Test Weight, Hardness, and Breakage Susceptibility of Yellow Dent Corn Hybrids[1]

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ABSTRACT

Test weight, 100-kernel weight, percent of floaters, hardness (density, near-infrared reflectance, and several parameters obtained from the Stenvert hardness test), and breakage susceptibility (Stein test) were determined in three mixtures of hybrids dried under various conditions and 10 individual hybrids dried under mild conditions. Breakage susceptibility showed a significant correlation, and test weight and percent of floaters showed a large and very significant correlation with various measures of grain hardness. Kernel weight and hardness were not correlated.

Methods of corn hardness determination were studied by Pomeranz et al (1984), and the use of the Stenvert hardness tester (SHT) was described by Pomeranz et al (1985). Methods for determination of hardness and breakage susceptibility were compared by Pomeranz et al (1986a). We report here on several methods of corn hardness determination (density of whole corn, near-infrared (NIR) reflectance at 1,680 nm of ground corn, and several parameters of the SHT) and corn breakage susceptibility (Stein breakage tester) of commercially dried mixtures of hybrids and ambient-air-dried individual hybrids. The results of those tests are correlated and compared to those of test weight, 100-kernel weight, and percent of floaters.

MATERIALS AND METHODS

A total of 13 corn samples was used in this study. Sample 1 was a composite of five loads of corn dried on five farms. Sample 2 was a composite of about 60 truckloads of ear corn, dried with air at temperatures up to 20°C to about 13% moisture and shelled with a motorized hand-crank sheller. Sample 3 was a composite of 21% moisture shelled corn commercially dried about 6 hr to about 14% moisture. Samples 4–13 were each individual hybrids dried on the ear to about 13% moisture, and gently shelled using the motorized hand-crank sheller.

For the floaters test, the method of kernel density separation described by Wichser (1961) was followed. The chemical solution used was a mixture of sodium nitrate and water at a specific gravity of 1.25.

Whole kernels were analyzed for moisture by the ASAE method (ASAE 1982).

Corn density was determined on whole, sound kernels by the air-comparison pycnometer method described by Pomeranz et al (1984). NIR data at 1,680 nm of corn, ground on the modified Weber mill (McGinty et al 1977) at 1-mm mesh setting, were measured with a Technicon Infralyzer. Breakage susceptibility was determined by a 6-min test in the CK-2M Stein breakage tester as described by Miller et al (1981). The 6-min test differentiated better than the 4-min test, among samples that differed little in breakage susceptibility.

The Stenvert measure of hardness was determined as described by Pomeranz et al (1985). The time required to collect 17 ml of ground meal (an index of resistance to grinding) and coarse/fine (C/F) ratios were measured. Weight C/F denotes the ratio of sieved fractions after grinding on the tester; fraction C is larger than 0.7 mm in diameter, and fraction F is smaller than 0.5 mm in diameter. The amount of the intermediate fraction is small. Volume C/F denotes the ratio of fractions C and F determined visually by volume immediately after grinding on the Stenvert hardness tester.

Determinations of test weight, Stein breakage test, 100-kernel weight, and percent floaters were made in the laboratories of The Andersons, Maumee, OH who provided the samples. All other tests were made in the laboratories of the U.S. Grain Marketing Research Laboratory. All tests were made in triplicate and all results were averaged. Results were subjected to standard analyses using the ANOVA statistical package.

RESULTS AND DISCUSSION

Some selected physical parameters, hardness, and breakage susceptibility of the corn samples are given in Tables I and II. Among the three mixtures of hybrids, sample 3 had the lowest density, NIR value, SHT value (time, %C), and test weight and was highest in SHT(H) (height of column of ground corn), %F, Stein breakage and percent floaters—all indicative of a high-temperature dried corn. Three of the samples of individual hybrids (8, 9, and especially 11) were significantly softer than the other samples. Samples 5, 12, and especially 4 were significantly harder than the others.

Simple correlation coefficients for all the samples and for the samples of individual hybrids were of a similar magnitude and statistical significance. The wider range of values and lower correlation coefficient required for statistical significance (because of the greater number of samples) in the combined samples were compensated for by the more homogenous populations and more uniform drying conditions in the individual hybrid samples. Correlation coefficients for all the samples are shown in Table III.

TABLE I
Some Selected Physical Parameters of Corn Samples[a]

Sample No.	Test Weight (lb/bu)	Stein Breakage Test (%)	100-Kernel Weight (g)	Floaters (%)
1	56.2	34.0	28.1	97
2	59.2	4.0	27.4	86
3	51.2	43.8	27.9	99
4	62.5	1.4	29.3	8
5	60.3	1.9	30.0	65
6	60.4	3.7	30.9	76
7	62.6	1.4	30.8	29
8	58.6	2.0	23.2	87
9	58.4	2.6	22.2	95
10	62.4	1.8	32.3	37
11	58.7	5.5	25.4	95
12	64.8	0.5	27.2	12
13	60.7	4.2	30.4	69
LSD (5%)	0.330	2.04	0.716	6.44

[a] Samples 1–3 were commercially dried mixtures of hybrids; samples 4–13 were air-dried individual hybrids.

