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EVALUATION OF POTENTIAL FOOD APPLICATIONS OF DRIED DISTILLERS
SPENT GRAIN (DSG)

Final Research Report

MASTER

By
Wulf T. Doerry

February 6, 1981

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American Institute of Baking
Manhattan, Kansas

U.S. Department of Energy

Solar Energy

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FINAL RESEARCH REPORT

Presented to:

Mr. John B. Adams, Jr.
Vice President
A. Smith Bowman Distillery
11710 Sunset Hills Road
Sunset Hills, VI 22090

EVALUATION OF POTENTIAL FOOD APPLICATIONS OF DRIED DISTILLERS SPENT GRAIN (DSG)

Presented by:

Wulf T. Doerry
Project Coordinator
American Institute of Baking
1213 Bakers Way
Manhattan, KS 66502

February 6, 1981

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FINAL RESEARCH REPORT

Project Title: Evaluation of Potential Food Applications of Dried Distillers Spent Grain (DSG).

Project Sponsor: A. SMITH BOWMAN DISTILLERY, INC.

Contract No.: DE - AC01 - 80 CS 40 352 (D.O.E.)

Contract Dates: August 6, 1980 to February 6, 1981

Period Covered by This Report: August 6, 1980 to February 6, 1981

I. General Goal of Project: To determine the economics and potential food applications for dried distillers spent grains (DSG) obtained as a by-product from the ethanol production for nonfood use.

II. Specific Purposes of Project: The production of ethanol as a component for the manufacture of gasohol is expected to increase significantly during the coming years. This will make available large amounts of DSG as a by-product from this process. The starting material is food grade corn and malt (certified to be free of aflatoxins) and the finished by-product is high in protein, fibers, minerals and other micronutrients. The U.S. Department of Energy (D.O.E.) is interested to find new possible uses for the DSG for the following reasons.

A) To reduce the impact of large amounts of available DSG replacing soy meal in the feed market.

B) To increase the value of the nutritious by-product DSG in order to keep the cost of the ethanol at a level competitive to gasoline.

III. Summary of Results and Discussions: Between September and December, 1980, the American Institute of Baking (AIB) received 10 samples of distiller's spent grain (DSG) from three different suppliers. The mash bills for these samples varied significantly from processor to processor and to some extent also from day to day for the same distiller. Although only one supplier, J. E.

Seagram of Lawrenceburg, Indiana, furnished some processing conditions for the submitted samples, it appears that these conditions significantly affect the characteristics of the DSG and thus also the quality of the baked product prepared with it.

A search of the literature published about DSG used for human consumption revealed only very little information, since traditionally the spent grains have been disposed of as feed concentrates. The scarce information available does rarely relate the data to specific mash bills and processing conditions. No systematic approach to the characterization of DSG from various sources has been made prior to this current attempt by the AIB.

Five of the DSG samples were analyzed for their nutritional composition. Since two suppliers, Midwest Solvent and Jim Beam, did not differentiate between the three samples each submitted, other than by production date and shift, only one sample of each set was chosen as representative for DSG produced by the respective supplier.

Although the samples were generally similar in their composition, there were some significant differences between them, probably because they were produced from different mash bills. The predominantly corn-derived mash bills yielded DSGs with $25\% \pm 0.5\%$ protein, while the milo derived DSG (AIB Sample No. 5) analyzed for 31.8% protein. The DSG from milo grain also contained significantly less dietary fiber than the corn-derived product (29.2% vs. an average of 34.5%). The difference in ether extractable matter between the samples submitted by J. E. Seagram (AIB Samples No. 2, 3, & 4) and those obtained from Midwest Solvents (AIB Sample No. 5) and J. B. Beam (AIB Sample No. 8) may be attributable, at least in part, to processing conditions employed by these distillers. No significant differences between all samples were found in ash, moisture, crude fiber and nucleic acid contents.

All DSG samples contained relatively little sodium, but appeared to be more enriched in minerals and vitamins as compared to the amounts normally found in whole grain products. The milo-derived DSG Sample No. 5 analyzed especially high for iron and niacin, while it was slightly lower in vitamin B6 content.

The amino acid profile of all samples assayed was similar and resembles that of the raw materials used for the mash bill, with lysine being the limiting factor for human nutrition.

All DSG samples have similar effects on dough rheology. The particle size of milled product affects the peak consistency of DSG flour blends, as measured by the amylograph. While DSG milled through a 2mm screen increased the peak consistency slightly, the product milled through the 1mm screen depressed the peak consistency. Although the addition of spent grain did not affect the temperature when the flour paste consistency increases initially, it did cause the DSG-flour blend to reach the maximum viscosity at a higher temperature than the control (100% flour).

A replacement of 5%, 10%, or 20% of the flour with spent grain increased the absorption for doughs mixed on the farinograph. This increase varied from 1.1% for DSG from milo grain to 5.9% for the DSG manufactured from a mash bill of 75% corn, 13% rye, and 12% barley malt. The arrival, peak, and departure times of the farinograms were generally delayed by the partial replacement of flour with DSG, while the stability and tolerance of the doughs were reduced. It appears that the DSG particles weaken the dough structure. As indicated by Scanning Electron Microscopy, these particles are nonuniform in size and possess sharp points. They are not a part of the dough structure and may have the tendency to cut and to pierce the glutenous dough film which forms the cell walls of the loaves during the proofing stages. DSG milled through a 1mm

screen has a greater number of individual particles and thus it more severely affects the stability and tolerance of the resulting doughs than the coarser or unmilled product.

Although the resistance to the extension of doughs was not seriously affected by the replacement of 10% of the flour with DSG, the extensibility of the doughs was significantly reduced. The particle size of the spent grain did not appear to affect this dough property significantly.

One sample of DSG from each of the three suppliers was chosen for the study of how the spent grain affects the eating quality and the general characteristics of bread, where 15% of the flour has been replaced with DSG.

Although all three samples of DSG produced loaves of similar volumes, there were significant differences with respect to crumb color and taste of the bread. The DSG from J. B. Beam produced a bread with the mildest, but still with a distinctly sour taste and a yellowish appearing bread crumb. The milo-derived DSG from Midwest Solvents imparted to the bread the strongest flavor and a very dark brown crumb color, while the sample from J. E. Seagram produced results between those of the J. B. Beam DSG and the Midwest Solvents spent grains.

The replacement of 15% flour with DSG increases the dough absorption by 9% (based on flour=100%). The resulting doughs were, however, sticky and difficult to handle. The addition of 0.5% (based on flour=100%) sodium stearoyl-2-lactylate (SSL) improved the bread volume and crumb grain, but it had no effect on the dough characteristics. The addition of 10 ppm or 20 ppm of potassium bromate resulted in no significant improvement in bread quality or dough handling properties.

Replacing 15% of the flour with DSG reduced the total dough mixing time by approximately 25%. The dilution of the flour also resulted in a loss of

bread volume so that the best results were obtained, when the dough was baked in a slightly smaller pan especially designed for the production of variety bread.

Results from these experimental test bakes indicate that DSG can be used to replace up to 15% of the flour for the production of an acceptable variety bread, provided that the DSG is processed under optimum conditions for a satisfactory flavor and color development. The raw materials used for the mash bill may also affect the taste of the finished product.

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RESEARCH REPORT

PROJECT TITLE: Evaluation of Potential Food Applications
for Dried Distillers Spent Grain (DSG)

SUBTITLE: Compositional and Nutritional Aspects of DSG.

PROJECT SPONSOR: A. Smith Bowman Distillery, Inc.

