Experimental Micromilling: Reduction of Tempering Time of Wheat from 18–24 Hours to 30 Minutes

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ABSTRACT

Cereal Chem. 62(6):454–458

A micromilling method is described whereby a wheat was given a 2% pretemper for 15 min, a prebreak and a temper to the desired moisture level for 15 min, a second prebreak, and then micromilled; total time was about 40 min. The straight-grade flour had yield, protein, and ash values comparable to those of flour milled from wheat tempered for 18–24 hr. The 2% pretemper toughened the bran so that when the wheat was given the first prebreak through the Tag-Heppenstall rolls, the bran remained relatively intact and held together the shattered and fissured endosperm. Consequently, the endosperm acted like a sponge and quickly and relatively uniformly absorbed the temper water in about 15 min. A procedure is described for conditioning and micromilling the wheat, determining wheat and flour moisture and protein contents by near-infrared reflectance spectroscopy, estimating flour absorption, and running one or two mixograms, all in 50–60 min.

A micromilling procedure for 100-g samples of wheat (Finney and Yamazaki 1946) involved two or three prebreaks through the rolls of a Tag-Heppenstall moisture meter and one break and two reductions on a specially designed Hobart grinder. Flour ash and protein contents were comparable to those of straight-grade flours from conventional Allis-Chalmers and Bühler experimental mills. The micromilling procedure was successfully applied to 100-g, plant breeders' early generation progenies through the 1961 crop. In 1962, the special Hobart grinder was replaced by the break and reduction heads of the Brabender Quadrumat Senior mill (Finney et al 1963, Finney 1964). Since then, that assembly line, experimental micromilling procedure has been used to obtain straight-grade flours from 40–100 g of many thousands of early generation progenies of hard winter wheat. The ability to mill and record precisely the important milling properties of 40- to 100-g samples of those progenies (Finney 1964) greatly accelerates the release of new hard wheat varieties that have superior agronomic, milling, and breadmaking properties. This paper demonstrates how the prebreak can be used in experimental micromilling to reduce overnight tempering (18–24 hr) to only 30 min.

MATERIALS AND METHODS

Wheat Samples

All samples of hard winter wheat varieties were harvested at Hays and Hutchinson, KS, in 1981.

Moisture, Protein, and Ash Contents

Moisture, protein, and ash contents of wheats and flours were determined by AACC methods 44-15A, 46-11, and 08-01, respectively (AACC 1976).

Experimental Micromilling

Each 100-g sample of wheat was tempered from 15 min to 18–24 hr, its weight recorded, and processed through the micromill flow in Figure 1 (Finney and Yamazaki 1946, Finney 1964). Two sets of the 35-, 65-, and 100-mesh sieves are stacked and have two brush-

