Developing Agreement Between Very Short Flow and Longer Flow Test Wheat Mills

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ABSTRACT

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Variations in soft wheat moisture content and kernel texture greatly affected the flour yield produced by a small (short flow) microtest mill (Quadrumat Jr.). An algorithm was developed that adjusted Quadrumat Jr. flour yield to 15% wheat moisture content, precluding the need to temper the wheat before milling. Another algorithm was developed to adjust Quadrumat flour yield relative to a constant softness equivalent (measurement of kernel texture) obtained during the micromilling procedure. Predicting the flour yield of the longer flow Allis-Chalmers mill from Quadrumat Jr. unadjusted flour yield ($R^2 = 0.55$) was compared with predicting Allis-Chalmers flour yield from the Quadrumat Jr. adjusted flour yield ($R^2 = 0.90$) across five diverse confirmation data sets. An algorithm to adjust flour yield for softness equivalent was individually developed for soft and hard wheats. Representative micromilling flour yield and softness equivalent data could be produced using as little as 10 g of untempered wheat and ≈3 min of operator time.

The assessment of milling quality is an essential element of testing wheat for overall quality. Economic considerations often dictate that test milling be accomplished quickly, which requires a small size sample and a small mill. One purpose of micromilling wheat is to predict the flour yield potential and the kernel texture expressed by a particular wheat sample when milled using a much larger commercial mill that may have 25–35 pairs of rolls. However, small test mills process samples quickly with as few as three contiguous passes. Use of a micromill increases the likelihood that other factors such as wheat moisture content and kernel texture will influence the results.

Wheat moisture variation usually is eliminated by tempering to a constant moisture level. Normally, fluctuations in kernel texture within a cultivar or a within class of wheat are not considered an important influence on milling flour yield produced using longer flow mills. Tempering to a higher moisture content will make the kernels softer and consistent in texture but it reduces extractable flour yield (Approved Method 26-10A, AACC 1995) (Hook et al 1982a,b; Finney and Andrews 1986; Bass 1988). Also, the added time of tempering substantially increases sample handling time and tempering creates additional opportunity for error.

Whan (1974) observed that across a wide range of kernel texture, agreement between flour yield from a microtest mill (Quadrumat Jr.) and a Buhler mill could be improved if soft, hard, and very hard wheats were tempered to 13.5, 14.5, and 15.5% moisture contents, respectively, before milling. After tempering, correlation coefficients improved from ≈0.56 to ≈0.78 by tempering before Quadrumat Jr. milling.

A previous report (Finney and Andrews 1986) described a modified Quadrumat Jr. mill. Flour yield data from that mill had excellent agreement in ranking flour yield data from a longer flow Allis-Chalmers mill, but Quadrumat Jr. flour yield was strongly influenced by wheat moisture content. Others have also observed a need to temper wheat for Quadrumat Jr. milling (Whan 1974; Hook et al 1982a,b). However, the realities of test milling, especially for evaluating thousands of breeding lines, require that relatively small samples of wheat be milled using a small, short-flow mill without tempering and at an extremely wide range of kernel textures within and across cultivars and even between wheat classes.

The objectives of this study were to demonstrate the extent of the effect of wheat moisture content and kernel texture (measured as Quadrumat Jr. softness equivalent) on flour yield data from a particular short-flow microtest mill (Quadrumat Jr.). Next, algorithms to adjust for moisture content and softness equivalent (SE) were developed to improve agreement between the short-flow mill and a longer flow mill (Allis-Chalmers). The Allis-Chalmers mill normally mills tempered wheat, and total flour yield is not strongly influenced by wheat kernel texture within a class (measured as break flour yield). Those adjustment algorithms were then confirmed using other selected wheat sets. Using those adjustment algorithms, milling sample size was evaluated to determine the smallest amount of wheat that reliably could be milled using the adjusted micromilling system.

MATERIALS AND METHODS

Wheats

A total of eight sample sets were used in this study. Two were used for methods development, five for methods confirmation, and one for evaluating milling sample size.

First, a set of 17 soft wheat cultivars was selected to develop an adjustment algorithm for the influence of wheat moisture content milled using Quadrumat Jr. milling data. The 17 soft wheat cultivars were Argee, Arthur, Auburn, Blackhawk, Caldwell (2), Clark, Coker 9733, Compton, Fairfield, Fla 301, Fredrick, Pike, Pioneer 2550, Pioneer 2555, Ter 8117, Thorne, and Wheeler. The wheats exhibited a large range in Allis-Chalmers flour yield (5.2%) and Allis-Chalmers break flour yield (20.6%). Wheats were tempered to four moisture levels (10.0, 12.5, 14.3, and 15.3%) and milled using the Quadrumat Jr. mill. Subsets of wheats were tempered to 15% moisture and milled using the Allis-Chalmers mill. Unless otherwise stated, 25 g and 1,500 g of wheat were milled using the Quadrumat Jr. and the Allis-Chalmers mills, respectively.

