

# Effects of Brewer's Spent Grain on the Quality and Dietary Fibre Content of Cookies

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## ABSTRACT

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Dried and ground brewer's spent grain (BSG) was blended with soft wheat flour at levels of 5-25%. BSG preparations of fine (<212 µm), medium (212-425 µm) and coarse (425-850 µm) particle sizes were used in the production of wire-cut cookies. The protein content decreased and the dietary fibre content (acid detergent fibre, neutral detergent fibre and total dietary fibre) increased, as the particle size of the BSG samples increased. The results indicated that BSG preparations with high dietary fibre content have potential as a source of dietary fibre. The effects of BSG on the quality and dietary fibre content of cookies have been investigated. Total dietary fibre (TDF) contents of the cookies supplemented with different particle size BSG increased significantly ( $p < 0.05$ ) as the addition level increased. Cookies prepared with BSG of medium and coarse particle sizes resulted in better properties in terms of Spread Ratio, Hunter color values and overall sensory score as compared to those made with BSG of fine particle size. Cookies made with medium and coarse particle size BSG gave better cookie properties up to the 15% addition and deteriorated significantly above this level ( $p < 0.05$ ).

**Key words:** Brewer's spent grain, cookie quality, dietary fibre.

## INTRODUCTION

Brewer's spent grain (BSG) is defined as the extracted residue of barley malt, alone or in mixture with other cereal grains such as corn and rice grits, resulting from the manufacture of wort<sup>8</sup>. Although it is the main by-product of the brewing industry, BSG has received little attention as a marketable commodity. Its disposal is often a problem<sup>21</sup> and it is used mainly as an animal feed<sup>6,24</sup>. BSG commonly contains 26-30% protein, so it can hardly be considered spent<sup>19</sup>. BSG is a barley fibre source with high dietary fibre content<sup>12,17,21</sup>. It consists mainly of the husk, bran and embryo residual of the barley kernel. BSG could be useful for increasing both dietary fibre and protein in human nutrition through the use of this material in some formulated foods.

Dietary fibre has been a popular subject with nutritionists in recent years. It has been purported to have a role in the prevention of certain diseases such as diverticulosis, colon cancer, hemorrhoids, arteriosclerosis, varicose veins, and appendicitis<sup>5</sup>. BSG has been considered as a source of dietary fibre for humans, and its effects on serum lipids and fecal sterol excretion in ileostomy subjects were studied<sup>26</sup>. Zhang *et al.*<sup>25</sup> suggested that BSG has significant effects on the metabolism of bile acids and cholesterol as well as on the morphology of the small intestinal mucosa. Aman *et al.*<sup>1</sup> studied the excretion and degradation of dietary fibre constituents in ileostomy subjects consuming a low fibre diet with and without BSG. Hassona<sup>9</sup> suggested the potential utilization of BSG as a contribution in preventing the increase of plasma total lipids as well as cholesterol.

There is also a growing interest in the use of BSG in human foods such as flour mixes, bread<sup>8,9,17</sup>, cookies<sup>12,18,19,21</sup> and meat products<sup>21</sup>. Finley *et al.*<sup>7</sup> noted that the addition of 15 to 20% of a soluble protein extract from BSG suppressed the spread of sugar-snap cookies. Prentice *et al.*<sup>17</sup> found a similar response with ground BSG but compensated for the change in functionality by adding 1.0 to 2.0% (flour basis) of soy lecithin as a surfactant and conditioner. This modified dough system accommodated up to 40% of BSG in blends with soft-wheat cookie flour and still maintained spread and top-grain appearance of the control flour. Panel acceptability of the products was limited to a maximum of 15% BSG, because of an undesirable flavor imparted by the supplement. Later, Prentice *et al.*<sup>19</sup> also reported adding spent grains having different heating histories to cookie formulas with good success. The brewer's spent grains account for approximately 50,000 tons of products annually in Turkey and its relatively low cost and potential nutritional value makes

TABLE I. Formulation of cookies.

