Corn Hardness as Related to Yield and Particle Size of Fractions from a Micro Hammer-Cutter Mill

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Cereal Chem. 69(3):343–347

ABSTRACT

Hardness of corn grain can be measured by the percentage yield of large flaking grits from dry milling. Fourteen corn genotypes ranging from soft to very hard were ground in a micro hammer-cutter mill fitted with a 2-mm or 6-mm screen. The ground corn was sieved into seven fractions. Predicted dry-milling grits yield (hardness) from an earlier article was positively, significantly correlated with mean particle size and yields of the 774-, 1,015-, and 1,445-μm fractions. Predicted dry-milling grits yields were negatively and significantly correlated with yields of the 359- and 460-μm fractions from corn ground with a 2-mm screen. Predicted dry-milling grits yield (hardness) was positively and significantly correlated with yields of 3,095- and 4,680-μm fractions and mean particle size but negatively and significantly correlated with yields of 201-, 502-, and 1,058-μm fractions from corn ground with a 6-mm screen.

Corn hardness is important to processors and exporters. Exporters desire hard corn grain because it breaks less than soft corn grain during handling, which results in better quality grain upon arrival at the destination. Hard corn grain also yields more grits, which dry millers desire. Wet millers, on the other hand, prefer soft corn grain, which usually requires less steeping and gives a better starch-protein separation. Corn hardness measurement methods include compression, breakage, pearling, grinding resistance and energy, sieving after grinding (Tran et al 1981), particle size of ground corn, near-infrared reflectance after grinding, density (Pomeranz et al 1984), grinding time (Pomeranz et al 1985), and floaters (Peplinski et al 1989). Kirleis and Stroshine (1990) reported that corn kernel density was the best single predictor of dry-milling quality and that combining test weight and kernel density improved prediction of milling quality from a short-flow corn dry-milling procedure on three dent corn hybrids. Mestres et al (1991) found that vitreousness (commonly associated with hardness and dry-milling behavior) could be evaluated at almost 90% from density and dent kernel percentage or ash content. Wu and Bergquist (1991) reported that corn kernel density correlated with yields of total grits ($r = 0.894$, $P = 0.0001$) in dry milling of 15 corn genotypes.

Tran et al (1981) defined a grinding index as the percentage of initial sample weight remaining after shaking 3 min on a 1.70-mm aperture sieve after grinding corn in a disc mill (Fisher Scientific) with the clearance between two corrugated metal discs adjusted to 3 mm. Pomeranz et al (1984) determined average particle size of corn ground on a Falling Number mill at a number 3 setting from four sieved fractions after shaking 10 min.

The objectives of this study were to relate corn grain hardness, as measured by total predicted yield of grits from dry milling,

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to yields of various sieved fractions and mean particle sizes (MPSs) from a micro hammer-cutter mill equipped with 2-mm and 6-mm screens (grinding time of this mill reported by other investigators was not used here). The 6-mm screen was close to the size of a degermer screen in dry milling (Wu and Bergquist 1991), and we are interested in the feasibility of obtaining hardness data as dry milling yield, except with a much smaller sample and in a much shorter time.

MATERIALS AND METHODS

Corn Grain

Fourteen corn genotypes from a wide variety of locations and years and with a wide range of kernel density (Table I) were used. All Pfister hybrids were dried at 38°C to about 10% moisture after harvest. Drying conditions for the remaining corn genotypes were not available.

