Milling Properties of Sorghum Grain with Different Proportions of Corneous to Floury Endosperm[1]

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ABSTRACT

A laboratory grit-milling procedure was evaluated and used to assess the milling performance of grain from several different types of sorghum selected from the world collection. These sorghums had grain with varying proportions of corneous to floury endosperm, ranging from all corneous to all floury. The most efficient milling and highest quality grits were obtained when the grain was milled for 2 min. The proportion of corneous to floury endosperm in sorghum-grain kernels influences milling yields and grit composition. The varieties with corneous endosperm gave the highest yield of grits with the lowest ash and lipid content. Sorghum kernels with all floury endosperm shattered during milling and gave low yields of endosperm fragments which were high in ash. Grit yields were highly related to endosperm texture rating, hardness, and density. Prediction equations were calculated and offer the potential of being used by plant breeders to predict the milling performance of sorghum grains and therefore aid in the selection of breeding lines.

Several techniques have been used to study the milling properties of sorghum grain. These include abrasive milling, break milling, pin milling, or a combination of

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these techniques. A Buhler laboratory flour mill has been used to produce flour from grits (1) and whole grain (2). Anderson et al. (2) used a barley pearler and rice hullers for debranning sorghum and an Alpine Kollaplex pin mill or NU experimental brush degerminator to release germ from endosperm. The pin mill was also used to impact tempered whole grain to produce endosperm, germ, and bran. These techniques require relatively large samples and are capable of producing grits and flour with acceptable low levels of ash and fat. These methods have been used to determine milling properties of commercial sorghum grains and to compare milling methods, but, because of the large sample required, are not useful in evaluating the milling properties of numerous grain samples, such as those from a breeding project.

The milling properties of sorghum grain can be significantly improved by breeding and selecting for better milling characteristics. A wide array of genetic potential is available for use in a breeding program because 8 to 10,000 sorghum lines have been collected from throughout the world (3). Grains from these lines vary significantly in kernel characteristics and probably vary greatly in milling properties. Rooney and Sullins (4) described a laboratory grit-milling procedure which requires small samples of grain.

The purpose of the experiments described in this paper was to evaluate the laboratory grit-milling procedure and to use it to determine the relative milling performance of the various types of sorghum and the relationship between milling performance and easily measured physical properties of the grain. The experiments were divided into initial (phase A) and secondary (phase B) efforts.

The objectives of phase A were: 1) to evaluate the milling properties of different sorghum types for yield of product, ease of fraction separation, and composition of the fractions; 2) to test the influence of milling time on the milling performance of different grains; and 3) to obtain information on the relation between milling performance and easily measured physical tests on the grain.

In phase B, sorghum lines which were similar in kernel size, shape, and color, but which varied from all corneous to all floury endosperm proportions were selected to provide more reliable information and hence confirmation of the data obtained in phase A.

METHODS AND MATERIALS

Samples

In phase A, 11 varieties of sorghum were grown at the Texas A & M University Research and Extension Center, Lubbock, in 1967. These samples represented a range of kernel color, hardness, and endosperm type (Table I), and were used to study the effect of milling time and physical properties of the grain on milling performance.

In phase B, seven sorghum varieties which produce grain of similar kernel size, shape, and pigmentation, but which varied from all corneousto all floury endosperm characteristics, were selected (Table II, Fig. 1). Grain from all seven varieties was produced under comparable conditions at the South Plains Research and Extension Center, Lubbock, in 1968.

