Milling and Baking Properties of Dried Brewer's Spent Grains

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ABSTRACT

Cereal Chem. 57(3):166–168

Dried brewer's spent grains from two different breweries were milled in a pilot scale flour mill at various moisture levels (7.4–16.4%). Results indicate that when the spent grains were drier, the coarse bran yield decreased and the flour increased as much as six fold. A coarse bran fraction with high fiber content (1.33% N, 26.4% fiber), a high protein flour fraction (7.62% N), and two intermediate fractions (shorts and fine bran) were recovered. The various fractions were incorporated into bread at 6 and 12% flour replacement levels. Coarse or fine bran significantly increased the fiber content of the bread and, although all loaf volumes were somewhat depressed and the colors darker than that of the control, the bread with 6% additive had acceptable appearance, texture, and grain.

Brewer's spent grains, one of the major by-products of the brewing industry and a major disposal problem, represent a potential source of protein and fiber for use in fabricated food. Spent grains contain husk, bran, and embryo residues of the malted barley kernel and residues of corn bran where corn grits are used as adjuncts. Spent grains may also include yeast and trub (which consists mainly of proteins, phenolics, and lipids that are precipitated during the boiling process in brewing), as well as other brewery by-product streams. In the "lauter tun," the wort and spent grains are separated. The spent grains, after washing, are pressed to remove some of the water and soluble solids and are then dried in a grain dryer. The disposal of the liquid portion has been described earlier (Finley et al 1976). The dried spent grains, combined with the trub, account for over 700,000 tons of product annually in the United States. This spent grain product is presently used primarily as an animal feed; it may be more profitable, however, as an ingredient in human food products (Hunt 1969).

Dietary fiber 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 (Burkitt 1975). Prentice and D'Appolonia (1977) reported the addition of finely ground, heat-treated spent grains to bread formulas. Later, Prentice et al (1978) reported adding spent grains to cookie formulas with good success. The current work is an extension of that earlier work, but it studies the incorporation of various mill fractions of spent grains into bread formulations and evaluates their effect on the properties of the bread. Anheuser-Busch recently publicized the use of flour from brewer's grains in various food fabrications (Anonymous 1978). We anticipate that the dry milling fractions produced in this work may have some unique applications in food fabrications.

[1]Reference to a company and/or product named by the USDA is only for purposes of information and does not imply approval or recommendation of the product to the exclusion of others that may also be suitable.

METHODS AND MATERIALS

Brewer's Spent Grains

Brewer's spent grains from two separate breweries were obtained after they were dried either in the brewery or by a contracted grain dryer. Spent grains from Brewery A contained unspecified amounts of yeast, trub, and recovered spent grain protein (Finley et al 1976). Brewery A used a rice adjunct in preparation of the mash. The grains were dried in a feed grain dryer at 250° F with the grains reaching 185° F at the exit of the dryer. Brewery B furnished simple spent grains produced from a mash with a corn adjunct and dried by the brewer. Drying was at 250° F with the grains reaching 195° F at the exit of the dryer. Both samples were free of hop residues.

Milling

The spent grains were passed through a Hobart coffee mill to break up clumps and make a product that fed into the flour mill more uniformly. Moisture was adjusted either by drying the grains on trays in a dry room at room temperature (15–18° C) or by adding water in a fine spray and equilibrating 48 hr in double 8-mil plastic bags. Milling was performed in a Quadramat Senior pilot flour

TABLE I
Milling Yields of Brewer's Spent Grains at Various Moistures

Moisture at Start of Milling	Yield of Mill Fraction as Percent of Starting Material				
	Coarse Bran	Fine Bran	Shorts	Flour	Total[a]
Brewery A					
16.37	40.0	38.5	13.8	7.9	98.5
12.51	18.8	42.1	19.9	17.7	100.0
8.67	7.3	24.5	17.1	50.3	99.2
Brewery B					
7.39	16.7	29.4	25.8	27.5	99.4
12.40	25.4	40.2	18.4	16.1	100.1

[a]Actual yield of the percent of solids in the starting material recovered as mill fractions.

mill. After recovery and sampling, materials were sealed in glass jars and stored in a freezer.

