Effect of Variations in Tempering on Micromilling of Hard Winter Wheat[1]

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ABSTRACT

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Three variations in tempering were used to micromill 100-g samples of 12 hard red winter wheat varieties that varied widely in weight per bushel, kernel weight, protein and ash contents, and kernel hardness. In all three variations, the wheat was tempered to 15% moisture and was passed through two prebreak treatments. In variation A, the first prebreak was made 1¼ hr after water addition and the wheat was rested for ¼ hr before the second prebreak. In the other two variations (B and C), the two prebreak treatments were made 2 and 24 hr after water addition, respectively, with practically no intermediate rest. The three variations in tempering were also applied to three hard red winter wheats of different hardness characteristics, each from four locations. The yields of flours milled by the three variations in tempering were about 69% and flour ash contents were about 0.35%. Flours obtained by micromilling by the three variations in tempering time were comparable in protein content and breadmaking characteristics (gassing power, water absorption, mixing time, loaf volume, and crumb grain). The prebreak treatments make it possible, within 2 hr, to produce flours for determination of gross composition and for evaluation of milling and breadmaking characteristics.

The objectives of experimental milling are to prepare flour for evaluation of chemical, physical, or end-use properties; to screen wheats in plant breeding programs to eliminate selections of unsatisfactory milling properties; and to parallel results from commercial milling. Those three objectives present increasing levels of desirability and difficulty. Whole wheat meals, with and without sifting, are not satisfactory for evaluating breadmaking properties (Bruinsma et al 1978). Many types of experimental mills have been designed, manufactured, and used. Those used most extensively are the Allis-Chalmers, Bühler, Brabender Quadrumat Junior and Senior, Miag Multomat, and Ross (Shellenberger and Ward 1967). Both continuous (usually automatic) and batch type mills are available. Results of experimental milling can be used to predict the milling operations of a specific commercial mill, but experimental milling fails to yield reliable results about the performance of wheats in the whole milling industry.

Approved Methods of the AACC (1976) describe sample preparation, tempering (conditioning), and short-flow or long-flow experimental milling. Tempering times of 18–24 hr are recommended. No method for experimental milling is included in the Standard Methods of the International Association for Cereal Chemistry (ICC Standards). The Standard Methods of the West German Association of Cereal Research (Arbeitsgemeinschaft Getreideforschung 1978) recommend use of a Bühler automated mill (or equivalent) plus a bran separator. The wheat (2–4 kg) is conditioned for 24 hr to obtain a flour of about 74% milling yield and maximum ash of 0.47% (14% mb).

The many attempts to standardize experimental milling procedures have met with limited success. The speed and ease of operating the Bühler mill make it possible to prepare a flour of about 65% extraction, which compares in breadmaking properties with commercially milled flour. The Bühler mill also differentiates between wheats varying widely in milling properties. The rigid flow of the semiautomatic Bühler mill is, however, a disadvantage in evaluating mixed wheat grists or wheat varieties that cover a narrow, yet meaningful, and practical range of milling properties. Under such conditions, a mill that has a more flexible diagram provides more complete information in the hands of an experienced operator. Micromills capable of providing small samples of flour that can be evaluated by microquality tests are required in plant breeding programs (Hehn and Barmore 1965). The Bühler mill requires at least 1-kg samples and therefore is not useful for preliminary quality evaluation of early (F_3) generations.

We have recently reported on a new method to follow the rate of water penetration into the wheat kernel (Pomeranz et al 1984). The results of that study showed that, as determined by decrease in conductance, penetration was stabilized about 2 hr after adding the water. The present study compared wheats milled after conditioning for 2 hr or 18–24 hr or after a modified 1½ hr tempering procedure. The objective was to determine whether short tempering (up to 2 hr) combined with a procedure that

TABLE I
Description of 12 Hard Red Winter Wheats Harvested at Manhattan, KS, in 1983

