Revised Microtesting for Soft Wheat Quality Evaluation

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ABSTRACT

A revised two-phase quality evaluation microprocedure for early generation screening of wheat is described. Improved milling and baking predictability and labor savings were accomplished by enlarging the sieve housing and adding a 94SS sieve to the Quadrumat Jr. micromilling method. The added sieving enabled relative wheat hardness to be differentiated, which saved labor by replacing the Labconco-ground particle size index test. Furthermore, use of the additional sieve improved milling quality predictability by relating Quadrumat to Allis-Chalmers break-flour yields with a correlation coefficient of about 0.98. Additional labor savings and improved predictability resulted, because tempering of wheats before experimental milling was unnecessary if two regression coefficients expressing the effects of wheat moisture on Quadrumat break-flour yield and Quadrumat flour yield were used to correct all data. With or without tempering, the throughs of the Quadrumat 94SS correlated best with the Allis-Chalmers mill alkaline water retention capacity (AWRC) values. However, acceptable Allis AWRC predictability was accomplished on the combined flours of the 94SS overs and throughs. The combined flours had the advantage of yielding AWRC values essentially unaffected by variable wheat moisture content during milling.

A principle function of state and federal wheat quality laboratories is to evaluate promising breeding lines and commercially grown varieties. To save money and time, microtests have been developed to predict important milling and baking qualities so that undesirable lines can be eliminated before reaching an advanced generation (Finney and Yamazaki 1946, Finney et al 1950, Seeborg and Barmore 1957, Shoup et al 1957, Kemp et al 1961, Yamazaki et al 1968, Finney and Shogren 1972, Yamazaki and Donelson 1972).

A two-phase quality evaluation microprocedure for early-generation screening is utilized at the Soft Wheat Quality Laboratory. Phase one is based on milling 25 g in a modified Brabender Quadrumat Jr. mill. The flour quantity obtained after sieving through a 54SS screen has a highly significant correlation with straight-grade flour and the endosperm separation index (ESI) milling data derived from a modified, precision-improved, Allis-Chalmers mill (Yamazaki and Andrews 1982a,b). Phase two is based on two key tests: Labconco-ground particle size index (PSI), which is associated with wheat hardness and flour granularity, and flour alkaline water retention capacity (AWRC). Historically, PSI has been associated with milling break-flour yield, whereas AWRC has been associated with cookie quality (Yamazaki 1953, 1954; Kitterman and Rubenthaler 1971).

This paper describes revised microtesting procedures and their applications for predicting milling and baking quality of early generation soft wheat breeding lines.

MATERIALS AND METHODS

Wheats

Initial studies of milling and baking quality were conducted on 17 eastern soft red or white winter wheat samples, termed set 1, and one sample of hard red winter wheat.

Set 2, 12 eastern soft red or white winter wheat samples ranging greatly in milling and baking quality, was used to evaluate the effect of wheat moisture content on milling and baking predictability of the revised microtest procedure.

Set 3 consisted of 51 wheat samples, including one club, five hard red, seven soft white winter, and 38 soft red winter wheats. These samples were used to confirm the results of the preliminary and moisture-effect studies.

Analytical Methods

Moisture, protein, and ash contents of wheats and flours were determined by AACC methods 44-15A, 46-11, and 08-01, respectively. AWRC was determined as described by Yamazaki et al (1968). Damaged starch levels were estimated as described by Donelson and Yamazaki (1962).

Allis-Chalmers Milling and Labconco Grinding

When applicable, the hard wheats were tempered to 16% and the soft wheats to 15%. Allis-Chalmers (Allis) milling was accomplished as described by Yamazaki and Andrews (1983). PSI grinding and sifting were accomplished as described by Yamazaki and Donelson (1983).

Revised Micromilling Method

Because the PSI test has always been associated with wheat hardness and more recently with milling break-flour yield, we hypothesized that the PSI test could be accomplished on mill stream from the 25-g Quadrumat Jr. (Quad) micromilling by adding an appropriate sieve. Preliminary studies indicated sieve sizes between 85SS and 120SS would likely separate and differentiate wheat flour produced on the Quad mill according to the inherent hardness of the wheats. A 94SS sieve size was chosen for these studies.

After 25 g (or more) of wheat passed through the Quad mill, the Plexiglas front was tapped to loosen any adhering stock. The channel leading from the last roll pass to the collecting container was cleaned with a test tube brush inserted through a rubber-stoppered opening in the Plexiglas. The sample was sifted for 1 min over a set of 54 and 94 stainless steel (SS) sieves (54W and 94W in Fig. 1) on a modified Great Western sifter rotating 190 rpm with a 4-in. throw. Screen frames were 12 × 12 in., with each functional sieve resting on a frame with a 0.5-in. wire screen attached containing screw balls that maintain sifting efficiency by bouncing against their respective 54 and 94SS sieves.

