A Simple, Rapid Method to Measure Wheat Hardness by Grinding Time and Speed Reduction in a Micro Hammer-Cutter Mill[1]

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ABSTRACT

Wheat hardness can be simply and quickly measured by determining the time required to collect 17 ml of ground wheat from a 20-g sample in a commercial micro hammer-cutter mill at 3,600 rpm. Hard and soft wheats differ in grinding time and in the amount that the machine's speed is reduced. No correction was necessary for grinding time and speed reduction at moisture levels of 9.3–12.7%.

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Hardness is one of the most important quality characteristics of wheat. Grain hardness significantly influences the milling behavior of wheat and the suitability of the wheat flour for end uses. Hard wheat usually yields more flour with suitable color, and hard wheat flour has high water absorption that results in more bread. Soft wheat flour is suitable for cake or cookies. Some wheats may be difficult to classify as hard or soft from visual observation of kernel size, shape, and color. For example, Arkan (Martin et al 1983) is a hard red winter (HRW) wheat resulting from a cross between hard and soft varieties. Other wheats, such as Brule (a HRW variety) has some soft parents and has both hard and semihard kernels (Schmidt et al 1983), making it difficult to classify. Wheat hardness measurements have been summarized in several reviews (Obuchowski and Bushuk 1980, Miller et al 1982, Wu et al 1990).

Some authors used grinding time to determine wheat hardness. Kosmolak (1978) used a Brabender SM1 grinder (no longer commercially available). It took longer to grind 4.8 g of soft wheats than the same amount of hard wheats. Miller et al (1981, 1982) measured time to collect 4 g of ground wheat in a modified Brabender automatic micro hardness tester (also no longer commercially available) and reported longer grinding times for soft wheats than for hard wheats. Sampson et al (1983) studied grinding

[1]Mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.

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time for 20 g of wheat in a Wiley laboratory mill and found that soft wheats grind faster than hard wheats. Stenvert (1974) used a micro hammer mill (Type 14-580, Glen Creston) at 6,100 rpm to determine the relative hardness of English wheat varieties. Samples with grinding times less than 26 sec were arbitrarily classified as soft, and those with grinding times greater than 26 sec were designated as hard. Pomeranz et al (1988) also used a Stenvert hardness tester (Glen-Creston 14-580 mill) to measure hardness by various methods and reported mean times for HRW, hard red spring (HRS), soft red winter (SRW), soft white winter (SWW), and club wheats. The mill used by Stenvert and Pomeranz was a 220-V machine, as used in the United Kingdom.

Recently a commercial micro hammer-cutter mill became available that reveals both grinding time and reduction of the machine's speed during grinding. We have therefore used this instrument to investigate wheat hardness by simultaneously measuring the time to collect 17 ml of wheat meal and the speed reduction.

MATERIALS AND METHODS

Wheats

Arkan (HRW), Newton (HRW), Centurk 78 (HRW), and Sage (HRW) wheats were grown in Kansas in 1984. Arthur (SRW), Hart (SRW), and Ruler (SRW) wheats were grown in Ohio in 1984. Brule (HRW) wheat was from Nebraska in 1987. Daws (SWW) wheat came from Washington in 1981. Scout 66 (HRW) wheat was from Kansas in 1986. Len (HRS), Butte (HRS), and Stoa (HRS) wheats were grown in North Dakota in 1987 and 1988. The SWW varieties Augusta and Frankenmuth and SRW wheats Cardinal and Pioneer 2550 came from Washington and Michigan in 1988. Wheaton (HRS) wheat was from Minnesota in 1988, and Marshall (HRS) wheat came from Minnesota and North Dakota in 1988. The durum wheat varieties Vic, Cando, Lloyd, Monroe, Renville, and Ward came from Fargo, ND, in 1988. All wheats were stored at 1°C before use. Portions of some wheats were equilibrated for 14 days at 25°C and 48% rh before milling analysis.