Part A

Report Prepared and Submitted by:

Gur S. Ranhotra, Ph.D.
Director - Nutrition Research

Janette Gelroth
Senior Research Chemist

Franny Torrence
Research Biologist

Ann Bock

Gay Winterringer

Graduate Research Assistants

February 6, 1981

SUMMARY

A total of five DSG samples were analyzed for their compositional-nutritional values. Expressed on air-dry basis, the protein content of these samples averaged about 25% and the fiber (dietary) content about 33%. All samples were also high in ether extractable material (6.3 to 11.5%) and in ash content (over 4%). The nitrogen-free extract (starches and related compounds) represented 41.9% to 50.7% of the dry matter. About 3% of the material was represented by nucleic acid. All samples were low in sodium and yet high in a number of other nutritionally significant minerals such as potassium, phosphorus and magnesium. The content of calcium, iron, zinc, copper and chromium was also appreciable. Most B vitamins analyzed were present in amounts appreciably higher than values normally associated with whole grains. The amino acid profile was reflective of the pattern typifying whole grains. Lysine (most limiting in grains) was present in amounts ranging from 2.55g to 3.74g (on 100g protein basis). In brief, the compositional data show that the DSG samples tested are high in nutritional profile in comparison to the grains initially used in the mash bill.

OBJECTIVES

To determine the compositional-nutritional value of five different DSG samples.

MATERIALS AND METHODS

The five selected samples (Table I) were first ground to a uniform (1 mm) particle size before proceeding with the analytical work.

Protein, ash, lipid (ether extract), moisture and fiber (crude) were determined by the standard "American Association of Cereal Chemists" (AACC) methods. Dietary fiber was determined by the neutral-detergent method recently approved by the AACC. Nitrogen-free extract values were calculated by difference. The nucleic acid content was determined by degrading nucleic acid (alkali hydrolysis) to nucleotides, precipitating out protein, centrifuging to remove insoluble materials and reading the absorbance (260 nm) both total and that due to aromatic amino acids (Lowry method). By subtracting the absorbance due to amino acids from the total, the nucleic acid content is obtained.

Phosphorus was determined colorimetrically using the standard AACC method. All other minerals were determined by atomic absorption spectrophotometry. Vitamins were determined either fluorometrically - colorimetrically (thiamin, riboflavin and niacin) or microbiologically (others). Individual amino acids were determined following protein hydrolysis, by ion-exchange chromatography using "Dionex Kit Analyzer".

RESULTS AND DISCUSSION

The information (mash bill, source, etc.) on the five DSG samples tested is presented in Table I. More detailed information on these samples is given in our previously submitted reports.

The data presented in Table II indicates that corn-based samples contained about 25% protein while the protein in sample no. 5 (milo) was over 30%. The crude fiber content in these samples was 7% or better while the dietary fiber

content averages about one-third of the total weight (air-dried). All samples also contained a substantial amount of material extractable with ether; not all extractable material is lipid, however. All ether residues were highly pigmented (pigments are normal constituents of ether extracts). The ash content of samples exceeded 4% which is well above the level normally associated with whole grains. The calculated values for nitrogen-free extract ("available carbohydrates") suggest that not all of the starch (and related components) was utilized during fermentation. The yeast contributes substantially to the nucleic acid content of spent grains, brewers' or distillers'. This was amply reflected in the high nucleic acid content of samples tested.

The mineral composition (most, but not all, minerals were analyzed) of DSG samples (Table III) indicates that all samples were low in sodium and yet high in a number of other nutritionally significant minerals including potassium, phosphorus and magnesium. The milo sample (no. 5) was strikingly higher in iron in comparison to other samples. The profile of various vitamins determined suggests that DSG samples tested are good sources of these vitamins. The levels of most vitamins were appreciably higher compared to values normally associated with whole grains. Obviously, the loss of dry matter (starches used up) and the contribution from the yeast added substantially to the increases.

Table IV lists the amino acid profile of DSG samples. Lysine, the most limiting amino acid in grains, typified values normally associated with whole grains. Yeast cells might have made some contribution to the overall amino acid profile of DSG samples. The amino acid tryptophan which requires separate hydrolysis of the samples was not determined due to technical difficulties in methodology. Based on amino acid makeup, the "true" protein content of DSG samples calculated out about 6 to 11% lower. This is because nonprotein nitrogenous (NPN) compounds are excluded (are included in Kjeldahl protein determination) when "true" protein values are based on "amino acid profile". These NPN compounds include nucleic acid, certain amines, nitrites and nitrates, etc.

TABLE I
TEST SAMPLES OF DSG^a

Sample No. ^b	Source	Mash Composition (%)				Particle Size(mm)
		Corn	Rye	Barley	Milo	
2 (or A)	Seagram	93.09	5.31	1.60	--	1
3 (or B)	Seagram	95.93	3.03	1.04	--	1
4 (or C)	Seagram	98.50	1.50	--	--	1
5 (or D)	Midwest Solvent	--	--	--	100	1
8 (or E)	Jim Beam	75.0	13.0	12	--	1

^aDetailed information in previously submitted progress reports.

^bAs in previously submitted reports.

TABLE II
PROXIMATE AND NUCLEIC ACID
COMPOSITION OF DSG SAMPLES

	Sample number				
	2	3	4	5	8
Protein (N x 5.7), %	25.2	25.2	25.3	31.8	24.5
Ash, %	4.36	4.45	4.45	4.64	4.55
Ether extract, %	10.6	10.3	11.5	6.3	6.5
Moisture, %	6.80	7.13	6.64	6.85	6.76
Fiber (crude), %	7.9	7.4	7.5	8.5	7.0
Fiber (dietary), %	35.6	35.8	34.1	29.2	32.4
N-free extract ^a , %	45.14	45.52	44.61	41.91	50.69
Nucleic acid, %	3.3	3.1	3.2	3.1	3.4

^aCalculated values considering crude (not dietary) fiber.

TABLE III
MINERALS AND VITAMINS IN DSG SAMPLES

	Sample number				
	2	3	4	5	8
<u>Minerals</u>					
Sodium, %	0.06	0.13	0.06	0.12	0.03
Potassium, %	1.07	1.07	1.02	0.85	0.98
Chromium, ppm	4.62	4.48	4.50	4.74	4.43
Calcium, %	0.068	0.071	0.076	0.082	0.049
Phosphorus, %	0.82	0.85	0.89	0.79	0.86
Zinc, mg/100g	5.94	6.86	6.04	6.98	6.86
Copper, mg/100g	2.09	2.53	2.37	1.50	1.99
Magnesium, mg/100g	325	328	336	315	328
Iron, ppm	9.3	10.0	11.0	29.9	7.7
<u>Vitamins</u>					
Thiamin, mg/100g	0.19	0.19	0.18	0.60	0.61
Riboflavin, mg/100g	0.39	0.43	0.49	0.36	0.62
Niacin, mg/100g	6.66	6.57	6.62	10.37	7.17
B ₆ , mg/100g	1.20	0.97	0.90	0.75	1.05

TABLE IV
AMINO ACID COMPOSITION OF DSG SAMPLES
(g/100g Protein)^a

Amino Acid	Sample number				
	2	3	4	5	8
Aspartic acid	7.88	9.31	7.89	7.82	8.10
Threonine	4.13	4.00	3.90	3.67	4.01
Serine	5.18	5.06	5.15	4.81	5.27
Glutamic acid	17.87	16.61	16.69	18.50	18.99
Proline	7.91	6.69	7.73	7.95	8.06
Glycine	4.75	4.55	4.47	3.94	4.65
Alanine	9.83	9.53	9.91	11.83	9.77
Half cystine	1.10	1.63	1.51	0.94	1.15
Valine	2.41	2.57	2.59	2.58	2.42
Methionine	3.62	4.50	4.58	2.87	3.36
Isoleucine	1.76	1.82	1.91	1.92	1.79
Leucine	11.25	10.38	10.76	11.47	10.22
Tyrosine	4.76	4.81	4.90	4.40	4.49
Phenylalanine	5.13	6.56	5.71	6.03	5.13
Histidine	3.92	3.77	4.01	3.30	3.87
Lysine	2.55	3.42	3.74	2.50	3.27
Ammonia	2.53	2.11	1.88	2.51	2.07
Arginine	3.38	2.69	2.67	2.98	3.38
Nitrogen, %	2.95	2.98	2.52	3.43	3.15
Protein ^b , %	16.82	16.99	14.36	19.55	17.96

^aCorrected to 100% recovery protein basis.