For simplicity and accuracy, the weight of the overs was used to calculate yield of the 54SS. That weight was subtracted from the wheat weight, then divided by the wheat weight and designated Quad percent straight-grade flour yield. Next the overs of the 94SS sieve were weighed and subtracted from the weight of the throughs of the 54SS, and that was divided by the throughs of the 54SS and designated Quad percent break-flour yield. The Quad break-flour yield was expressed as percent of total flour rather than as percent of wheat milled in order to reduce the effect that milling quality (flour yield) has on softness (break-flour yield), since milling quality and softness are generally inversely related.

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The overs and throughs of the 94SS were then combined in sample bottles and blended by tumbling. Protein and moisture analyses and AWRC evaluations were completed on the blended flours. For some studies, the overs and throughs of the 94SS sieve were also analyzed separately.

RESULTS AND DISCUSSION

Allis Versus Quad Break-Flour Yield

Two-hundred grams of each wheat in set 1 was used in the first revision of the Quad micro procedure. For Pike and Shawnee wheats, break-flour yield ranged from 40.9 to 20.7% and from 67.8 to 43.0% for the Allis and Quad mills, respectively (Table I). Allis and Quad break-flour yields related highly, with a correlation coefficient of 0.981. On set 1, PSI related to Allis and Quad break-flour yields with correlation coefficients of 0.728 and 0.752, respectively.

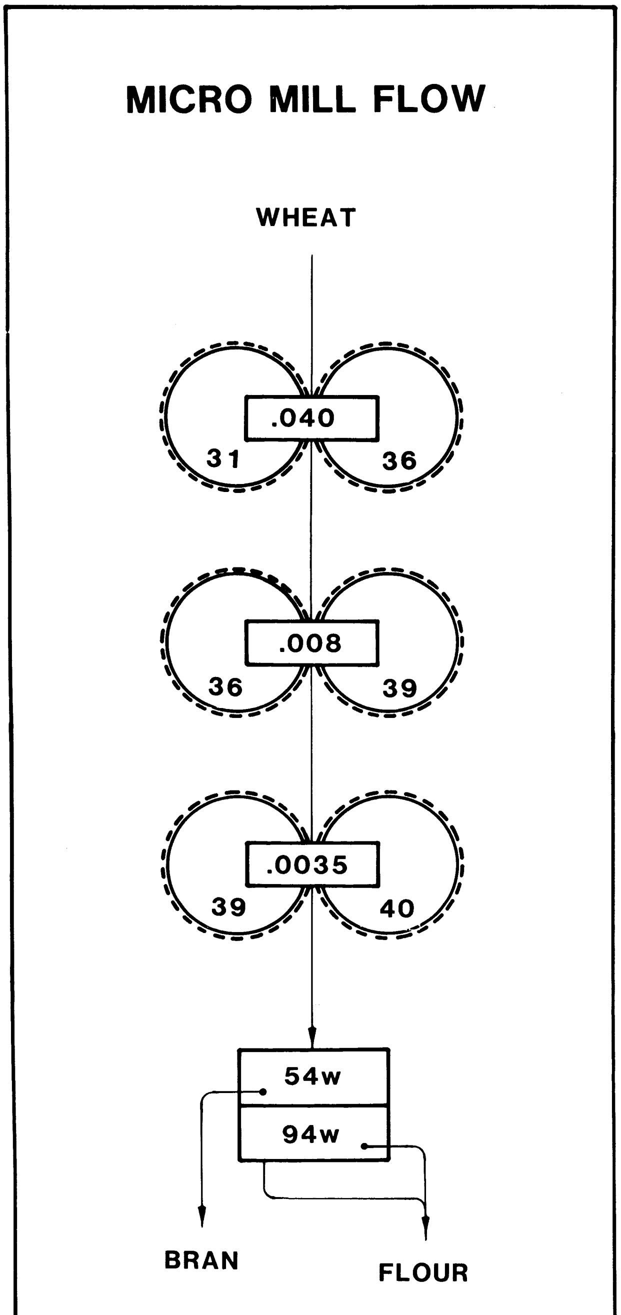

Fig. 1. Flow diagram for the Quadrumat Jr. micromill. The first, second, and third break rolls have corrugations of 31 and 36, 36 and 39, and 39 and 40, respectively.