Baking

The base wheat flour used for the blends and control was a hard wheat flour of 11.2% protein. The basic formula was 2% salt, 4% sugar, 3% shortening, 2.5% yeast, and 0.5% dough conditioner (sodium stearoyl-2-lactylate). At the 6% replacement level, the absorption of samples containing spent grain increased from 1 to 3%, and at the 12% replacement level absorption increased from 5 to 6% over the base flour absorption. At both the 6 and 12% replacement levels, mixing time was increased from 1 to 2 min over the base flour mixing time. Baking was for 25 min at 425° F by the procedure of Bean et al (1976) and methods described by the Agricultural Stabilization and Conservation Service (1972).

Analyses

Nitrogen, moisture, ash, fat, and crude fiber analyses were conducted according to the AOAC procedures (1965). Neutral detergent fiber was determined according to Goering and Van Soest (1970).

RESULTS AND DISCUSSION

Table I shows the effects that the moisture content of the starting material had on the yields of the various mill fractions. As the moisture in the material from Brewery A decreased, the flour yield increased greatly at the expense of the bran factions. The spent grains from Brewery A yielded over 50% flour at the lower moisture values, which may be indicative of the presence of yeast and recovered protein in the spent grain starting material. The fine yeast cells, when dry, would easily pass the screens and be included with the flour portion. The yields from Brewery B spent grains are more like what might be expected in commercial practice, because yeast would probably not be added before drying if the spent grains were to be dry milled for use in bakery products.

Table II contains the proximate analysis of the various fractions from the milling experiment. Despite the wide range of yield in flour from Brewery A at different milling moistures, the nitrogen content of the flour fractions remained fairly constant. The flour fractions did exhibit some variation in fat and fiber, however, with marked reductions in both at lower milling moistures. The unmilled spent grains from Brewery B were somewhat higher in nitrogen, fat, fiber, and ash than were the grains from Brewery A. Except for the ash content, the coarse bran fractions from the two lots of spent grains were strikingly similar. The high fiber content of the coarse bran suggested that it might be a source of fiber to add to bread. The coarse bran samples were light in color and contained a wide range of particle sizes. The overall trends from moist to dry spent grains showed improved differentiation between the fractions, particularly between the coarse bran and flour fractions, as indicated by yields and nitrogen contents. The fine bran fraction from the drier material contained more fiber than did that from the more moist material, again suggesting somewhat better differentiation. Except for the fat content, the fine brans from the two low-moisture samples were quite comparable. The fine bran, like the coarse bran, might provide a source of dietary fiber.

Baking studies were conducted using mill fractions of spent grains from Brewery B because that lot contained only spent grains and was more representative of what might be used in a practical application.

Table III shows the effects on test bread volume and texture of replacing flour (at the 6 and 12% levels) with spent grain mill fractions. All replacements with mill fractions at the 6% level caused some depression of loaf volume, the shorts showing the greatest loss and the two brans the least. Fig. 1 shows photographs of breads with 6% flour replacement; all breads are considerably darker than the control. The breads containing bran were, subjectively, about the same color as whole wheat bread although somewhat grayer in appearance. The 12% replacement produced considerably more reduction in loaf volume, and the bread quality scores were also much lower. The fine bran fraction at this level caused a large loss in loaf volume and breads that had rather poor quality scores compared with breads containing 6% of the same material. We concluded that flour replacement with 12% of any spent grain fraction would be likely to yield an unsatisfactory product.