TABLE I. DESCRIPTION OF 11 VARIETIES OF SORGHUM STUDIED IN PHASE A

Variety	Endosperm		Pericarp	
	Texture Rating	Description	Color	Thickness
NSA 740	5	All floury	White	Thick
SC 84-6	5	All floury	Brown	Thick
Tx 09	4	Regular	White	Thick
7078	3	Regular	Red	Thick
Tx 2538	3	Yellow	White	Thick
B 398 (Martin)	2	Regular	Red	Intermediate
DeKalb hybrid G 600	2	Yellow	White	Thin
Tx 2536	2	Yellow	White	Thin
SC 303-6	1	Corneous	White	Thin
SC 283-6	1	Corneous	White	Thin
SC 283-6	1	Corneous	Red	Thin

TABLE II. DESCRIPTION OF SEVEN VARIETIES OF SORGHUM STUDIED IN PHASE B

Variety	Endosperm		Pericarp	
	Texture Rating	Description	Color	Thickness
NSA 740	5	All floury	White	Thick
Tx 09	4	Floury	White	Thick
DeKalb hybrid C42Y	3	Intermediate	White	Intermediate
B 3197	3	Intermediate	White	Intermediate
SC 110	3	Intermediate	White	Thin
SC 170	2	Corneous	White	Thin
SC 283	1	All corneous	White	Thin

Endosperm Texture Rating

Endosperm texture is a subjective rating based upon visual estimation of the following proportions of corneous and floury endosperm.

Endosperm Texture Rating	*Proportion of Endosperm*	
	Corneous	*Floury*
1	1	0
2	0.75	0.25
3	0.5	0.5
4	0.25	0.75
5	0	1

To arrive at a rating, longitudinal sections of several kernels were observed. Longitudinal sections of sorghum kernels studied in phase B and their corresponding endosperm textures are presented in Fig. 1.

Hardness

Hardness values are determined by milling 50 g. sorghum grain for 2 min. in a Strong-Scott laboratory barley pearler. The milled grain is sieved through a U.S. No. 12 screen on a Tyler Rotap for 3 min. Hardness is expressed as the percent No. 12 overs.

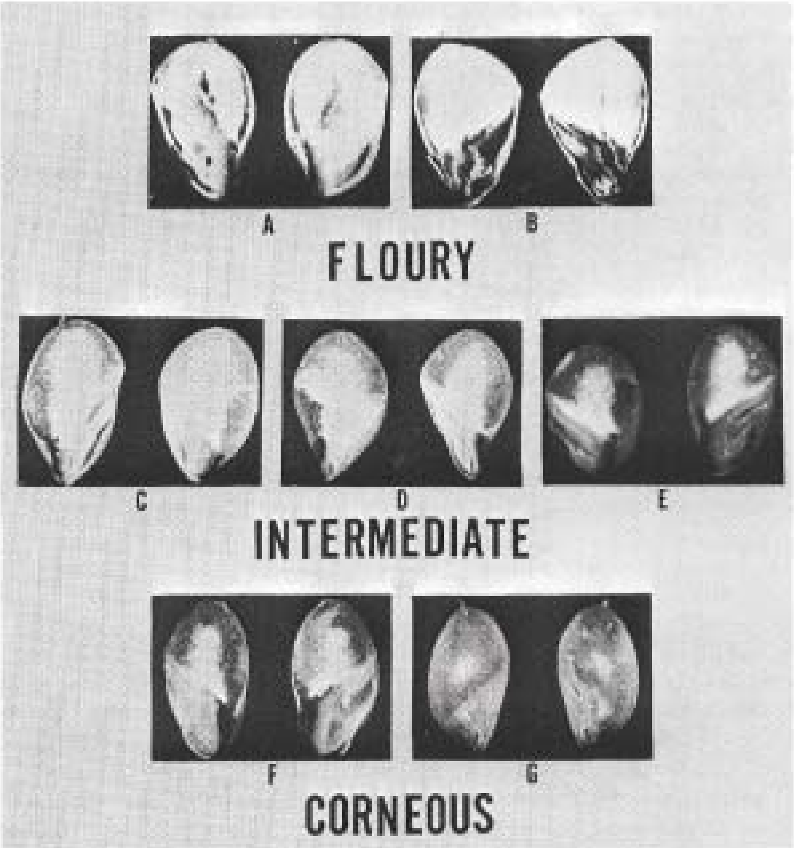

Fig. 1. Mean longitudinal sections of seven varieties of grain sorghum studied in phase B showing variation in endosperm texture. NSA 740, Tx 09, B 3197, DeKalb hybrid C42Y, SC 110, SC 170, and SC 283, respectively, a through g. Endosperm texture ratings are 5, 4, 3, 3, 3, 2, 1, respectively, a through g.