Seven soft wheat cultivars (Arthur, Caldwell, Cardinal, Frankenmuth, Mallard, Pioneer 2548, and Tyler) were selected to develop an adjustment algorithm for the influence of kernel texture on Quadrumat Jr. milling data. The seven cultivars were each grown at four to six various locations (totaling 120 samples). They were tempered to three wheat moisture contents (11, 13, and 15%) and milled using the Quadrumat Jr. mill. Subsets of wheats were tempered to 15% moisture and milled using the Allis-Chalmers mill.

Confirmation of the adjustment algorithms was accomplished using five sets of selected samples. The first confirmation set consisted of eight soft wheat cultivars that exhibited a range in SE. After tempering wheats to 11, 13, or 15% moisture content, they

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were milled using the Quadrumat Jr. mill. At 15% moisture content, the range in Allis-Chalmers flour yield was 4.3% and the range in Quadrumat Jr. SE was 23.7%. Three wheats (Glacier, Caldwell, and Wakefield) were soft (67, 67, and 63 SE, respectively), two (Clarkan and Mallard) were intermediate (57 and 56 SE, respectively) and three (Compton, Coker 9733, and Hillsdale) were relatively hard for soft wheats (50, 50, and 44 SE, respectively). Subsets of wheats were tempered to 15% moisture and milled using the Allis-Chalmers mill. SE was evaluated according to Finney and Andrews (1986). SE is highly associated with break flour yield from a larger mill calculated as:

$$[(\mathrm{Wt} - \mathrm{Ov}_{42}) - \mathrm{Ov}_{16}]/(\mathrm{Wt} - \mathrm{Ov}_{42}) \times 100 \qquad (1)$$

where Wt = milled wheat weight, Ov_{42} = overs of the 0.42-mm aperture sieve, Ov_{16} = overs of the 0.16-mm aperture sieve.

A second confirmation set of soft wheats was evaluated on an as-is moisture content basis. It consisted of 52 test lines, each composited across growth environments. Wheat moisture contents were normal as-is for the eastern half of the United States (13.9–15.2%). Moisture content range was 13.9–15.2%. Allis-Chalmers flour yield and break flour yield were 3.9 and 15.3%, respectively. They were milled using the Quadrumat Jr. mill, and subsets were tempered to 15% moisture and milled using the Allis-Chalmers mill.

A third confirmation set of soft wheats was relatively dry in moisture content. Fifty-seven soft wheat cultivars (Augusta, Argee, Arthur, Atlas66, ATW270, Auburn, Becker, Blazer, Blueboy, Bradford, Caldwell, Cardinal, Charmany, Chelsea, Cherokee, Clark, Clarkan, Coker 9024, Coker 9105, Coker 9323, Coker 9766, Coker 9803, Coker 9835, Columbia, Compton, Delta Queen, Fairfield, FFR-555W, Fla301, Fla302, Fla 303, Freedom, GA100, Geneva, GR876, Hart, Hillsdale, Howell, Knox 62, Madison, Massey, McNair 1003, NY6432-10, OTL, Pioneer 2551, Pioneer 2555, Pioneer 2548, Pioneer S76, PTL, Ruler, Sawyer, Severn, Thorne, Titan, Verne, Wakefield, Wheeler), each from a different growth environment were milled at a relatively dry as-is moisture content (11.0–13.2%) using the Quadrumat Jr. mill. Subsets of wheats were tempered to 15% moisture and milled using the Allis-Chalmers mill.

