Relation of Corn Grain Density to Yields of Dry-Milling Products

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ABSTRACT

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Grain density of corn is positively correlated with yields of certain dry-milled fractions. Grain hardness of corn determined by density correlated positively with yields of total grits and with second- plus third-break grits ($P < 0.01$), and negatively with yields of degerminator fines, low-fat flour, high-fat flour, and total flour ($P < 0.01$). Grain density and percent moisture were found to be negatively correlated.

Corn hardness is of interest to processors. Dry millers desire hard corn grain, because it yields higher prime products. Wet millers prefer soft corn grain, because a softer grain requires less steeping time and gives better starch-protein separation. Kirleis and Stroshine (1990) found that corn kernel density was the best single predictor of dry-milling quality and that a prediction model combining test weight and kernel density improved prediction of milling quality from a short-flow corn dry-milling procedure on three dent corn hybrids. The objective of this study was to correlate hardness measurements (density, floaters) with milling yields.

MATERIALS AND METHODS

Corn Grain

Commercial corn hybrids Pfister 2600, Pfister Kernoil-4, Pfister 3450, Pfister 3900, and Pfister 3410 were from Pfister Hybrid Corn Co. (El Paso, IL) and grown in 1986. Pfister no. 1 and Pfister no. 2 were experimental corn hybrids grown in 1989. All Pfister hybrids were dried at 38°C to about 10% moisture after harvest. Experimental F337 was an open-pollinated, quality protein maize synthetic produced in Texas in 1988. White dent-1 was a quality protein maize synthetic from the International Maize and Wheat Improvement Center, grown in Mexico in 1988. Cornnuts hybrid 88 was grown in 1988 from Cornnuts Inc. (Oakland, CA). Flint maize grain came from Cargill S.A.C.I. in Argentina. The high-lysine hybrid containing opaque-2 gene was from Crow's Hybrid Corn Co. (Milford, IL). Waxy grain was a mixture of corn varieties from National Starch and Chemical Corp. (Watseka, IL). Weaver 104 popcorn was grown in Illinois. Commercial dent, DeKalb 615F, and LH119 × LH51 were commercial hybrids produced in Illinois.

Dry Milling

Corn grain (4,500 g) was tempered to 16% moisture content for 16 hr, raised to 21% for 1.75 hr, and then to 24% for 15 min before degerming. Corn with added water was rotated slowly in a stainless steel drum for about 15 min and then maintained at room temperature (24–26° C). An experimental horizontal drum degermer with a steel screen with 7.9-mm diameter round holes as described by Brekke et al (1971) was used to degerm the tempered corn. A steel screen with 6.4-mm diameter round holes was used for Pfister no. 1 and Pfister no. 2 corns, and one with with 3.2-mm diameter round holes was used for Weaver 104 corn because of the smaller sizes of these kernels.

Degermed grain was spread out and allowed to dry at room temperature to 17 ± 1% moisture. Three pairs of corrugated rolls, a Bates laboratory aspirator, and a box sifter with three 30 × 30 cm screens were used to process the degermed grain into degerminator fines; low-fat meal; low-fat flour; high-fat meal; high-fat flour; first-, second-, and third-break grits; bran meal; first, second, and third germs; and hull fractions. This laboratory milling flowsheet was described in detail by Peplinski et al (1984).

Density

Grain density was determined by dividing kernel mass (grams) by kernel volume (cubic centimeters). The volumes of kernels were determined by a Beckman model 930 air comparison pycnometer (Fullerton, CA). All grains except popcorn, Pfister no. 1, Pfister no. 2, and LH119 X LH51 were equilibrated to about 11% moisture at constant temperature and humidity for four to seven days before measuring density. Lower moisture values for grain were obtained by partial drying in an air oven at different temperatures. Higher moisture values for grain resulted from grain kept in desiccators above saturated salt solutions with higher relative humidity. Change in density with moisture content from 4 to 14% for DeKalb 615F and Crow's high-lysine corn was determined. Density was determined in triplicates.

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TABLE I
Dry Milling Yields of Corns (%, dry basis)

