HIGH-FIBER COOKIES CONTAINING BREWERS' SPENT GRAIN[1]

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ABSTRACT

Dried and milled brewers' spent grain (BSG) was blended with flour at levels from 5 to 60% BSG for cookie formulation. Functionality of BSG was related inversely to the heating history of the samples. Additions of soy lecithin to the dough systems improved sugar cookie performance (spread and top grain formation). Under optimum conditions, maintaining acceptable physical qualities of the product with 40% BSG was possible, corresponding to a 74% increase in nitrogen and a tenfold increase in crude fiber. Organoleptic evaluations showed that 15% incorporation, corresponding to a 27% increase in nitrogen, a fourfold increase in crude fiber, and a threefold increase in dietary fiber, was the upper limit for sugar cookies as well as for such specialty cookies as chocolate chip, oatmeal, and raisin. At this level of incorporation, consumer panels indicated that organoleptic quality was lowered, but the cookies were still in the acceptable range. The particle size–nitrogen-fiber relationships in milled BSG might be optimized to improve acceptability of cookies.

The main by-products of the brewing industry are the so-called spent brewers' grain that remains after mashing and the yeast that is removed after fermentation of the wort. Traditionally, these by-products received little attention as

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marketable commodities, and disposal was often a problem. In recent years, attention has been given to environmental pollution and to efficient recovery of potential foods (1–3). Inasmuch as spent grain commonly contains 26–30% protein (N × 6.25), it can hardly be considered spent.

Recently, evidence has suggested that low dietary fiber is related to a number of noninfectious diseases (4). Brewers' grain, high in fiber because of the barley bran and husk, might be useful in increasing both fiber and protein in human nutrition through the use of this material in baked products.

MATERIALS AND METHODS

Brewers' Spent Grain

Brewers' spent grain (BSG) was a composite of experimental mashes prepared in the USDA Barley and Malt Laboratory, Madison, WI. The pilot brewing equipment has a capacity of one-half barrel, and has been described by Burkhart et al (5). The BSG, with a moisture content of about 80%, was freeze-dried (BSG-1). Separate portions of the wet material were dried overnight in a forced draft oven at 45° C (BSG-2), at 100° C for 8 hr (BSG-3), and at 150° C for 1.5 hr (BSG-4).

Chemical Analyses

Samples were analyzed for Kjeldahl nitrogen, crude fat, crude fiber, ash, and moisture (6). For starch plus β-glucan, the BSG or flour (20 g) was refluxed for 4 hr in 1*N* sulfuric acid (750 ml). The filtrate was neutralized with barium carbonate, and the glucose was assayed with an Aminex AG 50W-X4 column (7). Percentage of dietary fiber was calculated by subtracting the percentage of starch and β-glucan, protein, crude fat, and ash. Hydration properties of dry blends were measured by the microalkaline water-retention capacity (AWRC) test of Yamazaki et al (8).

Milling

Samples of BSG were milled with a Cyclone Sample Mill (Tecator-Udy Co., Boulder, CO 80302).

Particle Size Determination

Particle size analysis of milled BSG samples was made by separating 20-g aliquots on a nest of sieves (32, 65, 80, 100, 150, and 200 mesh/in.) for 5 min with a Tyler Ro-Tap machine. Sieve separates from two samples (BSG-1 and BSG-2) were analyzed for nitrogen to determine the relationship of particle size to nitrogen distribution.

Cookie Preparation

Sugar Cookies. A straight-grade composite wheat flour (SWF) was prepared from soft wheat varieties grown in 1973 and milled with an Allis-Chalmers mill. For test bakings of sugar cookies, up to 60% of this flour was replaced with BSG. Cookies were prepared by the Micro-Method III of Finney et al (9). In some preparations, phosphatidyl choline (lecithin) (Central CA, Central Soya Co., Chicago, IL 60639) was included as described previously (10, 11). Sugar cookies used for organoleptic tests were prepared with all-purpose flour (APF) and BSG-

2, BSG-3, and BSG-4.