Milling and Sieving

A type IV micro hammer-cutter mill (Glen Mills, Inc., Maywood, NJ) equipped with a 2-mm or 6-mm screen and a collection tube was used. The 2-mm screen was close to minimum size to allow for free passage of ground corn. The 14 corn genotypes were equilibrated in a constant temperature (25.5 ± 0.2°C) and constant relative humidity (rh) (60.6 ± 1.6% rh) room for four to seven days (final moisture 11.4–12.9%, except 9.9% for Argentine flint) before grinding in the micro hammer-cutter mill at an initial speed of 3,600 rpm until no more ground corn emerged. The speeds of the mill during grinding DeKalb 615F corn (hard kernel) decreased to a minimum of 2,920 rpm for the 2-mm screen and 3,100 rpm for the 6-mm screen, and for Crow's high-lysine corn (soft kernel), the minimum speed of the mill was 3,290 rpm for the 6-mm screen. More than 90% of the ground corn (20.0 g) passed through the screen, and the fine material that stuck to the wall of the mill was collected and combined with the material that passed through the screen. Duplicate runs were made for each corn genotype for each screen size.

A Ro-Tap Testing Sieve Shaker (W. S. Tyler Co., Cleveland, OH) with six 8-in. diameter brass sieves separated the ground corn from the micro hammer-cutter mill into seven fractions. The sieves used for separating ground corn samples were chosen from preliminary experiments to give fractions of reasonable yields. The sum of the products by weight of each fraction and average particle size for that fraction divided by the total weight of all fractions gave the MPS of each ground corn. Sieve openings were 1,190, 841, 707, 500, 420, and 297 μm for ground corn that passed through the 2-mm screen and 3,360, 2,830, 2,000, 1,410, 707, and 297 μm for ground corn that passed through the 6-mm screen. In a separate Ro-Tap screening, all materials remaining on the 1,190-μm sieve passed through a 1,700 μm opening, and all materials remaining on the 3,360 μm sieve passed through a 6,000 μm opening. The percent of corn ground through a 2-mm screen that passed through a 105-μm-opening sieve was 1% for Crow's high-lysine corn and 0% for DeKalb 615F corn. Therefore, for all practical purposes, all materials can be considered larger than 105 μm. The average size of the fraction remaining on the 1,190-μm sieve (1,445 μm) was the average of 1,700 and 1,190 μm; the average size of the fraction remaining on the 3,360-μm sieve (4,680 μm) was the average of 6,000 and 3,360 μm; and the average size of the fraction through the 297-μm sieve was the average of 297 and 105 μm. Average particle sizes used for this calculation were 1,445, 1,015, 774, 603, 460, 359, and 201 μm, respectively, for corn ground through the 2-mm screen. Average particle sizes were 4,680, 3,095, 2,415, 1,705, 1,058, 502, and 201 μm, respectively, for corn ground through the 6-mm screen. Each corn genotype was ground in duplicate, and each ground sample was screened once.

Another method of calculating particle size from sieving was to use the geometric mean diameter for each fraction to calculate the geometric mean diameter by mass of sample, D_{gw}, assuming that these distributions were logarithmic normally distributed (ASAE 1991).

The effect of 10 and 20 min of shaking on particle size distribution was studied for Crow's high-lysine (soft endosperm) and DeKalb 615F (hard endosperm) corn ground with a 6-mm screen. Each corn genotype was ground in duplicate and each ground corn was screened once. The mass of Crow's high-lysine corn on the smallest sieve (297-μm opening) changed 0.28% as a percent of the total sample mass between the 10- and 20-min sieving times. The mass of DeKalb 615F corn on the smallest sieve changed 0.36% between the 10- and 20-min sieving times. It would have changed less than 0.2% from 15- to 20-min sieving time assuming a linear change between 10 and 20 min. If the mass on the smallest sieve containing any material changed by 0.2% or less of the total sample mass during a 5-min period after an initial sieving time of 10 min, the sieving was considered complete (ASAE 1991). Also, the 20-min screening time gave more reproducible average sample mass for the seven fractions compared to a 10-min screening time (average coefficient of variation for the 20-min screening time was less than half of that for the 10-min screening time). Therefore, 20 min of screening time was chosen for all subsequent sieving.