Corn	Deg.[a] Fines	LF[a] Meal	LF Flour	1st-Break Grits	2nd- + 3rd-Break Grits	HF[a] Meal	HF Flour	Bran Meal	Hull	1st, 2nd, and 3rd Germs
Commercial dent	2.3±0.2[b]	10.8±0.1	4.3±0.1	10.3±0.8	34.6±0.3	6.4±0.0	1.2±0.1	8.3±0.1	6.0±0.6	15.7±0.3
Crow's high-lysine	9.2±0.7	10.4±0.4	6.9±0.3	4.6±0.4	20.0±1.0	11.5±0.3	8.0±5.0	5.0±3.5	7.8±1.2	16.6±0.8
Pfister 2600	2.5	9.5	3.5	16.9	33.7	8.9	3.4	3.1	6.0	12.6
Pfister Kernoil-4	2.2	10.3	4.0	13.4	33.2	7.8	3.5	3.0	4.6	18.1
Pfister 3450	2.5	11.3	4.6	13.5	33.2	5.6	1.1	6.7	6.9	14.5
Pfister 3900	1.6	11.7	4.5	11.9	35.7	5.1	1.1	7.3	6.5	14.6
Pfister 3410	3.5	12.4	5.6	11.5	32.6	7.9	5.5	1.8	5.1	14.0
Cornnuts 88	5.3	10.7	5.8	4.8	25.8	13.9	8.6	4.5	6.0	14.5
Flint	0.6	9.9	2.6	21.7	38.3	6.2	1.3	3.4	4.6	11.3
Waxy	2.7	8.1	2.7	7.8	26.8	11.9	4.3	4.1	18.4	13.3
DeKalb 615F	1.7±0.1	9.5±0.1	3.2±0.0	18.6±0.6	33.7±1.4	7.5±0.5	2.8±0.3	3.2±0.2	5.7±0.0	14.0±0.1
Weaver 104	3.6	7.3	1.4	8.1	43.9	11.0	1.6	6.9	6.7	9.4
Pfister no. 2	1.5	11.2	3.4	10.7	38.9	8.9	2.8	3.6	6.1	13.0
Pfister no. 1	1.1	9.1	2.6	12.8	38.2	9.7	2.8	4.5	5.2	13.9
LH119 × LH51	1.1	10.1	3.2	19.2	36.0	6.3	1.7	3.1	3.8	15.6

[a] Deg. = degerminator; LF = Low-fat; HF = high-fat.
[b] Values following ± are standard deviations from duplicates except DeKalb 615F from triplicates.

Percent Floaters

A sodium nitrate solution with a specific gravity of 1.275 in a 25°C room was used to measure, in triplicate, the percentage of floating corn kernels (100 kernels in 2 L of solution). Specific gravity of the solution was checked with a hydrometer before, during, and after the measurement.

Analyses

Moisture value for tempering corn was determined from three replicates by a Brabender Moisture/Volatiles tester, type SAS (C. W. Brabender Instruments, Inc., Hackensack, NJ) after corn was cracked in an Enterprise model 00 grain mill (Philadelphia, PA). Moisture content of dry-milled fractions was measured in duplicate by drying in an air oven at 135°C for 2 hr (AACC 1983).

Statistical correlations are Pearson's coefficients with probability of a zero coefficient.

RESULTS AND DISCUSSION

Dry Milling Yields of Corns

Yields of individual fractions from dry milling of corn are listed in Table I. Waxy corn had a much higher percentage of hull than dent and popcorn samples. Crow's high-lysine and Cornnuts 88 had low grit yields. Waxy corn grit yields were higher than Crow's high-lysine and Cornnuts 88, but less than those of other corn hybrids.

Density of Corns

Density and percent moisture of DeKalb 615F (correlation coefficient [r] = −0.977, $P < 0.01$) and Crow's high-lysine corn ($r = -0.946$, $P < 0.01$) were correlated. An increase of moisture from 11 to 12% decreased density by 0.0029 and 0.0064 g/ml, respectively, of DeKalb 615F and Crow's high-lysine grains. Cornnuts 88 and Crow's high-lysine had soft endosperms, and the equation for Crow's high-lysine corn was used for correcting density. The equation for DeKalb 615F was used for correcting density of other corns having hard endosperms. An increase in density with increasing corn hardness is shown in Table II (from 1.1839 and 1.2011 for soft Cornnuts 88 and Crow's high-lysine corns to 1.3523 and 1.3860 for hard flint and popcorns).

Percent Floaters

The percentage of kernels that floated on sodium nitrate (sp gr 1.275) ranged from 19% for flint corn (hard) to 100% for Crow's high-lysine and Cornnuts 88 (soft) (Table II).

Correlation Coefficients of Dry-Milled Corn Fractions

Yields of various dry-milled corn fractions and density of corn kernels were related (Table III). Bran meal was negatively correlated with first-break grits ($P < 0.05$); low-fat meal was positively correlated with low-fat flour ($P < 0.05$); hull was negatively correlated with prime products ($P < 0.01$) and with total grits ($P < 0.05$); germ recovery was negatively correlated with second- + third-break grits ($P < 0.05$) and with corrected density ($P < 0.05$) but positively correlated with percent floaters ($P < 0.05$). (Not all of these relationships are shown in Table III for reasons of space.)