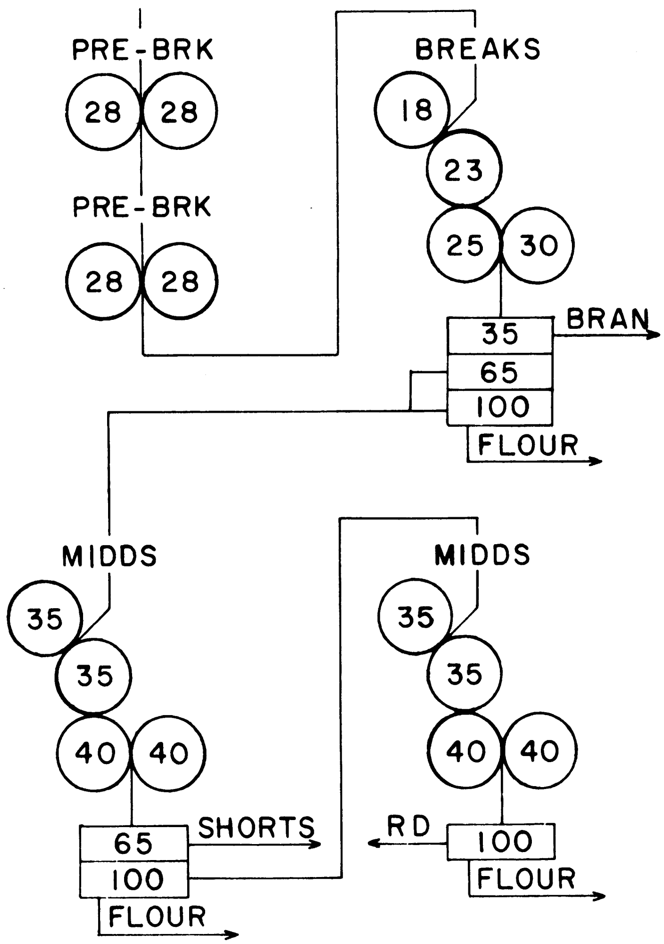

Fig. 1. Experimental micromill flow of prebreak, break, and reduction or middlings (midds) stock, together with roll corrugations per inch and Tyler sieve openings per linear inch. Prebreak roll spiral is zero. From top to bottom, break roll spirals are 1.5, 1.0, 1.0, and 0.5 in./ft, and reduction or middling roll spirals are 1.0, 0.5, 1.0, and 0.5 in./ft. Distances between pre-, first-, second-, and third-break rolls are 0.063, 0.03, 0.0035, and 0.002 in., respectively. Distances between first-, second-, and third-middling rolls are 0.0015, 0.002, and 0.0015 in., respectively. The speed of the prebreak drive roll is 31 rpm. From top to bottom, speeds of break rolls are 1,200, 545, 1,200, and 545 rpm, and speeds of middling rolls are 1,180, 535, 1,180, and 535 rpm. Differential of prebreak rolls is 1.0. Differential of first-, second-, and third-break rolls and of first-, second-, and third-middling rolls is 2.2. RD is an abbreviation for red dog.

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sieve cleaners on the 65, two on and two underneath the 100, and two brushless cleaners on the 35. Only one set of the sieves is used for 50-g samples. The micromill is composed of one pair of prebreak rolls of the Tag-Heppenstall moisture meter, a Brabender 3-break milling head, two Ro-Tap sifters, and a Brabender 3-reduction milling head (Fig. 2). After passing the prebroken wheat through the break rolls, the overs of the 35 were removed after sifting 2 min, and the overs of the 65 and 100 were removed after sifting an additional 2 min. Stock through the reduction rolls for the first time was sifted 2 min. Softer-than-normal wheats may require 3 min. Stock through the reduction rolls the second time was sifted 2 min.

At any given time, six samples can be in the milling process, and about eight samples can be milled per hour by a single operator. With a second person to weigh the fractions, about 12 samples can be milled per hour. When tempering for 18–24 hr in previous work with thousands of diverse varieties of wheat, flour yields of 71 ± 4% and flour ashes of 0.40 ± 0.05% were typical, and depended on variety, kernel plumpness, and hardness. Each flour was blended for 5 min.

The difference between any two yield values (average of duplicates) required for significance at $P = 0.05$ is 2.2%.

The determination of relative hardness or softness as a part of the micromilling test is given by Finney and Yamazaki (1967). The ratio of middlings flour to break flour, an important criterion of hardness, is generally 1.1–1.5 for micromilled hard winter wheats and less than 1.0 for soft winter wheats.

Tempering Treatments

In the studies involving initial wheat moisture contents of 8–14% and tempering for 15 min, an appropriate amount of each variety and variety composite of wheat was slowly dried by fan at room temperature to 8% moisture. Appropriate amounts of each were pretempered to 10, 12, and 14% moisture and allowed to equilibrate for several days. Then, each 100-g sample of wheat was given a pretemper of 2% moisture for 15 min, followed by a prebreak through the Tag-Heppenstall (Tag) rolls and then tempered to 15% moisture for 15 min. Then each tempered sample was given a second prebreak and immediately micromilled.

Pretemper and temper water was pipetted slowly as a fine stream into each 100-g sample of wheat as it was mechanically rotated counterclockwise at 43 rpm in a pint Mason jar at a 30° angle from the horizontal. After adding water (15–30 sec), the jar cap was screwed on during rotation. Blending continued for 5 min, but at the end of each minute, the jar and its sample were rotated by hand and at the same time oscillated between 30° and 150° angles from the horizontal for 10–15 sec. Blending time during and after the addition of pretemper and temper water (about 6 min) was a part of the pretemper and temper times.

Mixograms

Flour moisture and protein analyses were made before running a mixogram. Mixograms (10 g of flour) were made as described by Finney and Shogren (1972).