Kernel Size Index

Kernel Size Index (KSI) (5) is determined by sieving 200 g. of grain on U.S. Nos. 5, 6, 7, and 8 Tyler screens for 3 min. on a Tyler Rotap. KSI is calculated as follows:

$$[(>\text{No. }5)(0.5) + (>\text{No. }6)(0.6) + (>\text{No. }7)(0.7) + (>\text{No. }8)(0.8)]/2$$

A larger KSI number means that the average kernel size is smaller.

Test Weight

Macro test weights were determined with a Winchester Bushel meter. Micro test weights were determined by the method of Gilmore[3] which employs a copper

[3]Gilmore, E. Unpublished data.

kettle (1.5 in. diameter and 2.75 in. deep). The sample is poured through a plastic funnel (spout = 11/16 in. I.D.) 2 in. above the kettle. The excess grain is removed in the same manner as for macro test weight. The contents of the kettle are weighed in grams and read as lb. per bu. (i.e., 58 g. = 58 lb. per bu.).

Density

A Beckman model 930 air pycnometer was used to determine the density of grain from each variety.

Proximate Analysis

Petroleum ether extract, ash, and protein (N X 6.25) were determined by AACC procedures (6). Starch determinations were achieved by an enzymatic method developed by Norris and Rooney (7).

Experimental Grit Milling

The procedure of Rooney and Sullins (4) was used for grit production. All varieties were subjected to both 1.5- and 2-min. milling times. The term 'fines' is used in this paper to refer to the No. 30 throughs. Sodium nitrate solution (s.g. 1.34) was used to separate the germ and fine grits from the combined germ-rich grits fractions of five replicates for each of the seven varieties used in phase B studies.

Experimental Flour Milling

Sorghum samples were milled with a Brabender Quadrumat Sr. mill. Two 1,000-g. replicates were tempered to 16% moisture and milled into bran, shorts, and flour fractions. The Quadrumat Sr. mill yields a high percentage of shorts when sorghum is milled; therefore, the shorts were remilled with a Brabender Quadrumat Jr. mill. The stock was sifted through U.S. Nos. 60-, 70-, and 80-mesh Tyler screens for 3 min. on a Tyler Rotap. The No. 60 overs were added to the bran fraction and the No. 80 throughs were added to the flour fraction. The Nos. 70 and 80 overs were remilled through the Quadrumat Jr. mill. The No. 80 throughs were added to the flour and the Nos. 70 and 80 overs were added to the bran fraction.

RESULTS AND DISCUSSION

Grit-Milling Performance

The yield and composition of the grits obtained from grain of the varieties studied in phase A are presented in Table III (1.5-min. milling) and Table IV (2-min. milling). High yields of coarse and fine grits for the corneous varieties and Martin indicate the superiority of these varieties for grit milling. The low fat content of the grits indicates that the fractions were easily separated to produce a grit of high quality.

The grit yields of grain from varieties with floury endosperm were low, indicating that these varieties have inferior milling properties. The high fat values of the grits indicate that the fractions are difficult to separate and that the small quantity of grits produced is of poor quality. The high yields of germ-rich grits and fines obtained from these varieties are further evidence that fraction separation is difficult.