Low-fat flour, high-fat flour, and sum of low-fat and high-fat flours were all negatively correlated ($P < 0.01$) with corrected density (Table III). Since flour was derived from soft endosperm and corrected density measures hardness, higher yield of flour fractions implies lower proportion of hard endosperm and lower corn hardness. First-break grits, second- + third-break grits, and total grits were all positively correlated ($P < 0.05$, $P < 0.01$, and $P < 0.01$, respectively) with corrected density (Table III). Since grits were derived from hard endosperm, higher yields of grits indicate a higher proportion of hard endosperm and harder corn. Prime products—the sum of total grits, low-fat meal, and low-fat flour—were negatively correlated with degerminator fines, low-fat flour, high-fat meal, and high-fat flour ($P < 0.01$, $P < 0.05$, $P < 0.01$, and $P < 0.05$, respectively) but are positively correlated with first-break grits, second- + third-break grits, total

TABLE II
Corn Density and Percentage of Floaters

Corn	Moisture (%)	Density (g/cm³)	Corrected Density[a] (g/cm³)	Percent Floaters[b]
Commercial dent	11.7	1.3006	1.3027 ± 0.0002	65.3 ± 3.3
Crow's high-lysine	12.1	1.1943	1.2011 ± 0.0036	99.7 ± 0.5
Pfister 2600	11.1	1.3155	1.3158 ± 0.0007	40.3 ± 3.8
Pfister Kernoil-4	11.3	1.2963	1.2971 ± 0.0015	85.3 ± 0.5
Pfister 3450	11.9	1.3040	1.3066 ± 0.0005	74.3 ± 1.7
Pfister 3900	11.7	1.3126	1.3145 ± 0.0005	86.0 ± 0.8
Pfister 3410	11.6	1.2535	1.2553 ± 0.0007	98.3 ± 0.9
Cornnuts 88	11.4	1.1810	1.1839 ± 0.0013	100.0 ± 0
Flint	9.8	1.3557	1.3523 ± 0.0004	19.0 ± 5.1
Waxy	10.9	1.2819	1.2816 ± 0.0006	ND[c]
DeKalb 615F	11.6	1.3288	1.3305 ± 0.0010	ND
Weaver 104	12.1	1.3828	1.3860 ± 0.0010	ND
Pfister no. 2	8.5	1.3303	1.3231 ± 0.0010	ND
Pfister no. 1	9.3	1.3372	1.3323 ± 0.0010	ND
LH119 × LH51	12.5	1.3383	1.3427 ± 0.0005	ND

[a] Density corrected to 11% moisture.
[b] Determined in a 1.275 sp gr solution of sodium nitrate. Values following ± are standard deviations from triplicates.
[c] Not determined.

TABLE III
Correlation Coefficients of Dry-Milled Corn Fractions[a]

Fraction	Degerminator Fines	LF Flour	1st-Break Grits	2nd- + 3rd-Break Grits	HF Meal	HF Flour	Prime Products	Total Grits	Corrected Density
Degerminator fines	...								
LF flour	0.713**	...							
1st break grits	−0.742**	0.470	...						
2nd- + 3rd-break grits	−0.704**	−0.756**	0.453	...					
HF meal	0.608*	0.109	−0.662**	−0.421	...				
HF flour	0.434*	0.408	−0.420	−0.542*	0.714**	...			
Prime products	−0.813**	−0.527*	0.844**	0.801**	−0.750**	−0.537*	...		
Total grits	−0.846**	−0.728**	0.835**	0.869**	−0.627*	−0.568*	0.963**	...	
Corrected density	−0.761**	−0.880**	0.629*	0.882**	−0.497	−0.724**	0.771**	0.894**	...
HF + LF flour	0.665**	0.789**	−0.562**	−0.726*	0.541*	0.869**	−0.636*	−0.761**	−0.942**

[a] * $P < 0.05$, ** $P < 0.01$. Number of observations = 15. LF = low-fat; HF = high-fat; corrected density = density corrected to 11% moisture. Prime products = total grits + low-fat flour + low-fat meal.

grits, and corrected density (all $P < 0.01$, Table III). Since grits accounted for a major part of prime products, similar correlation coefficients for total grits and for prime products versus identical fractions are reasonable.

Corrected density was negatively correlated ($P < 0.05$) with percent floaters (not shown in Table III), because harder corn gave a higher density but a lower percentage of floaters. Density can be measured more accurately than percent floaters, partly because some corn kernels may neither float nor sink in the solution. Relative standard deviations of density were smaller than those for percent floaters in Table II.

Moisture contents of corn varied from 8.5 to 12.5% when density was measured (Table II). Practically the same correlation coefficients and the same probabilities were obtained whether as-is density or density corrected to 11% moisture was used (as-is density correlation coefficient values are not shown in Table III); therefore, it may not be necessary to correct density values for moisture in the 8.5–12.5% mc range.

CONCLUSIONS

Density measurement is one method for determining corn hardness (Pomeranz et al 1984). Corn density can be measured objectively and accurately; and positive correlation of density versus total grits yield, a measure of corn hardness, is shown in Table III ($P < 0.01$). In addition, yields of second- + third-break grits and of prime products were positively correlated with density ($P < 0.01$); yields of degerminator fines, low-fat flour, high-fat flour, and high-fat + low-fat flour were negatively correlated with density ($P < 0.01$, Table III).

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