RESULTS AND DISCUSSION

In preliminary experiments, temper time was varied from 15–60 min. There was little or no improvement in flour yield, ash, or protein values, compared to those of the controls, when using a

TABLE I
Flour Yield, Moisture, Ash, and Protein Values for Experimentally Micromilled High- and Low-Protein Wheat Varieties[a]

Wheat Moisture (Initial) (%)	Pretemper for 15 Min (%)	Temper After 1st Prebreak[b] (%)	Tempering Time[c] (min)	Flour Yield (%)	Flour Moisture (%)	Flour Ash (%)	Flour Protein (N × 5.7) (%)
			High-Protein Larned				
10.8	15% temper for 18–24 hr			70.9	13.8	0.40	13.7
8	2	5	15	67.2	13.3	0.42	13.7
10	2	3	15	69.7	13.2	0.41	13.8
12	2	1	15	70.4	13.5	0.40	13.8
14	0	1	15	71.3	13.5	0.39	13.8
				Avg. 69.7			
			High-Protein Eagle				
9.9	15% temper for 18–24 hr			70.0	13.4	0.41	14.5
8	2	5	15	70.1	13.3	0.43	14.5
10	2	3	15	71.7	12.9	0.39	14.6
12	2	1	15	71.3	13.1	0.41	14.5
14	0	1	15	72.4	13.0	0.41	14.5
				Avg. 71.4			
			Low-Protein Larned				
11.1	15% temper for 18–24 hr			72.5	13.6	0.40	9.1
8	2	5	15	69.0	13.5	0.40	9.3
10	2	3	15	70.7	13.5	0.40	9.2
12	2	1	15	72.1	13.4	0.37	9.0
14	0	1	15	73.4	13.5	0.37	9.1
				Avg. 71.3			
			Low-Protein Eagle				
10.5	15% temper for 18–24 hr			72.8	13.3	0.40	10.0
8	2	5	15	70.0	13.4	0.39	10.0
10	2	3	15	71.6	13.3	0.41	10.0
12	2	1	15	74.0	13.0	0.40	10.1
14	0	1	15	74.1	12.9	0.39	10.1
				Avg. 72.4			

[a] Samples of each variety varied from 8-14% initial moisture and were tempered to 15% for 15 min. Chemical data are on a 14% mb.
[b] Wheat was given the first prebreak at the end of the pretempering period.
[c] Wheat was given the second prebreak at the end of the tempering period and then micromilled. After tempering 18–24 hr, wheat received two consecutive prebreaks.

temper time longer than 15 min (data not given). Unless indicated otherwise, only a 15-min temper was used in subsequent studies.

Temper 15% for 15 Min by Variety

When initial moisture content of high-protein Larned wheat was an unlikely 8%, the flour yield of 67.2% was significantly below the control but was satisfactory for testing purposes (Table I, refer to discussion under Mixograms). For initial moisture levels of 10–14%, flour yields were comparable to the control (70.9%). When the initial moisture content of high-protein Eagle wheat was only 8%, flour yield (70.1%) was equal to that (70.0%) of the control. For initial moisture levels of 10–14%, flour yields for Eagle wheat were somewhat to significantly greater than the control.

Highly satisfactory flour yields also were obtained for the low-protein Larned and Eagle wheats, except when the initial wheat moisture level was 8.0% (Table I). All flour ash and protein contents were comparable to those of the controls.

In three of four instances (Table I), when initial wheat moisture content was 8%, flour yield was significantly below that of the corresponding control (2.2% required for significance at $P = 0.05$). As initial wheat moisture increased from 10 to 14%, however, flour yields increased and were somewhat lower or higher (not significantly) than that of the corresponding control.

In practice, wheat moisture content is not likely to be less than 10%, and often is 12% or greater. When wheat moisture content is appreciably less than 12%, pretempering to 12% for 1–3 days before the 2% pretemper would ensure relatively high flour yields.

Mixograms

In bread wheat breeding programs, flour protein content (14% mb) and a mixogram are used to determine or predict important physical dough and breadmaking properties of early generation progenies of wheat (Finney and Shogren 1972). For flours representing 8–14% initial wheat moisture levels and corresponding controls within a variety or a protein level, mixograms were essentially identical and protein contents comparable, irrespective of flour yield. Thus, flour yields that were lower or even significantly lower than that of the corresponding control were considered satisfactory for testing purposes. Typical mixograms are reproduced in Figure 3.