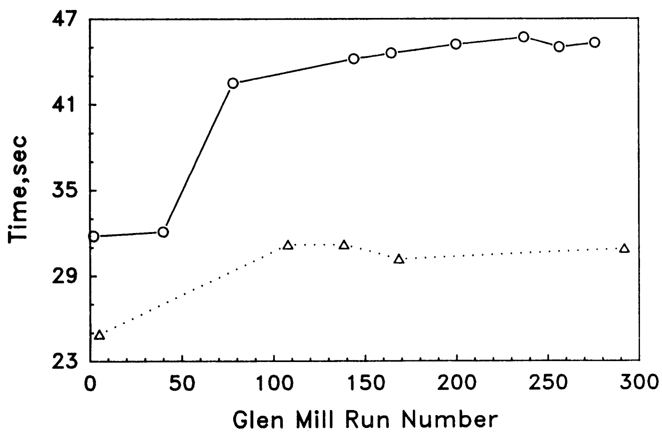

Fig. 1. Grinding time of Scout 66 (○) and Daws wheats (△) as a function of number of runs on a Glen mill.

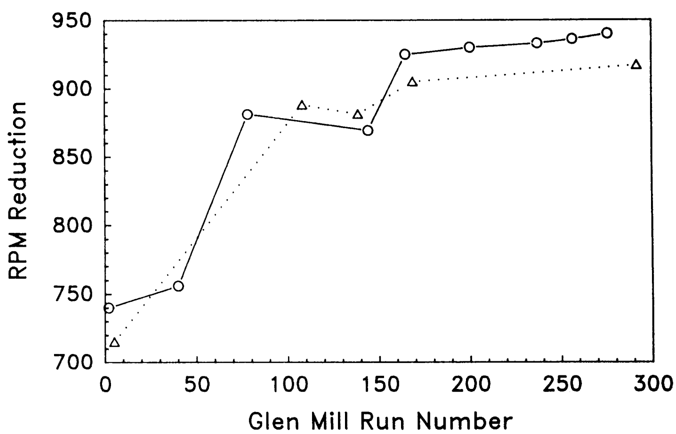

Fig. 2. Speed reduction of Scout 66 (○) and Daws wheats (△) as a function of number of runs on a Glen mill.

Micro Hammer-Cutter Milling

A Type IV micro hammer-cutter mill (Glen Mills, Inc., Maywood, NJ) equipped with a 2-mm screen, a tachometer, and a calibrated transparent meal collection tube was used. Wheat samples of 20.0 g, of known moisture content, were milled at 3,600 rpm. The time to grind enough wheat to fill the transparent collection tube to 17 ml and the minimum speed to which the mill slowed during grinding were recorded. Each wheat was analyzed in triplicate in 1988.

Near-Infrared Reflectance

Hardness by near-infrared reflectance (NIR) was determined by AACC Method 39-70 (1983) using a Pacific Scientific 6250 near-infrared spectrophotometer (Silver Springs, MD). The instrument was calibrated with 10 standard wheats from the Federal Grain Inspection Service. Each wheat was ground in a Udy cyclone mill with a 1-mm screen. The best-fit regression of the calibration wheats for predicting NIR hardness was:

$$\text{hardness} = -274.14 - 1{,}152.08\,[\log(1/R)]_{1,680} + 1546.24\,[\log(1/R)]_{2,230}\,,$$

where the subscripts in the equation denote wavelengths (nm), and R is reflectance.

Analyses

Moisture was determined in duplicate by heating wheat or ground wheat to 102°C in an air oven to a constant weight. For statistical analyses, all correlations presented are Pearson's coefficients, with probability values representing the probability of a zero coefficient.

