Utilization of Dried Distillers Grain from Sorghum in Baked Food Systems[1]

M. M. MORAD, C. A. DOHERTY, and L. W. ROONEY, Cereal Quality Lab, Department of Soil and Crop Sciences, Texas A&M University, College Station 77843-2474

ABSTRACT

Five sorghum varieties representing brown, yellow, white, and white waxy types were fermented into alcohol. The residual dried distillers grains (DDG) and commercial samples of DDG obtained from a brewery and a distillery were analyzed chemically and rheologically and were tested for possible applications in baked food systems. Sorghum DDG were higher in protein and lower in starch than the commercial DDG. Replacement of wheat flour with up to 15% DDG decreased mixing and stability times of the doughs. Bread loaf volume decreased as substitution levels increased. Crumb color was directly related to the color of the DDG and level of substitution. Neutral detergent fiber and crude protein were higher in the sorghum and commercial DDG than wheat or sorghum flour. This resulted in higher neutral detergent fiber and crude protein in bread and cookies as substitution levels increased. With the exception of color, the quality of DDG sugar cookies at substitution levels up to 15% was comparable to that of controls. Molasses cookies containing up to 25% white sorghum DDG were superior to the control.

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Sorghum is the third leading cereal in the United States and the number one cereal crop in Texas. Genetic variation exists in sorghum, and this can be used to optimize the type of grain to produce the most alcohol and the best quality by-products, thereby optimizing profits from alcohol production. To do that, basic information is required on the potential value and uses of sorghum by-products from different classes of sorghum and for various foods.

Dried distillers grains (DDG), a by-product of the alcoholic fermentation of cereal grains, are rich in protein and fiber (Miller and Eisenhauer 1982). Fiber is thought to play a role in the prevention of certain human diseases such as diverticulosis, colon cancer, hemorrhoids, atherosclerosis, varicose veins, and appendicitis (Burkitt and Trowell 1975). Small-scale ethanol production from sorghum at Texas A&M University showed DDG to contain over 14% crude fiber (Coble et al 1981). DDG have been traditionally used as feed concentrates (Loosli and Warner 1958, Thong et al 1978, Ward and Matsushima 1980). A related product, brewers spent grains (BSG), has been used in baked systems (Prentice and D'Appolonia 1977, Finley and Hanamoto 1980). In general, up to 10% of BSG could be substituted for wheat flour in breadbaking. Prentice and D'Appolonia (1977) successfully added BSG at 10% substitution in sugar cookies. Dreese and Hoseney (1982) used BSG at 15% substitution in bread and reported an increase of 16% in water absorption. The BSG decreased loaf volume and produced a less desirable crumb. Loaf volume improved with the incorporation of sodium stearoyl-2-lactylate (SSL) or increasing the amount of shortening in the bread formula. Tsen et al (1982) successfully used commercial DDG up to 15% in bar, spice, and chocolate chip cookies.

The objectives of this study were to determine the effects of specific sorghum varieties on the chemical, rheological, and

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functional properties of their DDG and to use sorghum DDG as a partial replacement for wheat flour in the production of high-protein bread and cookies. Also, the chemical, functional, and baking properties of the DDG from sorghum were compared to DDG from a commercial distillery and brewery.

MATERIALS AND METHODS

DDG

Five sorghum varieties representing brown (Tx2566 and ATx 623×SC0103-*12*), yellow (ATx399×RTx430), and white (77CS5) market classes and a white waxy endosperm sorghum (BTx615) were fermented into alcohol. The genetic description of the samples and the alcohol fermentation procedure were described by Doherty et al (1983). By-products remaining after fermentation were collected by centrifugation at 60 rpm for 20 min. The pellet was dried for 24 hr at 50°C to obtain the DDG. Sorghum DDG were compared with two commercial DDG samples obtained from a distillery (Commercial I) and a brewery (Commercial II). All sorghum and commercial DDG were milled with a Udy laboratory mill (Udy Corp., Fort Collins, CO) to pass a 1.0-mm screen mesh.