Allis ESI Versus Quad Yield

The Allis ESI is a test procedure that designates ease of endosperm separation from the bran (Yamazaki and Andrews 1982a). Specifically, the test determines the relative amount of work or energy required to isolate the endosperm. The lower the ESI value, the smaller the amount of energy that was required to make the separation. On wheat from set 1, Allis ESI ranged from 7.1% for NY 6432-43 to 16.3% for Oasis and OH 185 (Table I). Quad yield ranged from 68.5 to 77.2% for OH 185 and NY 6432-43, respectively. On set 1, Allis ESI related to the Quad yield with a correlation coefficient of −0.971.

Moisture Effects on Quad Prediction of Allis Yield and ESI

The effects of wheat moisture on the revised Quad milling and PSI tests were assessed using 25-g sublots of set 2, composed of 12 wheats that were dehydrated and then incrementally tempered and allowed to equilibrate for at least one week. Increases in wheat moisture between about 8.5 and 10.5% resulted in increases in total yield for 10 of 12 varieties, excluding Frankenmuth and Oasis (Fig. 2). As wheat moisture content was increased above 10–10.5%, total flour yield decreased at a similar rate for all 12 varieties (Fig. 2). For purposes of predicting Allis ESI or yield, wheat moisture levels of 11% or above appeared best, with correlation coefficients above 0.97 (Table II).

TABLE I
Milling Data from the Allis-Chalmers and Quadrumat Junior Mills and the Labconco Grinder Particle Size Index Test (PSI) on 18 Soft Red or White Winter Wheats

Entry	Allis Break Flour (%)	Quad Break Flour (%)	Labconco PSI (%)	Allis ESI[a] (%)	Quad Yield Th. 54SS (%)
Pike	40.9	67.8	44.8	12.4	72.0
Ruler	38.6	65.2	42.7	14.7	70.3
JMS 222	36.9	65.1	42.5	9.1	74.7
Argee	35.7	61.0	38.5	7.6	76.6
OH 185	35.6	61.0	48.4	16.3	68.4
Adena	35.5	61.7	40.7	11.5	73.1
Ruler	35.1	60.1	42.0	15.6	70.0
Caldwell	34.6	61.1	38.0	10.4	74.3
Severn	33.6	62.4	40.7	7.3	76.2
Wheeler	33.3	60.5	44.3	8.5	75.3
S-78	32.1	55.8	38.0	13.5	71.6
Scotty	30.0	55.6	36.4	9.4	74.9
Callahan 115	28.1	53.3	36.2	12.6	73.4
Oasis	27.5	53.5	36.6	16.3	70.6
Paha	26.5	53.0	36.2	8.1	75.8
NY 6432-3	25.7	51.1	41.1	7.9	76.1
NY 6432-43	24.2	49.3	39.2	7.1	77.2
Shawnee	20.7	43.0	27.1	10.2	74.1

[a] ESI, endosperm separation index.

TABLE II
Correlation Coefficients (r) Relating Micromilling Tests for 12 Soft Red or White Winter Wheats Known to Differ Greatly in Degree of Softness and Ease of Milling

	Correlation Coefficient					
	Wheat Moisture (%)					
Relationship	9	10	11	12	13	14
Allis bk. fl. vs. Quad bk. fl.[a]	···	−0.971	−0.980	−0.985	−0.990	−0.992
Allis bk. fl. vs. Labconco PSI[b]	···	0.658	0.776	0.837	0.871	0.889
Allis ESI vs. Quad yield[c]	−0.910	−0.933	−0.971	−0.980	−0.991	−0.990

[a] Allis-Chalmers break flour yield correlated with the micro Quadrumat Junior over 94SS (as percent of total flour). All Allis-Chalmers wheats were tempered to 15.0% moisture.
[b] Allis-Chalmers break flour yield correlated with the Labconco through 35SS (particle size index test).
[c] Allis-Chalmers endosperm separation index correlated with the micro Quadrumat Junior over 54SS.

ESI, also defined as the approximate quantity of endosperm remaining attached to the bran pieces after break and first reduction passed, was very accurately predicted by the Quad yield (100 minus overs of 54SS) with correlation coefficients increasing from −0.910 to −0.990 as wheat moisture content was increased from 9 to 14% (Table II).

Moisture Effects on Quad Prediction of Allis Break Flour

As the moisture content of the wheats increased from about 9.5 to about 14.5%, both PSI and Quad over-94SS (as percent total flour) invariably increased (Figs. 3 and 4). However, for predictive purposes the Quad break-flour yield related more highly than PSI to Allis break-flour yield, with correlation coefficients increasing from 0.971 to 0.992 as wheat moisture content increased from 10 to 14%. PSI related to Allis break flour with increasing correlation coefficients of 0.658–0.889, as wheat moisture content increased from 10 to 14% (Table II).