Grain from the other varieties studied in phase A performed intermediately in

TABLE III. MEAN MILLING AND CHEMICAL COMPOSITION DATA OF GRAIN FROM 11 SORGHUM VARIETIES STUDIED IN PHASE A MILLED FOR 1.5 MIN.[a]

Variety	Endosperm Texture Rating	Coarse Grits[b] %	Germ-Rich Grits[b] %	Coarse and Fine Grits[b] %	Fines[b] %	Coarse and Fine Grits: Protein[c] %	Coarse and Fine Grits: Ether extract[c] %
NSA 740	5	2.1g	24.3c	42.9f	28.3ab	16.7	1.30
SC 84-6	5	0.2g	36.6a	31.1g	31.0a	13.6	1.50
Tx 09	4	19.0f	31.0b	43.9f	23.0c	13.2	0.44
7078	3	40.2e	11.4d	65.4d	18.9d	11.6	0.91
Tx 2538	3	40.2e	11.2d	57.4e	26.5b	14.5	0.25
B 398 (Martin)	2	64.1b	2.4f	76.1b	18.4d	13.7	0.38
De Kalb hybrid G 600	2	51.0d	5.9e	71.9c	20.4cd	10.5	0.61
Tx 2536	2	49.1d	6.1e	71.8c	19.2d	11.2	0.51
SC 303-6	1	58.2c	4.2e	78.8b	14.9e	12.2	0.33
SC 283-6, white	1	76.4a	2.8f	81.2ab	13.9e	12.4	0.20
SC 283-6, red	1	79.3a	1.3f	83.4a	13.2e	12.4	0.33

[a]Values with the same letters are not significantly different at the 5% level.

[b]As-is moisture basis.

[c]Calculated from yield and protein values of coarse and fine grits and reported on dry-weight basis.

TABLE IV. MEAN MILLING AND CHEMICAL COMPOSITION DATA OF GRAIN FROM 11 SORGHUM VARIETIES STUDIED IN PHASE A MILLED FOR 2 MIN.[a]

Variety	Endosperm Texture Rating	Coarse Grits[b] %	Germ-Rich Grits[b] %	Coarse and Fine Grits[b] %	Fines[b] %	Coarse and Fine Grits: Protein[c] %	Coarse and Fine Grits: Ether extract[c] %
NSA 740	5	1.1h	26.2b	39.6g	29.8a	15.6	1.30
SC 84-6	5	0.1h	38.4a	30.2h	30.0a	13.5	1.40
Tx 09	4	8.2g	39.9a	32.9h	24.5b	13.6	0.61
7078	3	23.7f	19.6c	53.3e	22.9b	12.0	0.74
Tx 2538	3	28.2e	17.6c	48.8f	29.7a	14.7	0.45
B 398 (Martin)	2	53.2b	3.2e	72.3bc	19.1c	14.5	0.39
DeKalb hybrid G 600	2	38.4d	10.2d	65.3d	23.0b	10.3	0.29
Tx 2536	2	30.7e	5.1e	70.2c	21.5bc	11.1	0.57
SC 303-6	1	45.7c	5.4e	75.0b	16.1d	13.9	0.24
SC 283-6, white	1	71.5a	0.7f	82.1a	14.8d	12.1	0.23
SC 283-6, red	1	70.7a	1.1f	80.3a	16.4d	12.4	0.26

[a]Values with the same letters are not significantly different at the 5% level.

[b]As-is moisture basis.

[c]Calculated from yield and protein values of coarse and fine grits and reported on dry-weight basis.

comparison to the floury and corneous varieties previously discussed. However, it was noted that milling yields and grit composition varied for the varieties with intermediate endosperm texture.

TABLE V. MILLING YIELDS FROM SEVEN VARIETIES OF SORGHUM GRAIN STUDIED IN PHASE B WITH 1.5-MIN. MILLING TIME[a]

Variety	Endosperm Texture Rating	Coarse Grits %	Germ-Rich Grits %	Coarse and Fine Grits %	Fines %
NSA 740	5	19.6f	14.3a	60.3d	21.2a
Tx 09	4	27.2e	3.9b	73.3c	20.4a
DeKalb hybrid C42Y	3	54.1d	2.0bc	78.3b	17.5b
B 3197	3	66.0c	2.1bc	78.9b	15.9b
SC 110	3	56.8d	2.2bc	83.8a	12.4c
SC 170	2	70.4b	1.6c	84.6a	11.9cd
SC 283	1	78.7a	1.4c	85.9a	10.3d

[a]Values with the same letters are not significantly different at the 5% level. Values are on an as-is moisture basis.