Density

A Beckman Air Comparison Pycnometer model 930 (Fullerton, CA) was used to measure the volume (about 26 cm^3) of whole corn kernels in a cup from the pycnometer. The weight of corn kernels was determined by an analytical balance. Corn density was determined by dividing the mass of the kernels (grams) by the volume (cubic centimeters). All corn genotypes were equilibrated to about 11% moisture in a 25°C and 61% rh room before density measurements were made. Changes in density with moisture content from 5 to 14% for DeKalb 615F (hard kernel) and Crow's high-lysine corn (soft kernel) were determined, and

TABLE I
Description of Corn Genotypes

Corn	Location	Year	Description	Kernel Density[a] (g/cm^3)
Cornnuts	Oakland, CA	1988	Soft kernel	1.1839 (0.0013)
Crow's high-lysine	Milford, IL	1984	Soft kernel	1.2011 (0.0036)
B73 × MO17	W. Lafayette, IN	1989	Hard kernel	1.2474 (0.0004)
Pfister 3410	El Paso, IL	1986	Hard kernel	1.2553 (0.0007)
Waxy	Galesburg, IL	1985	Hard kernel	1.2816 (0.0006)
Pfister Kernoil-4	El Paso, IL	1986	Hard kernel	1.2971 (0.0015)
Commercial dent	Decatur, IL	1988	Hard kernel	1.3027 (0.0002)
Pfister 3450	El Paso, IL	1986	Hard kernel	1.3066 (0.0005)
Pfister 3900	El Paso, IL	1986	Hard kernel	1.3145 (0.0005)
Pfister 2600	El Paso, IL	1986	Hard kernel	1.3158 (0.0007)
Texas F337	Texas	1988	High-lysine hard kernel	1.3178 (0.0005)
White dent-1	Mexico	1988	High-lysine hard kernel	1.3272 (0.0005)
DeKalb 615F	Illinois	1988	Hard kernel food corn	1.3305 (0.0010)
Argentine flint	Argentina	1988	Very hard kernel	1.3523 (0.0004)

[a] Density corrected to 11% moisture. Values in parenthesis are standard deviations of triplicate samples.

the density of each corn genotype was adjusted to 11% moisture based on the relationship observed for DeKalb 615F corn, except that Cornnuts (soft kernel) was adjusted based on Crow's high-lysine corn. An increase of moisture from 11 to 12% decreased the density of DeKalb 615F corn by 0.0029 g/cm^3 compared to 0.0013–0.0033 g/cm^3 for the eight corn genotypes reported by Pomeranz et al (1986). Lower moisture values for corn kernels were obtained by partial drying in an air oven. Higher moisture values for corn kernels resulted from grain kept in desiccators above saturated salt solutions with higher relative humidity. All density measurements were determined in triplicate.

Analyses

The moisture content of whole corn kernels was measured in duplicate by 1) corn cracked in an Enterprise model 00 grain mill (Philadelphia, PA) and dried to constant weight at 105°C in an air oven; 2) corn ground through a 3-mm screen and dried in an air oven at 135°C for 2 hr (AACC 1983); and 3) whole corn kernels dried in a forced-air oven at 103°C for 72 hr by ASAE Method S352.2 (ASAE 1991).

Predicted Dry-Milling Yields of Grits

The sum of the yields of first-break grits (1,190–2,000 μm), second-break grits (707–1,190 μm), and third-break grits (707–1,410 μm) from conventional corn dry milling (Wu and Bergquist 1991) was the predicted dry-milling grits yield.

RESULTS AND DISCUSSION

Moisture Content of Whole Corn Kernels

Corn kernels were cracked in an Enterprise grain mill by hand, and the cracked corn was dried at 105°C in an air oven to constant weight. Eleven duplicate corn genotypes dried from cracked kernels averaged 12.5% moisture. The same 11 corn genotypes in duplicate were ground through a 3-mm screen and dried at 135°C for 2 hr, resulting in an average moisture of 12%. Whole corn kernels from the same 11 genotypes in duplicate dried in a forced-air oven for 72 hr at 103°C gave an average moisture of 10.4%. It appeared that drying whole corn kernels at 103°C in a forced-air oven for 72 hr resulted in a low moisture value, and that grinding corn through a 3-mm screen and drying it at 135°C for 2 hr was a reasonably accurate method for whole-kernel moisture determination. The moistures of all 14 corn genotypes were determined subsequently by drying ground corn at 135°C for 2 hr.