There are a number of reasons why the revised Quadrumat Jr. microprocedure improves upon the PSI test. For each of the 12 wheat varieties the relationships between wheat moisture content and PSI are definitely curvilinear, whereas they are nearly linear for the Quad break-flour yield. Most importantly, the regression coefficients fan out in a disorderly fashion for the PSI values (Fig. 3). That is, for the PSI values many of the curves crisscross with increasing wheat moisture content, whereas there is essentially one regression line (with differing y-intercepts for each variety) expressing the effect of wheat moisture content on Quad break-flour yield (Fig. 4). Note also that for any moisture level the Quad method broadens the range between and among the 12 varieties compared to the Labconco PSI method. For example, at 10% wheat moisture content, the Quad through-94SS ranges from 43.3 to 60.0% (as percent total flour) for the hardest and softest wheats, respectively (a difference of 17.9% percentage points); whereas the PSI through-35SS values ranged from 34.5 to 47.1% for the hardest and softest wheats (a difference of 13.6 percentage points). At the 14% wheat moisture level, the superior varietal differentiability of the Quad mill was maintained over the Labconco grinder, with 19.3 versus 16.2 percentage point spreads, respectively (Figs. 3 and 4).

Moisture Effects on Quad Versus Labconco AWRC Values

Variations in wheat moisture content during milling or grinding influenced the AWRC values of the respective flours or meals. As wheat moisture content was increased from about 9% to about 14.5%, AWRC values decreased an average of about 4.7 percentage points for Labconco through-35SS flour (Fig. 5, top). The same increase in wheat moisture content had about half the effect on Quad AWRC: it decreased about 2.5 percentage points and increased about 2.3 percentage points, respectively, for the overs and throughs of 94SS (Fig. 5, middle and bottom).

AWRC values calculated from the combined Quad 94SS overs and throughs were essentially unaffected by the moisture content of the wheat during milling. Thus for routine AWRC microtesting of wheat samples we combined the 94SS overs and throughs, thereby eliminating the need for tempering wheats to a constant moisture level.

The more pronounced effect of wheat moisture on Labconco compared to Quad milling and AWRC values can be partially explained by the ash, protein, and damaged starch of their respective meals and flours. Increasing wheat moisture content

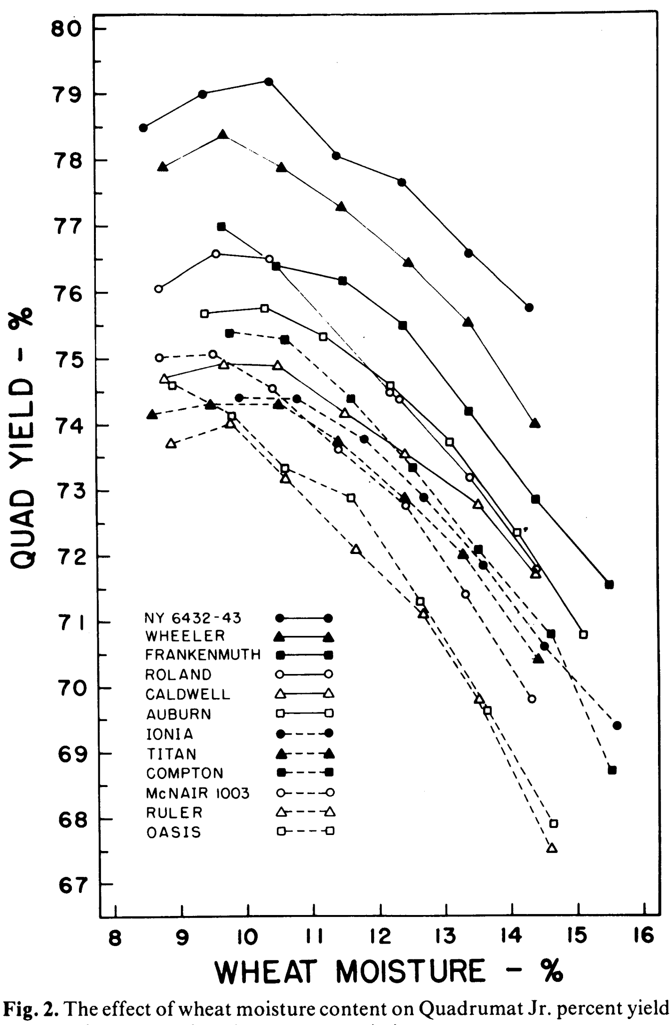

Fig. 2. The effect of wheat moisture content on Quadrumat Jr. percent yield for 12 soft red or white winter wheat varieties.