Chemical Analysis

Crude protein (N × 6.25 for sorghum, N × 5.7 for wheat) was determined using a modified micro-Kjeldahl method (Technicon Industrial method 369-74A/A+). Starch, total sugars, and reducing sugars in the whole grain and DDG were measured by automated methods of analysis (Technicon Industrial methods SF4-0046FA8, 142-71A). Tannins were determined by the modified vanillin-HCl method (Maxson and Rooney 1972). In vitro protein availability via pronase hydrolysis was determined using the method of Hahn et al (1982). Color was evaluated for DDG and sugar cookies with a Hunter Lab Color Difference meter. "L," "a," and "b" values were recorded for each sample. Neutral detergent fiber (NDF) was measured using a modification of a procedure by Goering and Van Soest (1978). Neutral detergent fiber is defined as hemicellulose, cellulose, lignin, and ash.

Rheological Properties

Mixographs were performed according to Finney and Shogren (1972). Farinograms were prepared as described in the AACC (1976) method. Gas production of the DDG was determined using a gasograph (Rubenthaler et al 1980).

Bread and Cookie Preparation

The bread-baking procedure of Finney et al (1977) for 100 g of total flour (14% mb) was used for producing U.S. white pan bread. The formula included 2.2% dry bakers yeast (Fermipan), 1.5% salt, 6% sugar, 0.25% diastatic malt (54 dextranizing units [DU]/g, 20° C), 3% vegetable shortening (Crisco), and an optimum amount of water and ascorbic acid. The bread was produced by replacing 0, 5, 10, and 15% of wheat flour with DDG.

Cookies were prepared according to the AACC method (1976). Cookies were produced by replacing 0, 5, 10, and 15% of the cookie flour with DDG. Spread ratio (W/T) of the cookies, where W is the average diameter and T is the average thickness, was determined according to the AACC method (1976).

Molasses cookies were prepared in the laboratory and in a commercial bakery using cookie flour replaced by DDG at 0, 25, and 50% levels. The formula included 45% sugar, 30% molasses, 40% shortening, 0.5% salt, 1.3% baking powder, and 25% water. One egg was also added per 300 g of flour. The cookies were baked at 400° F for 10 min. Cookies produced in the commercial bakery were organoleptically evaluated by 31 regular customers. The panelists were asked to report whether they liked, disliked, or neither liked nor disliked the color and the taste of the cookies. They were also asked if they would buy the cookies if they were made available.

RESULTS AND DISCUSSION

Chemical Composition of Grains and DDG

The chemical composition of ground, whole sorghum and their resulting DDG are presented in Tables I and II. Protein was effectively concentrated while starch was reduced in the DDG, due to the conversion of starch to alcohol. The commercial DDG

TABLE I
Chemical Composition of Sorghum Varieties on a Dry Weight Basis

Variety	Starch (%)	Protein (%)	Neutral[a] Detergent Fiber (%)	Total Sugars (%)	Tannins[b]	In vitro[c] Protein Digestibility
Tx2566 (brown)	69.5	11.8	11.4	2.6	0.24	253
ATx623×SC0103-*12* (brown)	70.7	11.7	10.3	2.3	2.12	228
77CS5 (white)	71.4	12.1	12.6	3.4	···	290
ATx399×RTx430 (yellow)	74.6	11.6	9.3	3.2	···	273
BTx615 (white)	76.3	11.7	13.4	4.0	···	339

[a]SD = 5.12 for fiber means. CV <7% for all means.
[b]Expressed as Catechin equivalents/100-mg sample.
[c]Expressed as micrograms of α-amino N/Total N.