Cultivar	Test Weight (lb/bu)	Kernel Weight (mg)	Protein (N × 5.7, %)[a]	Ash (%)[a]	NIR[b] at 1,680 nm
Arkan	57.6	30.5	10.2	1.67	180
Bounty 100	57.2	40.9	9.7	1.57	201
Garst HR64	56.9	28.4	10.6	1.80	248
Hawk	60.5	34.5	9.1	1.72	225
HW 1010	51.4	28.8	10.4	1.67	196
Larned	59.6	32.2	12.4	1.43	192
Mustang	51.7	29.6	11.8	1.57	178
Newton	56.8	29.1	11.6	1.61	196
Scout 66	57.6	30.5	11.9	1.72	199
TAM 105	56.9	29.6	9.8	1.52	203
Triumph 64	60.1	34.8	10.9	1.61	164
Vona	54.8	26.3	9.6	1.64	208

[a] 14% moisture basis.
[b] Near-infrared reflectance.

TABLE II
Description of Three Hard Red Winter Wheats from Four Locations in Kansas

Cultivar	Test Weight (lb/bu)	Kernel Weight (mg)	Protein (N × 5.7, %)[a]	Ash (%)[a]	NIR[b] at 1,680 nm
Newton					
Range	56.2–63.0	23.7–33.6	9.9–13.1	1.49–1.69	158–216
Average	59.2	28.3	11.7	1.61	192
Scout 66					
Range	56.3–63.3	26.9–35.9	10.8–13.2	1.37–1.72	166–226
Average	59.9	31.5	12.2	1.59	201
Triumph 64					
Range	56.3–63.6	29.7–35.8	10.9–14.4	1.58–1.73	164–194
Average	60.8	33.4	12.6	1.62	178

[a] 14% moisture basis.
[b] Near-infrared reflectance.

[1] Mention of firm names or trade products does not constitute endorsement by the U.S. Department of Agriculture over others not mentioned.

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employs two prebreaks can produce flour comparable to that from micromilling wheat tempered for 18–24 hr.

MATERIALS AND METHODS

Twelve hard red winter wheats harvested at Manhattan, KS, in 1983 varied widely in test weight (51.4–60.5 lb/bu), kernel weight (26.3–40.9 mg), protein (9.1–12.4%, 14% mb) and ash (1.43–1.80%, (14% mb) contents, and hardness (164–248 near-infrared reflectance [NIR] at 1,680 nm) (Table I).

Three hard red winter wheats grown in Kansas in 1983 were selected from each of four locations (Manhattan, Ft. Hays, St. John [fallow], and Hutchinson). Generally, Scout 66 wheat was hardest, Triumph 64 softest, and Newton intermediate (Table II). The locations were selected to cover a wide range in protein contents. Ranges and averages of some grain characteristics of the three wheats grown at four locations are summarized in Table II. For determination of breadmaking characteristics (including mixograph studies), the flours from the four locations were composited by variety.

The 100-g wheat samples were tempered to 15% moisture in glass jars. The micro-experimental mill and its flow (Fig. 1) were described by Finney and Yamazaki (1946, 1967) and by Finney (1964).

The wheats, 100-g samples, were milled after three variations in the temper and prebreak time. In all three variations we used two prebreak treatments as shown in Figure 1. In variation A, the wheat was rested for ¼ hr after the first prebreak, which was made 1¼ hr after water addition. In the other two variations (B and C), two prebreaks were given 2 and 24 hr after the addition of water with practically no intermediate rest. The milling method was constant.

Two sets of the 35, 65, and 100 mesh sieves are stacked and have two brush-sieve cleaners on the 65, two on and two underneath the 100, and two brushless cleaners on the 35. The micromill is composed of prebreak rolls of the Tag-Heppenstall moisture meter, a Brabender three-break milling head, two Ro-Tap sifters, and a Brabender three-reduction milling head. 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 was sifted 2 min. 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. Flour yields of 69 ±6% and flour ashes of 0.40 ±0.05% are typical. If necessary, flour can be rebolted over a 9XX flour cloth before blending for 5 min. The difference between any two comparable flour yield values required for significance at $P = 0.05$ is 2.2%. Generally, the ratio of middlings flour to break flour for micromilled hard winter wheats is 1.1–1.5 and the decrease in protein contents from wheat to straight-grade flour about 1%.