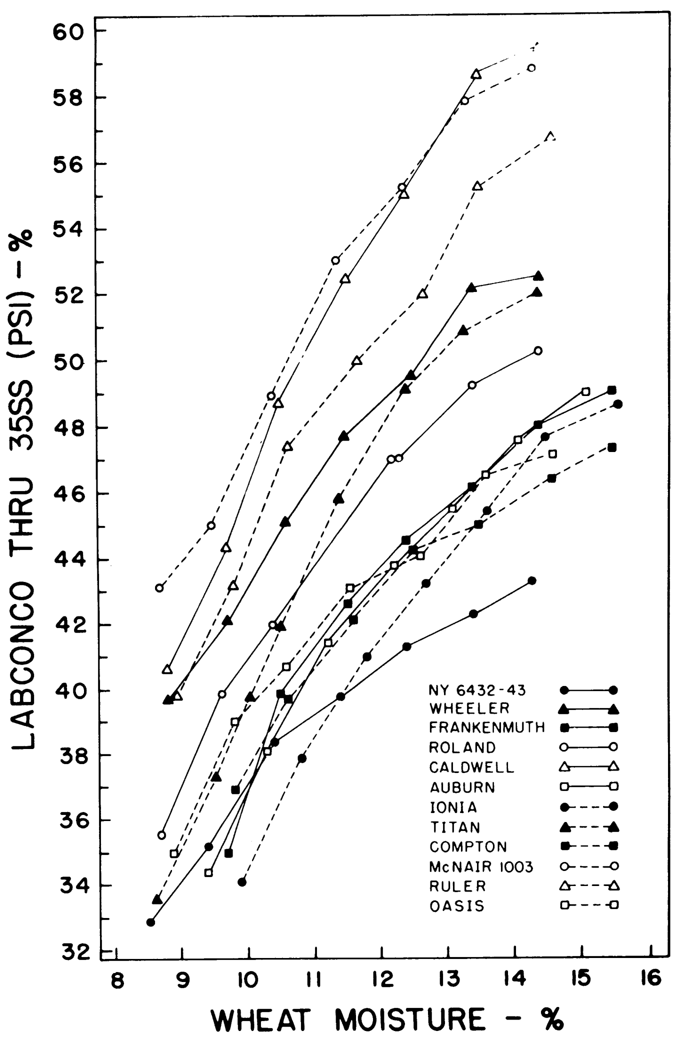

Fig. 3. The effect of wheat moisture content on Labconco particle size index values (through 35SS) run on ground meals from 12 soft red or white winter wheat varieties.

TABLE III
Ash Contents, Protein, and Damaged Starch of Flours or Meals Produced by Quadrumat Junior Milling or Labconco Grinding of 12 Low- or High-Moisture Wheats[a]

	Quadrumat Junior				Labconco	
	Through 94SS		Over 94SS		Through 35SS	
Sample	Low (%)	High (%)	Low (%)	High (%)	Low (%)	High (%)
Ash contents[b]						
NY 6432-43	0.49	0.35	0.69	0.41	1.27	0.85
Wheeler	0.45	0.32	0.81	0.47	0.96	0.71
Frankenmuth	0.47	0.33	0.83	0.46	1.07	0.79
Roland	0.49	0.34	0.81	0.48	1.13	0.78
Caldwell	0.45	0.31	0.95	0.49	0.86	0.57
Auburn	0.45	0.30	0.85	0.43	0.97	0.69
Ionia	0.46	0.31	0.97	0.47	1.12	0.82
Titan	0.48	0.32	0.96	0.50	1.03	0.64
Compton	0.46	0.33	0.79	0.44	1.12	0.83
McNair 1003	0.41	0.32	0.89	0.57	0.86	0.63
Ruler	0.49	0.33	0.85	0.50	1.00	0.70
Oasis	0.54	0.36	0.87	0.46	1.15	0.78
Protein[c]						
NY 6432-43	10.80	10.96	10.83	10.23	11.83	12.57
Wheeler	10.59	10.43	11.69	11.24	11.41	11.75
Frankenmuth	9.57	9.32	10.65	10.00	9.99	10.70
Roland	9.08	8.82	9.66	9.65	10.03	10.10
Caldwell	7.47	7.39	9.62	9.19	7.83	8.04
Auburn	8.90	8.66	10.74	10.03	9.36	10.10
Ionia	7.96	7.51	9.62	8.79	8.31	8.78
Titan	8.13	8.06	9.50	9.76	8.61	8.82
Compton	10.00	9.91	11.30	10.29	10.98	11.57
McNair 1003	8.07	7.93	9.37	8.76	8.44	8.76
Ruler	9.91	9.00	10.65	10.21	10.03	10.38
Oasis	11.89	11.96	13.21	13.34	12.84	13.96
Damaged starch[d]						
NY6432-43	2.76	3.01	0.69	0.53	5.06	3.45
Wheeler	1.98	2.04	0.43	0.11	3.17	2.24
Frankenmuth	2.38	2.49	0.48	0.45	3.99	2.70
Roland	2.51	2.57	0.53	0.39	4.00	2.63
Caldwell	1.96	2.13	0.46	···	2.99	1.95
Auburn	2.26	2.28	0.49	0.34	3.45	2.38
Ionia	2.51	2.62	0.60	0.47	3.83	2.47
Titan	2.46	2.55	0.29	0.42	3.57	2.43
Compton	2.65	2.44	0.49	0.34	3.97	2.61
McNair 1003	1.88	2.13	0.22	0.21	2.52	2.27
Ruler	2.18	2.49	0.42	0.42	3.53	2.97
Oasis	2.23	2.17	0.46	0.39	3.60	2.47