RESULTS AND DISCUSSION

Effect of Aging (Breaking-In) of the Glen Mill on Grinding Time and Speed Reduction

In the first batch of 76 analyses of 17 wheats (data not shown), Scout 66 wheat at 12.6% moisture had a grinding time of 30.4 sec and a speed reduction of 799; Daws wheat at 11.5% moisture had a grinding time of 23.2 sec and a speed reduction of 743. In the second batch of 52 analyses of the same 17 wheats, each wheat had greater grinding time and speed reduction than the same wheat in the first batch. A third set of 143 analyses of 30 wheats (as-is moisture) had greater grinding times and speed reductions than the identical wheats in the second batch, but differences were much smaller than between the first and second batches. The same relative differences between varieties existed for each sample set, but absolute differences were not the same. Ratios of grinding time between the third and first sample sets for the same wheats at the same moisture contents were 1.41–1.47 for six HRS wheats, 1.44–1.51 for six HRW wheats, 1.39–1.50 for three SRW wheats, and 1.30 for a SWW wheat. Grinding time and speed reduction for Scout 66 and Daws appeared to reach constant values during the third sample set, as indicated by plots of grinding time or speed reduction versus the number of runs made on the mill (Figs. 1 and 2).

Grinding Time and Mill Speed Reduction for Various Wheats at the Same Moisture Content

Grinding time correlates ($r = 0.778$, $P<0.01$) with NIR hardness (Fig. 3), as hard wheats required a longer grinding time. Durum wheat, which is still harder than HRS and HRW wheats, had the longest grinding time of all wheats tested except Centurk 78. Figure 3 also shows differences in grinding time between hard and soft wheats—the lowest grinding time of hard wheats (for Brule, 33.4 sec) is above the highest grinding time of soft wheats

(Daws, 29.1 sec).

Mill speed reduction for various wheats also correlates (r = 0.497, P <0.05) with NIR hardness (Fig. 4). Arkan, derived from a cross between hard and soft wheats, had a lower grinding time than most HRW wheats, indicating that it is softer. The variety Brule apparently has intermediate hardness, and individual kernels also vary in hardness; it also had the lowest grinding time and speed reduction among all hard wheats. Indeed, the speed reduction value of Brule was lower than that of several soft wheats.

Grinding Time and Mill Speed Reduction for Wheats As Received

Figures 5 and 6 show grinding times and mill speed reduction of various wheats as received (9.3–12.7% moisture). Milling is much simpler if no moisture adjustment or correction needs to be made. The correlation coefficient between NIR hardness and grinding time was 0.876 (P <0.01). The correlation coefficient between NIR hardness and mill speed reduction was 0.820 (P<0.01).

Analysis of t-tests for grinding time (Fig. 5) at the 0.05 level showed that durum wheats differ from wheats of all other classes. No difference exists between HRS and HRW wheats, but these two classes do differ from durum and soft wheats. No difference exists between SRW and SWW wheats, but both differ from durum and hard wheats.

Speed reduction t-tests (Fig. 6) at the 0.05 level also showed that durum wheats differ from wheats of all other classes. No difference exists between HRS and HRW wheats, but these classes do differ from durum and the soft wheats. SRW wheats are different from SWW wheats, and the soft wheats differ from durum and hard wheats.

Grinding times of hard and soft wheats differ. The shortest grinding time for hard wheats (Brule, 38.0 sec) was longer than the longest grinding time for soft wheats (Frankenmuth, WA, 31.5 sec) (Fig. 5). The lowest speed reduction for hard wheats (931 for Scout 66) was also higher than the highest speed reduction for soft wheats (930 for Ruler, Hart, and Pioneer 2550 MI). Grinding time separates hard from soft wheats better than speed reduction does.

Grinding times and speed reductions for Augusta and Frankenmuth wheats from Michigan and Washington (Figs. 5 and 6) differ, indicating greater hardness (longer grinding time and higher speed reduction) for Washington wheats.