TABLE II
Chemical Composition of Dried Distillers Grain from Sorghum, a Commercial Distillery, and a Brewery on a Dry Weight Basis

Variety	Starch (%)	Protein (%)	Neutral[a] Detergent Fiber (%)	Total Sugars (%)	Tannins[b]	In vitro[c] Protein Digestibility
Tx2566 (brown)	0.60	37.3	46.4	0.7	0.20	418
ATx623×SC0103-*12* (brown)	0.41	44.0	49.0	0.8	1.95	197
77CS5 (white)	0.58	43.2	55.6	0.5	···	453
ATx399×RTx430 (yellow)	0.58	44.5	50.6	0.6	···	469
BTx615 (white)	2.18	40.5	46.4	1.2	···	651
Commercial I	2.18	35.1	35.2	6.0	0.29	405
Commercial II	12.57	27.1	74.4	1.2	···	522

[a]SD = 5.12 for fiber means. CV <7% for all means.
[b]Expressed as Catechin equivalents/100-mg sample.
[c]Expressed as micrograms of α-amino N/Total N.

obtained from a distillery (Commercial I) and a brewery (Commercial II) contained more starch and less protein than the sorghum DDG. This is due to differences in both the fermentation procedures and the grains used for fermentation.

Neutral detergent fiber (NDF) ranged from 46 to 55% for the sorghum DDG (Table II). Commercial II, originating primarily from barley, was highest in NDF (74.4%).

Tannin content of the ground sorghums and their resulting DDG were comparable. Tannins were present only in brown sorghums (ATx623×SC0103-*12*, Tx2566) and their DDG. High tannin content was associated with low in vitro protein digestibility (Table I). The action of tannins binding with proteins and reducing digestibility is well documented (Price and Butler 1979). Greater in vitro protein digestibility of the DDG compared to their parent grains may reflect more sites present for enzyme cleavage due to denaturation of protein encountered during alcohol production. In vitro protein digestibility of the brown sorghum DDG from ATx623×SC0103-*12* was lower than that of its parent grain (Tables I, II).

TABLE III
Color Values of Commercial and Sorghum Dried Distillers Grains[a]

Variety	Color Value L	a	b
Standard white tile	92.0	−1.2	0.3
Tx2566 (brown)	47.7	13.7	15.3
ATx623×SC0103-*12* (brown)	42.9	15.0	14.5
77CS5 (white)	59.4	11.1	18.6
ATx399×RTx430 (yellow)	54.0	13.8	18.5
BTx615 (white)	60.2	11.1	20.5
Commercial I	41.2	14.0	17.1
Commercial II	62.7	7.7	18.3

[a] Average of three replicates. SD = 0.50.

The color of the DDG was significantly affected by the sorghum variety (Table III). Brown sorghum and Commercial I DDG were the darkest, while the DDG of the white, white waxy, yellow sorghum, and Commercial II were the lightest in color. In general, food product color is a very important characteristic affecting consumer acceptability. Light-colored DDG are more suitable for bread supplementation, while dark DDG are more suitable for variety breads and some types of cookies.

Mixograph, Farinograph, and Gasograph Properties

Replacing wheat flour with 0, 5, 10, and 15% of DDG adversely affected dough properties measured by the farinograph and mixograph (Table IV). The properties of sorghum DDG were similar to those of Commercial I. No significant differences were found among sorghum varieties. As DDG level increased, water absorption increased while mixing time and dough stability decreased. Commercial II, obtained from a brewery, had the best dough-forming properties of all the samples. Gas (CO_2) production decreased slightly when DDG were substituted for 10 and 15% of the wheat flour. No significant differences in gas production were found between sorghum and Commercial DDG. The deterioration in these properties (water absorption, mixing time, stability) with increasing DDG levels had a direct effect on bread-baking performance.

Bread-baking Performance

In general, loaf volume of white pan bread decreased significantly as the amount of DDG in the formula increased (Table V). Bread volumes of white and brown sorghum DDG and Commercial I were slightly higher than bread volumes of white

TABLE IV
Rheological Properties of Dried Distillers Grains Supplemented for Wheat Flour[a]