[a] Moisture content ranged from 8.5–9.9% in low-moisture wheats and from 14.3–15.6% in high-moisture wheats. All determinations were made on 14% mb.
[b] SD = 0.02; LSD = 0.04 (n = 72).
[c] Determined as N × 5.7. SD = 0.697; LSD = 0.139 (n = 72).
[d] SD = 0.0738; LSD = 0.1476 (n = 71).

TABLE IV
Correlation Coefficients (r) Relating Percent Allis-Chalmers Break Flour Yield to Quadrumat Junior Break Flour and Labconco Particle Size Index (PSI)[a]

Treatment	Tempered (T) or Untempered (U)	Wheat Class	Allis % Break Flour[b] (r)
Quad break flour	T	Mixed	−0.976
	T	Soft	−0.966
	U	Mixed	−0.964
	U	Soft	−0.949
Labconco PSI	T	Mixed	0.920
	T	Soft	0.874
	U	Mixed	0.697
	U	Soft	0.462

[a] The sample comprised 51 wheats (46 soft and 5 hard) either tempered (14%) or untempered and corrected to 11% moisture equivalent by regressing the data from Fig. 2.
[b] Soft and hard wheats tempered to 15 and 16%, respectively.

decreased bran contamination in all the meals and flours, as evidenced by ash percentages; however, Labconco ash values were decreased more than Quad ash values with increased wheat moisture (Table III). Whereas protein contents of Quad flours were essentially unaffected by wheat moisture during milling, increasing wheat moisture resulted in significiant increases in protein of Labconco-ground meals (Table III). Increased wheat moisture produced only minor changes in the quantity of damaged starch of Quad-milled flours, whereas sizable reductions in the starch damage content resulted in Labconco-ground meals (Table III).

Confirmation Studies of Yield

To confirm the value of the revised micromilling methods, the 51 wheat samples in set 3 were evaluated as 25-g unknowns. Allis milling yields ranged from 79.4 to 73.0%, and Quad milling yields for the untempered and the tempered wheats (both corrected to 11% moisture) ranged from 79.9 to 73.4% and from 79.4 to 73.9%, respectively. Correlation coefficients for Allis yield versus untempered and tempered Quad yields were 0.935 and 0.94, respectively. When the five hard wheats were excluded, these correlations increased to 0.944 and 0.960, respectively. Values for Allis ESI correlated with the untempered and tempered Quad yields were −0.95 and −0.971, respectively.

Confirmation Studies: Allis and Quad Break-Flour Yields Versus Labconco PSI

Using the 51 untempered and tempered wheats in set 3, Labconco-ground PSI, Allis-Chalmers break-flour yield, and