Particle Size Distribution of Ground Corn

Tables II and III show yields of sieved fractions and particle sizes of corn ground with 2-mm and 6-mm screens, respectively. Tables II and III show the arithmetic MPS calculated from arithmetic average particle size of sieved fractions as well as the D_{gw} calculated from the geometric MPS of sieved fractions (slightly lower than the arithmetic average particle size of sieved

TABLE II
Particle Size Distribution of Ground Corn from a Micro Hammer-Cutter Mill with 2-mm Screen[a]

	Yield (%) by Weight of Sieved Fractions							Mean Particle	
Corn	201 μm	359 μm	460 μm	603 μm	774 μm	1,015 μm	1,445 μm	Size[b]	D_{gw}[c]
Cornnuts	15.4 (1.5)	28.9 (1.9)	11.6 (0.7)	21.8 (0.5)	6.8 (0.0)	10.3 (0.4)	5.4 (0.5)	553 (1)	463 (4)
Crow's high-lysine	22.4 (8.2)	29.1 (4.5)	10.6 (0.9)	17.6 (1.7)	6.5 (0.8)	9.9 (0.7)	4.0 (0.6)	512 (27)	421 (33)
B73 × MO17	21.5 (0.8)	16.7 (0.9)	8.8 (1.7)	20.8 (0.6)	9.8 (1.1)	16.4 (1.1)	6.0 (0.2)	598 (9)	483 (5)
Pfister 3410	9.9 (6.9)	25.4 (6.0)	9.6 (0.1)	26.9 (3.8)	9.1 (0.8)	13.8 (1.7)	5.3 (0.5)	605 (4)	520 (20)
Waxy	10.4 (3.0)	18.9 (3.3)	6.4 (0.3)	15.9 (0.0)	13.7 (0.3)	25.8 (0.8)	8.9 (0.0)	710 (2)	598 (8)
Pfister Kernoil-4	21.1 (2.0)	16.5 (4.1)	6.6 (0.2)	22.6 (0.8)	8.9 (0.6)	16.8 (1.7)	7.4 (0.5)	615 (13)	495 (6)
Commercial dent	11.7 (2.6)	18.4 (2.9)	8.3 (1.7)	22.8 (0.3)	11.6 (0.4)	19.6 (1.3)	7.5 (0.0)	663 (13)	559 (15)
Pfister 3450	8.6 (0.6)	22.6 (3.0)	6.7 (0.8)	17.2 (5.0)	11.8 (1.0)	23.8 (3.5)	9.3 (1.2)	700 (3)	592 (3)
Pfister 3900	12.3 (4.8)	20.3 (4.3)	6.0 (0.7)	18.3 (1.4)	11.3 (0.6)	22.6 (0.7)	9.3 (0.2)	685 (5)	570 (15)
Pfister 2600	8.1 (0.4)	22.1 (4.1)	8.4 (2.0)	19.6 (1.0)	12.1 (0.5)	21.4 (1.2)	8.3 (1.0)	683 (19)	583 (16)
Texas F337	24.8 (1.4)	9.0 (1.0)	5.4 (0.0)	14.6 (0.5)	13.0 (0.3)	24.9 (1.4)	8.3 (0.2)	668 (7)	524 (9)
White dent-1	21.4 (1.4)	8.5 (1.0)	5.2 (0.1)	14.0 (0.2)	13.3 (0.2)	28.7 (0.2)	8.9 (0.6)	704 (8)	562 (9)
DeKalb 615F	19.2 (2.5)	13.6 (2.1)	4.7 (0.1)	12.8 (0.3)	12.3 (0.3)	26.5 (0.7)	10.9 (0.9)	707 (1)	565 (9)
Argentine flint	16.0 (1.3)	10.8 (0.6)	4.6 (0.3)	13.1 (0.2)	12.7 (0.5)	30.4 (0.1)	12.6 (0.1)	758 (4)	618 (7)

[a] Values in parenthesis are standard deviations of duplicate samples.
[b] Mean particle size in μm.
[c] D_{gw} = geometric mean diameter in μm by mass of sample.