Specialty Cookies. Fifteen percent of the APF was replaced with BSG-2 in the following varieties of cookies: chocolate chip, peanut butter, applesauce raisin, gingersnap, Jan Hagels, oatmeal, raisin icebox, and soft molasses. The formulas for chocolate chip, oatmeal, raisin icebox, and Jan Hagels—the four types that showed best acceptance—are shown in Table I. Preparation and baking were done by conventional procedures.

Cookie Evaluation

Physical and Chemical Evaluation. Standard physical and chemical procedures, which are used as a measure of soft wheat flour baking properties, have been developed for sugar cookies, but are not applicable to specialty cookies.

Sugar cookies were measured across four directions and the means reported as the diameters of two cookies. Top grain scores were judged by standards for wheat-flour sugar cookies on a scale of 0 to 9, denoting a range from no top grain formation (0) to a uniform top appearance (9). The lower limits of acceptability were: diameter value, 17.5 cm, and top grain score, 7.

Organoleptic Evaluation. Preliminary Panels—Small preliminary panels provided the basis for selection of the heat treatment of BSG for use in cookies for the large (consumer) panel and of the types of cookies that the consumer panel would evaluate. On the basis of color, flavor, aroma, mouth-feel, and texture, the panels indicated that the desirability of the particular cookies. For analysis of variance data, values of 1 to 7 were used, corresponding to increasing desirability. A score of 3.5 was considered the lowest acceptable value.

Consumer Panels—Each person received two cookie samples, a control

TABLE I
Specialty Cookie Formulas

Ingredients	Chocolate Chip (g)	Oatmeal (g)	Raisin Icebox (g)	Jan Hagels (g)
Butter	224	188	112	112
White sugar	150	200	...	200
Brown sugar	150	200	200	...
Whole egg	113	113	57	57
Water	2	...	...	...
Vanilla	3.7	3.7	3.7	...
APF[a]	239	106	186	106
BSG-2[b]	42	19	33	19
$NaHCO_3$	4	...	...	...
NaCl	6	3	1.5	...
Baking powder	...	4	8.2	...
Cinnamon	...	1.9	0.9	0.9
Nutmeg	...	0.4	...	...
Chocolate chips	334	...	...	...
Rolled oats	...	216	...	...
Raisins	...	...	146	...
Sliced almonds	...	...	...	86

[a]APF = all-purpose flour.
[b]BSG-2-brewers' spent grain heat-dried overnight at 45°C.

prepared with APF, and an experimental sample in which 15% of the APF had been replaced with BSG-2. Desirability scores were as described for the preliminaary panels.

RESULTS AND DISCUSSION

Sugar Cookies

Chemical and Physical Analyses. Analytic and cookie baking data are given in Table II for all SWF-BSG blends tested. The effects of nitrogen fortification of