TABLE VI. MEAN MILLING AND CHEMICAL COMPOSITION DATA OF GRAIN FROM SEVEN SORGHUM VARIETIES STUDIED IN PHASE B MILLED FOR 2 MIN.[a]

		Milling Fraction Yield[c]					Total Grits		
Variety	Endosperm Texture Rating	Coarse Grits %	Germ-Rich Grits %	Coarse and Fine Grits %	Total Grits[b] %	Fines %	Ether extract[d] %	Protein[d] %	Ash[d] %
NSA 740	5	3.6f	59.9a	3.6e	56.5	26.0a	0.85ab	21.2a	3.70a
Tx 09	4	20.9e	36.3b	36.1d	69.0	21.6b	0.59c	18.5b	1.37b
DeKalb hybrid C42Y	3	47.9d	14.4cd	62.7c	75.3	18.3c	0.60c	12.1f	0.56d
B 3197	3	51.8c	13.5cd	62.4c	72.7	18.6c	0.78bc	15.5cd	0.91c
SC 110	3	50.2c	18.0c	63.7c	79.7	14.0d	0.69bc	15.3d	0.57d
SC 170	2	65.5b	9.0de	73.9b	80.8	13.5d	1.01a	15.8c	0.53d
SC 283	1	74.6a	3.3e	81.5a	84.1	10.7e	0.68bc	14.6e	0.37e

[a]Values with the same letters are not significantly different at the 5% level.
[b]Includes coarse grits, fine grits, and grits from $NaNO_3$ flotation.
[c]As-is moisture basis.
[d]Dry-weight basis.

Milling yields and grit composition of the varieties studied in phase B are presented in Table V (1.5-min. milling) and Table VI (2-min. milling). The yields of SC 283 confirmed the data obtained in phase A, which indicated the superior milling performance of this variety. Grain from the varieties with floury endosperm was inferior for grit-milling performance. High ash values were indicative of the poor quality grit obtained from the varieties with a high proportion of floury endosperm.

The forces involved in abrasive milling caused disintegration of the all floury kernels. The coarse-grits fraction of these varieties consisted of small, intact kernels or kernel fragments consisting of the aleurone layer, often with the pericarp attached. The high ash content of these grits is explained by the high bran content.

Conversely, the coarse grits from the varieties with corneous endosperm consisted of nearly intact, debranned, degermed endosperm. The excellent milling performance of the corneous variety is shown by the 80+% yield of grits which are low in ash and fat. Hubbard et al. (8) list the endosperm content of sorghum as 80 to 84.6% of the kernel. The high yield of grit obtained from the varieties with corneous endosperm is explained on the basis of a nearly intact endosperm upon milling and the thin pericarp and small germ of the whole kernel (Fig. 1).

TABLE VII. ANALYSIS OF VARIANCE FOR MILLING TIME ON THE YIELD AND CHEMICAL COMPOSITION OF VARIOUS MILLED FRACTIONS FROM 11 VARIETIES OF SORGHUM STUDIED IN PHASE A[a]

				Ether Extract		Protein	
Source	Coarse Grits	Fine Grits	Germ-Rich Grits	Coarse Grits	Fine Grits	Coarse Grits	Fine Grits
Variety (V)	**	**	**	**	**	**	**
Replications (R)	NS	NS	NS	NS	NS	NS	NS
Milling time (MT)	**	**	**	**	*	**	NS
V X R	NS	NS	NS	NS	NS	NS	NS
V X MT	**	**	**	**	**	**	**
R X MT	NS	NS	NS	NS	NS	NS	*

[a]** = Significant at 99% level; * = significant at 95% level; NS = nonsignificant.