Analysis of the various bread samples containing spent grain are shown in Table IV. Replacement with either fine or coarse bran at

TABLE II
Proximate Analysis of Mill Fractions Obtained at Various Moisture Levels

Moisture at Milling	Fraction[a]	Moisture (%)	N (%)	Fat (%)	Crude Fiber (%)	Neutral Detergent Fiber (%)	Ash (%)
Brewery A							
···	Unmilled spent grains[b]	0	4.26	5.28	11.8	33.7	3.81
16.37	CB	15.34	2.80	5.53	13.5	77.1	3.26
	FB	15.74	3.69	4.81	9.0	24.0	3.24
	S	13.30	4.65	5.13	8.9	24.0	3.31
	F	11.81	5.71	8.51	9.4	25.2	3.71
12.51	CB	11.32	2.66	4.19	15.1	44.8	3.58
	FB	11.59	3.47	6 37	8.9	27.3	3.27
	S	10.25	4.03	6.96	7.7	22.0	3.24
	F	9.52	5.80	7.14	6.4	18.1	3.25
8.67	CB	7.73	1.28	1.81	25.9	73.2	4.52
	FB	7.75	2.46	4.11	17.5	48.3	4.44
	S	7.84	3.66	6.42	10.7	28.7	3.79
	F	7.85	5.72	7.09	6.0	17.3	3.91
Brewery B							
···	Unmilled spent grains[b]	0	5.01	8.13	12.9	36.0	9.39
7.39	CB	7.45	1.33	4.29	26.5	77.1	5.67
	FB	7.50	2.87	7.78	17.0	45.5	5.16
	S	7.25	5.29	10.02	8.4	25.1	3.54
	F	7.13	7.62	9.35	3.9	26.2	2.53
12.40	CB	11.28	1.81	3.35	18.7	57.1	5.10
	FB	11.31	3.60	7.54	9.1	26.3	4.86
	S	9.91	5.31	9.39	7.3	19.2	3.62
	F	8.89	7.68	9.40	3.8	10.6	2.91

[a]CB = coarse bran, FB = fine bran, S = shorts, F = flour.

TABLE III
Effect of Flour Replacement with Spent Grain Mill Fractions in White Bread[a]

Sample	Replacement Level	Volume (ml)	Weight (g)	Bread Scores[b]: Break and Shred	Grain	Texture
Base flour	···	720	124	4.5	14.0	14.0
Spent Grain Fraction						
Whole grain	6%	670	125	4.3	13.8	14.0
	12%	660	125	3.5	13.5	13.5
Flour	6%	685	124	4.0	13.0	13.0
	12%	602	126	3.3	13.0	13.0
Shorts	6%	660	125	4.3	13.0	13.5
	12%	597	136	2.8	12.5	12.0
Fine bran	6%	700	125	3.5	14.0	14.0
	12%	577	126	2.8	13.0	13.0
Coarse bran	6%	700	125	4.0	14.0	13.8
	12%	625	126	3.3	13.5	13.5
Minimum acceptable scores	···	···	···	4.0	13.5	13.0
Mean		654	125.2	3.7	13.4	13.4
Standard deviation		45.6	0.74	0.6	0.5	0.6

[a]Values represent the average of two sets of duplicates baked on separate days.
[b]Maximum possible scores for bread judging: break and shred, 5; grain, 15; texture, 15.

TABLE IV
Effect of Flour Replacement with Spent Grain Mill Fractions on the Proximate Analysis of Final Bread Samples

Sample	Replacement Level	Moisture in crumb (%)	Proximate Analysis[a] Nitrogen (%)	Fat (%)	Crude Fiber (%)	Neutral Detergent Fiber (%)	Ash (%)
Base flour	...	28.96	2.13	2.77	0.58	1.41	2.58
Spent grain fraction							
Whole grain	6%	30.6	2.41	2.3	1.0	3.0	2.71
	12%	31.6	2.40	2.8	1.8	5.1	2.85
Flour	6%	31.3	2.47	2.3	0.8	2.6	2.55
	12%	32.3	2.85	3.0	1.1	3.4	2.75
Shorts	6%	31.7	2.31	2.7	0.9	2.9	2.61
	12%	33.2	2.48	3.1	1.6	9.2	2.72
Fine bran	6%	30.9	2.26	2.1	1.4	8.4	2.75
	12%	32.5	2.24	3.6	2.3	10.1	2.87
Coarse bran	6%	29.8	2.12	1.6	1.9	9.1	2.76
	12%	33.3	2.11	2.5	3.5	10.9	2.98

[a]Moisture-free basis.