Variety	Percentage	Water Absorption[b] (%)	Mixing Time[c] (min)	Stability[b] (min)	Gas Production[d] (gasograph units)
Control		64.0	5:25	17:00	29.9
Tx2566 (brown)	5	64.3	5:00	10:00	30.0
	10	66.0	4:35	8:00	28.3
	15	68.3	4:20	6:30	26.7
ATx623×SC0103-*12* (brown)	5	65.0	4:30	10:00	30.2
	10	66.2	4:30	8:30	28.7
	15	67.5	4:30	8:00	27.4
77CS5 (white)	5	64.5	4:40	10:00	29.9
	10	66.2	4:40	8:00	28.2
	15	68.2	5:00	7:00	26.5
ATx399×RTx430 (yellow)	5	65.0	4:30	8:30	30.0
	10	65.6	4:30	8:00	28.4
	15	67.6	4:45	6:15	27.4
BTx615 (white)	5	64.8	4:30	8:00	30.6
	10	66.2	4:30	7:00	29.7
	15	67.8	4:30	6:15	28.7
Commercial I	5	63.0	4:00	7:30	30.6
	10	62.7	4:15	5:45	29.9
	15	61.6	4:45	5:45	28.5
Commercial II	5	67.3	5:10	13:00	29.5
	10	71.8	5:15	10:45	29.0
	15	75.5	5:00	9:30	28.7

[a] Average of two replicates.
[b] From the farinograph.
[c] From the mixograph.
[d] From the gasograph (cm^3 of CO_2 = gasograph unit × 2.38) (Rubenthaler et al 1980).

waxy and yellow sorghum DDG and Commercial II. Adding 0.5% SSL significantly improved loaf volume and dough handling, especially at 5% substitution. This was noted by Dreese and Hoseney (1982). Crumb and crust color were highly affected both by the original color of the DDG and by the level of substitution (Figs. 1–4). The dark color was more pronounced with DDG from brown sorghum and Commercial I DDG. In breadmaking, the DDG from white sorghum could be used successfully at the 5–10% level. A composite flour containing 90% wheat flour and 10% DDG has an increased protein content of 30% and an increased NDF content of 250% when compared to wheat flour alone. Although 10% DDG is the maximum substitution to produce acceptable white pan bread, a higher level of substitution could be successful in a variety bread, in which high volume and light color are less important criteria. For instance, we have successfully produced Egyptian pita Balady bread with 20% DDG. The pocket formation was excellent, and the color and taste were acceptable. Commercial DDG and DDG from brown and yellow sorghums were not as desirable for breadbaking as were white sorghum DDG.

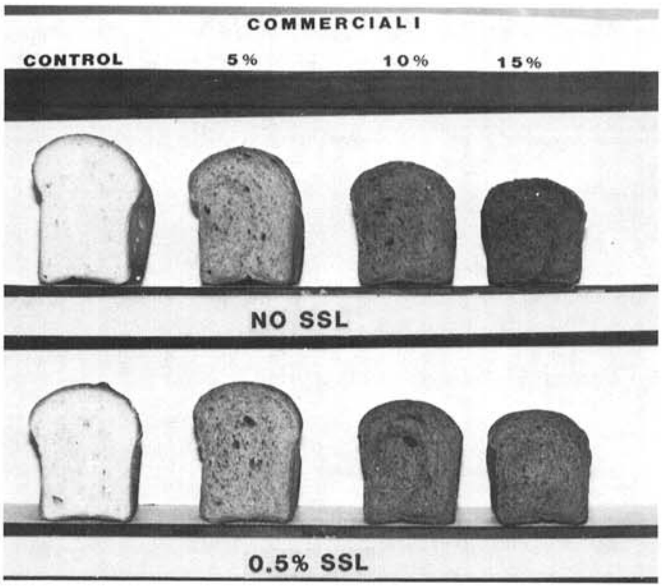

Fig. 1. Internal appearance of pup loaves obtained from dried distillers grains (DDG) substituted for wheat flour with or without sodium stearoyl-2-lactylate treatment. Made from Commercial I DDG obtained from a distillery.