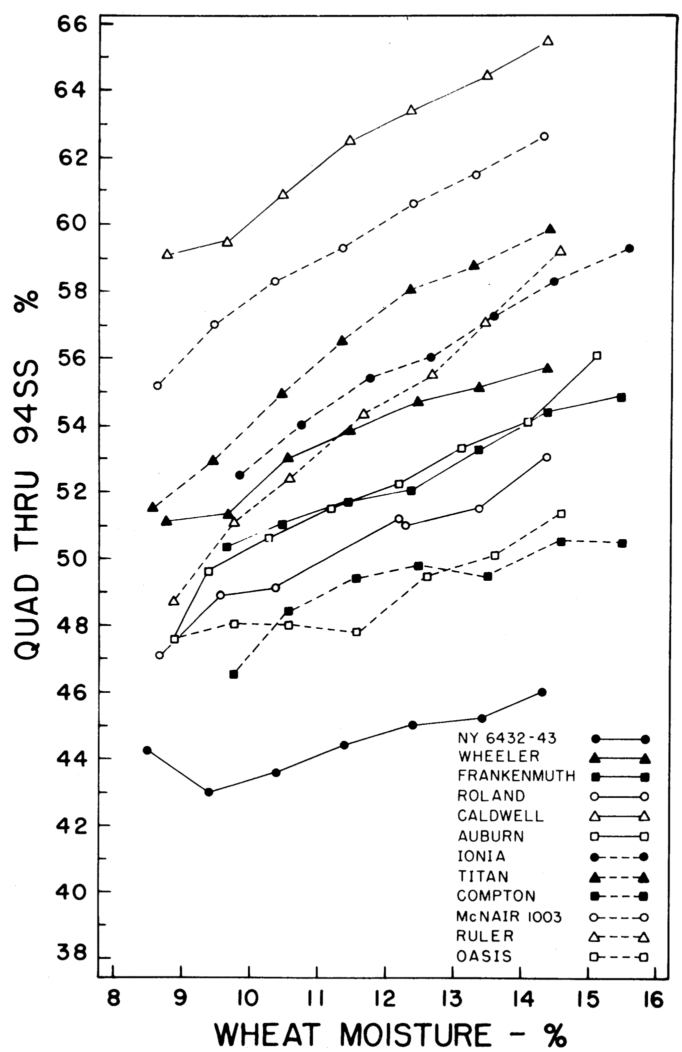

Fig. 4. The effect of wheat moisture content on percentage of flour through 94SS from the Quadrumat Jr. micromill run on 12 soft red or white winter wheat varieties.

Quad break-flour yield were statistically analyzed with and without the five hard wheats. Tempering very materially improved the PSI correlation with Allis break-flour yield, with *r* values increasing from 0.462 to 0.874 (softs only) and 0.697 to 0.920 (hards and softs). Tempering was not necessary to produce high correlation between Quad percent flour through 94SS (percent flour over 94SS was weighed) and Allis break-flour yield, with *r* values of 0.949 and 0.964 for the soft and mixed wheats, respectively. Tempering improved both those relationships (Table IV).

Effect of Milling Procedure on AWRC

The effects of milling, grinding, sieving, and tempering on the AWRC values were pronounced (Table V). The revised Quad micromethod of flour preparation correlated best with the AWRC values of Allis-milled flours when the through-94SS fraction was used. Tempering slightly improved both the soft and the mixed class groupings. AWRC values of the traditional untempered Labconco-ground meals related poorly to the AWRC of Allis-milled flours, with correlation coefficients of 0.418 and 0.729 for the soft and mixed wheats, respectively (Table V).

CONCLUSIONS

The revised micromilling method was accomplished by enlarging the sieve housing and adding a 94SS sieve to the Quadrumat Jr. micromilling method. In short, one weighing per sample of the