TABLE II
Flour Analyses and Baking Data for Sugar Cookies

Flours[a]	Flour Analyses[b]					Baking Data[c]					
						Without Lipid		+1% Lipid		+2% Lipid	
	Ash (%)	Crude Fiber (%)	Dietary Fiber (%)	N (%)	AWRC[d] (%)	Diam (cm)	TG	Diam (cm)	TG	Diam (cm)	TG
SWF[d]	0.48	0.6	3	1.86	60.2	17.8	7A	19.0	9	19.2	9
+5% BSG-1	0.57	1.3		2.03	67.6	17.6	8	18.2		18.1	9
+10% BSG-1	0.86	2.0		2.19	77.1	16.8	7.5	17.4	9	17.6	9
+15% BSG-1	1.06	2.8		2.39	91.7	16.1	7	16.8	9	16.8	9D
+20% BSG-1	1.20	3.5		2.56	104.2	15.5	5.5	15.9	9	15.8	9D
BSG-1	4.30	15.3		5.28	410.7	...	...	...	...	...	...
+5% BSG-2	0.65	1.3	5.4	2.03	67.6	17.9	7.5A	18.8	9	18.7	9
+10% BSG-2	0.88	2.0	7.5	2.20	71.9	17.6	7A	18.1	9	18.4	9
+15% BSG-2	1.08	2.7	10.2	2.37	79.0	17.1	8	17.9	9	18.0	9
+20% BSG-2	1.22	3.4	12.6	2.55	86.5	16.8	8	17.3	9	17.6	9
BSG-2	4.65	15.1	51.0	5.19	353.5	...	...	...	...	...	...
+5% BSG-3	0.67	1.2		2.06	64.0	17.9	7A	18.8	9	19.0	9
+10% BSG-3	0.87	1.9		2.24	65.8	17.9	6A	18.6	9	18.8	9
+15% BSG-3	1.09	2.6		2.49	70.0	17.9	6A	18.8	9	18.4	9
+20% BSG-3	1.28	3.3		2.62	74.8	17.8	6A	18.5	9	18.5	9
+30% BSG-3	1.62	4.7		2.92	84.4	17.3	4.5A	17.9	9	17.9	9
+40% BSG-3	2.03	6.2		3.24	95.9	16.9	4.5A	17.5	9	17.6	9
+50% BSG-3	2.37	7.6		3.59	113.3	16.1	4.5A	17.0	9	17.3	9
+60% BSG-3	2.73	9.0		3.94	132.2	15.3	3A	16.4	8.5	16.6	9
BSG-3	4.56	14.5		5.52	289.8	...	...	...	...	...	...
+10% BSG-4	0.93	2.0		2.22	63.4	17.9	7A	18.8	9	18.6	9
+20% BSG-4	1.32	3.4		2.47	73.4	17.5	5A	18.2	9	18.4	9
+30% BSG-4	1.67	4.8		2.76	83.8	17.2	5A	17.7	9	17.9	9
+35% BSG-4	1.88	5.5		2.95	89.4	16.7	5A	17.4	8	17.6	9
+40% BSG-4	2.04	6.2		3.08	96.0	16.5	4.5A	17.5	8	17.5	9
+50% BSG-4	2.49	7.6		3.35	110.3	16.2	3A	16.9	7	16.7	9
+60% BSG-4	2.84	9.1		3.62	130.2	15.3	2A	16.1	6	16.3	8
BSG-4	4.47	14.7		4.79	233.3	13.6	...	...	...	...	...

[a]SWF = straight-grade composite wheat flour; BSG-1 = brewers' spent grain with 80% moisture content, freeze-dried; BSG-2 = heat-dried overnight at 45°C; BSG-3 = heat-dried at 100°C for 8 hr; BSG-4 = heat-dried at 150°C for 1.5 hr.

[b]Values are on dry weight basis.

[c]% Lipid = soy lecithin (60% phosphatides in soybean oil) flour weight basis, TG = top grain, A = open grain, D = closed grain.

[d]AWRC = microalkaline water-retention capacity.

SWF with BSG paralleled the responses found with wheat gluten (10). BSG-1 produced the greatest increase in the hydration properties of blends and gave the greatest suppression of cookie spread when compared with BSG-2 and BSG-3 at comparable levels. Experience with wheat flours suggests that a difference of 2% AWRC between flours produces a significant difference in cookie spread. Thus, the data show that dry blends of BSG and SWF are more tolerant of increases in hydration properties than is SWF alone. Without the addition of soy lipids, the dough system could accommodate up to 5% by weight of BSG-1, 10% of BSG-2,