^bTrue protein based on nitrogen in amino acids except tryptophan.

RHEOLOGICAL PROPERTIES OF DISTILLERS SPENT GRAIN

Final Report

February 6, 1981

Part B

Karel Kulp, Director
Cereal Science Research

Wulf Doerry, Group Leader
Cereal Technology

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SUMMARY:

A series of distillers spent grain (DSG) samples was investigated for rheological effects on baker's patent flour. The following conclusions were reached:

(1) Pasting properties (amylograph) of flours showed an apparent weakening when DSGs were added. This effect was attributed to both dilution and shearing action of DSG particles.

(2) Flour strength (farinograph) was generally reduced by incorporation of DSGs. This effect became more pronounced as the particle sizes were reduced.

(3) Extensigraphic data showed that DSGs had little effect on resistance to extension of dough but noticeably reduced their extensibility.

(4) DSGs were highly acidic as compared to flour and other ingredients. This condition may adversely affect their baking potential and needs further attention.

(5) Scanning electron microscopy demonstrated that DSG-particles remained discrete, embedded in mixed dough structures. They did not become part of the dough system but interrupted the network, thus reducing the dough strength.

In general, DSG seems to behave like many non-wheat type materials, e.g., fiber. Similar technological measures should be used in attempting to use DSG in bakery foods.

OBJECTIVE:

Distiller's Spent Grain (DSG) samples from three distilleries, reflecting present industrial practice in mash bill composition and operational variations, were evaluated for rheological effects on bread dough properties in order to provide guidelines for their potential applications in bakery foods.

MATERIALS AND METHODS:

Sample Description: A total of 10 DSG samples were received from Jos. E. Seagram, Lawrenceburg, IN (4 samples), Midwest Solvents Company, Inc., Atchison, KS (3 samples), and J. B. Beam Distilling Co., Clermont, KY (3 samples). Description of these samples, including mash bill and pertinent manufacturing data supplied by the distilleries are detailed in Table I.

Sample Treatment: The samples received were thoroughly blended and portions of them were milled to reduce the particle size. Sample #1 was processed with a Wiley Laboratory Mill to pass a 2mm size screen and then hammermilled (Weber Hammermill) to pass 1mm size screen. The particle sizes of all other samples were reduced to two granulations (to pass 1mm and 2mm sieves) by means of Wiley Laboratory Mill.

Particle Size Distribution: The particle sizes of original (as is) and milled samples were determined by sieving the samples through a set of U.S. standard sieves with screen opening ranging from 2.36mm to 0.18mm (Sample No. 1) or from 2.3mm to 0.18mm using Rotap (Samples No. 2 through No. 10).

Rheological Measurements:

Amylography: A Brabender Visco/Amylograph was used to study the effects of DSG on pasting properties of flours according to the conventional AACC Method No. 22-10 (American Association of Cereal Chemists, Approved Methods of AACC, 7th edition, 1962. The Association, St. Paul, MN). The control flours were untreated baker's patent flours that had been supplemented in the laboratory with diastatic barley malt to produce a normal (400-600 B.U.) hot paste peak consistency. This was done in order to keep the measurements within the range of the instrument. The DSG was added to replace 5, 10, and 20% of the control flour. Additions of DSG as well as the amounts of flours were added on the 14% moisture basis. Since some of the DSG preparations were acidic, the buffer

(pH = 5.25) was insufficient to keep the pH of flour-DSG blends at optimal pH. Consequently, the pH of suspensions of blends were adjusted to the required pH values whenever necessary.

Farinography: The AACC procedure No. 54-21 (constant flour weight) was used to determine effects of replacement of flour with DSG on dough mixing properties and stability.

Extensigraphy: Changes of rheological dough properties affected by incorporation of DSG were further studied by means of the extensigraph. Measurements were made according to the general AACC procedure (AACC Method No. 55-10), except that the instrument for Sample No. 1 was calibrated so that 500 B.U. load equaled 500g; for other samples 500 B.U. corresponded to 600 grams.

Water Holding Capacity (WHC): This determination was conducted according to AACC Method No. 88-04.

Oil Holding Capacity (OHC): The procedure was that generally used by ADM for evaluation of soy preparations. Five grams of DSG-sample was placed in a series of test tubes. Soy oil was added in 0.5g increments, mixed thoroughly, and kept for 2 hours. Then the tubes were inspected for oil separation. The OHC is the mid-point between the ratio of the maximum of oil/material (indicated by no oil separation) and that of the minimum oil/material (indicated by lowest oil separation).

Determinations of pH and Titratable Acidity (TTA): pH-values were obtained potentiometrically by AACC procedure No. 02-52. TTA was estimated as follows: 10 grams of DSG was dispersed in 100 ml water, stirred for 1 hour and titrated to end point pH = 6.6 with 0.1 N sodium hydroxide. The values are reported in ml of 0.1 N sodium hydroxide.

Scanning Electron Microscopy: Dried DSG samples were sprinkled into double-sided adhesive tape attached to specimen stubs; they were coated in vacuo with

approximately 60 Å of carbon and then 100 Å of gold-palladium. Samples were viewed with ETEC Autoscan scanning electron microscope operating at 5 KV accelerating voltage. Images were photographed on Polaroid film type 55, at a magnification of 20. The doughs made from flours and DSG were mixed to optimum consistency in a Mixograph, frozen quickly in liquid nitrogen, freeze-dried, and viewed as described above. Pictures of doughs were taken at 10 KV and magnification of 200.

RESULTS AND DISCUSSION:

Particle Size of Samples: Particle size distributions of DSG samples before and after milling are given in Tables II-IX. The objective of milling was to evaluate the effect of particle size on the rheological properties of DSG and to determine whether this treatment would be of value in improving the functionality of DSG in bakery applications. The effect on individual rheological parameters were evaluated and are given in further discussion.

Compositional and Manufacturing Variables of DSG Samples: The received samples varied in composition of the mash bill. They can be divided essentially into three groups: (a) that which contains predominantly corn and low amounts of rye and barley (Samples 1-4); (b) that which consists mainly of milo (Samples 5-7); and finally, (c) that composed of medium level of corn (75%) with appreciable amounts of rye and barley. Operational variations were only partly made available, not permitting to evaluate their influence on the DSG properties (Table I).

Amylographic Data (Tables X-XV): A flour with a hot paste peak consistency of 540-560 B.U. was used as a control and 10% and 20% of it were replaced with various types of DSG of varied degrees of granulation. These data are given in Tables X-XV for samples 1, 2, 3, 4, 6, and 9. The indices shown are peak viscosity, peak temperature and temperature of initial rise. There are two

factors involved that affect these values -- particle size of DSG and dilution effect of starch caused by the replacement of flour with DSG.

Effect of DSG Level: Generally, with increasing level of incorporation of DSG the peak viscosity was decreased, indicating that DSG does not contribute the hot paste consistency. The temperature of initial consistency rise was virtually unaltered as compared to that of control flour. However, higher temperature than that for control flour was necessary to reach maximum (peak) viscosity of the paste in the presence of DSG -- the higher level of DSG was present, the higher temperature was required (for control flour this temperature was 61°C, for blend with 10% DSG-75-80°C, and for that with 20% DSG-76-83°C).

