Comparison of Screening Methods for Indirect Determination of Sorghum Hardness

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ABSTRACT

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Hardness of sorghum was determined by four indirect methods: time to grind by the Brabender microhardness tester, resistance to grinding by the Stenvert hardness tester (SHT), and two methods for determination of average particle size: particle size index (PSI) and near-infrared (NIR) reflectance at 1,680 nm of ground sorghum grain samples from Nebraska (two years), Indiana, and Texas. A total of 65 samples differing widely in texture and composition was evaluated. The SHT method was found to be useful for rapid and reliable differentiation among the samples; the NIR method was useful for testing samples, provided an appropriate mill was available. Results of the Brabender microhardness tester and NIR or SHT were negatively correlated and the NIR and SHT methods were highly positively correlated.

Endosperm texture of cereal grains, including sorghum, is important in storage, milling, and processing into foods (Maxson et al 1971; Cagampang et al 1982, 1984; Cagampang and Kirleis 1984). Methods for measuring sorghum texture include rating of the proportion of vitreous endosperm in cut grain (Maxson et al 1971, Kirleis et al 1984) and pearling and milling methods. The former are subjective, laborious, and require analyzing large numbers of individual kernels. Some of the shortcomings can be overcome by quantitative measurement of the image from a microscope (Hallgren and Murthy 1983). Pearling and milling methods are affected by the size and shape of the kernel, by the thickness and adherence of the pericarp, and by the milling or pearling equipment. Indirect methods for testing hardness of sorghum grain are based on density grading in an organic solvent (Kirleis and Crosby 1982) or a sodium nitrate solution (Hallgren and Murthy 1983). The percentage of kernels floating in the $NaNO_3$ solution was correlated with percentage vitreousness ($r = -0.96$), grain hardness determined as work required for grinding ($r = -0.88$ to -0.92), breaking strength of individual kernels ($r = -0.42$), and flour particle size ($r = 0.93$).

We have evaluated the use of four methods in the indirect determination of kernel hardness in wheat and corn (Pomeranz and Miller 1983; Pomeranz et al 1984, 1985a). Those methods include time to grind (in seconds) on the Brabender microhardness tester (BMHT), resistance to grinding (in seconds) on the Stenvert hardness tester (SHT), and particle size of ground grain as determined by sieving (PSI, %) or by measuring near-infrared reflectance at 1,680 nm (NIR). This report compares the use of the four methods in indirect determination of hardness in grain sorghum.

MATERIALS AND METHODS

Materials

Four groups of grain sorghum were studied: 25 samples from Purdue University (20 Indian, 5 Purdue selections), 16 samples from Texas A&M University, and 12 samples each from 1983 and 1984 from USDA, ARS, University of Nebraska. The 65 samples were selected to cover a wide range in endosperm texture, grain hardness, pericarp thickness, and overall kernel composition and properties.

Methods

The indirect hardness tests were described previously by Miller et al (1981) (for the BMHT), by Miller et al (1982) and Pomeranz et al

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TABLE I
Mean and Coefficient of Variation of Hardness by Four Methods in Sorghum Grain Samples from Nebraska, Indiana, and Texas

Hardness Test and Source[a]	Number of Varieties	Mean	Coefficient of Variation[b] (%)
BMHT (sec)			
Nebraska 1983	12	50.12	50.1
Nebraska 1984	10	69.71	77.3
Indiana	25	50.72	65.5
Texas	16	47.20	64.2
NIR (arbitrary units)			
Nebraska 1983	12	357.4	13.9
Nebraska 1984	10	303.5	16.2
Indiana	25	327.9	18.7
Texas	16	359.2	15.0
PSI (%)			
Nebraska 1983	12	4.65	44.9
Nebraska 1984	10	19.98	21.5
Indiana	25	13.59	55.2
Texas	16	8.76	38.7
SHT (sec)			
Nebraska 1983	12	24.22	30.4
Nebraska 1984	12	23.55	29.6
Texas	16	32.58	44.6

[a]BMHT, Brabender microhardness tester; NIR, near-infrared reflectance; PSI, particle size index; SHT, Stenvert hardness tester.
[b]Each variety was analyzed in triplicate.