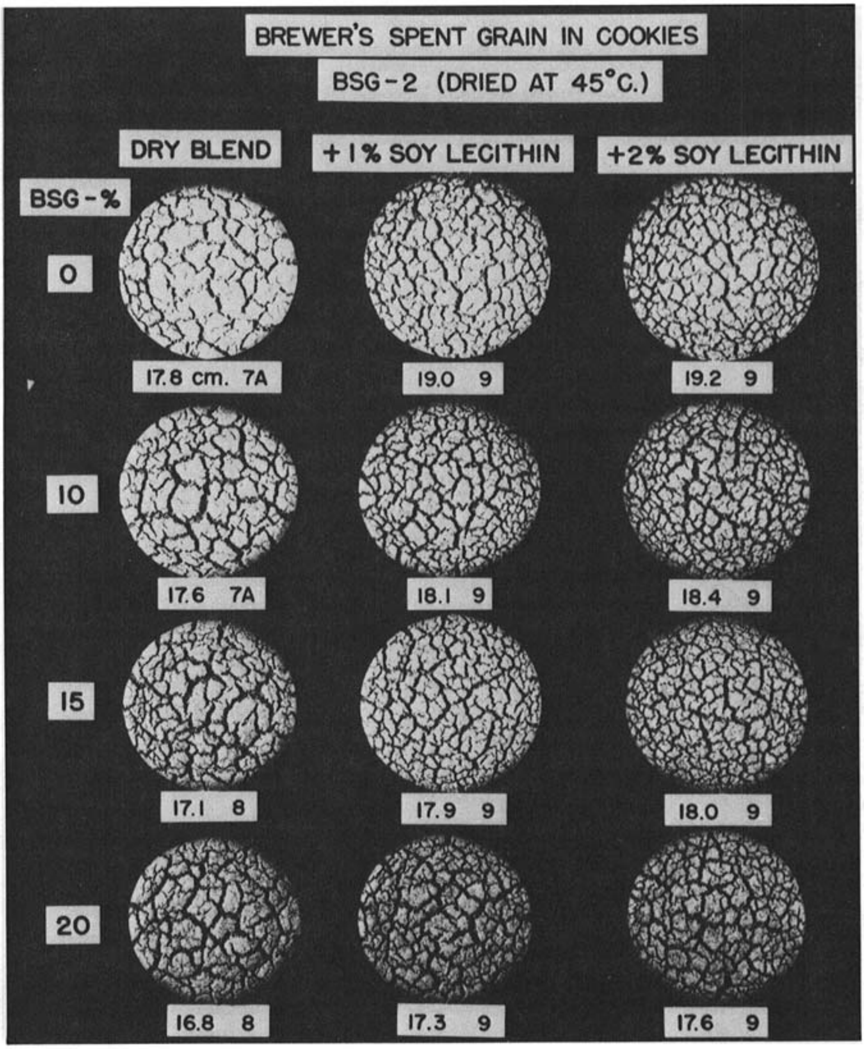

Fig. 1. Sugar cookies from blends of straight-grade composite wheat flour with 0, 10, 15, and 20% of BSG-2 by weight.

and 20% of BSG-3 and BSG-4 before performance was significantly reduced. These compositions corresponded to flour nitrogen increases of 9, 18, 41, and 33%, respectively, over the control. Crude fiber was increased 2.4, 3.4, 5.6, and 5.8 times. For 10% BSG-2, dietary fiber was increased 2.5 times. Fig. 1–3 show that fortification of SWF with BSG-2, BSG-3, and BSG-4 could be increased if low levels (1–2% of SWF weight basis) of soy lecithin are added as a surfactant to the fat phase during dough preparation. With 1% lecithin, 15% BSG could be

