes enriched with soy polysaccharides indicated that only the 4% level of addition significantly decreased sponge cake quality. The main defects were impairment of crumb grain, larger cell size, and presence of deformed cells. Adding bran imparted a darker tint to the sponge cake and produced lower cake volumes.

TABLE II
Effect of Soy Polysaccharides and Wheat Bran on Steamed Bread

Fiber Source/ Addition Level (%)	Water Absorption (%)	Mixing Time (min: sec)	Volume[a] (cm³)	Texture[a] (g/cm²)
Control				
0	49.5	1:21	875 a	64 e
Soy polysaccharides				
5	60.0	1:53	801 c	87 c
10	66.0	2:20	645 d	177 a
Wheat bran, coarse				
5	54.0	1:25	845 b	78 d
10	58.0	1:40	785 c	103 b
Wheat bran, fine				
5	54.0	1:15	860 ab	77 d
10	58.0	1:30	795 c	102 b

[a]Volume and texture values are averages of two experiments. Means in each column with the same letter are not significantly different at the 0.05 level.

TABLE III
Effect of Soy Polysaccharides and Wheat Bran on Cookie Diameter[a] (cm)

Addition Level (%)	Control	Fiber Source: Soy Polysaccharides	Wheat Bran: Coarse	Wheat Bran: Fine
0	19.1 a	···	···	···
3		18.4 de	19.0 ab	19.1 ab
5	···	18.2 e	18.8 b	18.5 c
7	···	17.8 f	18.7 bc	18.6 bc
10	···	17.2 g	18.5 cd	17.7 f
15	···	16.3 i	18.1 e	17.0 g

[a]Each diameter value is the average of two experiments. Means with the same letter are not significantly different at the 0.05 level.

Japanese udon noodles. Overall scores of noodles enriched with soy polysaccharides indicated better quality than those enriched with bran (Table V). Increasing levels of soy polysaccharides imparted a yellowish tint, whereas adding bran increased brown color. When eating quality was evaluated, no noodles fortified with soy polysaccharides were gritty, whereas 8% bran imparted a slightly gritty mouthfeel. Both fiber sources impaired texture of the cooked noodles significantly only at the highest level of addition (8%, flour basis).

Analytical and Functional Characteristics of Individual Soy Polysaccharide Samples

The soy polysaccharides used in the tests described above were composited from five batches. Analytical and/or functional differences among the original five batches were, therefore, of interest.

A distinctive characteristic of the soy polysaccharide samples was their color. All soy preparations exhibited a white-yellowish color, but differences among the samples were already visible without instrumental aid. Using a colorimeter, the samples were ranked according to decreasing ΔL values, from S1, the lightest colored sample, to S5, the darkest (Table VI). The color difference values indicated that soy polysaccharide sample S5 differed considerably from the other preparations. It was by far the darkest sample ($\Delta L = -4.24$) and exhibited a more reddish ($\Delta a = 2.37$) and yellowish ($\Delta b = 1.41$) color. Differences in color might reflect variations in soybean quality and/or in processing of soy polysaccharides such as heat treatment and/or varying grinding conditions.

Gross chemical analysis indicated a relatively uniform composition of the five soy polysaccharide samples. Moisture was 3.6–4.8%, average protein 9.9% (±0.3%) and average ash 4.2% (±0.1%). Total dietary fiber, as determined by the AOAC method, ranged from 76.7 to 79.2% (average 77.8%). Insoluble fiber

TABLE IV
Quality Characteristics and Scores of Japanese Sponge Cakes Enriched with Soy Polysaccharides and Fine Wheat Bran

Fiber Source/ Addition Level (%)	Volume (cm³)	Score[a]: External Factors	Crumb Grain	Texture	Overall
Control					
0	1,315 a	32 ab	24 a	24 ab	80 ab
Soy polysaccharides					
1	1,325 a	32 ab	22 bc	25 a	79 b
2	1,330 a	33 a	23 ab	25 a	81 a
4	1,295 b	31 bc	21 cd	24 ab	76 c
Wheat bran, fine					
1	1,270 c	30 c	21 cd	24 ab	75 cd
2	1,285 bc	31 bc	21 cd	23 b	75 cd
4	1,265 c	30 c	20 d	24 ab	74 d

[a]Each value is the average of two experiments. Means in each column with the same letter are not significantly different at the 0.05 level.