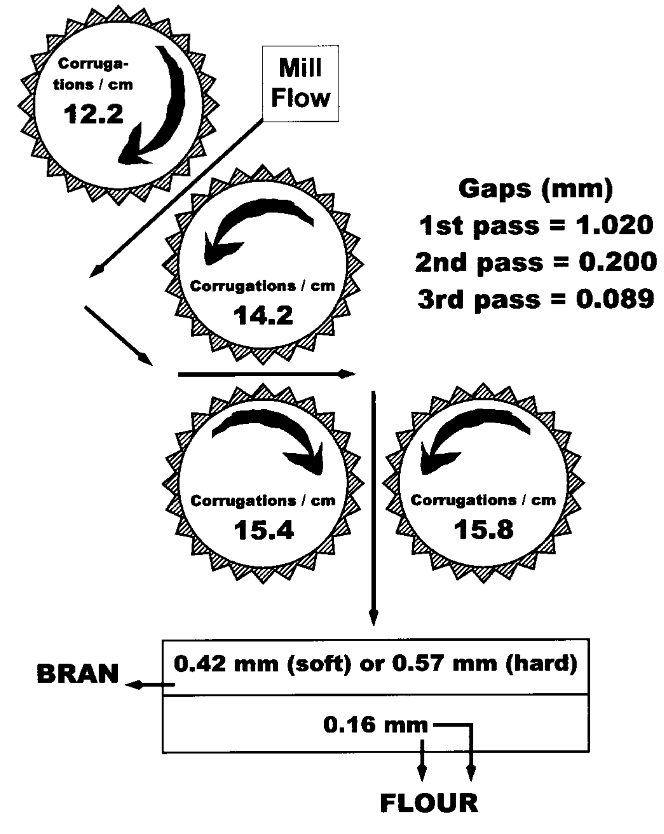

Fig. 1. Quadrumat Jr. mill flow.

A fourth confirmation set consisted of nine hard wheat cultivars (Butte 86, Guard, Hawk, Marshall, Newana, Ruby, Stoa, Thunderbird, and Wheaton) chosen to estimate the value of applying the soft wheat-derived algorithms to hard wheat. They were tempered to 11, 13, and 15% moisture content, and milled using the Quadrumat Jr. mill. They exhibited relatively wide ranges in Allis-Chalmers break flour yield (7.6%), flour yield (3.6%), and kernel (tempered) moisture content (4%). Wheat (100 g) was milled using the Quadrumat Jr. mill. Subsets of wheat were tempered to 16.5% moisture and milled using the Allis-Chalmers mill.

A fifth set of 10 soft wheats and 11 hard wheats were evaluated to study the algorithmic adjustment for both classes. The soft wheats were Argee (SRW), Augusta (SWW), Cardinal (SRW), Cayuga (SWW), Mallard (SRW), Nugaines (SWW), Paha (Club), Pioneer 2643 (SRW), Ruler (SRW), and Treasure (SWS). The hard wheats were Arkan (HRW), Bronze Chief (HRS), Butte 86 (HRS) Hawk (HRW), Guard (HRS), Len (HRS), Marshall (HRS), Newton (HRW), Stoa (HRS),Thunderbird (HRW), and Wheaton (HRS).

To investigate the effect of milling sample size on Quadrumat Jr. flour yield, a selection of three soft wheats (Becker, Fla 302, and Oasis) were tempered to 15% moisture and milled at 2, 5, 10, 15, 20, 25, 50, 100, and 200 g wheat weights. Becker, Fla 302, and Oasis had test weights of 58, 55, and 60 lb/bu (AACC 1995), respectively, and had densities of 1.270, 1.335, and 1.334 g/cm^3, respectively, as measured by hexane displacement (Gaines et al 1998). Flour sieving time was 1.5 min for the 100- and 200-g samples and 1.0 min for the smaller-sized samples.

Quadrumat Jr. Milling

Short-flow micromilling was accomplished using a modified Quadrumat Jr. mill (Brabender Instruments, South Hackensack, NJ) following Approved Method 26-50 (AACC 1995) as modified by Finney and Andrews (1986). Tempering was accomplished overnight. Mill flow, roll gaps, corrugations per roll, and sieve openings are shown in Fig. 1. The mixed set of hard and soft wheats used two scalp screens with a 0.42-mm aperture for the soft wheat cultivars and a 0.57-mm aperture for the hard wheat cultivars. The front of the mill had a clear plastic cover with holes near the clean-out positions to which a blower was attached to facilitate cleaning between samples. The exhaust of a vacuum cleaner blew through the mill rather than using suction to facilitate cleaning. The mill had a total of four rolls positioned to allow three contiguous passes during milling. Mill temperature was 37 ± 1°C, room temperature was 21 ± 1°C, and relative humidity was 57 ± 3%. Soft wheats were either milled at as-is moisture content or tempered overnight to the reported levels. Hard wheats were tempered three days before milling. In the mixed class study, soft wheats were tempered to 15% and hard wheats were tempered to 16% moisture content. Milling stock was sieved for 1.5 min when wheat weight was ≥100 g and sieved for 1.0 min when wheat weight was <100 g. As-is (nonadjusted) Quadrumat Jr. flour yield was calculated as:

$$\mathrm{Yield} = 100 \times [1 - (\mathrm{Ov}_{42}/\mathrm{wheat\ wt})] \qquad (2)$$