The granulation of DSG was not linearly correlated with peak consistency. Reduction of size to pass 2mm screen tended to increase the peak consistency. Finer grinding (size to pass 1mm screen) had a depressing effect on the peak hot paste consistency. This trend suggests that fine grinding produces particles that, through shearing action, reduces the consistency of starch pastes. Thus, in manufacturing of DSG, the particle size should be optimized. Further, it should be kept in mind that in these experiments, the pH-values were adjusted to meet the requirements of the amylograph test. In actual application, the acidity of samples would further cause a reduction in paste consistency, the degree of which would depend on the buffering capacity of the system in which the DSG preparation is used and on the temperature exposure.

Farinography: Individual farinogram indices are summarized in Tables XVI-XXI and the farinograph curves are given in Figures 1-6. They were prepared with control flour, and at 5, 10, and 20% replacement levels with DSG.

Replacement of flour with DSG increased the absorption values of the blends only slightly. The maximum increases in absorption for samples 1, 2, 3, 4 (mash bill: corn/barley/low rye) were within a narrow range of 2.3-3.8%

absorption above control; for DSG derived from a milo mash bill, low absorption change of 1.1% above control was observed; high level of rye in mash bill produced an appreciable increase in this value (Sample No. 9 - increase 5.9% above control). The effect of granulation of DSG was also minor, except for Sample No. 9 where probably the rye gums became more accessible by grinding and contributed to consistency.

As far as mixing rate and stability are concerned, doughs with DSG showed increased arrival, peak and departure times; the dough stabilities and tolerances were decreased and the doughs broke down more rapidly than those of control. Briefly, incorporation of DSG weakened the dough. This effect was more pronounced when the particles were reduced by milling. Of the samples tested, most weakening was observed in No. 6 followed in descending order by 3>9>1>4, and 1 = 2 (as is series). For fine granulations, the weakening effect was in descending order 10>6>9 = 4>1 = 2.

The expected effects of DSG on baking operation are longer pick-up mixing times of doughs with DSG and reduced stability. This behavior is similar to the effect of soy flour which requires either different mixing technology and/or use of higher levels of oxidants and dough strengtheners. Further, it should be pointed out that these experiments were carried out without any adjustment of pH values of dough. Consequently, the weakening may be partly attributed to a low acidity of samples as evident from pH and titratable acidity (TTA) values of samples given in Table XXII.

Extensigraphy: Data in Tables XXIII-XXVIII show the extensigraph indices and the actual curves are shown in Figures 7-12. Changes in dough properties attributable to the use of DSG were tested at 10% replacement of DSG in flour.

The observed effects were: (a) the resistance to extension were practically unaltered by replacement of 10% DSG; (b) the dough extensibility was

substantially reduced, however, and (c) the particle size of DSG was not a factor in this effect since no appreciable differences among the extensigrams prepared with DSGs of varied particle sizes were observed.

Scanning Electron Microscopy: In Figures 13 to 16, the scanning micrographs of individual DSG samples, both in as received form and also milled to fine granulation (Wiley mill at setting to pass 1mm sieve size) are presented. It is evident that the particles in the samples are non-uniform in size at both granulations, suggesting that they shatter during processing into various sizes and shapes. This condition was also confirmed by the distribution of particle sizes given in Tables II-IX. The shapes of all samples were quite similar except for No. 6 which was derived from a mash bill containing predominantly milo. The particles of Sample No. 6 (at both granulations) were rounder and of more uniform sizes than those of the other samples.

Micrographs of doughs with and without DSG are shown in Figure 16. It is evident that the DSG particles did not become part of the dough structure. They were merely embedded, causing disruptions in the network. This effect partly contributed to the weakening of doughs.

TABLE I
SAMPLE DESCRIPTION

AIB Sample No. → Distillery ↓	1	2	3	4	5	6	7	8	9	10
24 Jos. E. Seagram, Lawrence- burg, IN: Date Received: 9/9/80 11/18/80 11/18/80 11/18/80 Production Date: - 11/10/80 11/11/80 11/12/80 Mash Bill: Corn 99% 93.09% 95.93% 98.5% Rye - 5.31% 3.03% - Barley Malt 1% 1.60% 1.04% 1.5% Fermentation Time: - 70 hrs. 74 hrs. 60 hrs. Dryer Air Temp.: in - 77°F 73°F 79°F Dryer Air Temp.: out - 180°F 175°F 165°F Evaporator: Final effect temp. - 150°F 146°F 146°F Evaporator: Final effect pressure - 22" Hg 22" Hg 22" Hg										
Midwest Solvents Co., Inc. Atchison, KS: Date Received: Production Date: Mash Bill:					11/24/80	11/24/80	11/24/80			
					11/19/80	11/20/80	11/20/80			
					Basically derived from milo crop. No other information available.					
J. B. Beam Distilling, Co. Clermont, KY: Date Received: Production Date: Mash Bill: Corn Rye Barley Malt								12/3/80	12/3/80	12/3/80
								11/24/80	11/25/80	11/26/80
								75%	75%	75%
								13%	13%	13%
								12%	12%	12%

TABLE II

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 1

Sieve Analysis (Normal)

Sieve No.	U.S. Standard Testing Sieve Screen Opening, mm	Sample Treatment		
		As Is, DSG on Screen, %	Wiley Mill, 2mm Screen Opening, DSG on Screen, %	Weber Hammermill, 1mm Round Opening, DSG on Screen, %
8	2.36	0.25	0.00	0.00
14	1.40	6.95	<0.05	0.00
20	0.85	40.60	20.65	1.45
35	0.50	32.85	50.00	71.60
60	0.25	15.05	24.95	25.50
80	0.18	2.60	3.10	0.25
thru 80	-	0.50	0.15	0.05
Loss	-	1.20	1.10	1.15
TOTAL	-	100.00	100.00	100.00
Water Holding Capacity		1.56	1.55	1.25
Oil Holding Capacity		0.65	0.65	0.65

TABLE III

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 2

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Sieve No.	Screen Opening, mm	As Is,	Wiley Mill,	Wiley Mill,
		DSG on Screen, %	2mm Screen Opening, DSG on Screen, %	1mm Round Opening, DSG on Screen, %
8	2.36	0.5	-	-
10	1.70	5.1	-	-
14	1.18	15.0	0.4	0.1
20	0.85	26.6	12.8	1.4
28	0.60	15.8	27.3	22.7
35	0.43	20.3	36.3	45.8
48	0.30	7.8	12.3	16.2
65	0.21	8.0	6.5	8.6
Through 65	<0.21		3.1	4.7
TOTAL		99.1	98.7	98.5
Water Holding Capacity		1.19	1.19	1.06
Oil Holding Capacity		0.65	0.65	0.55

TABLE IV

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 3

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Sieve No.	Screen Opening, mm	As Is, DSG on Screen, %	Wiley Mill, 2mm Screen Opening, DSG on Screen, %	Wiley Mill, 1mm Round Opening, DSG on Screen, %
8	2.36	0.9	-	-
10	1.70	7.2	-	-
14	1.18	18.3	0.4	<0.1
20	0.85	28.2	16.2	0.3
28	0.60	16.1	28.2	11.4
35	0.43	17.4	35.1	53.8
48	0.30	6.6	10.8	21.0
65	0.21	2.4	5.2	7.9
Through 65	<0.21	1.3	3.0	4.7
TOTAL		98.4	98.9	99.2
Water Holding Capacity		1.08	1.10	1.03
Oil Holding Capacity		0.65	0.75	0.65