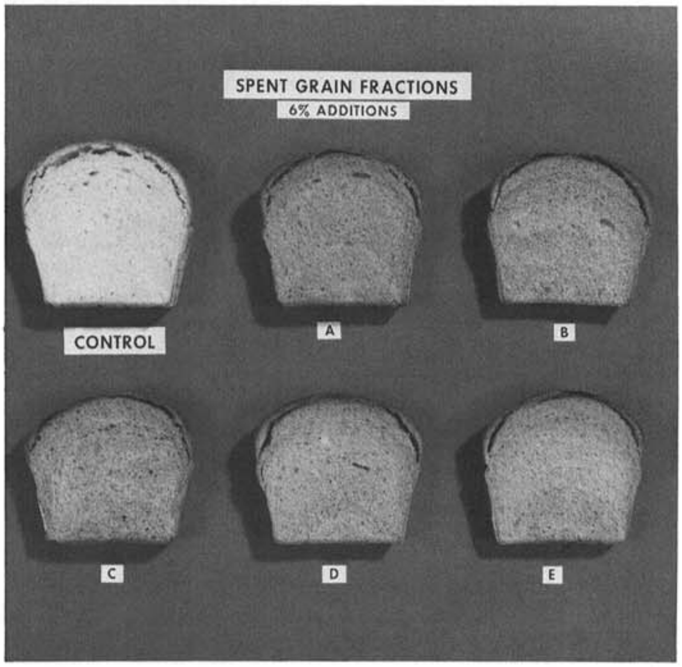

Fig. 1. Bread samples baked with spent grain mill fractions added to replace 6% of the flour. Fractions used: **A,** flour; **B,** shorts; **C,** whole spent grain ground to pass 80-mesh screen; **D,** fine bran; **E,** coarse bran.

the 6% level raised the fiber content of the bread to 1.42 or 1.88%, respectively; these values are lower than whole wheat bread (2.0–2.5%) but are significantly higher than the levels in most other breads (Anonymous 1978). Bread samples fortified with the flour fraction had the expected increased nitrogen content; however, fortification of bread with a cereal protein may not be as advantageous as fortification with other protein sources, such as soy, that complement the amino acid pattern of wheat proteins. Furthermore, the spent grain proteins have been heated in the presence of reducing sugars, which could reduce lysine availability.

Prentice and D'Appolonia (1977) reported that heat treatment of whole spent grains significantly reduced the color formation when spent grains were added to bread. They dried the spent grains at 45°C, which appeared to be the most favorable treatment before incorporation into a bread formula. If this effect would carry over to the various mill fractions, some of the color problems noted in this work might be overcome.

Prentice and D'Appolonia (1977) also reported extensive organoleptic evaluation of breads containing brewer's spent grain. The results suggested that the enriched breads were quite acceptable. Organoleptic evaluation was not conducted in the current study because the precise handling of the spent grains before we received them was unknown. Although bacterial contamination was not suspected, we chose not to risk having a taste panel consu... materials of unknown background that were not handled in food quality processing equipment.

In conclusion, brewer's spent grains can be dry milled in a conventional flour mill system yielding a high protein product, two bran fractions, and shorts. Both bran fractions offer some potential as bread additives; however, some darkening and loaf volume depression are to be expected. The high protein flour appears to have greater potential in extruded products or other fabricated foods than in bread products.

ACKNOWLEDGMENTS

The authors wish to thank A. P. Mossman for his assistance in the milling aspects of this work and L. B. Richards, D. B. Cox, and P. Inada for the analytical aspects of the work.

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[Received May 29, 1979. Accepted November 7, 1979]