SE was calculated from Quadrumat Jr. milling according to Finney and Andrews (1986). SE is highly correlated with break flour yield from a larger mill. As-is (nonadjusted) SE was calculated as:

$$\mathrm{SE} = 100 \times [(\mathrm{wheat\ wt} - \mathrm{Ov}_{42}) - \mathrm{Ov}_{16}] / (\mathrm{wheat\ wt} - \mathrm{Ov}_{42}) \qquad (3)$$

Allis-Chalmers Milling

Longer flow milling was accomplished using an Allis-Chalmers roll stand mill following Approved Method 26-32 (AACC 1995) as modified by Yamazaki and Andrews (1982). Wheat (1,500 g) was tempered overnight to 15% for soft wheats and 16% moisture content for hard wheats. Fifteen total roll set passes were accomplished during Allis-Chalmers milling. During milling room temperature was 21 ± 1°C and relative humidity was 57 ± 3%. Endosperm separation index (ESI) and friability were evaluated according to Yamazaki and Andrews (1982).

Friability is the relative tendency of wheat endosperm to reduce to flour as a result of corrugated and smooth roll action. Friability was calculated by dividing the total flour by the amount of stock (minus wheat weight) passing through the corrugated (break) and smooth (reduction) rolls. Thus, friability is the percent of flour obtained from the amount of stock worked on by all sets of rolls in the mill. It relates to the total energy consumed by the milling process.

Endosperm separation index was calculated by adding the weights of the overs of one middling stream and three break streams and the final bran weight. That total weight was divided by the total recovery of all fractions and from the result was subtracted 14.5% and 2.5% constants for bran and germ, respectively, representing their theoretical proportion of a soft wheat kernel.

Straight-grade flour yield (FY), break flour yield, friability (FR), and endosperm separation index (ESI) were determined. A milling score (MS) was calculated as:

$$\begin{aligned} \text{MS} = {} & [(\text{FY} \times 3.703) - 262.949] + [(\text{FR} \times 3.333) - 73.381] \\ & + [50.064 - (\text{ESI} \times 2.779)] \end{aligned} \qquad (4)$$

The milling score equation was based on an arbitrary equal (33.3%) weighting score for a flour yield of 80%, a friability of 32%, and an endosperm separation index of 6.0%. A score of zero was equivalent to a flour yield of 71%, a friability of 22%, and an endosperm separation index of 18.0%.

Evaluation

Data were analyzed using Statistica99 (StatSoft, Tulsa, OK) software. Wheats were milled in duplicate and means of duplicate millings were compared using analysis of variance for treatment effects. Treatment effects were evaluated for simple linear model least squares regression (for predicting larger mill milling parameters from smaller mill milling parameters). Standard variance was expressed as coefficient of variation. Unless otherwise stated, all R^2 values were statistically significant ($P < 0.05$).

RESULTS AND DISCUSSION

Moisture Adjustment Algorithm

Seventeen soft wheats were used to establish the moisture adjustment algorithm. Increasing wheat moisture content decreased Quadrumat Jr. flour yield (Fig. 2A) and increased kernel softness (Fig. 2B) as shown previously (Hook et al 1982a,b; Finney and Andrews 1986; Bass 1988). Moisture adjustment algorithms were developed to align Quadrumat Jr. flour yield and SE data to a constant moisture content. Fifteen percent moisture content was chosen because that is the same moisture content used to temper soft wheat for the Allis-Chalmers mill. The algorithms were:

$$\begin{aligned} \text{Yield}_{15} &= \text{Yield} + [(15 - \text{moisture content}) \times -1.308] \\ \text{SE}_{15} &= \text{SE} + [(15 - \text{moisture}) \times 1.153] \end{aligned} \qquad (5)$$

The simple least squares linear regression model R^2 for predicting Allis-Chalmers flour yield data from Quadrumat Jr. flour yield improved from 0.14 to 0.59 when the moisture correction was applied for flour yield (Fig. 3A). The regression model R^2 for predicting Allis-Chalmers break flour yield from Quadrumat Jr. SE improved from 0.77 to 0.94 when the moisture correction was applied for kernel texture (Fig. 3B).

The regression slope for predicting Quadrumat Jr. flour yield$_{15}$ from SE was a very low –0.09. When data from all wheats were combined, flour yield from the longer flow mills was not influenced by kernel texture. Also, the moisture adjustment algorithm produced a regression slope for the prediction of Quadrumat Jr. flour yield$_{15}$ from wheat moisture that was not significantly different from zero (–0.07, $P = 0.56$), showing the effect was eliminated.