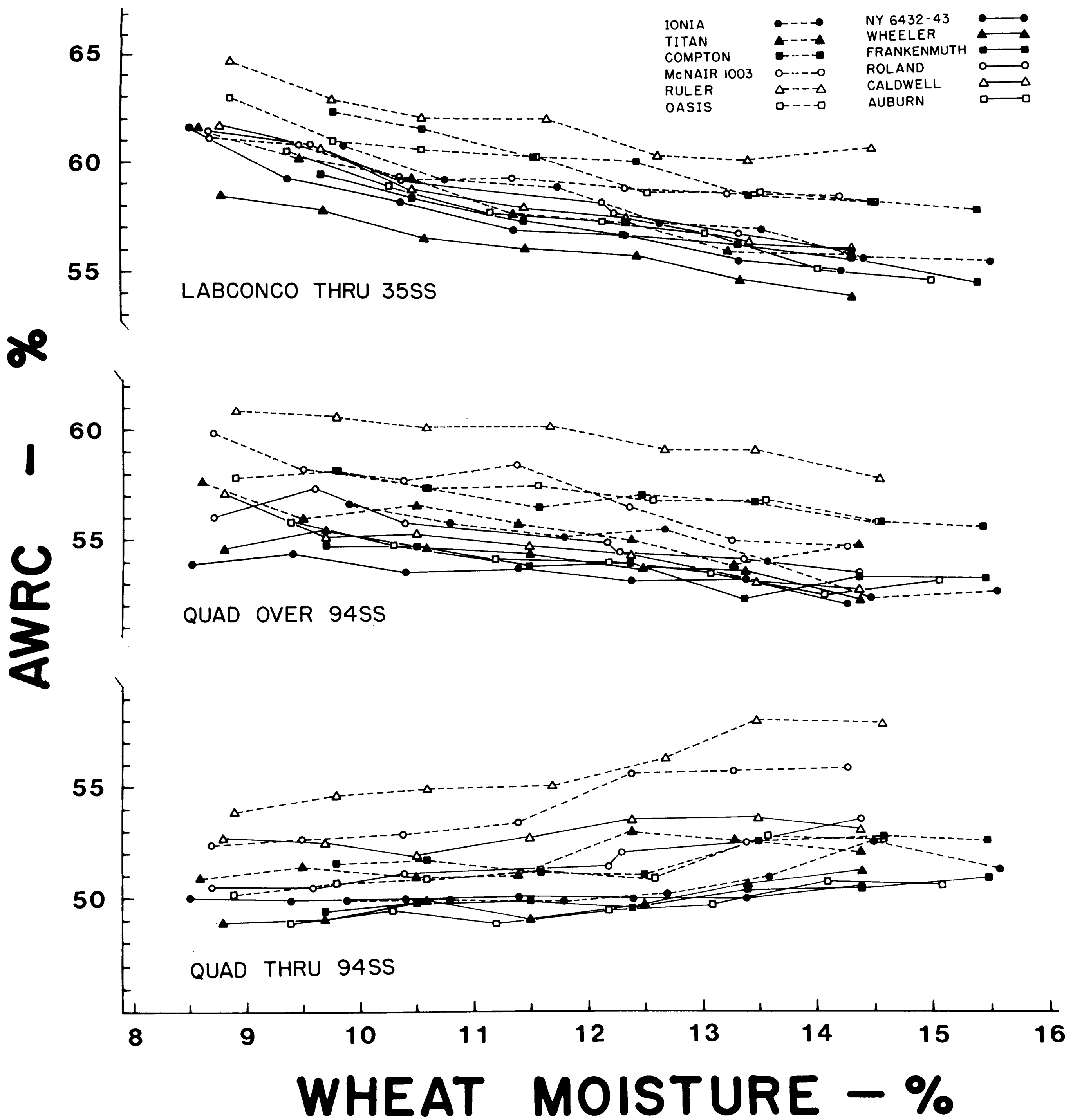

Fig. 5. The effect of wheat moisture content on the AWRC values of (**top**) Labconco ground meals (through 35SS); (**middle**) Quadrumat Jr. milled flours (over 94SS); and (**bottom**) Quadrumat Jr. milled flours (through 94SS) from 12 soft red or white winter wheat varieties.

TABLE V
Correlation Coefficients (*r*) Relating the Effects of Milling or Grinding, Tempering, and Class of Wheat on Alkaline Water Retention Capacity (AWRC) of 51 Wheats

Flour or Meal Preparation	Tempered (T) or Untempered (U)	Wheat Class	Allis Break Flour AWRC (*r*)
Quad through			
94SS AWRC	T	Mixed	0.938
	T	Soft	0.884
	U	Mixed	0.913
	U	Soft	0.856
Quad over			
94SS AWRC	T	Mixed	0.783
	T	Soft	0.660
	U	Mixed	0.799
	U	Soft	0.687
Labconco through			
35SS AWRC	T	Mixed	0.836
	T	Soft	0.696
	U	Mixed	0.729
	U	Soft	0.418

overs or throughs of 94SS materially saved microtesting labor by eliminating the Labconco PSI test. The added sieving operation differentiated relative wheat hardness by predicting Allis break-flour yield with a correlation coefficient of about 0.98. Also, this simple addition in the micromilling method effected greater accuracy in predicting soft wheat baking quality by improving the correlation between AWRC of Quad and Allis micromilled flours.

The effect of wheat moisture content on milling and AWRC values was determined. Tempering of wheats before experimental milling was found unnecessary because one regression coefficient expressed the effect of wheat moisture on Quad break-flour yield whereas another regression coefficient expressed the effect of wheat moisture on Quad flour yield. Furthermore, when combining the Quad overs and throughs of the 94SS sieving operation, the AWRC value was essentially unaffected by the moisture content of the wheat during milling. The net results were labor savings and improved predictions of soft wheat milling and baking quality.

As a result of the studies reported here, beginning with the 1984 crop year, the Labconco-ground PSI, formerly used to estimate relative wheat softness, was replaced by Quad break-flour yield and designated the softness equivalence (SE) value.

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