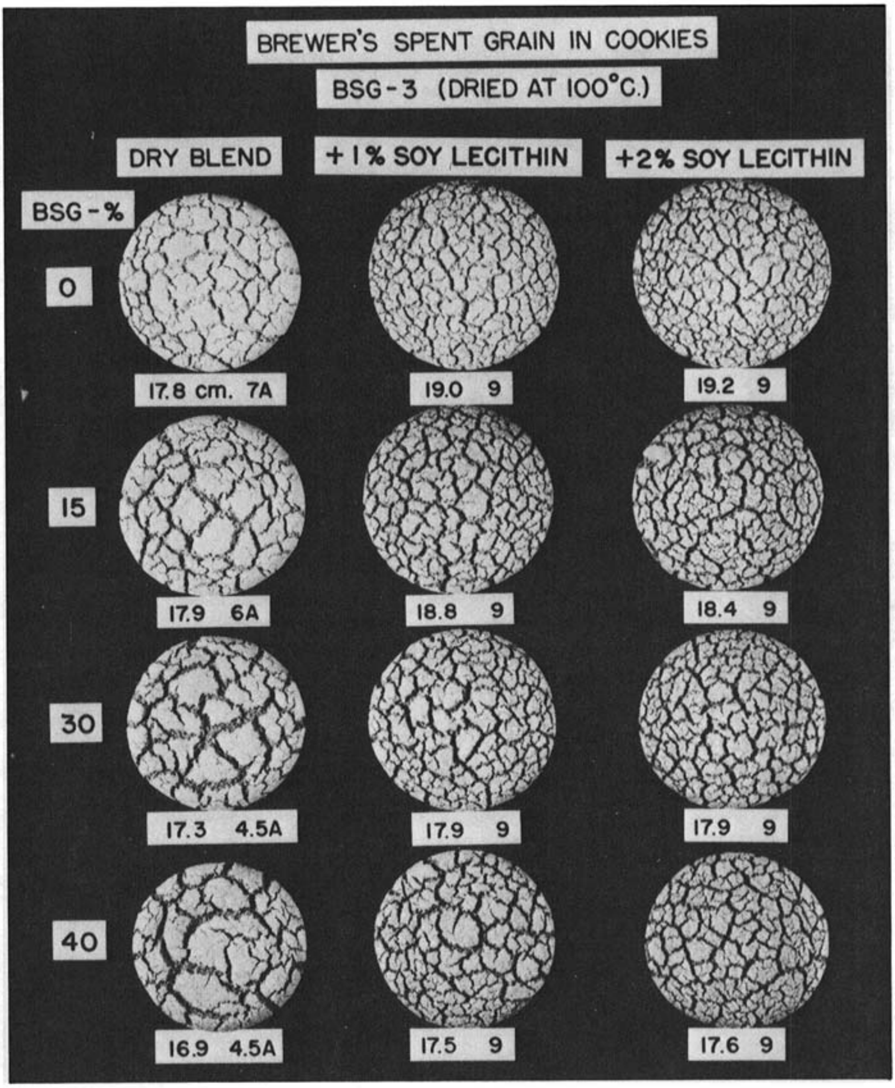

Fig. 2. Sugar cookies from blends of straight-grade composite wheat flour with 0, 15, 30, and 40% of BSG-3 by weight.

used, and with 2% lecithin, a maximum of 20% BSG could be used while maintaining acceptable physical characteristics of the cookies. The cookies had an undesirable brown color with more than 20% BSG. Similar results were obtained for BSG-1, the performance of which was not improved by freeze-drying rather than the less expensive oven-drying.

Organoleptic Evaluation. Sugar Cookies—Although the physical characteristics of the sugar cookies containing BSG, even up to 40% flour replacement, could be adjusted by suitable quantities of surface-active agent, the