The Brabender Quadrumat Senior heads are mounted on wooden frames over receiving pans. The break head is used once and the reduction head twice. The same procedure may be followed when the heads are mounted on the Quadrumat Senior frame by removing the conveyor socks attached to the sifter section and catching the ground materials in pans placed under the heads. The heads require no modification. A double stack of sieves was used for material coming from the break head. Small grains other than wheat (i.e., barley, rye, and triticale) as well as sorghum grain have been milled according to the flow sheet.

Mixographs were determined according to Finney and Shogren (1972), gas production during fermentation according to Rubenthaler et al (1980), and baking tests according to Finney (1984). The 90-min fermentation option was used. The loaf volume difference between any two treatment means required for significance was 21 cc at $P = 0.05$.

Moisture, ash, and protein were determined according to AACC Approved Methods (1976) and wheat hardness by the NIR method (Bruinsma and Rubenthaler 1978, Miller et al 1982). Moisture was determined in tempered wheat by the Tag-Heppenstal conductance method as described by Pomeranz et al (1984).

All determinations were made in duplicate and the results were subjected to analysis of variance.

TABLE III
Average Moisture[a] in Tempered Wheat and Average Yield, Moisture, Protein, and Near-Infrared Reflectance (NIR) of Flours Milled from 12 Hard Red Winter Wheats, Milled by Three Variations in Tempering

Tempering Variation	Wheat Moisture (%)[b]	Flour Yield (%)	Moisture (%)[c]	Protein (%)[c]	NIR at 1,680 nm
A	17.8 c	69.4 c	13.5 c	9.7 c	196 c
B	15.8 d	68.8 c	13.0 d	9.9 c	196 c
C	15.1 e	69.6 c	13.2 d	9.9 c	199 c

[a] Means followed by the same letter are not significantly different.
[b] Tag-Heppenstal conductance.
[c] NIR method.

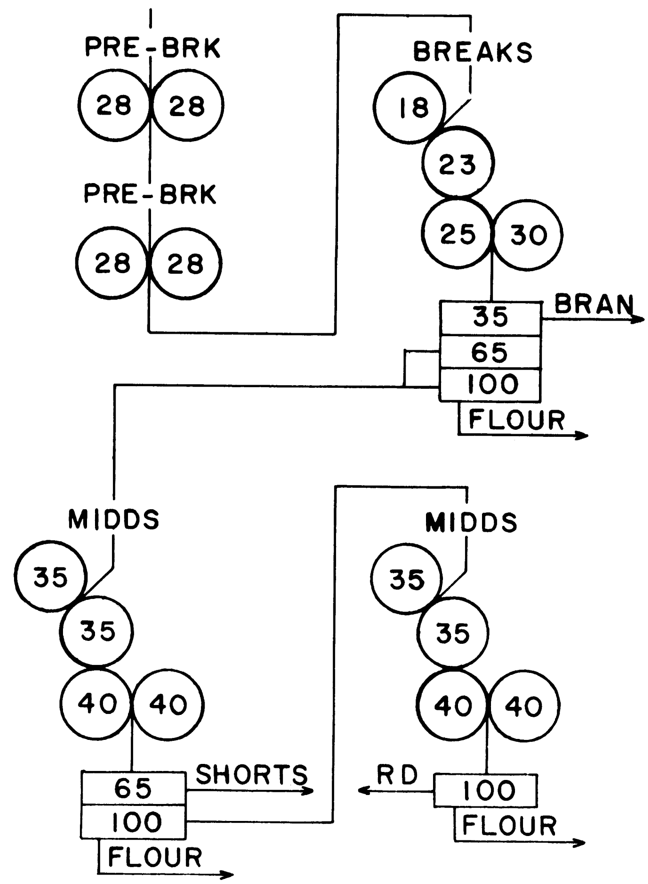

Fig. 1. Microexperimental mill flow of prebreak, break, and reduction or middlings stock, together with roll corrugations per inch and Tyler sieve openings per linear inch. Prebreak roll spiral is zero. Going from top to bottom, break roll spirals are 1.5, 1.0, 1.0, and 0.5 in./ft, and reduction or middling 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. RD is an abbreviation for red dog.