In a separate experiment, the volumes of ground wheat meal from 20 g of as-received wheats were recorded. The ground meals from the six HRS wheats of Fig. 5 had volumes ranging from 30.9 (Marshall, ND) to 33.1 ml (Wheaton). The ground meals from the five HRW wheats of Fig. 5 (not including Brule) produced volumes of 32.9 (Centurk 78) to 34.1 ml (Scout 66), but Brule meal had a volume of 37.5 ml. The ground meal from Daws (SWW) wheat amounted to 35.3 ml, and those from three SRW wheats had volumes of 38.8 (Hart) to 42.7 ml (Ruler). In general, the volume of 20 g of ground wheat meal increases with decreasing hardness, and the hard wheat meals produce smaller volumes than soft wheat meals.

Effect of Different Glen Mills on Grinding Time and Speed Reduction

All the data presented so far (Figs. 1–6) are from a single micro

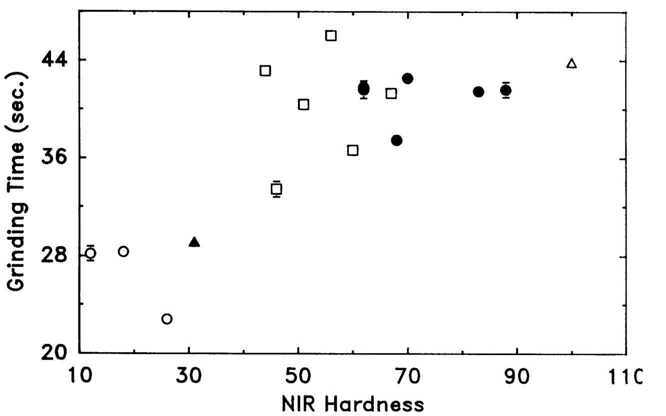

Fig. 3. Grinding time as a function of near-infrared reflectance (NIR) hardness for wheats at 10.4% moisture. △ = durum, ● = hard red spring, □ = hard red winter, ▲ = soft white winter, ○ = soft red winter. Vertical bar is standard error (not shown if smaller than individual point).

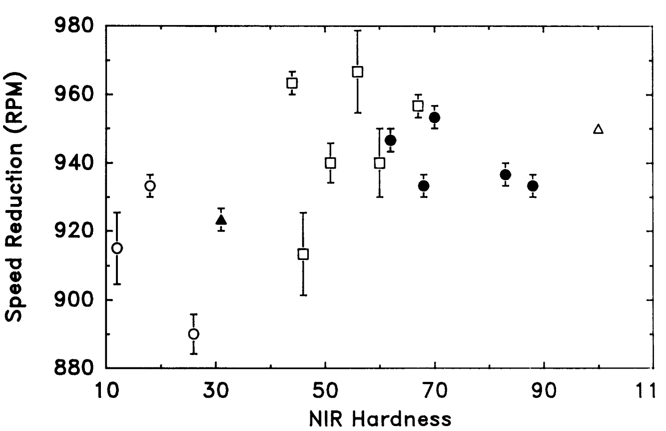

Fig. 4. Speed reduction as a function of near-infrared reflectance (NIR) hardness for wheats at 10.4% moisture. △ = durum, ● = hard red spring, □ = hard red winter, ▲ = soft white winter, ○ = soft red winter. Vertical bar is standard error (not shown if smaller than individual point).

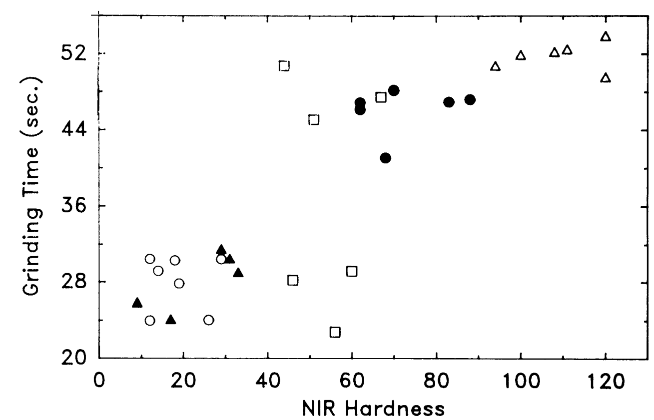

Fig. 5. Grinding time as a function of near-infrared reflectance (NIR) hardness for wheats as received. △ = durum, ● = hard red spring, □ = hard red winter, ▲ = soft white winter, ○ = soft red winter. Vertical bar is standard error (not shown if smaller than individual point).