TABLE VIII. SOME PHYSICAL AND CHEMICAL PROPERTIES OF GRAIN FROM 11 SORGHUM VARIETIES STUDIED IN PHASE A[a]

Variety	Endosperm Texture Rating	Micro Test Weight lb./bu.	1,000 Kernel Weight g.	Density g./cc.	Hardness	Ether extract[b] %	Protein[b] %
NSA 740	5	52.6f	25.1f	1.24g	1.0h	3.6	14.3
SC 84-6	5	54.1e	19.6h	1.27f	0.0h	3.3	13.1
Tx 09	4	56.5d	31.0c	1.33e	1.3h	3.2	13.8
7078	3	59.2c	27.5e	1.34d	13.1g	3.8	12.3
Tx 2538	3	57.3cd	59.2a	1.33e	22.2f	3.7	13.8
B 398 (Martin)	2	60.4b	27.5e	1.37b	36.7c	4.1	15.1
DeKalb hybrid G 600	2	60.5b	32.9b	1.36c	26.6e	3.0	11.5
Tx 2536	2	60.6b	28.9d	1.35c	30.6d	3.4	12.2
SC 303-6	1	59.7bc	19.0h	1.38b	37.4c	3.1	14.0
SC 283-6, white	1	62.1a	25.0f	1.40a	60.9b	3.6	13.8
SC 283-6, red	1	63.5a	24.4fg	1.40a	65.5a	3.4	13.9

[a]Values with the same letters are not significantly different at the 5% level.
[b]Dry-weight basis.

Effect of Milling Time

Milling times of 1.5 and 2 min. were used. This variation in time influenced the yields and composition of milled fractions (Tables III and IV). Table VII summarizes the analysis of variance of the yield and composition of various fractions obtained from the grain in phase A of this study. There were significant differences for both milling time and milling time X variety interaction. In phase B, an increase in milling time caused a decrease in coarse- and fine-grits yield and an increase in yield for both fines and germ-rich grits (Tables V and VI). Figure 2 is a graphic representation of the milling time X variety interaction found in phase B of

TABLE IX. SOME PHYSICAL AND CHEMICAL PROPERTIES OF GRAIN FROM SEVEN SORGHUM VARIETIES STUDIED IN PHASE B[a]

Variety	Endosperm Texture Rating	KSI	1,000 Kernel Weight g.	Macro Test Weight lb./bu.	Density g./cc.	Ash %	Hardness	Ether Extract[b,c] %	Protein[c] %	Starch[c] %
NSA 740	5	62.7d	24.9	48.1e	1.18e	1.94a	0.9e	3.6	17.5a	66.8c
Tx 09	4	59.8e	32.9	51.8d	1.32d	1.79b	2.0e	3.2	16.5b	70.4ab
DeKalb hybrid C42Y	3	62.7d	32.4	59.2b	1.34b	1.31e	11.8d	3.3	12.2e	73.7a
B 3197	3	65.8c	28.6	57.7c	1.33c	1.53d	12.7cd	3.1	15.5c	72.1a
SC 110	3	66.0b	26.5	57.6c	1.32d	1.47d	14.0c	3.4	14.8d	71.9ab
SC 170	2	65.6c	27.2	57.3c	1.32d	1.65c	23.5b	3.4	16.5b	69.0bc
SC 283	1	71.4a	23.0	61.9a	1.38a	1.31e	29.6a	2.9	15.2c	72.8a

[a]Values with the same letters are not significantly different at the 5% level.

[b]Nonsignificant F test for varietal difference.

[c]Dry-weight basis.