TABLE III
Particle Size Distribution of Ground Corn from a Micro Hammer-Cutter Mill with 6-mm Screen[a]

	Yield (%) by Weight of Sieved Fractions							Mean Particle	
Corn	201 μm	502 μm	1,058 μm	1,705 μm	2,415 μm	3,095 μm	4,680 μm	Size[b]	D_{gw}[c]
Cornnuts	15.8 (0.3)	22.3 (0.6)	20.0 (0.5)	13.5 (0.8)	17.7 (0.4)	8.4 (0.9)	2.3 (1.1)	1381 (48)	910 (17)
Crow's high-lysine	17.6 (0.7)	13.6 (0.8)	18.1 (0.7)	12.6 (1.1)	20.3 (0.2)	13.3 (0.5)	4.4 (1.7)	1619 (59)	1047 (19)
B73 × MO17	12.6 (0.2)	12.3 (0.3)	14.9 (0.1)	11.9 (1.2)	24.3 (0.5)	17.8 (2.1)	6.3 (0.3)	1875 (43)	1285 (31)
Pfister 3410	13.8 (0.2)	11.8 (0.3)	16.0 (0.8)	12.4 (1.3)	21.9 (1.7)	16.6 (1.1)	7.7 (2.9)	1867 (94)	1252 (41)
Waxy	8.3 (0.1)	9.9 (0.0)	15.0 (0.3)	13.8 (0.3)	30.3 (0.4)	18.8 (0.3)	4.0 (0.7)	1957 (23)	1467 (11)
Pfister Kernoil-4	13.8 (0.1)	11.6 (0.5)	14.9 (1.0)	11.8 (0.1)	22.4 (2.2)	19.1 (1.4)	6.6 (2.5)	1880 (90)	1271 (48)
Commercial dent	13.0 (0.1)	12.2 (0.3)	16.9 (0.0)	13.8 (2.7)	23.6 (1.5)	14.8 (3.4)	5.8 (0.5)	1800 (50)	1235 (23)
Pfister 3450	11.6 (0.3)	11.0 (0.0)	14.2 (0.1)	13.0 (0.6)	25.3 (1.0)	18.7 (0.8)	6.2 (2.1)	1930 (40)	1355 (6)
Pfister 3900	10.3 (0.7)	9.6 (0.2)	13.6 (0.1)	11.7 (0.8)	26.2 (1.8)	19.9 (0.8)	8.8 (2.0)	2069 (66)	1476 (45)
Pfister 2600	12.7 (0.6)	12.3 (0.0)	15.6 (0.3)	11.9 (1.2)	22.1 (0.7)	19.1 (2.1)	6.3 (0.0)	1873 (32)	1279 (28)
Texas F337	10.6 (0.3)	10.8 (0.1)	14.9 (0.7)	11.4 (0.9)	21.1 (0.9)	18.3 (0.8)	12.9 (0.3)	2105 (36)	1453 (34)
White dent-1	9.9 (0.0)	10.8 (0.1)	15.6 (0.3)	12.5 (0.9)	21.0 (2.1)	19.7 (2.4)	10.6 (1.0)	2062 (12)	1449 (5)
DeKalb 615F	10.3 (0.2)	9.4 (0.0)	12.8 (0.8)	11.7 (0.7)	26.1 (2.3)	21.6 (1.9)	8.2 (1.7)	2082 (63)	1493 (31)
Argentine flint	8.9 (0.3)	10.2 (0.1)	15.1 (0.6)	12.8 (0.2)	21.9 (1.3)	19.3 (0.2)	11.9 (1.3)	2128 (33)	1520 (11)

[a] Values in parenthesis are standard deviations of duplicate samples.
[b] Mean particle size in μm.
[c] D_{gw} = geometric mean diameter in μm by mass of sample.