Kernel Texture Adjustment Algorithm

Seven soft wheat cultivars were each grown at four to six locations that produced a large range in Allis-Chalmers break flour within each cultivar. They were used to establish the SE adjustment algorithm by using pure cultivars grown at different locations because cultivars differ in their kernel texture response to locations (Gaines 1991). Across all cultivars and locations, SE values were 13.2, 14.4, and 14.8% for the 11, 13, and 15% wheat moisture levels, respectively. An algorithm was developed to adjust Quadrumat Jr. flour yield$_{15}$ to a 52% SE value. The 52% value is a norm for Eastern U.S. soft red winter wheats. A different value for another wheat class likely would work equally well. The adjustment algorithm was:

$$\text{Adjusted flour yield} = \text{yield}_{15} + [(52 - \text{SE}_{15}) \times -0.158] \qquad (6)$$

The simple least squares linear regression model R^2 values for predicting Allis-Chalmers flour yield data from Quadrumat Jr. unadjusted flour yield and flour yield$_{15}$ were 0.17 and 0.45, respectively. Applying the algorithm to adjust Quadrumat Jr. flour yield$_{15}$ values to 52% SE increased the regression R^2 for predicting Allis-Chalmers flour yield from adjusted Quadrumat Jr. flour yield to 0.56. The regression R^2 for predicting Allis-Chalmers mill score from adjusted Quadrumat Jr. flour yield was 0.72.

Algorithm Confirmations

Tempered wheats. Eight other soft wheat cultivars were selected that exhibited a wide range in Allis-Chalmers break flour. They were tempered to 11, 13, and 15% wheat moisture to confirm the validity of the moisture and texture adjustment algorithms. The

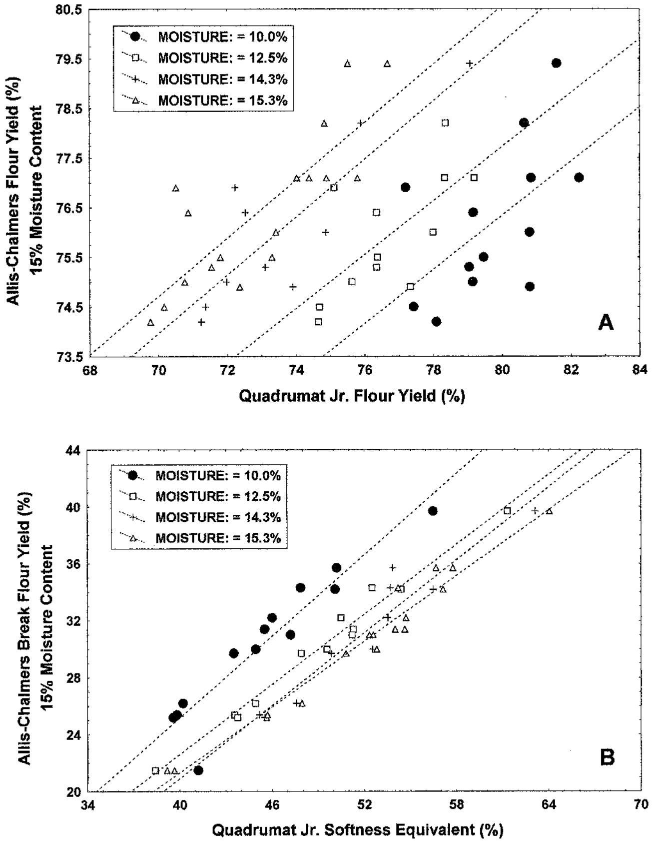

Fig. 2. Effect of wheat moisture content on the relationship between (**A**) Quadrumat Jr. flour yield and Allis-Chalmers flour yield and (**B**) Quadrumat Jr. softness equivalent and Allis-Chalmers break flour yield.

regression model R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. flour yield, flour yield$_{15}$, and adjusted flour yield were 0.17, 0.45, and 0.85, respectively. The regression R^2 for predicting Allis-Chalmers mill score from Quadrumat Jr. adjusted flour yield was 0.85.

Normal moisture wheats. Fifty-two composited soft wheat test lines were used to test the moisture and texture adjustment algorithms when milled on the Quadrumat Jr. mill at as-is nontempered moisture content. Regression model R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. flour yield, flour yield$_{15}$, and adjusted flour yield were 0.49, 0.55, and 0.74, respectively. Quadrumat Jr. adjusted flour yield predicted adjusted flour yield and mill score with a regression model R^2 of 0.74 for both.