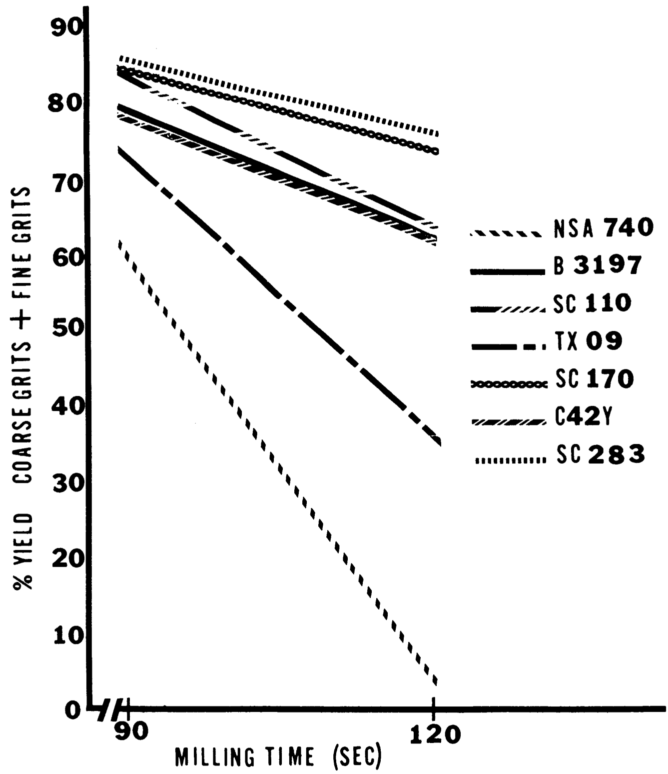

Fig. 2. Effect of increased milling time on the yield of coarse grits and fine grits for the seven varieties of sorghum grain studied in phase B.

TABLE X. PREDICTION EQUATIONS FOR THE YIELD OF VARIOUS MILL FRACTIONS BASED ON DATA OBTAINED IN PHASE A

	r	r^2 X 100
Endosperm Texture Rating (ETR)		
Coarse Grits (%) = 74.9818−15.6310 (ETR)	−0.93	86
Germ-rich Grits (%) = −7.8266+8.7411 (ETR)	0.91	83
Coarse and Fine Grits (%) = 91.1004−12.1415 (ETR)	−0.96	92
Fines (%) = 13.6391+3.3713 (ETR)	0.90	81
Density[a] (D)		
Coarse Grits (%) = −580.4985+457.4801 D	0.91	83
Germ-rich Grits (%) = 316.8237−224.6214 D	−0.78	61
Coarse and Fine Grits (%) = −380.5627+327.4333 D	0.87	76
Fines (%) = 157.4390−100.4758 D	0.90	81
Hardness (H)		
Coarse Grits (%) = 4.5477+1.0886 H	0.98	96
Germ-rich Grits (%) = 30.4352−0.5668 H	−0.89	79
Coarse and Fine Grits (%) = 38.0604+0.7833 H	0.93	86
Fines (%) = 28.1964−0.2111 H	−0.85	72

[a]Density is expressed as g. per cc.

TABLE XI. PREDICTION EQUATIONS FOR THE YIELD OF VARIOUS MILL FRACTIONS BASED ON DATA OBTAINED IN PHASE B

	r	$r^2 \times 100$
Endosperm Texture Rating (ETR)		
Coarse Grits (%) = 123.0801−22.756 (ETR)	−0.97	94
Germ-rich Grits (%) = −24.0788+14.056 (ETR)	0.99	98
Coarse and Fine Grits (%) = 125.6425−23.6097 (ETR)	−0.92	85
Fines (%) = 4.757+4.2609 (ETR)	0.94	88
Total Grits = 94.1142−6.700 (ETR)	−0.93	86
Density[a]		
Coarse Grits (%) = −387.6977+329.5434 D	0.83	69
Germ-rich Grits (%) = 397.0389−285.6205 D	−0.88	77
Coarse and Fine Grits (%) = −451.6075+385.7772 D	0.89	79
Fines (%) = 105.3567−66.8898 D	−0.79	62
Total Grits = −98.6334+131.5055 D	0.89	79
Hardness		
Coarse Grits (%) = 14.546+2.2518 H	0.95	90
Germ-rich Grits (%) = 43.8521−1.6142 H	−0.83	69
Coarse and Fine Grits (%) = 24.6001+2.2416 H	0.86	74
Fines (%) = 23.8677−0.4687 H	−0.92	85
Total Grits = 65.1305+0.6580 H	0.74	55

[a]Density is expressed as g. per cc.

this study. The reduction in yield is related to endosperm texture rating, with the floury varieties showing the greatest reduction in yield. These differences in yield are explained by the more-pronounced effect of the abrasive action on varieties with a high proportion of floury endosperm.