TABLE IV
Correlation Coefficients of Ground Corn Fractions from a Micro Hammer-Cutter Mill with 2-mm Screen[a]

	Fraction Yield (%)								
	359 μm	460 μm	603 μm	774 μm	1,015 μm	1,445 μm	MPS[b]	Density[c]	D_{gw}[d]
MPS	−0.678[f]	−0.859[f]	−0.586[g]	0.929[f]	0.960[f]	0.942[f]			
Density	−0.777[f]	−0.904[f]	−0.519	0.857[f]	0.900[f]	0.880[f]	0.911[f]		
D_{gw}	−0.474	−0.710[f]	−0.424	0.871[f]	0.861[f]	0.863[f]	0.963[f]	0.826[f]	
DM Grits[e]	−0.767[f]	−0.781[f]	−0.385	0.700[f]	0.782[f]	0.783[f]	0.783[f]	0.910[f]	0.697[f]

[a] The 14 corn genotypes were equilibrated in a room of 25°C and 61% rh.
[b] MPS = mean particle size (arithmetic).
[c] Density = density corrected to 11% moisture.
[d] D_{gw} = geometric mean diameter by mass of sample.
[e] DM Grits = predicted dry-milling grits yield (Wu and Bergquist 1991).
[f] Significant at P<0.01.
[g] Significant at P<0.05.

TABLE V
Correlation Coefficients of Ground Corn Fractions from a Micro Hammer-Cutter Mill with 6-mm Screen[a]

	Fraction Yield (%)						
	201 μm	502 μm	1,058 μm	2,415 μm	3,095 μm	4,680 μm	MPS[b]
MPS	−0.848[f]	−0.901[f]	−0.881[f]	0.497	0.924[f]	0.816[f]	
D_{gw}[c]	−0.927[f]	−0.880[f]	−0.879[f]	0.615[g]	0.908[f]	0.720[f]	0.979[f]
Density[d]	−0.799[f]	−0.775[f]	−0.767[f]	0.381	0.846[f]	0.734[f]	0.894[f]
DM Grits[e]	−0.673[f]	−0.575[g]	−0.628[g]	0.063	0.722[f]	0.827[f]	0.802[f]

[a] The 14 corn genotypes were equilibrated in a room of 25°C and 61% rh.
[b] MPS = mean particle size (arithmetic).
[c] D_{gw} = geometric mean diameter by mass of sample.
[d] Density = density corrected to 11% moisture.
[e] DM Grits = predicted dry-milling grits yield (Wu and Bergquist 1991).
[f] Significant at P<0.01.
[g] Significant at P<0.05.

TABLE VI
Equations Relating Predicted Dry Milling Yields of Grits to Yields of Sieved Fractions from Micro Hammer-Cutter Mill with 2-mm Screen[a]

$y = b + mx$		r^2
1,445-μm fraction yield	= −0.4270 + 0.1884 (DM grits yield)[b]	0.61
1,015-μm fraction yield	= −3.218 + 0.5364 (DM grits yield)	0.61
774-μm fraction yield	= 3.252 + 0.1712 (DM grits yield)	0.49
460-μm fraction yield	= 15.47 − 0.1818 (DM grits yield)	0.61
359-μm fraction yield	= 42.63 − 0.5368 (DM grits yield)	0.59
Mean particle size	= 399.8 + 5.689 (DM grits yield)	0.63
Corrected density[c]	= 1.078 + 0.004703 (DM grits yield)	0.83

[a] Fourteen corn genotypes, moisture-equilibrated, were tested.
[b] DM grits yield = predicted dry-milling grits yield.
[c] Corrected density is density corrected to 11% moisture.

fractions and not shown in tables). Cornnuts and Crow's high-lysine corn have soft kernels, low MPS, and low densities, but Argentine flint has very hard kernels, high MPS, and high densities (Tables I–III).