Ingredients <sup>1</sup>	Weight (g)
Sucrose (fine granulating)	25.6
Brownulated granulated sucrose	8.0
Nonfat dry milk	0.8
Salt	1.0
Sodium bicarbonate	0.8
All-purpose shortening (fat)	32.0
High-fructose corn syrup (HFCS)	1.2
Ammonium bicarbonate	0.4
Deionized water	variable
Flour <sup>2</sup>	80.0

<sup>1</sup> Ingredients at 21±1°C.

<sup>2</sup> 13% moisture basis.

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BSG an attractive adjunct for human food. Although, there are a few studies investigating the effects of BSG on the quality of sugar-snap cookies (AACC Method 10-50), we have not encountered a study on the effects of BSG on the quality of wire-cut cookies. To the best of our knowledge, the information on the effects of BSG addition on total dietary fibre content (TDF) of cookies is also missing in the related literature.

The current work investigates, for the first time, the incorporation of various particle sizes of BSG into wire-cut cookie formulations at different addition levels and evaluates their effects both on the properties and total dietary fibre content of the cookies.

## MATERIALS AND METHODS

### Materials

Brewer's spent grain (BSG) was supplied from a commercial brewery (Anadolu Efes Brewing Co., Kazan, Ankara, Turkey). It was a malt-rice adjunct mash spent grain. The pH of the spent grain was 5.7 when it was received. The soft wheat flour used in this study contained 10.6% protein, 0.61% ash and 1.40% total dietary fibre.

### Preparation of brewer's spent grain

The BSG was been dried at 45 °C for about 24 hours in an electric oven until reaching moisture content below 10%. The dried BSG was milled using a laboratory grinder and sifted through a series of sieves having apertures of 850, 425 and 212 µm. The dried BSG was packed in sealed polyethylene bags and stored in a refrigerator at 4 °C until used.

### Analytical methods

The BSG and soft wheat flour samples were analyzed for moisture, protein and ash by using AACC (American Association of Cereal Chemists) Methods<sup>3</sup>. The BSG samples were also analyzed for neutral detergent fibre<sup>23</sup> (NDF), acid detergent fibre<sup>22</sup> (ADF), cellulose, hemicelluloses, lignin<sup>22</sup>, total dietary fibre<sup>3</sup> (AACC Standard Method No 32-07), water-holding capacity<sup>15</sup> and bulk density<sup>14</sup>. Hemicelluloses and cellulose were obtained by the differences between NDF and ADF and between ADF and lignin, respectively. Total dietary fibre (TDF) contents of soft wheat flour and cookies were determined by using AACC Standard Method<sup>3</sup>. Duplicate samples of dried and milled samples were defatted using petroleum ether (boiling range of 40-60 °C) and sequential enzymatic digestion was applied using heat stable α-amylase, protease and amyloglucosidase to remove starch and protein. For TDF, enzyme digestate was treated with alcohol to precipitate soluble dietary fibre before filtering, and TDF residue was washed with alcohol and acetone, dried and weighed. TDF residue values were corrected for protein, ash and blank. The tests were performed at least in duplicate and mean values are reported.

### Cookie formulation and evaluation

Brewer's spent grain preparations of coarse (425-850 µm), medium (212-425 µm) and fine (<212 µm) particle size were added into the cookie formulations at the levels of 5, 10, 15, 20 and 25%. The amounts of BSG added were corrected according to the moisture content of BSG samples (13% m.b.). The cookie qualities of BSG supplemented flours were determined by AACC Method

TABLE II. Physical and chemical composition of BSG<sup>1</sup> samples.