Tag Moisture Indicates the Degree of Water Penetration

When 100 g of hard winter wheat (10.7% moisture) was given a 2% pretemper for 15 min and then tempered to 15% for 15 min, Tag moisture content was 27.2%. When another 100 g of the same wheat was prebroken 15 min after adding the 2% pretemper, and tempered to 15% for 15 min, Tag moisture content was steady and only 17.4% instead of 27.2%. Thus, prebreaking greatly facilitated the penetration of moisture. Pomeranz et al (1984) demonstrated that Tag moisture was a good index of the degree of penetration of added water. If the penetration of moisture was not quite complete when the wheat went to the mill, the breaking operations of micromilling may have served as an equilibrator.

Related Studies

Since obtaining data on the micromilling method after a 30-min temper, two variations were found to increase the flour yield of hard red winter wheat with initial moisture of only 10.7%. Passing the bran through the Quadrumat break rolls a second time yielded 1.72 g of break flour and about 1 g of middlings flour per 100 g of wheat. Also a pretemper of 2% for 5 min instead of 15 min and an increase in final temper time from 15 min to 25 min (still 30 min of total temper) yielded 69.4% of flour compared to 69.7% for the control hard red winter wheat tempered for 24 hr.

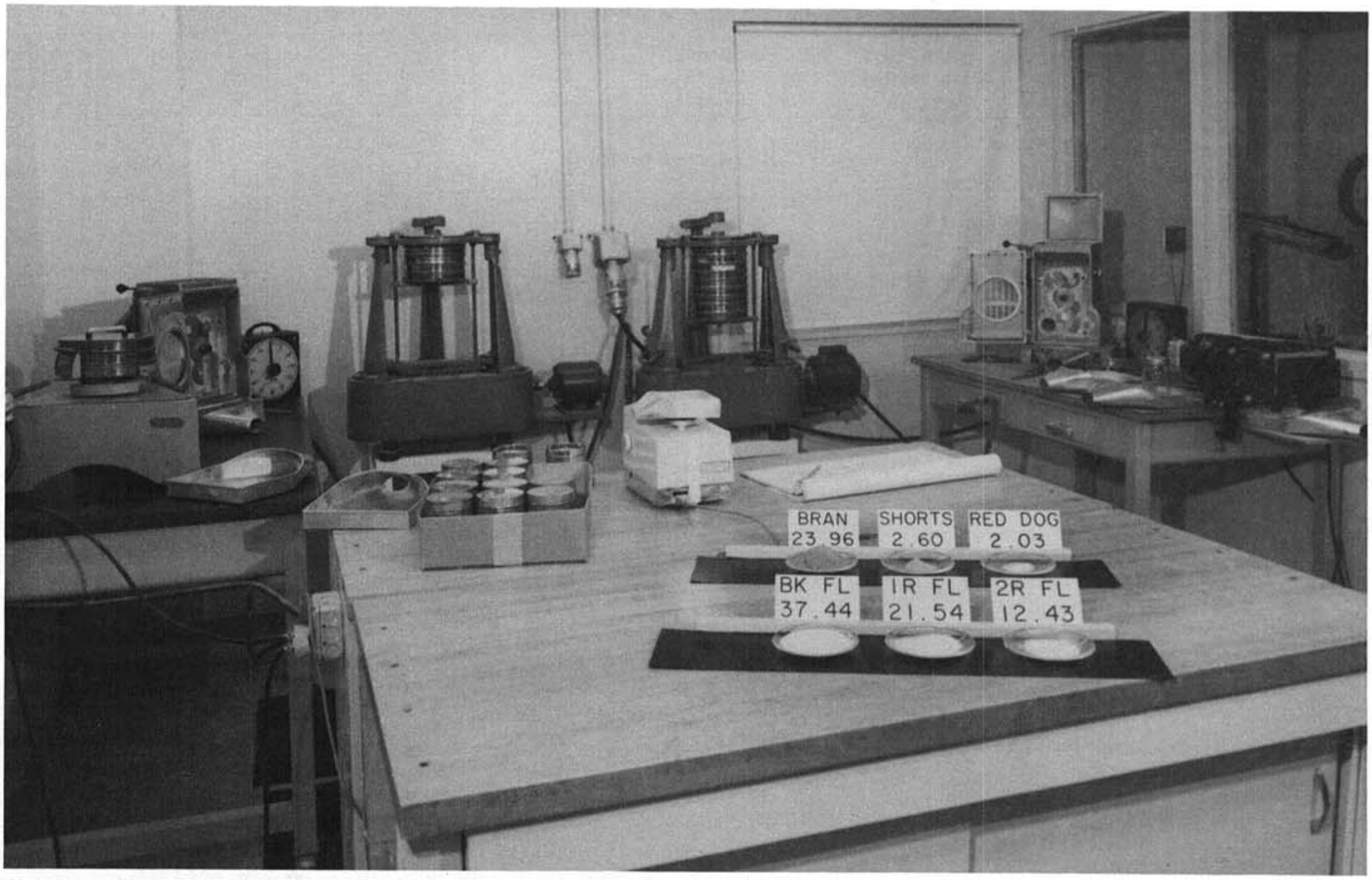

Fig. 2. View of experimental micromill primarily for 40 to 100 g of wheat. As little as 15–20 g or several hundred grams can be readily milled. Starting at the far right and going counterclockwise are the prebreak rolls of the Tag-Heppenstall moisture meter, a timer, a Brabender 3-break milling head, two Ro-Tap sifters, a timer, a Brabender 3-reduction milling head, a rebolt sifter, sample cans, a balance, and typical yields of bran, shorts, red dog, break flour, first reduction flour, and second reduction flour.

When 1,500-g samples of a composite of several hard winter wheat varieties harvested in 1983 were tempered to 15% moisture for 15 min and milled in duplicate on our Allis-Chalmers experimental mill, average flour yield (71.1%) was essentially equal to that (72.3%) for the average of duplicate controls tempered for 18–24 hr. Flour ash and protein values for the 15 min and 18–24 hr tempers were comparable. The composite wheat contained 10.8% moisture and 14.7% protein (14% mb).