Correlation Coefficients of Sieved Fractions from Corn Ground Through a 2-mm Screen

Table IV lists the correlation coefficients of yields of sieved fractions and MPSs from 14 corn genotypes equilibrated in a 25°C and 61% rh room and ground with a 2-mm screen. Yield of the 359-μm fraction increased as MPS decreased ($r = -0.678$, significant at $P < 0.01$). Density and predicted dry-milling grits yield were positively, significantly correlated with yields of the 774-, 1,015-, 1,445-μm fractions, with MPS, and with geometric mean diameter by mass. But they were negatively correlated with the yields of the 359- and 460-μm fractions (all P<0.01).

Table IV shows that the correlation coefficients of MPS vs. density and fraction yields were higher in absolute value (statistically more significant for yields of 359- and 603-μm fractions) than the correlation coefficients of D_{gw} vs. density and fraction yields. Therefore, MPS appeared more suitable than D_{gw} as the particle size of choice in this study with a 2-mm screen.

Correlation Coefficients of Sieved Fractions from Corn Ground Through a 6-mm Screen

Table V lists the correlation coefficients of density, sieved fraction yields, and MPSs from 14 corn genotypes equilibrated in a 25°C and 61% rh room and ground with a 6-mm screen. The correlation coefficients of MPS vs. density and fraction yields were comparable to those of D_{gw} vs. density and fraction yields, and there was no distinct advantage of MPS or D_{gw} as particle size of choice with the 6-mm screen. Density and predicted dry-milling grits yield were positively, linearly, and significantly correlated with MPS and yields of 3,095- and 4,680-μm fractions but negatively correlated with yields of 201-, 502-, and 1,058-μm fractions (all $P < 0.01$ except two $P < 0.05$).

Equations That Relate Predicted Dry-Milling Grits Yield to Sieved Fraction Yields

Table VI lists equations that relate predicted dry-milling grits yield to sieved fraction yields, MPS, and density for corn ground through a 2-mm screen. Only the significant correlations (P<0.05) are shown. Predicted dry-milling grits yield can be readily calculated from the linear equation $y = b + mx$, where y is the fraction yield, MPS, or density in Table VI; x = predicted dry-milling grits yield; m = slope; and b = intercept. Similar equations relating predicted dry-milling grits yield to sieved fraction yields from a micro hammer-cutter mill with a 6-mm screen were determined (not shown).

CONCLUSIONS

Corn hardness as measured by the predicted dry-milling grits yield can be estimated by MPS or yields of the 359-, 460-, 774-, 1,015-, or 1,445-μm fraction ground through a 2-mm screen. Also, corn hardness as determined from the predicted dry-milling grits yield can be estimated by MPS or yields of the 201-, 502-, 1,058-, 3,095-, or 4,680-μm fraction ground through a 6-mm screen. Corn hardness as measured by predicted dry-milling grits yield can be estimated more quickly and easily by grinding through a 2-mm or a 6-mm screen in a micro hammer-cutter mill than by a traditional corn dry-milling procedure (Wu and Bergquist 1991) or by a short-flow corn dry-milling procedure (Kirleis and Stroshine 1990); all three methods give comparable significant correlation.

ACKNOWLEDGMENTS

The author thanks B. D. Deadmond for technical assistance; R. R. Bergquist for Pfister 3410, Pfister Kernoil-4, Pfister 3450, Pfister 3900, and Pfister 2600 corn; L. Rooney for Texas F337 corn; M. Bjarnason for white dent-1 corn; and A. W. Kirleis for B73 × MO17 corn.

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[Received May 13, 1991. Accepted November 5, 1991.]