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The highest correlation coefficients were among the various parameters of hardness: density, NIR, SHT (various measurements), floaters, and test weight. Intermediate to low correlations were established between the various hardness parameters and breakage susceptibility measurements (Stein breakage test). The correlations with 100-kernel weight were low and generally insignificant (a correlation coefficient of at least 0.553 was required at the 5% level). When partial correlations were calculated (holding test weight constant), there was an almost consistent lowering of values. The only values that were affected little were those among the various parameters obtained from testing by the SHT. The results point to the significance of the test weight as an index of corn hardness and related breakage susceptibility in clean samples of a comparable history and moisture content.

Table IV compares simple and partial correlation coefficients for several key parameters of corn hardness and breakage susceptibility. Included also is a comparison for those key parameters for all samples and the individual hybrid samples. Generally, there were few and small differences in correlation coefficients for the two groups.

Keeping kernel weight constant had no significant effect on the correlations between and among the various hardness and breakage parameters. Keeping Stein breakage constant lowered the correlation coefficients somewhat (and in at least two instances significantly). The largest effect was recorded when the test weight was kept constant. The correlation coefficients were drastically reduced except for one case (density vs. SHT, for hybrids). The results confirmed that kernel weight (within the limits used in this study) has little effect on breakage susceptibility or hardness (Pomeranz et al 1985). Breakage susceptibility modifies kernel hardness, and both must be considered in evaluation of physical properties of corn, in agreement with our findings on corn varying in shape and size (Pomeranz et al 1986b) or on corn dried under commercial conditions (Pomeranz et al 1986a).

Stroshine et al (1981) reviewed studies on the value of test weight and 100-kernel weight determinations as measures of corn quality. In a comparison of drying rates and quality parameters for selected corn inbreds and hybrids, they found a highly significant negative correlation between test weight and percent floaters and no significant correlation between kernel weight and percent floaters. Paulsen et al (1982) studied breakage susceptibility of common

TABLE II
Hardness and Breakage Susceptibility Parameters of Corn Samples[a]

Sample No.	Density (g/cc)	NIR[b] at 1,680 nm	SHT[c] (sec)	SHT(H)[c] (arbitrary units)	CW[d] (%)	FW[d] (%)	C/FW[d]	CV[e] (%)	FV[e] (%)	C/FV[e] (%)
1	1.2970	309.36	12.98	183.67	46.12	39.62	1.164	32.67	67.33	0.485
2	1.2893	329.66	12.65	184.67	45.78	39.89	1.148	31.95	68.05	0.470
3	1.2327	292.96	10.11	193.33	43.14	41.38	1.043	27.42	72.58	0.378
4	1.3450	402.78	20.41	166.33	53.47	32.34	1.654	43.69	56.31	0.776
5	1.3167	380.39	19.79	171.33	51.87	34.33	1.512	40.28	59.72	0.674
6	1.3123	323.39	17.25	177.00	48.64	37.51	1.297	38.42	61.58	0.624
7	1.3187	388.45	16.70	176.33	50.49	36.08	1.401	38.19	61.81	0.618
8	1.2980	337.72	16.60	182.00	49.21	35.85	1.373	35.89	64.11	0.560
9	1.2963	340.40	15.23	184.67	48.46	37.77	1.283	32.13	67.87	0.473
10	1.3237	387.26	16.17	177.67	49.09	37.05	1.325	36.21	63.79	0.568
11	1.2810	306.38	12.00	197.67	42.45	43.50	0.976	27.66	72.34	0.383
12	1.3583	433.22	19.98	172.00	53.17	33.58	1.584	40.12	59.88	0.670
13	1.3083	371.14	15.42	181.00	48.19	38.90	1.239	34.62	65.38	0.530
LSD (5%)	0.0271	1.63	0.38	1.74	0.94	2.48	0.059	1.01	5.77	0.026

[a]Samples 1–3 were commmerically dried mixtures of hybrids; samples 4–13 were air-dried individual hybrids.
[b]NIR = Near-infrared reflectance at 1,680 nm (arbitrary units).
[c]SHT and SHT(H) = Stenvert hardness tester (seconds) and column height, respectively.
[d]CW, FW, and C/FW = coarse, fine, and C/F ratio by weight from SHT, respectively.
[e]CV, FV, and C/FV = coarse, fine, and C/F ratio by volume from SHT, respectively.