Dry moisture wheats. The moisture and texture adjustment algorithm were evaluated using 57 soft wheat cultivars, selected for their relatively dry as-is moisture content. Allis-Chalmers flour yield range was 7.0% and break flour yield range was 14.7%. Regression model R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. flour yield, flour yield$_{15}$, and adjusted flour yield were 0.55, 0.85, and 0.90, respectively. Regression R^2 values for predicting Allis-Chalmers break flour yield from Quadrumat Jr. SE and SE$_{15}$ values improved from 0.77 to 0.85, respectively. Additionally, there was a regression R^2 of 0.90 for the prediction of Allis-Chalmers mill score from Quadrumat Jr. adjusted flour yield.

All soft wheats. Data from the soft wheat confirmation sets were combined and evaluated. Figure 4 shows the Allis-Chalmers flour yield associated with Quadrumat Jr. as-is flour yield, flour yield adjusted to 15% moisture, and flour yield adjusted to 15% moisture and 52% SE. Regression model R^2 values were 0.55, 0.85, and 0.90, respectively. Prediction of Allis-Chalmers mill score from adjusted Quadrumat Jr. flour yield had a regression R^2 of 0.90.

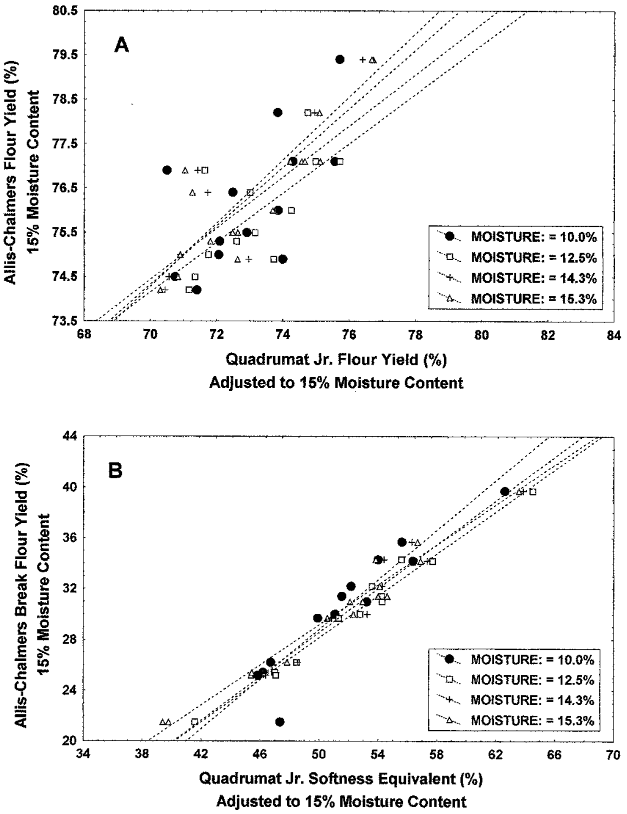

Fig. 3. Effect of wheat moisture content on the relationship between (**A**) Quadrumat Jr. flour yield adjusted to 15% moisture content and Allis-Chalmers flour yield and (**B**) Quadrumat Jr. softness equivalent adjusted to 15% moisture content and Allis-Chalmers break flour yield.

It is worth noting that Allis-Chalmers flour yield was not significantly predicted from Allis-Chalmers break flour yield or from Quadrumat Jr. SE ($P < 0.05$). For any wheat, the longer mill flow designs of larger mills normally demonstrate that there is no association between kernel texture, as measured on the mill as break flour, and flour yield, if the wheat is first cleaned of shriveled kernels (Gaines et al 1997). The regression model slope of the relationship between Allis-Chalmers flour yield and break flour yield was not significantly different from zero for all wheats combined (–0.005, $P = 0.99$). Adjusting the yields of the short-flow Quadrumat Jr. mill reduced the regression model slope for predicting Quadrumat Jr. flour yield from Quadrumat SE from –0.186 (for data unadjusted for moisture and kernel texture) to –0.079 (for adjusted values).