TABLE II
Correlation Coefficients[a] Among Four Hardness Tests in Sorghum Grain Samples from Nebraska, Indiana, and Texas

Hardness Test[b] and Source	BMHT[c]	NIR	PSI
NIR			
Nebraska 1983	−0.666*		
Nebraska 1984	−0.835**		
Indiana	−0.243		
Texas	−0.792**		
PSI			
Nebraska 1983	−0.349	−0.066	
Nebraska 1984	0.049	−0.432	
Indiana	−0.186	−0.723**	
Texas	−0.144	−0.083	
SHT			
Nebraska 1983	−0.488	0.934**	−0.089
Nebraska 1984	−0.558	0.904**	−0.532
Texas	−0.636**	0.925**	−0.106

[a]* and **, Significant at the 0.05 and 0.01 levels, respectively.
[b]NIR, near-infrared reflectance, PSI, particle size index; SHT, Stenvert hardness tester.
[c]BMHT, Brabender microhardness tester.

TABLE III
Hardness Values (by Four Methods)[a] of Sorghum Grain from Nebraska from Two Years

Genotype	Description[b]	BMHT (sec)		NIR at 1,680 nm		PSI (%)		SHT (sec)	
		1983	1984	1983	1984	1983	1984	1983	1984
P 721	high lysine	140.7	223.5	250.3	178.0	3.4	22.6	14.0	14.2
Spur Feterita	soft endosperm	75.1	···	329.7	···	3.2	···	15.4	9.1
RS 671 hybrid		48.7	47.3	337.0	299.0	3.2	21.2	19.5	22.0
Redbine-60		47.3	54.1	345.3	307.3	4.0	16.4	22.0	22.5
CK60-Korgi (70LN4949)	large seed	46.8	···	397.0	···	3.3	···	28.9	25.4
Darset	pigmented testa	43.4	88.5	350.3	304.7	5.7	15.3	19.6	25.2
Combine Kafir-60	normal endosperm	41.9	45.9	367.0	324.3	4.4	26.3	24.0	27.3
Texioca-54	waxy endosperm	40.0	49.2	349.7	289.3	9.3	20.9	22.4	22.3
Martin		39.6	42.7	417.7	349.0	3.9	18.1	31.8	32.1
RS 626 hybrid	low lysine	38.9	44.4	337.3	292.0	4.7	25.5	19.4	22.6
CK60-Korgi (70LN4914)	hard endosperm	36.5	61.8	457.0	371.0	3.4	12.3	42.1	36.6
IS 809	small seed	32.7	39.8	350.0	320.7	7.4	21.3	25.3	23.4
LSD (0.05 level)		5.5	1.2	3.8	2.1	1.9	0.3	1.1	0.4

[a]BMHT, Brabender microhardness tester; NIR, near-infrared reflectance; PSI, particle size index; SHT, Stenvert hardness tester.
[b]W. M. Ross, *personal communication.*

(1984) (for the PSI and NIR of ground grain), and by Pomeranz et al (1985a,b) (for SHT). The grain was cleaned on the Hart-Carter dockage tester, and foreign material and broken kernels were separated by hand. The cleaned grain was equilibrated to a moisture of 11.0% (±0.8%) as described by Miller et al (1981). All analytical tests were made in triplicate.

RESULTS AND DISCUSSION

Mean and coefficient of variation of hardness determination by the four methods on the sorghum grain samples from Nebraska, Indiana, and Texas are summarized in Table I. No SHT determinations were made on the Indiana samples because there was insufficient material. The method of determining PSI was filled with many difficulties and not recommended for indirect determination of hardness in sorghum. The small sample size was a source of error, the sieves were easily clogged by the ground sorghum grain that is rich in waxy material and were difficult to clean, and the results (not shown) were affected by small differences in moisture content and drying conditions after harvest. In addition, there were large differences in samples tested by the same operator on different days or by different operators.