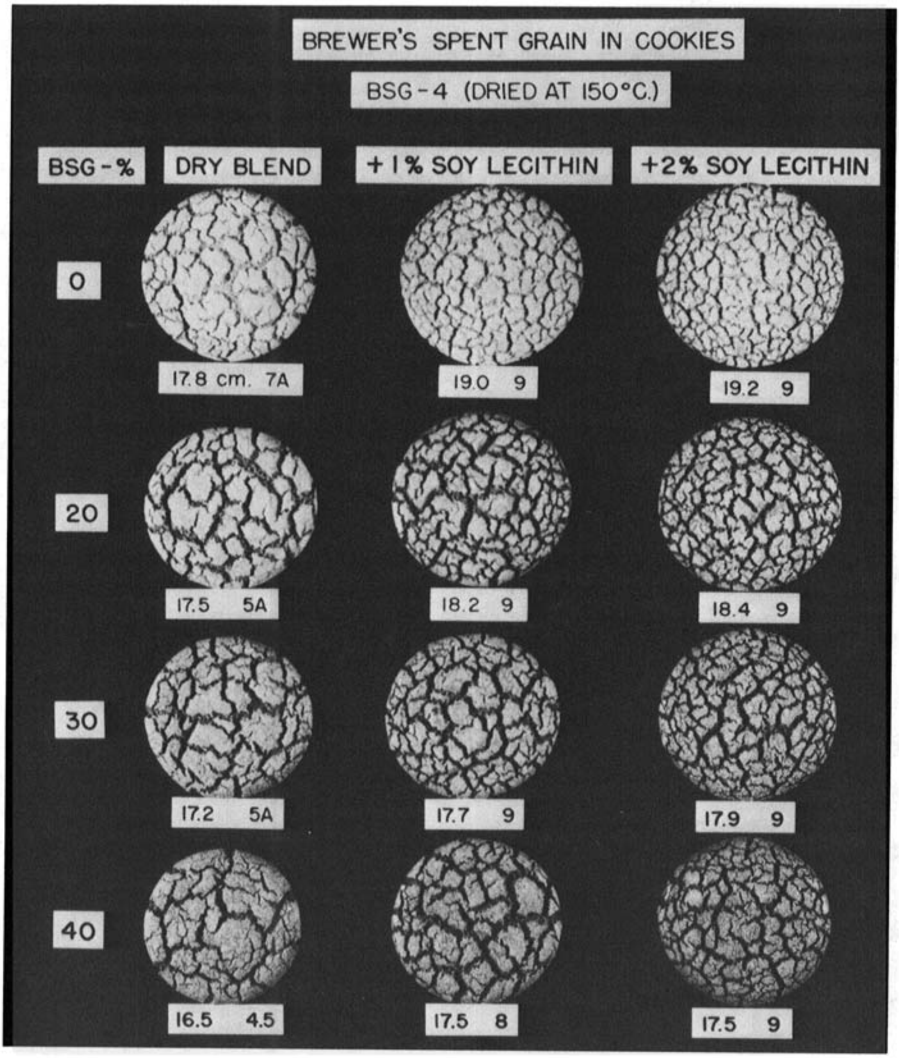

Fig. 3. Sugar cookies from blends of straight-grade composite wheat flour with 0, 20, 30, and 40% of BSG-4 by weight.

organoleptic qualities were altered by all BSG samples so that desirability fell below that of the SWF control as shown in Table III. The desirability scores were in the acceptable range, but 15% flour replacement appeared to be the upper limit. No benefit was apparent from heating BSG at 100 or 150° C.

Specialty Cookies—Standard physical measurements of specialty cookies have not been developed for the evaluation of baking ingredients as has been the case with sugar cookies, but the specialty cookies, being less bland than sugar cookies, appeared to be a good carrier for the BSG. Of the specialty cookies in which BSG was used at 15% flour replacement, chocolate chip, raisin icebox, oatmeal, and Jan Hagels appeared to have the greatest appeal (Table IV), although the preliminary panel's scores for all types indicated they were in the acceptable range.

The preliminary panel and the consumer panel compared chocolate chip and oatmeal cookies at the 15% BSG level with the corresponding cookie type without BSG. Table V shows that the desirability scores for cookies with BSG

TABLE III
Desirability of BSG-2 in Sugar Cookies—15% Flour Replacement[a]

	Desirability Mean Score[c]	
Flour[b]	Preliminary Panel (N = 28)[d]	Consumer Panel (N = 216)
SWF	5.4 a	5.3 a
BSG-2	4.3 b	4.1 b
BSG-3	3.8 b	
BSG-4	3.9 b	

[a]Minimum acceptable score 3.5.
[b]See Table II for abbreviations.
[c]Scores in same column with same letter are not significantly different at 5% level.
[d]N = number of panelists.