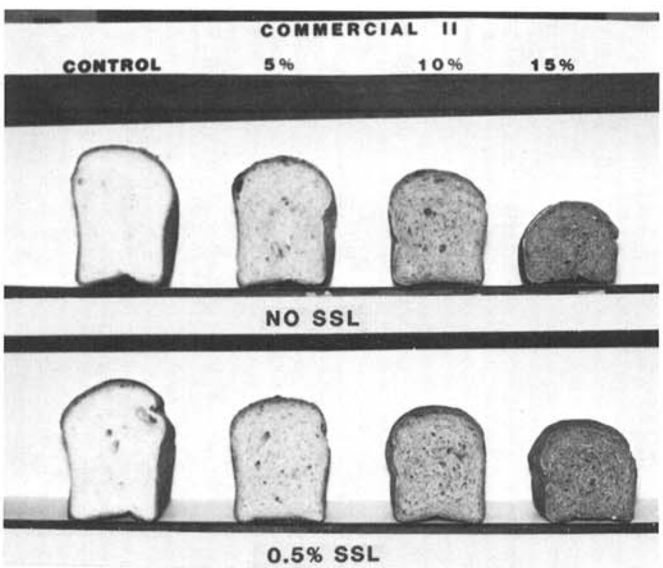

Fig. 2. Internal appearance of pup loaves obtained from dried distillers grains (DDG) substituted for wheat flour with or without sodium stearoyl-2-lactylate treatment. Made from Commercial II DDG obtained from a brewery.

Cookie Performance Test

Sugar cookie color ranged from golden yellow to dark brown, depending on the original color of the DDG and its level of substitution (Table VI, Fig. 5). The major differences between commercial and sorghum DDG substituted cookies were the color, aroma, and taste. Except for the brown variety (ATx623×SC0103-*12*), supplementation of cookie flour with 5% DDG slightly increased the spread ratio of sugar cookies (Table VII). However, the spread ratio decreased slightly at 10 and 15% substitution.

Molasses cookies prepared at 25 and 50% substitution levels in a commercial bakery were judged by 31 of its regular customers (Table VIII). The number of panelists who liked the taste and color and were in favor of buying the cookies if they were made available was significantly higher than the number of those who disliked the product at 25 and 50% substitution. Statistically, the white sorghum DDG at 25% was rated equal to or better than the control.

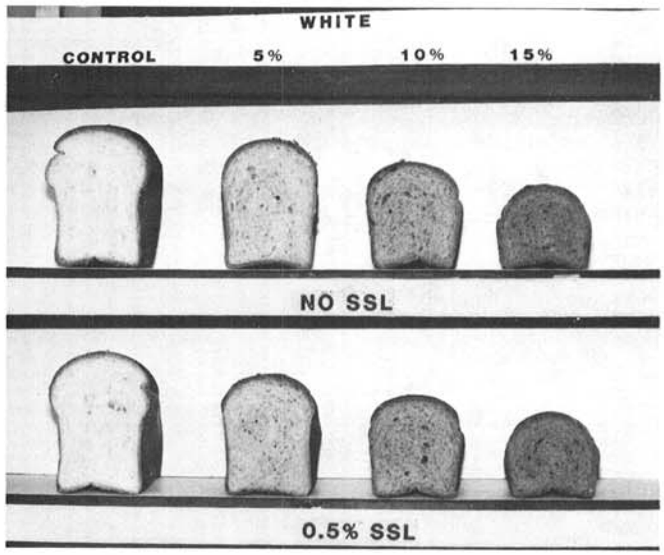

Fig. 3. Internal appearance of pup loaves obtained from dried distillers grains (DDG) substituted for wheat flour with or without sodium stearoyl-2-lactylate treatment. Made from white sorghum DDG (77CS5).