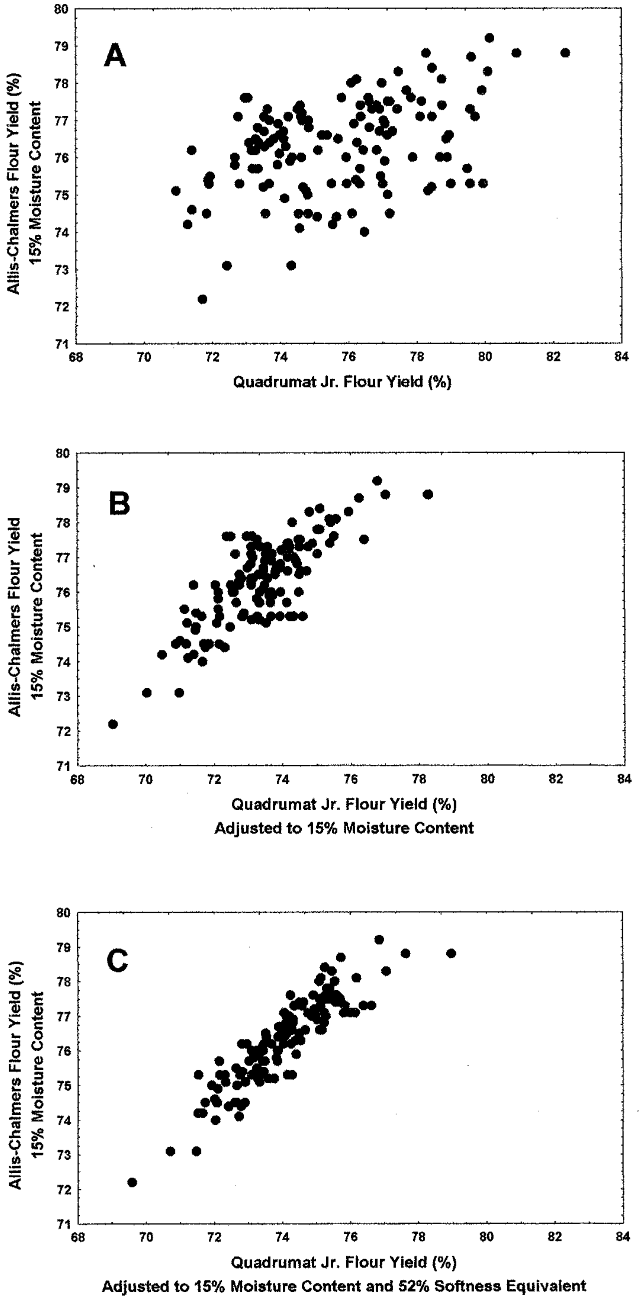

Fig. 4. Relationship between Allis-Chalmers flour yield and Quadrumat Jr. flour yield (**A**), flour yield adjusted to 15% moisture content (**B**), and flour yield adjusted to 15% moisture content and 52% softness equivalent (**C**).

Hard wheats. The above algorithms were derived from soft wheat samples. The adaptability of the adjustment algorithms to nine hard wheat samples was also investigated. Across moisture content, the regression model R^2 for the prediction of Allis-Chalmers flour yield from Quadrumat Jr. improved from 0.44 to 0.90 by correcting to 15% moisture content. Predicting Allis-Chalmers flour yield and Allis-Chalmers mill score from the adjusted flour yield had regression R^2 values of 0.72 and 0.92, respectively.

Soft and hard wheats in the same sample set. The adjustment of Quadrumat Jr. flour yield for hard wheat suggested that the 0.158 regression coefficient slope correction may not be ideal for hard wheats. Also, the 0.42-mm aperture scalp screen may need to have larger openings to better accommodate the larger particle size of hard wheat middlings. Mixed class sample sets could use two different slope correction factors and the same scalp screen. Unmixed sets could use different slope correction factors and different scalp screens.

A mixed set of 10 soft wheats and 11 hard wheats were evaluated for Allis-Chalmers flour yield and for Quadrumat Jr. flour yield using a scalp screen with 0.42- and 0.57-mm apertures. Using the 0.158 regression coefficient slope correction to adjust Quadrumat Jr. soft wheat flour yield produced a regression of $R^2 = 0.94$ for predicting Allis-Chalmers flour yield from Quadrumat Jr. adjusted flour yield when using either a 0.42- or a 57-mm aperture scalp screen for the soft wheat samples (Table I). However, the 0.158 slope correction value produced much lower regression R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. adjusted flour yield (0.50 and 0.69 for the 0.42- and 0.57-mm aperture scalp screens, respectively) for the hard wheat samples. When the 0.158 adjustment factor was applied to both soft and hard wheat samples together, the regression R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. adjusted flour yield were even lower (0.36 and 0.58 for 0.42- and 0.57-mm aperture scalp screens, respectively).

During the study, we observed that a 0.05 regression coefficient slope correction was better for hard wheat samples milled on our Quadrumat Jr. milling system. When that was applied to the hard wheat samples, the regression R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. adjusted flour yield increased to 0.67 and 0.81 for the 0.42- and 0.57-mm aperture scalp screens, respectively. When both soft and hard wheat samples were included in the regression with the 0.158 adjustment factor applied to soft wheat samples and the 0.05 adjustment applied to the hard wheat samples, the regression R^2 values for predicting Allis-Chalmers flour yield from Quadrumat Jr. adjusted flour yield increased to 0.72 and 0.90 for the 0.42- and 0.57-mm aperture scalp screens, respectively. Additionally, the larger aperture 0.57-mm aperture scalp screen appears to be best when hard and soft wheat samples are milled together, but a 0.42-mm aperture screen is equally good for soft wheat samples alone.