	Fine	Medium	Coarse
Moisture (%)	7.3	7.0	6.9
Protein (N × 6.25, %)	36.3	21.3	13.0
Ash <sup>2</sup> (%)	2.54	3.15	3.69
Neutral Detergent Fibre Content (%)	49.9	51.1	52.4
Acid Detergent Fibre (%)	30.7	31.5	32.8
Cellulose (%)	16.9	16.6	17.6
Hemicellulose (%)	19.2	19.6	19.6
Lignin (%)	14.6	14.9	15.2
Total Dietary Fibre (%)	60.3	63.6	71.2
Water Holding Capacity (g/g)	25.3	26.7	27.1
Bulk Density (mg/cm <sup>3</sup> )	462	418	409

<sup>1</sup> Brewer's Spent Grain.

<sup>2</sup> Dry basis.

TABLE III. Effects of brewer's spent grain (BSG) particle size on Spread Ratio (W/T) and overall sensory score of BSG supplemented cookies<sup>1</sup>.

BSG Addition %	Spread Ratio Value			Overall Sensory Score		
	Fine	Medium	Coarse	Fine	Medium	Coarse
0	7.68 b	7.68 a	7.68 b	4.96 a	4.96 a	4.96 a
5	9.10 a	7.32 b	8.62 a	4.86 a	4.86 a	4.86 a
10	6.85 c	7.30 b	7.48 c	4.46b	4.82 a	4.80 a
15	6.61 d	7.31 b	7.47 c	4.00 c	4.46 a	4.56 a
20	6.41 e	7.05 c	7.42 d	3.28 d	3.80 b	3.96 b
25	6.18 f	7.05 c	7.26 e	2.76 e	3.36 b	3.66 b
LSD (p<0.05)	0.081	0.036	0.026	0.096	0.170	0.172

<sup>1</sup> Means followed by the same letter are not significantly different using the LSD test.

No: 10.54 (Baking Quality of Cookie Flour-Micro Wire-Cut Formulation)<sup>3</sup>. Four cookies were prepared per bake. The formula used for baking cookies is shown in Table I.

The qualities of BSG supplemented cookies were evaluated in terms of width (W), thickness (T) and cookie Spread Ratio (W/T). Width and thickness measurements of the cookie samples were taken using a caliper. Hunter color values (L, a, and b) were determined with a Gardner Colorview Spectrophotometer (U.S.A). The instrument was standardized against a white tile before use. The sensory characteristics of the cookies were screened by a six-member panel that was well aware of the purpose of the investigation. The panel members individually evaluated appearance and taste of the products by giving scores ranging between 1 to 5, 5 being the most desirable. Then, the overall sensory scores were calculated as the average of the appearance and taste scores for each bake<sup>13</sup>. The baked cookies were left to be cooled, wrapped and allowed to stand at room temperature, then ground and prepared for TDF analysis.

### Statistical evaluation

Data were analyzed for variance using the MSTAT statistical package<sup>2</sup>. When significant differences were found the LSD (Least Significant Difference) test was used to determine the differences among means.

## RESULTS AND DISCUSSION

### Physical and chemical composition of brewer's spent grain

The physical and chemical compositions of BSG samples are presented in Table II. The particle size distribution of the coarse, medium and fine particle size brewer's spent grain samples were 425-850 µm, 212-425 µm and <212 µm, respectively. The chemical composition of BSG generally agreed with the previously published data<sup>1,8,10,11,17,21,24,25</sup>. Differences in results may be due to the variety of barley, malting process, the adjunct used and the processing procedure applied. The protein and ash contents of the BSG samples varied between 13.0-36.3% and 2.54-3.69%, respectively. The values reported by Ranhotra *et al.*<sup>20</sup> for protein (26.9-34.9%) and for ash (4.36-4.64%) content were slightly higher than our results. BSG is especially rich in dietary fibre, since it is the residue of malt and grain remaining in the mash-kettle after the liquefied and saccharified starch has been removed by

filtration<sup>4</sup>. In this study, NDF, ADF and TDF values of BSG were found to be between 49.9-52.4%, 30.7-32.8% and 60.3-71.2%, respectively (Table II). While NDF values of BSG were slightly lower than the one determined by Kanauchi and Agata<sup>11</sup>; ADF values of BSG were found to be within the same range reported by Prentice and D'Appolonia<sup>17</sup>. The TDF values of BSG samples obtained in this study were found to be almost equal to the one reported in the literature<sup>10</sup>. The water holding capacity (WHC) values are difficult to compare with the data in the literature because they are greatly affected by the measurement techniques and by the experimental conditions<sup>16</sup>. In this study, WHC values of BSG samples were found to be between 25.3-27.1 g/g (Table II). Bulk densities of BSG samples were slightly lower than the previously reported values<sup>10</sup>. The data revealed that BSG samples are