TABLE V
Quality Characteristics and Scores of Japanese Udon Noodles Enriched with Soy Polysaccharides and Wheat Bran

Fiber Source/ Addition Level (%)	Weight Increase (%)	Score[a]: Color: Raw	Color: Cooked	Texture	Yield	Overall
Control						
0	310 b	16 a	16 a	32 a	16 ab	80 a
Soy polysaccharides						
2	316 b	14 b	15 ab	30 b	16 ab	75 b
4	310 b	12 c	14 bc	30 b	16 ab	72 c
8	310 b	12 c	14 bc	28 c	16 ab	70 d
Wheat bran, fine						
2	327 a	12 c	13 cd	31 ab	17 a	73 c
4	311 b	11 c	12 d	30 b	17 ab	69 d
8	288 c	9 d	10 e	27 c	15 b	61 e

[a]Each value is the average of two experiments. Means in each column with the same letter are not significantly different at the 0.05 level.

TABLE VI
Color Differences[a] Among Five Soy Polysaccharide Samples[b]

Soy Poly-saccharide[c]	ΔL	Δa	Δb	ΔE
Sample S1	...	...	...	...
Sample S2	−0.07 a	0.48 d	0.21 c	0.52 d
Sample S3	−0.93 b	0.79 c	0.12 c	1.23 c
Sample S4	−2.21 c	1.20 b	0.87 b	2.67 b
Sample S5	−4.24 d	2.37 a	1.41 a	5.05 a

TABLE VII
Effect of Five Soy Polysaccharide Samples on Volume and Texture of Steamed Bread[a]

Soy Polysaccharide/ Addition Level (%)	Volume (cm^3)	Texture (g/cm^2)
Sample S1		
5	785 a	78 e
10	610 d	190 a
Sample S2		
5	755 b	107 c
10	630 c	168 b
Sample S3		
5	795 a	95 cd
10	605 d	181 a
Sample S4		
5	810 a	71 e
10	655 c	151 b
Sample S5		
5	790 a	85 de
10	635 cd	165 b

[a]Each value is the average of two experiments. Means in each column with the same letter are not significantly different at the 0.05 level.

accounted for 68.0–70.4% (average 69.1%) and soluble fiber for 8.3–9.0% (average 8.7%). A water hydration capacity test revealed no significant differences in water absorption among the samples. Each soy polysaccharide absorbed about 3.5 g/g of sample. The samples differed little in particle size distribution. Sample S5 was slightly higher in coarse particles (above 180 μm) and fine particles (below 45 μm) than the other four samples.

Because the soy polysaccharide samples exerted the most pronounced effects on quality of steamed bread and cookies, these products were selected to evaluate functional differences among the soy preparations.

In steamed bread, samples S4 and S5 performed best in terms of volume and texture (Table VII). However, the darkest soy polysaccharide sample (S5) imparted a darker color to the steamed bread.

No significant differences could be observed among the samples regarding their effects on cookie diameter. The darkest soy sample (S5) produced darker cookie edges but superior top surfaces; deeper and broader cracks were observed in samples baked with this soy sample.

CONCLUSIONS

A comparison between a soy polysaccharide blend and wheat bran showed that the performance in soft wheat flour based foods varied with the type of food and source of fiber. Products more suitable for soy polysaccharide enrichment included Japanese udon noodles and Japanese sponge cake. Cookies were more appropriate for enrichment with bran. In Chinese steamed bread, soy polysaccharides affected color less than bran but showed a more detrimental effect on volume and texture.

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