TABLE I
Regression Model R^2 Values for Predicting Allis-Chalmers Flour Yield from Adjusted Quadrumat Jr. Flour Yield Using Two Regression Coefficients for Adjustments for Soft and Hard Wheat Flours Milled Using 0.42- and 0.57-mm Aperture Scalp Screens During Quadrumat Jr. Milling

			Adjusted Quadrumat Jr. Flour Yield vs. Allis-Chalmers Flour Yield Regression R^2	
Wheat Class	Soft Wheat Regression Coefficient[a]	Hard Wheat Regression Coefficient[b]	Over 0.42-mm Aperture	Over 0.57-mm Aperture
Soft	0.158	· · ·	0.94	0.94
Hard	· · ·	0.158	0.50	0.69
Soft and hard	0.158	0.158	0.36	0.58
Soft	0.050	· · ·	0.86	0.83
Hard	· · ·	0.050	0.67	0.81
Soft and hard	0.158	0.050	0.72	0.90

[a] Soft wheat regression model: Adjusted Flour Yield = $\text{Yield}_{15} + [(52 - \text{SE}_{15}) \times -0.158]$.

[b] Hard wheat regression model: Adjusted Flour Yield = $\text{Yield}_{15} + [(52 - \text{SE}_{15}) \times -0.050]$.

Quadrumat Jr. Milling Sample Weight

Three soft wheats were milled using nine different wheat weights. Generally, sample weights ≥10 g could be milled without a decrease in adjusted flour yield, a decrease in the difference between the wheats, or an increase in the coefficient of variation (Table II). As for most well-controlled milling systems, coefficients of variation were all very low. Whan (1974) observed that sample sizes ≥5 g could be milled on a Quadrumat Jr. mill without significant increase in standard error. O'Brien et al (1993) published a routine procedure that uses 10 g of grain. However, it may be best not to vary sample weights during the milling of sample sets. Total time for weighing, milling, sieving, and reweighing of sample sizes <50 g could be accomplished in 3 min of operator time.

CONCLUSIONS

Short-flow milling performance is highly susceptible to the differences in wheat moisture content and kernel texture. In a short-flow milling scheme, those environmental factors have a relatively large effect on the initial reduction of the kernel because on short mills there is a greater proportion of large particles of endosperm in the mill stream.

When milling a small sample to predict performance of the sample if it were milled using a larger mill, these studies show 1) that it is not necessary to temper wheats to a uniform moisture level when using a small sample, as a moisture correction algorithm can be employed to reduce moisture induced variability, and 2) that an additional algorithm can correct for variation in short-flow mill flour yield data caused by differences in kernel texture. These algorithms, used together, express short-flow mill flour yield on a constant moisture and texture basis and greatly improve agreement between small scale (predictive) and larger scale milling systems and without the time-consuming need to first temper the wheat. A fast estimate of kernel texture (SE in this study) is determined during the actual milling process and is used to make the texture correction. These advancements are possible through the attempt to standardize a small mill against a larger mill. Regression model R^2 values as high as 0.90 may be expected for predicting the flour yield from a larger mill from the flour yield from a small mill.

Using a short-flow mill and adjusting flour yield for moisture and kernel texture can produce relatively fast, reliable milling quality predictions of how a wheat likely will perform on a larger mill in ≈3 min, milling as little as 10 g of wheat. This approach should work for many other pairs of small and larger mills, as long as the larger mill is long enough not to be influenced by kernel texture.

TABLE II
Adjusted Flour Yield and Coefficient of Variation for Samples of 2–200 g Milled from Three Soft Wheat Cultivars

Milled	Adjusted Flour Yield (%)			Coefficient of Variation (%)		
Weight (g)	Fla 302	Becker	Oasis	Fla 302	Becker	Oasis
200	71.0	69.0	64.1	0.3	0.3	0.1
100	71.5	69.7	65.0	0.0	0.1	0.3
50	70.7	68.7	64.1	0.1	0.1	0.1
25	70.7	68.7	64.4	0.0	0.1	0.0
20	70.5	68.8	64.0	0.1	0.1	0.7
15	70.2	68.7	64.1	0.1	0.2	0.1
10	69.9	68.2	63.9	0.6	0.7	0.8
5	68.6	66.8	63.1	0.1	0.2	0.1
2	66.6	63.2	60.7	1.0	1.6	1.4

ACKNOWLEDGMENTS

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