Abrasive milling for 1.5 min. did not completely debran or degerm the kernels, which caused an exceptionally high grit yield for the varieties with corneous endosperm (Tables III and V). A milling time of 2 min. emphasized differences in milling properties and produced grits of suitable quality. Consequently, data obtained from the 2-min. milling time are used to determine and establish relations between milling performance and physical properties of the grain.

Relation between Abrasive-Milling Performance and Physical Properties of the Grain

Physical Properties. Physical properties of grain from the varieties studied are presented in Tables VIII and IX. Some of these were highly correlated with milling performance. Endosperm texture was the property most highly correlated with milling yield (Tables X and XI). Density and hardness were correlated with milling yields for both phases of this study, but were not as highly correlated as endosperm texture.

Endosperm texture was negatively correlated to hardness in both phase A and phase B ($r = -0.91$ and -0.98, respectively) of this study. Endosperm texture was also negatively correlated with test weight ($r = -0.94$ and -0.91 for phases A and B, respectively) and density ($r = -0.95$ and -0.83 for phases A and B, respectively).

Linear Regression. Prediction equations were developed to show the relation between easily measured physical properties and milling performance of the grain.

TABLE XII. FLOUR YIELD AND COMPOSITION FOR SEVEN SORGHUM VARIETIES STUDIED IN PHASE B[a]

Variety	Yield[b] %	Protein[c] %	Ether extract[c] %	Starch[c] %
NSA 740	59.4c	15.4a	1.24	80.3c
Tx 09	63.8b	11.2d	1.20	86.5a
C42Y	68.1a	10.8e	1.13	86.3a
B 3197	61.0bc	12.6c	1.47	84.4ab
SC 110	61.1bc	12.6c	0.95	86.6a
SC 170	62.5bc	13.4b	1.21	81.9bc
SC 283	67.9a	12.9c	1.30	84.1ab

[a]Values with the same letters are not significantly different at the 5% level.

[b]As-is moisture basis.

[c]Dry-weight basis.

These equations, presented in Tables X and XI, illustrate the good relationship between milling performance and physical properties of the grain. Endosperm texture accounts for over 80% ($r = -0.90$) of the difference in milling performance and its value as a predictor of milling performance increases when kernels of similar size and shape are compared (Table XI).

These equations should aid plant breeders and geneticists in screening the world collection of sorghum for grain with superior milling potential. They would not find it necessary to grow large quantities of grain for initial screening. However, milling studies should be used to compare grain from varieties having a superior milling potential.

Caution should be exercised in the use of these prediction equations, as the extreme range in endosperm texture may have resulted in a highly correlated equation. It is not known whether these equations would hold true within a narrower range of endosperm texture, and further study within such a range should be done to provide a final check on the usefulness of these equations.

Researchers must determine the type of milling procedure they wish to use and then use this method as a standard in studying the milling properties of sorghum grain. We do not know how our method compares with methods used in industry. However, we feel that abrasive milling is the best technique for commercial dry-milling of sorghum and that our results are a useful guide in studying sorghum-milling properties.

Flour-Milling Performance

Grain from varieties studied in phase B was subjected to break milling for flour production. A range of 59.4 to 68.1% recovery (Table XII) was obtained. No significant correlations between flour yield or composition and physical properties of the grain were obtained. However, two varieties, DeKalb hybrid C42Y and SC 283, were superior for flour production. These were among the better varieties in abrasive grit-milling performance.

CONCLUSIONS

The laboratory grit-milling procedure, using a 2-min. milling time, is an excellent method for studying differences in the abrasive-milling properties of sorghum grain.

Milling performance is highly related to physical properties, especially to endosperm texture ($0.90 \leq r < -0.90$) of the grain. Varieties with corneous endosperm, when milled abrasively, produce higher yields of grits with low ash and fat content.

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