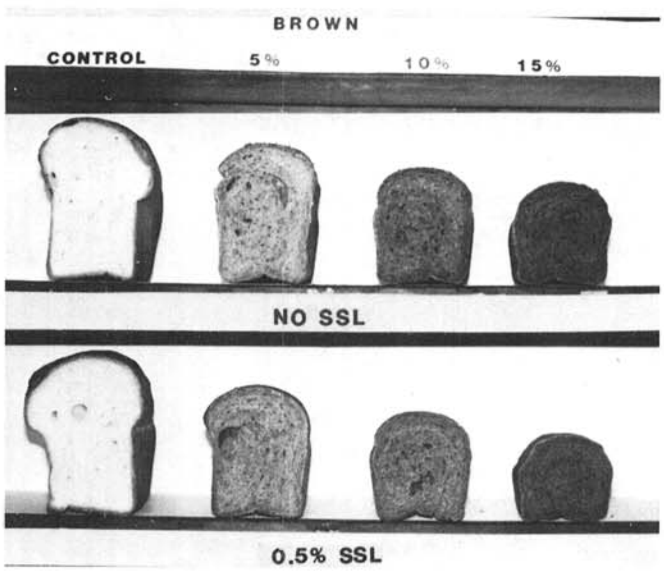

Fig. 4. Internal appearance of pup loaves obtained from dried distillers grains (DDG) substituted for wheat flour with or without sodium stearoyl-2-lactylate treatment. Made from brown sorghum DDG (ATx623×SC0103-*12*) sorghum DDG.

The white waxy sorghum DDG was also similar to the control at the 25% level. The overall acceptability scores for both white and white waxy DDG substitution were significantly higher than the scores for the brown sorghum DDG at 25 and 50% substitution. Substituting 25% DDG for wheat flour in a cookie formulation

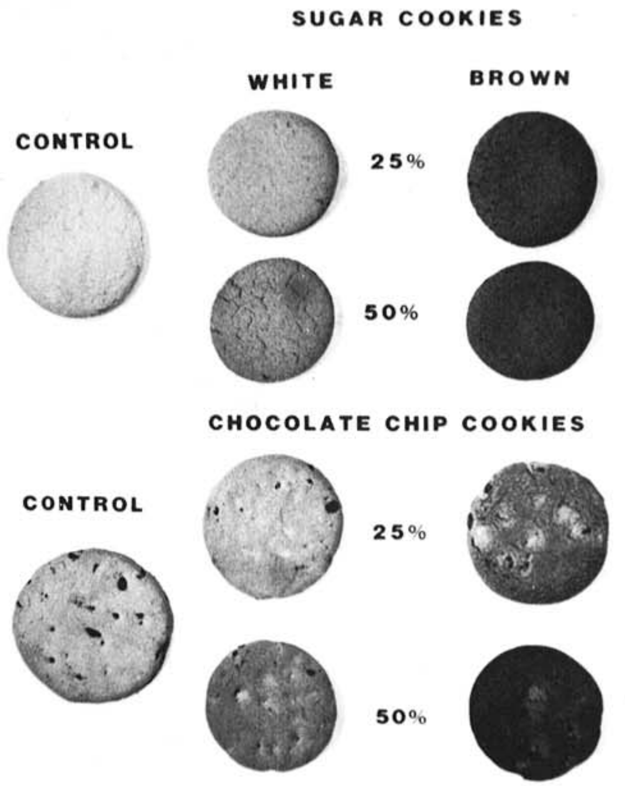

Fig. 5. External appearance of sugar and chocolate chip cookies made from white (77CS5) and brown (ATx623×SC0103-*12*) sorghum DDG.

TABLE V
Loaf Volume (cm^3) of Bread Made from Dried Distillers Grains (DDG)—Wheat Flour Blends[a]

	Percent DDG Substituted		
Wheat Flour	**5**	**10**	**15**
No SSL			
Tx2566	790 efgh	750 klm	597 t
ATx623×SC0103-*12*	782 fghi	645 rs	447 w
77CS5	805 defg	745 lm	695 nopq
ATx399×RTx430	775 hijk	740 lm	640 s
BTx615	722 mn	646 rs	577 t
Commercial I	805 defg	687 opq	580 t
Commercial II	700 nop	512 v	420 x
Control	905 b	··· ···	··· ···
With 0.5% SSL			
Tx2566	832 cd	780 ghij	640 s
ATx623×SC0103-*12*	810 def	667 qrs	537 uv
77CS5	820 cd	747 klm	710 no
ATx399×RTx430	817 cde	755 ijkl	657 rs
BTx615	752 jkl	672 pqr	582 t
Commercial I	840 c	695 nopq	580 t
Commercial II	712 no	550 u	450 w
Control	932 a	··· ···	··· ···

[a] Average of three replicates. SD = 13 for all means. Volumes with the same letter are not significantly different by Duncan's Multiple Range Test ($P < 0.01$).