TABLE III
Simple and Partial (Test Weight Constant) Correlation Coefficients for Corn Hardness and Breakage Susceptibility (Combined Samples)

Measurement	Density (D)	NIR[a]	SHT[b]	SHT(H)[b]	CW[c]	CV[d]	TW[e]	Stein[f]	100-Kernel Weight	Floaters
					SIMPLE					
D	···	0.882	0.890	−0.854	0.879	0.872	0.936	−0.698	0.304	−0.833
NIR[a]	0.413	···	0.838	−0.822	0.885	0.807	0.863	−0.621	0.348	−0.920
SHT[b]	0.688	0.500	···	−0.926	0.966	0.959	0.793	−0.668	0.253	−0.765
SHT(H)[b]	−0.732	−0.569	−0.839	···	−0.959	−0.980	−0.723	0.502	−0.451	0.798
CW[c]	0.720	0.693	0.915	−0.914	···	0.956	0.764	−0.591	0.254	−0.808
CV[d]	0.702	0.459	0.901	−0.959	0.894	···	0.761	−0.569	0.418	−0.806
TW[e]	···	···	···	···	···	···	···	−0.847	0.331	−0.812
Stein[f]	0.504	0.412	0.011	−0.299	0.166	0.216	···	···	−0.027	0.494
100-Kernel weight	−0.016	0.131	−0.016	−0.325	0.005	0.271	···	0.504	···	−0.483
Floaters	−0.356	−0.744	−0.340	0.523	−0.496	−0.496	···	−0.624	−0.389	···
					PARTIAL (TW CONSTANT)					

[a]NIR = Near-infrared reflectance at 1,680 nm (arbitrary units).
[b]SHT and SHT(H) = Stenvert hardness tester (seconds) and column height, respectively. .
[c]CW = Coarse weight from SHT.
[d]CV = Coarse volume from SHT.
[e]TW = Test weight (lb/bu).
[f]Stein = Stein breakage tester (% throughs, 6-min test).

TABLE IV
Simple and Partial Correlation Coefficients of Several Key Parameters of Corn Hardness and Breakage Susceptibility

Correlation and Group	Density vs.					NIR[a] vs.			SHT[b] vs.		Stein[c] vs.	Required Level of Significance	
of Samples	Test Wt.	NIR[a]	SHT[b]	Stein[c]	Floaters	SHT	Stein	Floaters	Stein	Floaters	Floaters	1.0%	0.1%
Simple													
All	0.936	0.882	0.890	−0.698	−0.833	0.838	−0.621	−0.920	−0.668	−0.765	0.494	0.684	0.801
Hybrids	0.918	0.911	0.843	−0.768	−0.924	0.743	−0.805	−0.902	−0.787	−0.695	0.724	0.765	0.872
Partial													
Kernel wt. constant													
All	0.929	0.869	0.882	−0.725	−0.823	0.827	−0.652	−0.916	−0.684	−0.759	0.549	0.708	0.823
Hybrids	0.910	0.893	0.826	−0.801	−0.909	0.710	−0.835	−0.886	−0.796	−0.657	0.787	0.798	0.898
Stein constant													
All	0.905	0.798	0.795	···	−0.785	0.726	···	−0.900	···	−0.672	···	0.708	0.823
Hybrids	0.861	0.771	0.604	···	−0.833	0.300	···	−0.780	···	−0.295	···	0.798	0.898
Test wt. constant													
All	···	0.413	0.688	0.504	−0.356	0.500	0.412	−0.744	0.011	−0.340	−0.624	0.708	0.823
Hybrids	···	0.519	0.888	−0.569	−0.433	0.540	−0.652	−0.407	−0.652	−0.434	0.439	0.798	0.898

[a]NIR = Near-infrared reflectance at 1,680 nm (arbitrary units).
[b]SHT = Stenvert hardness tester (seconds).
[c]Stein = Stein breakage tester (% throughs, 6-min test).

corn-belt genotypes. They reported a negative correlation (−0.80 and −0.93 for two groups of samples dried at 24 and 60°C, respectively) between test weight and percent floaters. The correlation coefficients between kernel weight and percent floaters were +0.74 and +0.81, respectively. These results were obtained, however, for unusually large kernels with 100-kernel dry matter weights of 30.7–46.0 g, compared to 17.0–34.0 g for the samples studied by Stroshine et al (1981). The 100-kernel weights of our samples (on a dry matter basis) ranged from 19.3 to 26.9 g and are comparable to those of Stroshine et al (1981).

Our results on the effects of test weight on hardness and on breakage susceptibility were of particular interest. Theoretically, test weight is an indirect measure of density. In practice, however, numerous factors (grain history, moisture content, shape, mechanical or heat treatment, and percentage and type of broken kernels and foreign material) affect the packing and weight of a bushel of corn. Still, for almost all data in Table IV, the correlation coefficients between density and test weight were the highest. Density was also very significantly correlated with all other measures of hardness (Table III). The results show clearly that there is a place for the simple and rapid determination of test weight in evaluation of hardness of plant breeding samples or of commercial samples of comparable history, moisture content, and percentage of broken kernels and foreign material.

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