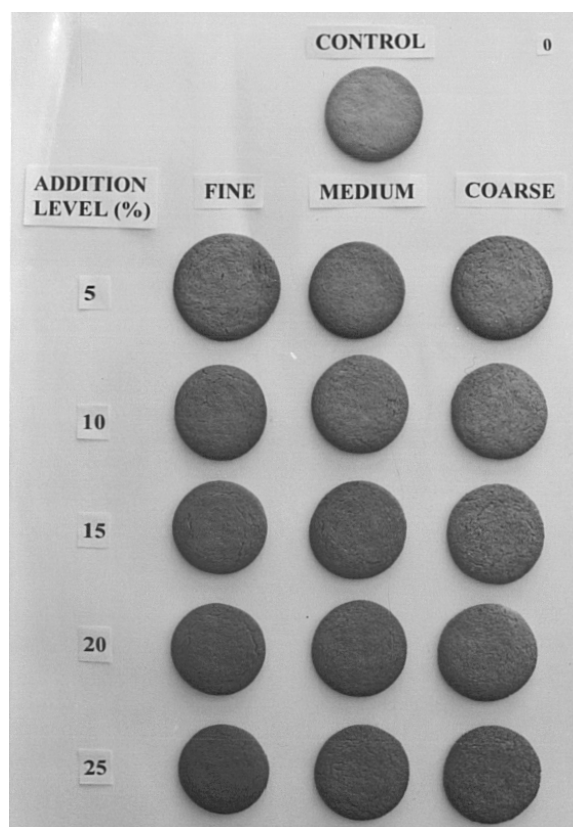


FIG. 1. Cookies supplemented with various levels of fine, medium and coarse particle size brewer's spent grain.

TABLE IV. Effects of brewer's spent grain (BSG) particle size on the color measurements of BSG supplemented cookies<sup>1</sup>.

BSG Addition %	Hunter Color Values <sup>1,2</sup>								
	Fine			Medium			Coarse		
	L	a	b	L	a	b	L	a	b
0	57.71 a	12.61 a	24.56 a	57.71 a	12.61 a	24.56 a	57.71 a	12.61 a	24.56 a
5	48.77 b	11.40 b	20.75 b	50.20 b	11.97 b	21.23 b	50.99 b	12.79 a	22.50 b
10	46.91 c	10.53 c	18.88 c	48.69 b	10.23 d	20.04 c	51.55 b	10.68 c	21.33 c
15	44.48 d	10.04 d	17.65 d	44.83 c	10.69 c	18.32 d	47.66 c	10.49 cd	19.61 d
20	42.33 e	9.75 e	16.57 e	44.07 c	10.18 d	17.78 e	45.60 d	11.29 b	19.41 d
25	41.12 f	9.53 f	15.99 f	43.94 c	9.01 e	16.61 f	43.89 d	10.34 d	18.19 e
LSD(p<0.05)	0.453	0.215	0.081	2.480	0.304	0.141	1.929	0.237	0.215

<sup>1</sup> Means followed by the same letter are not significantly different using the LSD test.

<sup>2</sup> L:Lightness; a: Redness; b:Yellowness.

rich in terms of dietary fibre and protein and can be used to supplement cereal based foods.