TABLE V

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 4

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Screen Opening,		As Is,	Wiley Mill,	Wiley Mill,
Sieve No.	mm.	DSG on Screen, %	2mm Screen Opening, DSG on Screen, %	1mm Round Opening, DSG on Screen, %
8	2.36	0.4	-	-
10	1.70	5.4	-	-
14	1.18	15.7	0.5	<0.1
20	0.85	27.0	13.5	0.2
28	0.60	17.1	25.7	9.1
35	0.43	20.8	37.0	55.6
48	0.30	8.5	15.0	24.7
65	0.21	2.7	4.1	5.5
Through 65	<0.21	1.6	3.0	3.4
TOTAL		99.2	98.8	98.5
Water Holding Capacity		1.03	1.13	1.11
Oil Holding Capacity		0.75	0.75	0.65

TABLE VI

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 5

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Sieve No.	Screen Opening, mm	As Is, DSG on Screen, %	Wiley Mill, 2mm Screen Opening, DSG on Screen, %	Wiley Mill, 1mm Round Opening, DSG on Screen, %
8	2.36	-	-	-
10	1.70	0.1	-	-
14	1.18	2.6	-	-
20	0.85	12.3	-	-
28	0.60	15.6	-	-
35	0.43	33.8	-	-
48	0.30	19.5	-	-
65	0.21	9.7	-	-
Through 65	<0.21	6.0	-	-
TOTAL		99.6	-	-
Water Holding Capacity		1.3	-	-
Oil Holding Capacity		0.75	-	-

TABLE VII

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 6

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Screen Opening,		As Is,	Wiley Mill,	Wiley Mill,
Sieve No.		DSG on	2mm Screen Opening,	1mm Round Opening,
mm		Screen, %	DSG on Screen, %	DSG on Screen, %
8	2.36	-	-	-
10	1.70	1.3	-	-
14	1.18	12.5	-	-
20	0.85	30.1	-	0.5
28	0.60	22.0	-	11.5
35	0.43	21.9	-	56.6
48	0.30	6.8	-	13.2
65	0.21	2.0	-	9.8
Through 65	<0.21	1.6	-	8.0
TOTAL		99.1	-	99.6
Water Holding Capacity		0.9	-	0.9
Oil Holding Capacity		0.65	-	0.65

TABLE VIII

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 7

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Screen Opening,		As Is,	Wiley Mill,	Wiley Mill,
Sieve No.		DSG on	2mm Screen Opening,	1mm Round Opening,
mm		Screen, %	DSG on Screen, %	DSG on Screen, %
8	2.36	-	-	-
10	1.70	0.4	-	-
14	1.18	2.8	-	-
20	0.85	12.7	-	-
28	0.60	15.6	-	-
35	0.43	32.8	-	-
48	0.30	19.5	-	-
65	0.21	9.1	-	-
Through 65	<0.21	5.7	-	-
TOTAL		98.6	-	-
Water Holding Capacity		1.5	-	-
Oil Holding Capacity		0.75	-	-

TABLE IX

PARTICLE SIZE DISTRIBUTION OF DISTILLERS SPENT GRAIN (DSG)

AIB Sample No. 9

Sieve Analysis (Rotap)

U.S. Standard Testing Sieve		Sample Treatment		
Sieve No.	Screen Opening, mm	As Is, DSG on Screen, %	Wiley Mill, 2mm Screen Opening, DSG on Screen, %	Wiley Mill, 1mm Round Opening, DSG on Screen, %
8	2.36	0.6	-	-
10	1.70	4.3	-	-
14	1.18	12.8	-	<0.1
20	0.85	24.8	-	0.4
28	0.60	17.6	-	8.0
35	0.43	23.5	-	53.1
48	0.30	6.7	-	18.0
65	0.21	5.8	-	11.6
Through 65	<0.21	3.4	-	8.2
TOTAL		99.5	-	99.3
Water Holding Capacity		1.2	-	1.1
Oil Holding Capacity		0.65	-	0.65

TABLE X
AMYLOGRAPH INDICES
AIB SAMPLE NO. 1

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	540	580	540
Peak Temperature, °C	72	76	80
Temperature of Initial Viscosity Rise, °C	60	62.5	62.5
<u>II. Wiley Mill - Thru 2 mm Screen:</u>			
Peak Viscosity, B.U.	540	520	550
Peak Temperature, °C	72	76	83
Temperature of Initial Viscosity Rise, °C	60	62	62
<u>III. Weber Hammermill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	540	500	640
Peak Temperature, °C	72	77	85
Temperature of Initial Viscosity Rise, °C	60	61	61

TABLE XI
 AMYLOGRAPH INDICES
 AIB Sample No. 2

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	560	480	420
Peak Temperature, °C	75	75	79
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>II. Wiley Mill - Thru 2mm Screen:</u>			
Peak Viscosity, B.U.	560	500	410
Peak Temperature, °C	75	75	79
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>III. Wiley Mill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	560	490	430
Peak Temperature, °C	75	75	76
Temperature of Initial Viscosity Rise, °C	61	61	62.5

TABLE XII
 AMYLOGRAPH INDICES
 AIB Sample No. 3

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	560	420	420
Peak Temperature, °C	75	80	83
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>II. Wiley Mill - Thru 2mm Screen:</u>			
Peak Viscosity, B.U.	560	590	470
Peak Temperature, °C	75	77	81
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>III. Wiley Mill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	560	460	310
Peak Temperature, °C	75	79	79
Temperature of Initial Viscosity Rise, °C	61	61	61

TABLE XIII
AMYLOGRAPH INDICES
AIB Sample No. 4

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	560	420	340
Peak Temperature, °C	75	77	79
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>II. Wiley Mill - Thru 2mm Screen:</u>			
Peak Viscosity, B.U.	560	470	440
Peak Temperature, °C	75	77	80
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>III. Wiley Mill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	560	340	270
Peak Temperature, °C	75	79	80.5
Temperature of Initial Viscosity Rise, °C	61	61	62.5

TABLE XIV
AMYLOGRAPH INDICES
AIB Sample No. 6

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	560	330	318
Peak Temperature, °C	75	79	82
Temperature of Initial Viscosity Rise, °C	61	61	62.5
<u>II. Wiley Mill - Thru 2mm Screen:</u>			
Peak Viscosity, B.U.			
Peak Temperature, °C			
Temperature of Initial Viscosity Rise, °C			
<u>III. Wiley Mill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	560	318	300
Peak Temperature, °C	75	79	79
Temperature of Initial Viscosity Rise, °C	61	61	61

TABLE XV
 AMYLOGRAPH INDICES
 AIB Sample No. 9

DSG Treatment	DSG Replacement Level, %		
	0	10	20
<u>I. Particle Size As Is:</u>			
Peak Viscosity, B.U.	560	380	360
Peak Temperature, °C	75	77	80
Temperature of Initial Viscosity Rise, °C	61	61	61
<u>II. Wiley Mill - Thru 2mm Screen:</u>			
Peak Viscosity, B.U.			
Peak Temperature, °C			
Temperature of Initial Viscosity Rise, °C			
<u>III. Wiley Mill - Thru 1 mm Screen:</u>			
Peak Viscosity, B.U.	560	350	280
Peak Temperature, °C	75	79	79
Temperature of Initial Viscosity Rise, °C	61	61	61