Micromilling and Quality Tests Within One Hour

Conditioning wheat for 30 min before micromilling yields important milling data and a typical straight-grade flour for other quality tests, such as a mixogram, all within an hour. As soon as the typical and thoroughly blended sample of wheat to be tested is received, 50–100 g is given a 2% pretemper for 15 min. During that time, a small sample can be ground for determination of moisture and protein by near-infrared reflectance (NIR) spectroscopy. Subsequent moisture and protein determinations require only a few minutes. Based on the wheat moisture plus the 2% pretemper, the water required to temper the wheat to the desired moisture level can be quickly determined. At the end of the 15-min pretemper, the 50–100 g of wheat is given the first prebreak and immediately tempered to the desired moisture level for 15 min, then given the second prebreak and micromilled in less than 10 min. The time up to this point is about 40 min.

During micromilling, the approximate water required for the mixogram (10 g of flour, 14% mb) is quickly calculated as described by Finney and Shogren (1972) from the mean absorption-protein regression line of good quality varieties (Comanche or Tenmarq). The flour protein content can be estimated from the wheat protein determined by NIR spectroscopy. Wheat protein minus one percentage point generally equals flour protein ± 0.2%. In our laboratory, 9.92 g of flour is weighed for the mixogram, because the average moisture content of micromilled flours is about 13.3%. In a few more minutes, flour moisture and protein can be quickly determined by NIR spectroscopy and, if necessary, adjustments made in the estimated absorption and moisture values. In any event, about 50 min is required from the time the sample of wheat is received and the mixogram is completed. If the mixogram dough is obviously stiff or slack during the first 3–4 min of the test, a second weighing of flour and adjusted water is prepared before the first mixogram is completed. The second mixogram requires less than an additional 10 min. Of course, to adhere to the above schedule, two workers are required, and all equipment must be in one room or adjoining rooms.