RESULTS AND DISCUSSION

The average moisture content of the 12 wheats described in Table I, as determined by the Tag-Heppenstal conductance method, was higher in wheats tempered by variation A than by the other two variations, indicating a large difference in water distribution (Table III). There were no significant differences in flour yield in samples milled from wheats tempered by the three procedures. Similarly, there were no significant or consistent differences in protein content and particle size (both determined by NIR) of the flours

TABLE IV
Results of Micromilling Three Hard Red Winter Wheats from Four Locations by Three Variations

Wheat Moisture, Flour Yield, and NIR	Newton		Scout 66		Triumph 64	
	Range	Avg.[a]	Range	Avg.	Range	Avg.
Wheat moisture (%)[b]						
Tempering variation						
A	16.5–18.2	17.3 c	16.1–17.9	16.9 c	16.3–18.0	17.1 c
B	16.0–16.9	16.6 d	15.8–16.5	16.2 d	16.0–17.0	16.4 d
C	14.4–15.3	14.9 e	14.3–15.0	14.6 e	13.9–15.2	14.7 e
Flour yield (%)[c]						
Tempering variation						
A	63.2–70.1	67.2	68.0–73.8	70.5	68.4–72.3	70.2
B	63.0–70.1	66.8	68.0–73.2	70.3	66.7–71.3	69.4
C	64.8–71.3	68.4	70.0–74.7	71.9	69.3–72.7	70.7
NIR reflectance at 1,680 nm						
Tempering variation						
A	177–225	203 c	211–261	234 c	187–230	207 c
B	172–220	201 c	207–260	232 c	189–228	205 c
C	174–220	201 c	207–262	233 c	188–228	205 c

[a] Means with the same letter are not significantly different.
[b] At first prebreak, determined by the Tag-Heppenstal electric moisture meter.
[c] Calculated on the basis of total products, 14% moisture basis.

TABLE V
Composition and Breadmaking Characteristics of Varietal Composites of Flours Milled from Three Hard Red Winter Wheats Each from Four Locations

Flour Composition and Breadmaking Characteristics	Variety		
	Newton	Scout 66	Triumph 64
Protein (%)[a]			
Tempering variation			
A	10.5	11.1	11.4
B	10.3	10.9	11.1
C	10.5	11.1	11.5
Ash (%)[a]			
Tempering variation			
A	0.36	0.35	0.35
B	0.35	0.36	0.35
C	0.36	0.33	0.35
CO_2 (GU)[b]			
Tempering variation			
A	58.9	59.8	58.9
B	59.2	59.4	58.2
C	59.8	60.8	57.8
Water absorption (%)[a]			
Tempering variation			
A	55.9	55.9	55.4
B	56.1	55.6	55.4
C	55.6	55.3	55.3
Mixing time (min)			
Tempering variation			
A	4¾	3⅞	2¾
B	4⅝	3¾	2¾
C	4⅞	3⅝	2⅝
Loaf volume (cc) and crumb grain[c]			
Tempering variation			
A	913 S	902 S	885 S
B	910 S	917 S	878 S
C	903 S	892 S	885 S

[a] 14% moisture basis.
[b] Gasograph units.
[c] S = satisfactory.