TABLE XVI
FARINOGRAM INDICES
AIB Sample No. 1

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min.	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	57.0	-	1.5	6.5	35.0	33.5	20	36
<u>As Is:</u>								
5% DSG	58.4	85	2.0	7.0	12.0	10.0	35	11.5
10% DSG	59.0	77	3.5	6.0	11.5	8.0	40	12.0
20% DSG	60.5	74.5	5.0	6.5	9.0	4.0	50	8.5
<u>Wiley Milled (2mm):</u>								
5% DSG	58.3	83	2.0	6.5	12.5	10.5	40	12.5
10% DSG	59.2	79	3.0	6.0	10.0	7.0	45	10.5
20% DSG	61.0	77	4.5	6.0	8.0	3.5	80	8.0
<u>Hammermilled (1mm):</u>								
5% DSG	58.2	81	2.0	6.5	12.0	10.0	40	10.5
10% DSG	59.0	77	3.5	6.0	9.0	5.5	60	9.0
20% DSG	60.8	76	3.5	5.5	7.5	4.0	85	7.0

TABLE XVII
FARINOGRAM INDICES*
AIB Sample No. 2

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min.	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	57.0	-	1.5	6.5	35.0	33.5	20	36.0
<u>As Is:</u>								
5% DSG	57.3	63.0	2.0	7.0	10.5	8.5	30	12.0
10% DSG	57.9	66.0	4.0	6.0	9.0	5.0	40	12.0
20% DSG	58.6	65.0	5.0	6.0	8.5	3.5	50	9.0
<u>Wiley Milled (2mm):</u>								
5% DSG	58.0	77.0	2.0	6.0	9.5	7.5	50	10.0
10% DSG	58.6	73.0	4.5	6.0	8.5	4.0	55	9.0
20% DSG	60.1	72.5	4.5	6.0	6.5	2.0	90	8.0
<u>Wiley Milled (1mm):</u>								
5% DSG	57.9	75.0	2.5	6.0	9.5	7.0	50	9.5
10% DSG	58.6	73.0	4.0	5.5	7.5	3.5	60	8.0
20% DSG	60.1	72.5	4.5	5.5	7.5	3.0	80	7.5

TABLE XVIII
FARINOGRAM INDICES
AIB Sample No. 3

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min. .	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	57.0	-	1.5	6.5	35.0	33.5	20	36.0
<u>As Is:</u>								
5% DSG	57.5	67.0	3.0	6.5	10.0	7.0	40	10.5
10% DSG	57.8	65.0	4.0	6.5	9.0	5.0	60	10.0
20% DSG	58.7	65.5	4.0	6.5	8.5	4.5	75	8.5
<u>Wiley Milled (2mm):</u>								
5% DSG	58.2	81.0	3.5	6.0	9.0	6.5	50	9.0
10% DSG	58.8	75.0	4.0	5.5	7.5	3.5	70	7.5
20% DSG	60.1	72.5	5.0	6.0	8.0	3.0	90	7.5
<u>Wiley Milled (1mm):</u>								
5% DSG	59.9	115.0	1.5	5.5	9.0	7.5	50	9.0
10% DSG	60.0	87.0	3.0	5.0	8.0	5.0	70	7.5
20% DSG	61.6	80.0	4.0	5.5	7.0	3.0	100	7.0

TABLE XIX
FARINOGRAM INDICES
AIB Sample No. 4

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min.	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	59.5	-	2.0	18.5	38.0	36.0	20	38.5
<u>As Is:</u>								
5% DSG	59.8	65.5	2.5	7.0	12.0	9.5	45	11.5
10% DSG	59.9	63.5	4.0	5.5	10.0	6.0	50	10.0
20% DSG	60.7	65.5	5.0	6.6	9.0	4.0	60	9.0
<u>Wiley Milled (2mm):</u>								
5% DSG	60.0	69.5	3.5	7.0	11.0	7.5	50	10.0
10% DSG	60.0	64.5	4.5	5.5	8.5	4.0	65	7.5
20% DSG	62.0	72.0	4.5	6.0	8.0	3.5	90	8.0
<u>Wiley Milled (1mm):</u>								
5% DSG	60.2	73.5	2.5	6.0	10.5	8.0	60	9.5
10% DSG	60.6	70.5	3.5	5.5	8.0	4.5	70	8.0
20% DSG	61.8	71.0	4.0	6.0	8.0	4.0	85	8.0

TABLE XX
FARINOGRAM INDICES
AIB Sample No. 6

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min.	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	59.5	-	2.0	18.5	38.0	36.0	20	38.5
<u>As Is:</u>								
5% DSG	59.4	57.5	3.5	7.0	11.5	8.0	60	10.0
10% DSG	59.3	57.5	4.5	6.0	9.5	5.0	65	9.0
20% DSG	60	62.5	5.0	7.0	9.5	4.5	85	9.0
<u>Wiley Milled (2mm):</u>								
5% DSG	-	-	-	-	-	-	-	-
10% DSG	-	-	-	-	-	-	-	-
20% DSG	-	-	-	-	-	-	-	-
<u>Wiley Milled (1mm):</u>								
5% DSG	59.6	61.5	2.0	6.0	9.5	7.5	65	8.0
10% DSG	59.7	61.5	3.0	5.5	8.5	5.5	80	7.5
20% DSG	60.6	65.0	4.0	6.0	8.5	4.5	90	8.0

TABLE XXI
 FARINOGRAM INDICES
 AIB Sample No. 9

DSG Replace- ment Level	Absorption, %	Absorption by DSG, %	Arrival Time, min.	Peak Time, min.	Departure Time, min.	Stability, min.	Tolerance B.U.	Time to Breakdown min.
<u>Control Flour</u>	59.5	-	2.0	13.5	33.0	36.0	20	38.5
<u>As Is:</u>								
5% DSG	60.4	77.5	3.0	7.5	13.5	10.5	40	12.5
10% DSG	61.2	76.5	4.5	7.0	11.5	7.0	50	11.0
20% DSG	64.2	83.0	6.0	7.5	10.0	4.0	70	10.0
<u>Wiley Milled (2mm):</u>								
5% DSG	-	-	-	-	-	-	-	-
10% DSG	-	-	-	-	-	-	-	-
20% DSG	-	-	-	-	-	-	-	-
<u>Wiley Milled (1mm):</u>								
5% DSG	60.9	87.5	3.0	6.5	11.5	8.5	40	11.5
10% DSG	62.0	84.5	3.5	6.0	10.0	6.5	55	9.0
20% DSG	65.4	89.0	4.5	6.5	8.5	4.0	85	8.5

TABLE XXII

pH AND TITRATABLE ACIDITY (TTA) OF DSG SAMPLES

DSG-AIB No.	pH	TTA,
		ml of 0.1 N NaOH
1	4.26	36.5
2	4.02	47.0
3	3.84	53.5
4	4.00	54.5
5	4.20	42.0
6	4.12	47.0
7	4.14	40.0
8	4.10	40.0
9	4.07	41.0
10	4.00	42.5

TABLE XXIII
EXTENSIGRAPH INDICES
AIB Sample No. 1

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	579	22.8	834	18.6	870	17.1
<u>DSG As Is:</u>						
5%	610	20.5	822	13.8	943	12.7
10%	586	17.9	909	11.2	952	10.4
20%	458	16.3	868	9.4	769	8.0
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	628	20.0	850	13.4	952	12.2
10%	632	17.4	943	12.2	1002	10.8
20%	540	14.8	909	8.6	962	8.4
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	610	20.5	822	13.8	943	12.7
10%	586	17.9	909	11.2	952	10.4
20%	458	16.3	868	9.4	769	8.0

TABLE XXIV
EXTENSIGRAPH INDICES
AIB Sample No. 2

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	690	20.1	1028	15.0	1077	12.8
<u>DSG As Is:</u>						
5%	-	-	-	-	-	-
10%	654	18.0	997	10.3	1111	9.2
20%	-	-	-	-	-	-
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	630	17.8	1056	10.1	1170	9.0
20%	-	-	-	-	-	-
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	718	15.5	1081	10.0	1133	9.1
20%	-	-	-	-	-	-