The BMHT method yielded the highest coefficients of variation and differentiation among the sorghum grain samples. Small amounts of broken kernels and especially impurities, however, had a large effect on the results. These impurities could not be separated by the Hart-Carter dockage tester and had to be removed by hand. Very soft sorghum samples clogged the burr mill of the BMHT, and even medium-soft samples required intermediate cleaning out with a semihard wheat sample.

Reproducible NIR results were obtained for material ground on the BMHT. Material ground on the SHT could not be used for NIR determination; the samples were too coarse and difficult to pack in the NIR cell, and the results were not reproducible and did not differentiate well among samples that differed widely in hardness. Still, the usefulness of the NIR method should not be dismissed if the hardness tests can be run on available equipment in combination with other determinations (i.e., gross composition). The problem would then be to select a general, rather inexpensive laboratory mill for preparation of samples.

No difficulties were encountered in the preparation of samples by the SHT. The results were affected little by small amounts of broken kernels and impurities left after cleaning on the Hart-Carter dockage tester, by differences in kernel size, and by the presence of the waxy layer on the grain surface. For instance, whereas all samples from the 1984 Nebraska crop could be tested by the SHT method, two of the samples presented problems in testing by the other three methods. The large sample and the intermediate coefficient of variation in the SHT method are desirable features in reducing the error and obtaining good differentiation.

TABLE IV
Hardness Values (by Four Methods)[a] of Sorghum Grain from Texas

Genotype	Description of Endosperm[b]	BMHT (sec)	NIR at 1,680 nm	PSI (%)	SHT (sec)
NSA 740	soft	129.6	241	5.8	11.4
RTx09		113.3	264	10.4	10.8
Funks G766W		52.8	330	5.0	21.8
Early Hegari		41.7	302	11.8	16.2
BTx3197	soft	40.3	338	12.7	23.3
BTx615	waxy	34.5	330	12.1	25.7
RedlanxTx430	intermediate	38.5	384	4.4	30.8
A623xTx430		37.7	357	9.4	33.1
ATx378xTx430		37.2	376	5.6	28.7
A623x77CS3		37.0	397	10.1	37.3
AT 625x77CS1		36.5	373	13.2	29.6
Combine Shallu	hard	34.6	393	5.6	44.1
79T70		32.2	414	7.5	50.2
CS3541		31.8	391	9.1	46.6
77CS2		30.6	416	9.0	49.1
SC0283C		29.9	439	8.4	62.5
LSD (0.05 level)		17.7	5.5	3.8	1.6

[a]BMHT, Brabender microhardness tester; NIR, near-infrared reflectance; PSI, particle size index; SHT, Stenvert hardness tester.
[b]L. W. Rooney, *personal communication.*

The four empirical, indirect methods of determining hardness were shown for wheat (Pomeranz et al 1985b) to be affected by several factors such as kernel size and shape, thickness and adherence of the pericarp, and other morphological factors. Some of these factors are likely to apply to sorghum. The principles for indirect determination of hardness by the four methods differ; they are time to grind on a burr mill in the BMHT, resistance to grinding in the SHT, and average particle size of the ground sorghum in the PSI (direct) and NIR (indirect) methods. The highest and most consistent correlation coefficients were between NIR and SHT, even though the methods differ widely (Table II). With the exception of the Indiana samples, the correlations between BMHT and NIR were all highly significant.