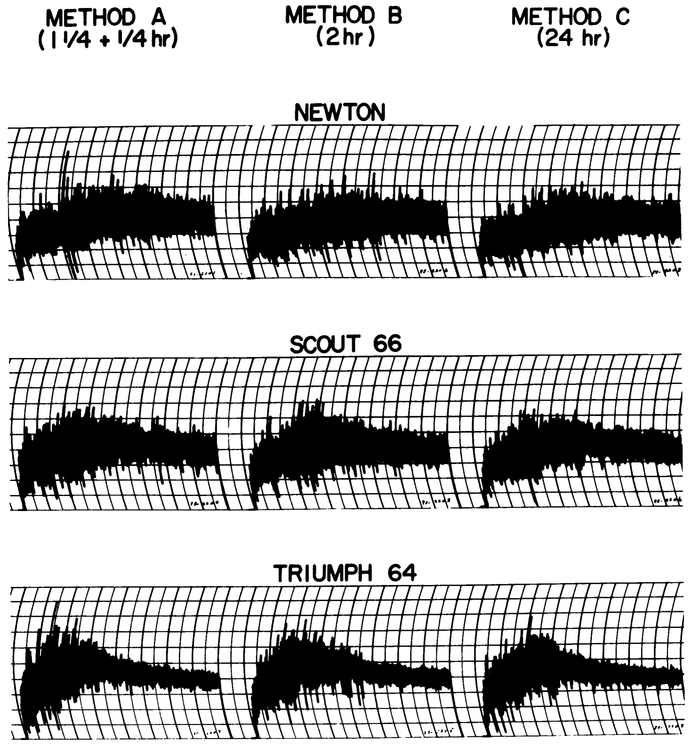

Fig. 2. Mixographs of flours milled after conditioning by three variations from three wheat cultivars (Newton, Scout 66, and Triumph 64). All flours were composites, each from four locations.

obtained by the three tempering variations of the micromilling method. The average protein contents of the 12 wheats (Table I) was 10.7% or about 1% more than of the flours (Table III).

Ranges and average results of micromilling by three tempering variations of three hard red winter wheats from four locations are summarized in Table IV. Moisture content, determined by the Tag-Heppenstal conductance method, was consistently highest in wheats tempered for 1½ hr (variation A) and lowest in wheats tempered for 24 hr (variation C); this reflects the more uniform distribution of water as conditioning time increased. Effects of variations in tempering on flour yields and particle size, as determined by NIR at 1,680 nm, were insignificant. Similarly, variations in tempering had no consistent effects on the ratio of break:reduction flour (data not shown).

Gross composition and breadmaking characteristics of the composites (by variety) of three wheats, each from four locations, are described in Table V and illustrated in Fig. 2. There were no consistent or significant effects of variation in tempering on ash and protein contents, gassing power, water absorption, mixing time, other mixogram characteristics, or loaf volume and crumb grain.

Correlation coefficients between test weight and/or kernel weight and yields of flour and among the flour yields by three tempering variations are summarized in Table VI. The correlation coefficients were calculated for the 12 hard winter wheats (Table I), the three hard winter wheats from four locations (Table II), and for both groups combined. Most correlation coefficients for the 12 hard red winter wheats (group 1) were significant, including those

TABLE VI
Correlation Coefficients Between Test Weight and/or Kernel Weight and Flour Yields from the Three Milling Variations

Hard Red Winter Wheat Group	N[b]	Correlation Coefficient[a] Between: T.wt. and K.wt.	T.wt. and 24 hr	T.wt. and 2 hr	T.wt. and 1½ hr	K.wt. and 24 hr	K.wt. and 2 hr	K.wt. and 1½ hr	24 hr and 2 hr	24 hr and 1½ hr	2 hr and 1½ hr
1) 12 wheats	12	0.770**	.527	.704*	.599*	.526	.655*	.630*	.961***	.953***	.945***
2) Three wheats from four locations	12	0.491	.113	.189	.057	.056	.444	.031	.637*	.741**	.693*
1 and 2 combined	24	0.538**	.207	.360	.203	.308	.552**	.335	.810***	.856***	.691***

[a] *, **, and *** denote significance at the 5, 1, and 0.1% levels, respectively; T.wt. = test weight; K.wt. = kernel weight; 1½ hr, 2 hr, and 24 hr denote flour yield from milling by variations A, B, and C, respectively.
[b] N = number of samples.

between test weight or kernel weight and flour yield. Correlations between the flour yields from wheats milled by the three variations in tempering were highly significant. The correlation coefficient between test weight and kernel weight for the three cultivars from four locations (group 2) was not statistically significant and the statistical significance between the flour milling yields for this group of samples was relatively low.