TABLE XXV
EXTENSIGRAPH INDICES
AIB Sample No. 3

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	690	20.1	1028	15.0	1077	12.8
<u>DSG As Is:</u>						
5%	-	-	-	-	-	-
10%	732	16.4	1233	9.6	1206	8.3
20%	-	-	-	-	-	-
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	746	16.4	1190	9.6	1218	8.5
20%	-	-	-	-	-	-
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	736	16.6	1203	10.0	1170	9.4
20%	-	-	-	-	-	-

TABLE XXVI
EXTENSIGRAPH INDICES
AIB Sample No. 4

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	690	20.1	1028	15.0	1077	12.8
<u>DSG As Is:</u>						
5%	-	-	-	-	-	-
10%	764	16.0	1198	9.8	1177	9.0
20%	-	-	-	-	-	-
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	691	18.2	1126	9.4	1157	8.3
20%	-	-	-	-	-	-
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	686	17.4	1145	9.8	1224	9.1
20%	-	-	-	-	-	-

TABLE XXVII
EXTENSIGRAPH INDICES
AIB Sample No. 6

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	690	20.1	1028	15.0	1077	12.8
<u>DSG As Is:</u>						
5%	-	-	-	-	-	-
10%	593	13.6	1018	9.8	1134	8.6
20%	-	-	-	-	-	-
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	-	-	-	-	-	-
20%	-	-	-	-	-	-
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	646	18.1	1117	10.3	1171	8.9
20%	-	-	-	-	-	-

TABLE XXVIII
EXTENSIGRAPH INDICES
AIB Sample No. 9

DSG Replacement Level, %	Rest Period, min.					
	45		90		135	
	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm	Resistance To Extension, B.U.	Extensibility, mm
0 (Control Flour)	690	20.1	1028	15.0	1077	12.8
<u>DSG As Is:</u>						
5%	-	-	-	-	-	-
10%	634	16.6	1010	9.5	1107	7.9
20%	-	-	-	-	-	-
<u>Wiley Mill (2mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	-	-	-	-	-	-
20%	-	-	-	-	-	-
<u>Wiley Mill (1mm Screen Opening):</u>						
5%	-	-	-	-	-	-
10%	630	16.4	952	9.5	1082	8.8
20%	-	-	-	-	-	-

Figure 1-A

Flour Replacement by Distiller's Spent Grain (Original Particle Size) Sample No. 1

Figure 1-B

Flour Replacement by Distiller's Spent Grain

(Wiley Laboratory Mill-thru 2mm screen) Sample No. 1

Flour Replacement by Distiller's Spent Grain (Weber Hammer Mill-thru 1mm screen) Sample No. 1

Figure 2-A

Flour Replacement by
Distiller's Spent Grain

DSG Sample No.2 (Original Particle Size)

Figure 2-B

Flour Replacement by
Distiller's Spent Grain

DSG Sample No.2 (Wiley Laboratory Mill-thru 2mm screen)

Figure 2-C

Flour Replacement by Distiller's Spent Grain

DSG Sample No.2 (Wiley Laboratory Mill -thru 1mm screen)

Figure 3-A

Flour Replacement by Distiller's Spent Grain

DSG Sample No.3 (Original Particle Size)

Figure 3-B

Flour Replacement by Distiller's Spent Grain

DSG Sample No.3 (Wiley Laboratory Mill-thru 2mm screen)

Figure 3-C

Flour Replacement by Distiller's Spent Grain

DSG Sample No.3 (Wiley Laboratory Mill -thru 1mm screen)

Figure 4-A

Flour Replacement by Distiller's Spent Grain

DSG Sample No.4 (Original Particle Size)

Figure 4-B

Flour Replacement by Distiller's Spent Grain

DSG Sample No.4 (Wiley Laboratory Mill-thru 2mm screen)

Figure 4-C

Flour Replacement by Distiller's Spent Grain

DSG Sample No.4 (Wiley Laboratory Mill-thru 1mm screen)

Figure 5-A

Flour Replacement by Distiller's Spent Grain

DSG Sample No.6 (Original Particle Size)

Figure 5-B

Flour Replacement by Distiller's Spent Grain

DSG Sample No.6 (Wiley Laboratory Mill -thru 1mm screen)

Figure 6-A

Flour Replacement by Distiller's Spent Grain

DSG Sample No.9 (Original Particle Size)

Figure 6-B

Flour Replacement by
Distiller's Spent Grain

DSG Sample No.9 (Wiley Laboratory Mill - thru 1mm screen)

FIGURE 7

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FIGURE 8

FIGURE 9,

FIGURE 10

FIGURE 11

FIGURE 12

FIGURE 13

AIB Sample No. 1 (as is).

AIB Sample No. 1 (Hammermilled, 1 mm opening).

AIB Sample No. 2 (as is).

AIB Sample No. 2 (Wiley Laboratory Milled, 1 mm opening).

FIGURE 14

AIB Sample No. 3 (as is).

AIB Sample No. 3 (Wiley Laboratory Milled, 1 mm opening).

AIB Sample No. 4 (as is).

AIB Sample No. 4 (Wiley Laboratory Milled, 1 mm opening).

FIGURE 15

AIB Sample No. 6 (as is).

AIB Sample No. 6 (Wiley Laboratory Milled, 1 mm opening).

AIB Sample No. 9 (as is).

AIB Sample No. 9 (Wiley Laboratory Milled, 1 mm opening).

FIGURE 16

Control Dough: 100% flour.

Dough: 10% AIB sample #2 (as is)
and 90% flour.

Dough: 10% AIB sample #2 (Wiley
Laboratory Milled, 1mm
opening) and 90% flour.

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BAKING PERFORMANCE OF DISTILLERS SPENT GRAIN

Final Report

February 6, 1981

Part C

Patrick Dreese, Cereal Chemist

BAKING PERFORMANCE OF DISTILLERS SPENT GRAINS

Introduction

Before a high quality baked product containing distillers spent grain (DSG) can be developed, it is necessary to have knowledge of the functional properties of DSG in a baking system. The following studies have been done in order to identify beneficial functional properties of DSG and also problems which may arise when DSG is put in baked products.

Materials and Methods

Distillers Spent Grain. Three samples of DSG which had been milled through a 1 mm screen were studied. Identifying information for the three samples is given in Table I.

Bread Formula and Procedure. See Table II.

Bread Pans. A white bread pan with measurements of 10" X 4-1/2" X 2-3/4" (length X width X depth) and a variety bread pan with dimensions of 9" X 4-1/2" X 3" (length X width X depth) were used.

Experimental Variables. Water absorption, potassium bromate, bread pan size, and sodium stearoyl-2-lactylate (SSL) added were all varied.

Results and Discussion

Two doughs were made for each of the distillers spent grain (DSG) samples. In one dough, the DSG was added to the sponge; in the other, the DSG was added to the dough. The dough absorption was 71% and all loaves were baked in white bread pans. No bromate or SSL was used.

All of the DSG doughs were sticky and weak and hard to handle. The top surface of the DSG loaves was somewhat collapsed in all cases, indicating that the doughs were too weak to bridge the surface area of the white bread pan.

It was decided to use the variety bread pans for all subsequent DSG baking. The variety bread pans were shorter and deeper than the white bread pans and give the dough more support during proofing and baking.

For all three spent grain samples, adding the DSG to the dough gave a better grain and higher volume than did adding the DSG to the sponge.

AIB #9 was baked at four levels of water absorption (65, 67, 69, and 71%) and three levels of potassium bromate (0, 10, and 20 ppm). The loaf volume data from these bakes are shown in Table III.

The doughs with the lower absorptions were only slightly stronger and easier to handle than the doughs with 71% absorption. The 71% absorption produced the bread with the best crumb grain (based on subjective evaluation) and largest loaf volume. This is 9% higher than the absorption of the flour without DSG. Final bread moistures were not determined, but it is probable that the DSG bread has a higher moisture than other variety breads, which would be economically advantageous.