TABLE IV
Desirability of BSG-2 in Specialty Cookies—15% Flour Replacement[a]

Cookie Type	Desirability Mean Score[b]
	N = 12[c]
Chocolate chip	4.97 a
Molasses	4.09 b,c
Peanut butter	3.76 c
Jan Hagels	4.49 a,b,c
Raisin icebox	4.66 a,b
	N = 15
Chocolate chip	4.93 a
Gingersnap	3.83 b
Applesauce raisin	3.72 b
Oatmeal	4.62 a

[a]Minimum acceptable score 3.5.
[b]Mean scores in same column with same letter are not significantly different at 5% level.
[c]N = number of panelists.

were lower than those for the corresponding controls without BSG, but were still in the acceptable range, a judgment that both panels made. These findings indicate that consumers who are cognizant of the nutritional benefits might accept certain types of high-fiber cookies, particularly if they are marketed as such.

TABLE V
Desirability of BSG-2 in Specialty Cookies—15% Flour Replacement[a]

Cookie Type	Desirability Mean Score[b]
	Preliminary Panel
Oatmeal	N = 30
APF control	5.3 a
BSG-2	4.8 b
Chocolate Chip	N = 28
APF control	5.3 a
BSG-2	4.1 b
	Consumer Panel
Oatmeal	N = 204
APF control	5.5 a
BSG-2	5.2 b
Chocolate Chip	N = 214
APF control	5.9 a
BSG-2	4.9 b

[a]Minimum acceptable score 3.5.
[b]Mean scores in same column with same letter are not significantly different at 5% level.

TABLE VI
Yield and Nitrogen Content of BSG Fractions Retained on Sieves[a]

	BSG-1[b]		BSG-2[b]		BSG-3[b]	BSG-4[b]
Sieve (Mesh/in.)	Fraction Yield (%)	N (%)	Fraction Yield (%)	N (%)	Fraction Yield (%)	Fraction Yield (%)
32	1.4	2.77	0.3	4.62	0.5	0.6
65	34.5	2.70	25.9	3.28	21.4	24.4
80	7.2	3.61	8.3	3.59	12.4	12.2
100	12.8	4.30	17.2	4.51	17.0	16.0
150	13.6	6.22	16.8	5.65	19.1	17.0
200	13.6	7.83	17.7	6.62	8.9	11.0
Through 200	16.9	9.17	13.8	7.87	20.7	18.8
Parent	100.0	5.27	100.0	5.55	100.0	100.0

[a]Yield adjusted to 100% recovery; all values on dry basis.
[b]See Table II for abbreviations.

Possibly the character of the milled BSG product could be altered by appropriate sieving, since milled BSG contained a large proportion of coarse fragments of bran and husk. Data for yield of sieve separates along with the nitrogen distribution among fractions from BSG-1 and BSG-2 are given in Table VI. All samples contained a negligible amount of light-flake material that was retained on the 32-mesh screen. The 65-mesh (210 μ) sieve retained 20–35% of the original weight of material, and this was mainly the bran and husk fragments. This fraction had the lowest nitrogen content of the series. About 10% of each sample was retained on the 80-mesh (175 μ) screen. Nitrogen increased as separates became increasingly finer. Samples with the greatest heat treatment, BSG-3 and BSG-4, appeared to mill more readily than did others, and had lower yields of the coarse fractions.

Since BSG is heterogeneous, both physically and chemically, it would be of interest to test some combinations of size fractions for factors that are functional in baked products. The data in Table VI indicate that a hypothetical truncation at the 80-mesh screen would cause the material passing through from BSG-1 to yield 57% of material containing 7.0% nitrogen, and from BSG-2, 66% of material containing 6.2% nitrogen. This fine fraction would be enriched 1.2 to 1.3 times over the nitrogen level of the respective parent material, and would be somewhat reduced in crude fiber, although still much higher than refined wheat flour. Suitable BSG milling and fractionation might help to optimize nitrogen and fiber contents of particles in the flour-fineness range, and the uniformly fine particle size might improve acceptability in cookies.

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