### Effects of BSG particle size on the quality and dietary fibre content of cookies

In order to investigate the effects of the particle size on cookie quality, brewer's spent grain preparations of coarse (425-850 µm), medium (212-425 µm) and fine (<212 µm) particle size were added into the cookie formulations at levels of 5, 10, 15, 20 and 25% (Fig. 1). Spread Ratio (W/T) values of BSG supplemented cookies are presented in Table III. The Spread Ratios of fine, medium and coarse particle size BSG supplemented cookies decreased significantly ( $p<0.05$ ) with increasing BSG levels. Cookies made with fine BSG resulted in the worst Spread Ratio values and the Spread Ratio values decreased significantly ( $p<0.05$ ) above 5% addition of BSG. Cookies made with medium particle size BSG gave better Spread Ratio values up to the 15% addition and deteriorated above this level. However, the Spread Ratios of the coarse particle size BSG cookies were higher than those made with medium particle size BSG.

Sensory evaluation of cookies prepared with varying levels of BSG are shown in Table III. Results indicated that cookies supplemented with medium and coarse particle size BSG had higher overall sensory scores than those supplemented with fine particle size BSG. The cookies supplemented with medium and coarse particle size BSG were accepted by the panelists up to a 15% addition level. However, above this level their sensory evaluation scores deteriorated significantly ( $p<0.05$ ). Previous studies also reported that the organoleptic limit of BSG addition was 15% due to an increasing unacceptable flavor<sup>12,19</sup>. On the other hand, the acceptable level of supplementation for the fine particle size BSG was determined to be as low as 5%.

BSG addition caused undesirable changes in color, the intensity of which increased with increasing addition of BSG. Although the Lightness (L) of the cookies supplemented with fine, medium and coarse particle size BSG decreased significantly ( $p<0.05$ ) as the percentage of BSG addition increased, cookies with fine particle size BSG had the highest decrease in L value (Table IV). Cookies supplemented with coarse BSG generally gave higher a and b values as compared to fine and medium particle size BSG supplemented cookies at all levels. Higher yellow and red colors were obtained for BSG supplemented cookies as the particle size of BSG increased.

TABLE V. Effects of brewer's spent grain (BSG) particle size on total dietary fibre contents of BSG supplemented cookies<sup>1</sup>.

BSG Addition (%)	Total Dietary Fibre %		
	Fine	Medium	Coarse
0	1.98 e	1.98 f	1.98 f
5	2.22 e	2.96 e	2.97 e
10	4.86 d	5.47 d	5.97 d
15	8.23 c	8.30 c	8.76 c
20	9.09 b	10.49 b	12.15 b
25	9.67 a	11.74 a	14.09 a
LSD ( $p<0.05$ )	0.415	0.315	0.581

<sup>1</sup> Means followed by the same letter are not significantly different using the LSD test.

Total dietary fibre (TDF) contents of the cookies supplemented with different particle size BSG increased significantly ( $p<0.05$ ) as the addition level increased (Table V). However, the TDF contents of the coarse particle size BSG supplemented cookies were higher than those made with fine and medium particle size BSG. This might be explained easily with the differences of fine, medium and coarse particle size BSG in terms of TDF, NDF and ADF contents. As indicated above, dietary fibre values of fine particle size BSG were lower than those of medium and coarse particle size BSG. Investigations on the use of BSG in high-fibre cookies have been previously reported<sup>12, 18,19</sup>. However, in these publications the dietary fibre content of the cookie samples was estimated from the composition of the ingredients rather than the actual analysis. In the present work, the effect of incorporation of various particle size BSG into cookie formulations was investigated for the first time to determine total dietary fibre content of the final product.

## CONCLUSIONS

BSG represent an inexpensive and abundant by-product that exists concentrated in nearly all brewing companies world-wide. Due to the large continuous supply, relatively low cost and potential nutritional value, BSG can be considered as an attractive adjunct for human food. The results show that BSG produced from brewer's spent grain has potential as a source of dietary fibre. Cookies supplemented with medium and coarse particle size BSG resulted in better cookie properties compared with those supplemented with fine particle size BSG. Overall sensory evaluation indicated many of the lower levels of medium and coarse particle size BSG substitutions produced cookies that were rated as being at least as good as the respective controls.

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