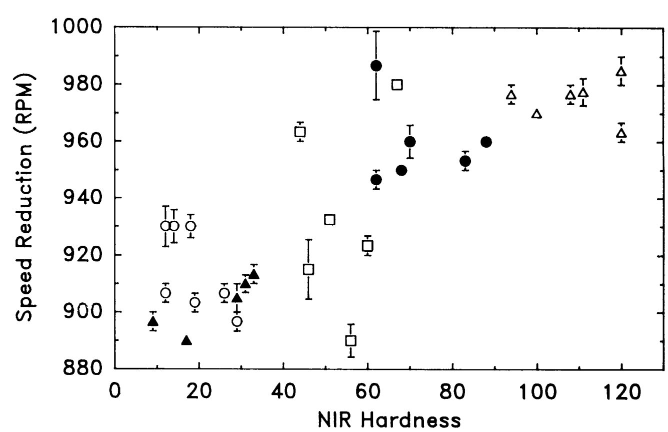

Fig. 6. Speed reduction as a function of near-infrared reflectance (NIR) hardness for wheats as received. △ = durum, ● = hard red spring, □ = hard red winter, ▲ = soft white winter, ○ = soft red winter. Vertical bar is standard error (not shown if smaller than individual point).

TABLE I
Effect of Four Different Glen Mills on Grinding Time and on Speed Reduction[a]

Serial No. of Glen Mill	Wheat	Time (sec)	Speed Reduction
12	Daws	33.8 (0.5)	793 (10)
	Scout 66	45.5 (1.0)	825 (25)
33	Daws	31.0 (1.7)	743 (6)
	Scout 66	41.3 (1.7)	765 (13)
43	Daws	30.5 (0.6)	763 (26)
	Scout 66	44.0 (1.2)	820 (24)
59	Daws	30.2 (0.9)	905 (6)
	Scout 66	45.1 (0.8)	943 (25)

[a] Averages of four runs. Standard deviations are in parentheses.

hammer-cutter mill, No. 59. Three additional, similar micro hammer-cutter mills of unknown history were used to grind identical wheat samples. The mills differed in grinding time at the 0.05 level (*t*-test), except for mills 43 and 59 (Table I). Also, differences (at the 0.05 level) exist among the mills in speed reduction, except between mills 12 and 43. Mills 12, 33, and 43 were rental units, which had probably been used longer and more extensively than our mill (No. 59), which had processed about 300 samples. Nevertheless, the relatively small spread in times to grind identical wheat (12% for Daws and 10% for Scout 66 wheats) for the four mills, combined with the relatively large ratio of Scout 66 grinding time to Daws grinding time (1.33–1.49) (Table I), suggest that Glen mill grinding time may serve as a standard of wheat hardness, especially if mills can be calibrated with wheat with known characteristics.

CONCLUSIONS

Both the grinding time and speed reduction can be obtained in 1 min for a wheat sample of 20 g. No correction of moisture content in the 9.3–12.7% range is necessary, as established from our results with as-is wheats. Grinding time appears to be among the fastest of any method of hardness determination currently available. The mill is portable and relatively inexpensive ($1,960 for the mill alone, $2,650 with tachometer). The operation of the mill is simple, and no sophisticated technical training is necessary for the operator. Good correlation of grinding time or speed reduction with NIR hardness showed that our method is reliable.

Hard and soft wheats differ in grinding time and speed reduction. In addition, SRW wheats are different from SWW wheats for speed reduction at the 0.05 level, as shown by *t*-tests.

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