TABLE VI
Color of Cookies (L Value) Made from Dried Distillers Grains (DDG)—Wheat Flour Blends[a]

	Percent DDG Substituted		
Variety	**5**	**10**	**15**
Tx2566	56.8 gh	51.4 j	46.4 l
ATx623×SC0103-*12*	55.2 hi	46.1 lm	43.9 n
77CS5	59.4 de	57.6 f	54.6 i
ATx399×RTx430	59.8 d	58.0 e	52.6 j
BTX615	61.8 c	57.3 f	54.7 i
Commercial I	56.7 fg	51.3 k	45.4 m
Commercial II	63.7 b	63.0 b	59.0 de

[a] Average of three replicates. L value for standard cookie flour is 71.0. Average of three replicates. Means with the same letter are not significantly different by Duncan's Multiple Range Test ($P < 0.01$).

TABLE VII
Spread Ratios for Cookies Made from Sorghum Dried Distillers Grains (DDG)[a]

	Percent DDG Substituted		
Variety	**5**	**10**	**15**
Tx2566	12.40 abc	11.43 def	10.78 fg
ATx623×SC0103-*12*	11.20 efg	11.37 def	10.57 g
77CS5	12.34 abc	11.78 cde	10.79 fg
ATx399×RTx430	12.52 ab	11.80 cde	11.10 fg
BTx615	12.60 a	12.26 abc	10.95 fg
Commercial I	12.37 abc	11.95 bcd	11.42 def
Commercial II	12.48 abc	11.52 def	11.04 fg
Control	11.90 bcd	11.9 bcd	11.90 bcd

[a] Average of three replicates. SD for all means is 0.68. Spread ratios with the same letter are not significantly different by Duncan's Multipe Range Test ($P < 0.01$).

TABLE VIII
Preference Test for Color and Taste of Molasses Cookies[a]

	77CS5		ATx623 × SCO103-12		BTx615		
Variables	**25%**	**50%**	**25%**	**50%**	**25%**	**50%**	**Control**
Color							
Like	97 a	83 b	64 d	58 e	75 c	65 d	82 b
Neither	0 k	13 i	25 f	13 i	21 g	20 g	12 i
Dislike	3 j	4 j	17 h	12 i	15 hi	15 hi	6 j
Taste							
Like	75 a	58 c	42 e	38 f	65 b	48 d	76 a
Neither	10 h	7 nm	34 g	25 h	14 l	5 n	18 jk
Dislike	15 kl	35 fg	24 hi	37 fg	21 ij	47 d	6 n
Preference[b]							
Yes	66 b	40 e	34 g	28 h	62 cd	40 e	65 bc
No	34 g	60 d	66 b	72 a	38 ef	60 d	35 gf

[a] Expressed as a percent of the total panelists.
[b] Yes for preference indicate percent of panelists who will buy the cookies and No for those who will not buy them if they were made available in the bakery. For each variable (color, taste, preference), values followed by the same letter are not significantly different by Duncan's Multiple Range Test ($P < 0.01$). Values followed by the same letter are only comparable within a column.

would increase the protein content by 100% and fiber content about sixfold without affecting cookie quality. Chocolate chip cookies could be successfully produced from white sorghum DDGs at high levels of substitution (Fig. 5). Thus, a low-calorie, nutritious, protein- and fiber-fortified food could be produced.

CONCLUSIONS

The successful utilization of the DDG in baked food products would have a positive effect on reducing the total cost of alcohol production. Since DDG are high in protein and fiber while low in starch, they would be advantageous in reduced-calorie formulas such as health foods. Sorghum DDG are inexpensive and have been successfully incorporated in bread and cookies.

White sorghums produce more alcohol in a shorter time period (Doherty et al 1983) and yield light-color DDG with higher in vitro protein digestibility than brown sorghums. White sorghum DDG produced white pan bread acceptable up to 10% substitution and acceptable molasses cookies up to 50% substitution. The quality of the cookies and bread prepared with white sorghum DDG were superior to those prepared from commercial and brown sorghum DDG.

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