Adding bromate had essentially no effect on the DSG bread. An absorption of 71% and no bromate was determined to be optimum for baking AIB #9.

The effect of sodium stearoyl-2-lactylate (SSL) on dough properties and bread quality was evaluated by baking samples with zero or 0.5% flour basis of SSL. The loaf volume data for these bakes are shown in Table IV. The SSL improved loaf volume and crumb grain with all three DSG samples.

Bread flavor, bread color, and dough mixing time were all profoundly affected by the DSG.

Dough mixing time was decreased by 25% when 15% of the flour was replaced by DSG. This decrease in mixing time was the same for all three DSG samples tested and could be a significant beneficial function for commercial baking of DSG. The component of the DSG which decreases mix time and the mechanism by

which it does so are not known. More research is needed to identify the mix time reducing component of DSG and assure that this beneficial function is used to its fullest advantage.

Bread color was made darker by all the DSG samples tested, but there was considerable variation between the three samples. AIB #9 gave a light yellowish brown crumb color. AIB #4 gave a much darker brown and less yellowish crumb color. The darkest color was given by AIB #6 which produced a crumb as dark or darker than pumpernickel. Variety breads are not intended to be white, but it was thought that the lighter color of AIB #9 would probably be preferable to most consumers.

All the DSG breads had a strong sour flavor. The intensity of this flavor varied between the samples in the same manner as crumb color darkness. AIB #6 had the strongest flavor and AIB #9 was the most bland. The flavor of AIB #6 and AIB #4 was judged too strong to be acceptable. The flavor of AIB #9 was quite strong but would probably be acceptable in some instances.

The extreme variation in crumb color and flavor given by the three DSG samples is an indication that the processing of the DSG will be important to its breadmaking qualities.

Conclusions

Distillers spent grain has been shown to increase water absorption and decrease mixing time when used to replace flour in a bread formula. With the use of SGL, proper water absorption, and properly sized loaf pans, it is possible to produce bread with loaf volume and crumb grain acceptable for variety breads.

There are two major disadvantages to the baking of DSG which can be seen at this time. They are: bread flavor and dough handling. The DSG doughs were all sticky and difficult to handle. The flavors of two of the DSG samples

tested were judged too strong to be acceptable and that of the third sample (#9) was strong enough to limit its market. It is possible that these two problems could be worked out with further research.

Summary

Three commercially obtained samples of distillers spent grain (DSG) were used to replace 15% of the flour from a bread formula. The DSG was shown to increase water absorption by 9% and to decrease mix time by 25%. The quality of DSG bread was not affected by potassium bromate but was greatly improved by the addition of SSL. The DSG gave bread a dark color and a strong sour flavor. The intensities of the flavor and color were considerably different for the three samples tested, which indicates that processing methods are important to the breadmaking quality of DSG. Bread dough was made sticky and weak by the inclusion of DSG and this, along with the strong sour flavor, may present obstacles to its use in breadmaking.

TABLE I
IDENTIFICATION OF DISTILLERS SPENT GRAIN SAMPLES

AIB Sample No.	Supplier Company	Plant	Mash Bill, %			
			Milo	Corn	Rye	Barley Malt
4	J. E. Seagram	Lawrenceburg, IN	-	98.50	-	1.50
6	Midwest Solvents	Atchison, KS	Predominantly	-	-	-
9	J. B. Beam	Clermont, KY	-	75	13	12

TABLE II
SPONGE AND DOUGH FORMULA AND PROCEDURE

<u>Sponge:</u>	<u>Bakers %</u>
Flour	70
Water	45
Instant Yeast	0.9
 <u>Dough:</u>	
Flour	15
Distillers Spent Grain	15
Water	Experimental Variable
Sugar (Sucrose)	6
Nonfat Dry Milk	4
Salt	2
Shortening	3
Sodium Stearoyl-2-Lactylate	Experimental Variable
Potassium Bromate	Experimental Variable

Scaling Weight: 18½ oz.

Sponge Fermentation: 3½ hrs. at 88°F.

Dough Fermentation: 20 minutes at 88°F.

Intermediate Proof: 10 minutes at 77°F.

Final Proof: To template at 100°F. (5/8" above top edge of pan).

Bake: 25 minutes at 430°F.

TABLE III

THE EFFECT OF BROMATE AND WATER LEVEL ON
LOAF VOLUMES OF DISTILLERS SPENT GRAIN BREAD
AIB #9

Water (% f.b.)	Loaf Volume (cc)		
	Bromate (ppm)		
	0	10	20
65	1837	1712	1625
67	1825	1850	1812
69	1937	2000	1912
71	2037	1925	2025

All loaves were baked in variety bread pans.

All data are averages of duplicate loaves.

TABLE IV

EFFECT OF DISTILLERS SPENT GRAIN TYPE AND
SODIUM STEAROYL-2-LACTYLATE ON LOAF VOLUMES
OF DISTILLERS SPENT GRAIN BREAD

DSG	Loaf Volumes	
	No SSL	0.5% SSL
AIB #9	2000	2225
AIB #4	2075	2150
AIB #6	2075	2175

All dough absorptions were 71%.

All loaves were baked in variety bread pans.

All data are averages of duplicate loaves.

CONCLUSION

The study of 10 samples of distillers spent grain (DSG) submitted by three producers revealed significant nutritional and functional differences between them. Some of these differences may be a consequence of the mash bill, others may have been caused by processing conditions. Because very little information about the latter has been provided with the samples, it is impossible to establish a cause-effect relationship between these variables. Therefore, many questions remain to be answered, before the differences found between these samples can be explained and accepted for real.

The milo-derived DSG (AIB Sample No. 5) contained approximately three times as much iron as the other three samples. What is the source of this iron? Was it the grain or was it the processing which introduced the iron? Is this iron in such a state that it can be absorbed by a body through metabolism?

The relatively high level of riboflavin in Sample No. 8 can be explained with the high barley malt level in the mash bill. But what contributed to the large difference in the thiamin content between the samples from Seagram and those from Midwest Solvents and J. B. Beam? The same question may be asked with respect to the ether extractable matter. Do all distillers prepare the corn in the same manner? Do some recover the corn oil while others do not?

With respect to the functional properties of DSG, we must still respond to the question of how much the acidity of the spent grains contributed to the rheological properties of the doughs made from a DSG-flour blend. Can the physical shape of the grain particles be modified by milling so that they may have a lesser detrimental effect on the extensibility of the dough? What is causing a reduced mixing time for the bread dough while the farinogram indicates that the doughs made from a DSG-flour blend need more time for mixing? What is the reason that the crumb of bread made with Sample No. 8 (75% corn) appears to

be yellow, while Sample No. 4 (98.5% corn) produces a brown crumb? Can the acidity of the DSG be modified before or during the drying process to yield a more acceptable taste of the product? How do the drying conditions affect the color and flavor of the DSG?

These are all questions which must be answered before distillers spent grains can be manufactured for food consumption on a continuous basis. But to obtain the necessary information for these answers, DSG samples must be prepared and collected under controlled conditions by a person who is knowledgeable of the purpose for these samples. Future work with DSG must be confined to product with a potential for human consumption and which is representative of DSG obtained as a by-product from the manufacture of anhydrous alcohol for gasohol.

We are confident that considerable quantities of DSG can be utilized in baked foods if it is manufactured under optimum conditions which may or may not include further processing to modify the acidity and physical shape of the spent grains. Distillers spent grains are nutritious and should be positioned on the market as such rather than as a cheap available by-product to increase the industry's profits.

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American Institute of Baking

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