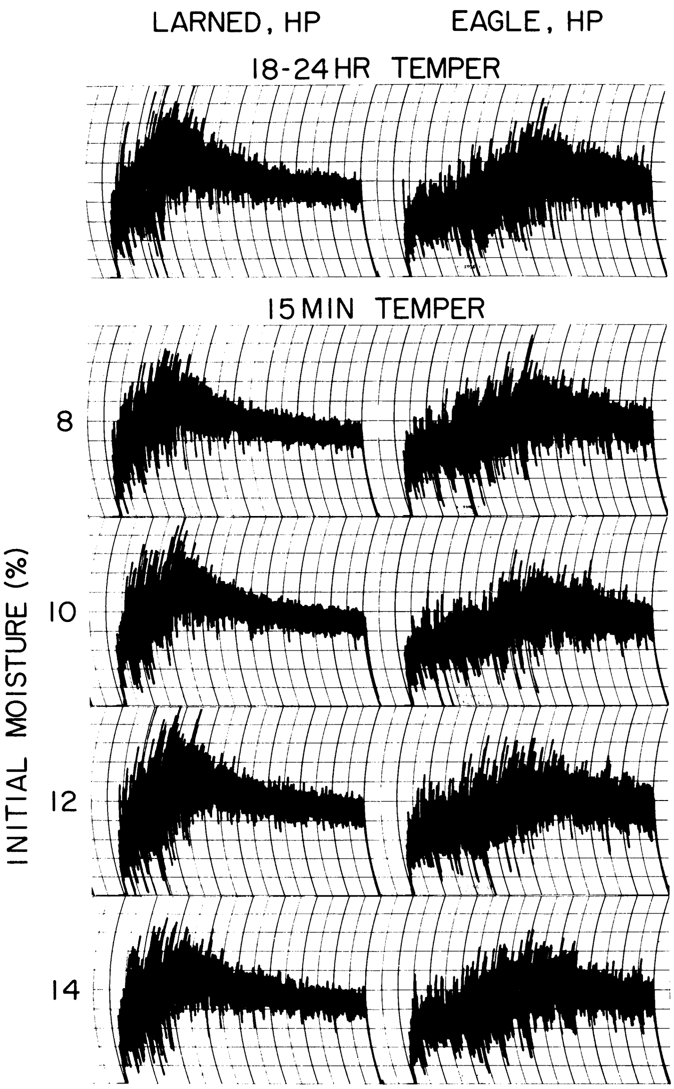

Fig. 3. Mixograms of flours (10 g) milled from high-protein Larned and Eagle hard winter wheats that contained initial moisture contents of 8–14% and were tempered to 15% moisture for 15 min. Mixing time is the time (min) to the peak (point of minimum mobility). Mixing tolerance is defined by the slope and width of the mixogram after the peak and by the stability of mixogram height on either side of the peak. Major arcs are at 1-min intervals.

Important Considerations

We understand that about 1 hr is available between successive loadings of wheat for export. If so, the procedure just described could be used to objectively record the mixing properties as well as the relative hardness of each loading of wheat. During micromilling, the bran cleanup, sifting properties, and ratio of reduction flour to break flour define relative hardness.

The 15-min temper, when preceded by a 2% pretemper for 15 min and a prebreak, may be applicable commercially. If so, it could eliminate the relatively long interval between tempering and milling, and, instead, permit the uninterrupted (continuous) processing of dry wheat to flour. Also, if a loss of power shut down a mill, disposal of tempered wheat would not be a problem.

AACC method 26-10 states that if wheat samples are unusually dry and moisture is to be raised 4 to 6% or more for proper milling, a longer tempering period is necessary to enable all parts of the endosperm to reach moisture equilibrium. In such cases, sufficient water is added to raise the moisture content to 13.5% for 48 hr; then sufficient water is added to raise wheat moisture to the desired level 18 hr before milling. Temper times may be reduced to 3–5 hr by adding a suitable wetting agent to the temper water (Sullivan 1941). Apparently, prebreaking generally is more effective than time or wetting agents.

CONCLUSIONS

The 2% pretemper toughened the bran so that when the wheat was given the first prebreak through the Tag rolls, the bran remained relatively intact and held together the shattered and fissured endosperm. Then, the endosperm acted like a sponge, and quickly and relatively uniformly absorbed the temper water in about 15 min.

When initial wheat moisture contents are about 11% or less, good conditioning practices would require that the wheats be pretempered to at least 12% for 1–3 days before conditioning for 30 min and micromilling. Preconditioning to about 12% moisture would maintain relatively high flour yields.

Micromilling wheat after conditioning it for only 30 min, in conjunction with a mixogram and NIR spectroscopy tests for moisture and protein content of flour, is applicable in wheat quality and testing laboratories and has potential use in trade channels.

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[Received July 2, 1984. Revision received December 31, 1984. Accepted April 11, 1985.]