Ranking for the same genotypes from two years from Nebraska is summarized in Table III. BMHT values correlated well for sorghums with soft, normal, and hard endosperm (the higher the value, the softer the endosperm); similar comparisons were obtained for the NIR and SHT values (the harder the endosperm the higher the value) but not for the PSI values. The usefulness of the methods is further confirmed for the samples from Texas (Table IV). The NIR and the SHT methods ranked the samples into three groups, and the results of the two methods were highly correlated (Table II). The correlations between the BMHT and NIR and BMHT and SHT were low. In addition, the high least significant difference (LSD) for BMHT (mainly due to the poor replication of the very soft samples) made it difficult to differentiate among the samples in each of the three hardness groups. LSD values for the samples from Purdue University were 16.0 for BMHT, 4.0 for NIR, and 2.8 for PSI. The samples BTx3197 and BTx615 are almost isogenic lines, except that one of them was of the waxy type (Table IV). The two samples had similar hardness values, as determined by the four methods.

The small number of samples is insufficient to determine the effects of kernel size, shape, or composition on hardness of grain sorghum. The results described in this paper indicate, however, that the Stenvert hardness tester (which measures resistance to grinding) is useful in rapid screening of sorghum cultivars or selections for hardness, and the results are highly correlated with the average particle size by the NIR method, provided an appropriate mill for grinding the samples is used.

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LITERATURE CITED

CAGAMPANG, G. B., and KIRLEIS, A. W. 1984. Relationship of sorghum grain hardness to selected physical and chemical measurements of grain quality. Cereal Chem. 61:100.

CAGAMPANG, G. B., GRIFFITH, J. E., and KIRLEIS, A. W. 1982. Modified adhesion test for measuring stickiness of sorghum porridges. Cereal Chem. 59:234.

CAGAMPANG, G. B., KIRLEIS, A. W., and MARKS, J. S. 1984. Application of small sample back extrusion test for measuring texture of cooked sorghum grain. J. Food Sci. 49:278.

HALLGREN, L., and MURTHY, D. S. 1983. A screening test for grain hardness in sorghum employing density grading in sodium nitrate solution. J. Cereal Sci. 1:265.

KIRLEIS, A. W., and CROSBY, K. D. 1982. Sorghum hardness: Comparison of methods for its evaluation. Page 231 in: Proc. Intern. Symp. Sorghum Grain Quality. L. W. Rooney, D. S. Murthy, and J. V. Mertin, eds. ICRISAT Center: Patancheru, India.

KIRLEIS, A. W., CROSBY, K. D., and HOUSLEY, T. L. 1984. A method for quantitatively measuring vitreous endosperm area in sectioned sorghum grain. Cereal Chem. 61:556.

MAXSON, E. D., FRYAR, W. B., ROONEY, L. W., and KRISHNAPRASAD, M. N. 1971. Milling properties of sorghum grain with different proportions of vitreous to floury endosperm. Cereal Chem. 48:478.

MILLER, B. S., AFEWORK, S., POMERANZ, Y., and BOLTE, L. 1981. Wheat hardness: time required to grind wheat with the Brabender automatic hardness tester. J. Food Sci. 46:1863.

MILLER, B. S., AFEWORK, S., POMERANZ, Y., BRUINSMA, B. L., and BOOTH, G. D. 1982. A comparison of methods for measuring the hardness of wheat. Cereal Foods World 27:61.

POMERANZ, Y., and MILLER, B. S. 1983. Wheat hardness: its significance and determination. Pages 399-403 in: Proc. 7th World Cereal and Bread Congress (Prague). Elsevier: Amsterdam.

POMERANZ, Y., MARTIN, C. R., TRAYLOR, D. D., and LAI, F. S. 1984. Corn hardness determination. Cereal Chem. 61:147.

POMERANZ, Y., CZUCHAJOWSKA, Z., MARTIN, C. R., and LAI, F. S. 1985a. Determination of corn hardness by the Stenvert hardness tester. Cereal Chem. 62:108.

POMERANZ, Y., PETERSON, C. J., and MATTERN, P. J. 1985b. Hardness of winter wheats grown under widely different climatic conditions. Cereal Chem. 62:463.

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