CONCLUSIONS

Straight-grade flour of about 69% extraction can be micromilled routinely from 100-g samples of hard red winter wheats after 1½ or 2 hr of conditioning in a two prebreak milling system. The flours from wheat conditioned for 1½ or 2 hr were comparable to flours milled from wheats conditioned for 24 hr in ash and protein content, milling, and breadmaking characteristics. The relatively high flour yields, low ash contents and wheat-to-flour protein decreases, and comparable average particle size and breadmaking characteristics indicate that the variations in tempering are well suited for micromilling small samples from plant breeding programs. The shortened time (about 2 hr) required for conditioning and milling still may be too long, however, for use in marketing channels. Studies to mill wheats for evaluation in marketing channels are underway in our laboratories.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of the AACC. 7th ed. Method 08-01, approved April 1961; Method 44-15A, approved April 1967; Method 46-11, approved April 1961; Methods 26-10, 26-20, 26-21, 26-30, and 26-95, approved April 1961. The Association: St. Paul, MN.

ARBEITSGEMEINSCHAFT GETREIDEFORSCHUNG. 1978. Standard-Methoden fur Getreide, Mehl, und Brot. 6th ed. Verlag Moritz Schaefer: Detmold, W. Germany.

BRUINSMA, B. L., ANDERSON, P. D., and RUBENTHALER, G. L. 1978. Rapid method to determine quality of wheat with the mixograph. Cereal Chem. 55:732.

BRUINSMA, B. L., and RUBENTHALER, G. L. 1978. Estimation of lysine and texture in cereals by NIR. Page X-BR-1. In: Proc. 8th Technical Int. Congr. 1978. Technicon Instruments Co., Ltd.: London, England.

FINNEY, K. F. 1964. Quality evaluation of early generation wheat progenies. Pages 74-83 in: Proc. 2nd Natl. Conf. Wheat Utilization Res. ARS-USDA: Peoria, IL.

FINNEY, K. F. 1984. An optimized, straight-dough, bread-making method after 44 years. Cereal Chem. 61:20.

FINNEY, K. F., and SHOGREN, M. D. 1972. A ten-gram mixograph for determining and predicting functional properties of wheat flours. Bakers Dig. 46(2):32.

FINNEY, K. F., and YAMAZAKI, W. T. 1946. A micro-milling technique using the Hobart grinder. Cereal Chem. 23:484.

FINNEY, K. F., and YAMAZAKI, W. T. 1967. Quality of hard, soft, and durum wheats. In: Wheat and Wheat Improvement. Quisenberry, K. S., and Reitz, L. P., eds. Am. Soc. Agron.: Madison, WI.

HEHN, E. R., and BARMORE, M. A. 1965. Breeding wheat for quality. Adv. Agron. 17:85.

ICC STANDARDS. Standard Methods of the International Association for Cereal Chemistry. Verlag Moritz Schaefer: Detmold, W. Germany.

MILLER, B. S., AFEWORK, S., POMERANZ, Y., BRUINSMA, B. L., and BOOTH, G. D. 1982. Measuring the hardness of wheat. Cereal Foods World 27:61.

POMERANZ, Y., BOLTE, L. C., and AFEWORK, S. 1984. Time-dependent moisture gradients in conditioned wheat determined by electrical methods. Cereal Chem. 61:559.

RUBENTHALER, G. L., FINNEY, P. L., DEMERAY, D. E., and FINNEY, K. F. 1980. Gasograph: Design, construction, and reproducibility of a sensitive 12-channel gas recording instrument. Cereal Chem. 57:212.

SHELLENBERGER, J. A., and WARD, A. B. 1967. Experimental milling. Pages 445-469 in: Wheat and Wheat Improvement. K. S. Quisenberry and L. P. Reitz, eds. Am. Soc. Agron.: Madison, WI.

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