Effect of Tempering Conditions on Milling Performance and Flour Functionality

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ABSTRACT

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Tempering conditions of wheat grain change the quality of the flour, yet most experimental milling systems use a standard tempering without optimization. The effect of tempering condition on milling performance and flour functionality for soft red winter (SRW) wheat grain was tested by measuring flour yield, ash, polyphenol oxidase (PPO), and solvent retention capacity (SRC) in grain samples from three SRW cultivars (Roane, Cyrus, and Severn). Tempering was conducted with a full factorial design of initial wheat moisture, tempered wheat moisture, tempering temperature, and tempering time at two levels. Tempered wheat moisture had the largest effect on milling performance and flour functionality. Flour yield was more reduced for all samples tempered at 15% moisture than for samples tempered to 12% moisture. Flour quality of the 15% tempered sample was better than the 12% tempered samples due to less bran contamination as measured by flour ash and PPO. Increasing the tempering moisture increased flour sucrose SRC and lactic acid SRC but reduced sodium carbonate SRC for samples. Changing tempered wheat moisture changed flour yield and quality much more than did changing the length of time for tempering, the temperature at wheat is tempered, or differences in the initial moisture of the wheat before tempering. The last three effects could be used to improve flour yield in both the 12 and 15% tempered wheat treatment but the detrimental effects of these treatments on flour quality were minimal when combined with the 15% tempered wheat moisture treatment.

Tempering is the process of adding water to wheat before milling to toughen the bran and mellow the endosperm of the kernel and thus improve the efficiency of flour extraction. Numerous researchers have reported studies on water uptake, movement, and diffusion during tempering (Stenvert and Kingswood 1976, 1977; Song et al 1998; Kang and Delwiche 1999, 2000; Delwiche 2000). Tempering temperature, moisture, and time affect rate of moisture uptake to wheat, and wheat cultivar, initial wheat water content, and kernel size and temperature also influence that rate (Posner and Hibbs 1997). Although the rate of water penetration into wheat during tempering varied for different cultivars, the mode of movement was essentially the same (Stenvert and Kingswood 1976). The rate also was influenced by endosperm structure and protein content and distribution (Stenvert and Kingswood 1977). Tempering toughens pericarp, and fewer small pericarp particles are formed during milling. However, as tempering moisture within the kernel increased, flour extraction rate decreased. Therefore, the tempering procedure should balance the level of flour extraction and acceptable level of bran in flour (Hook et al 1982a,b,c).

Most tempering studies have focused on tempering mechanism and milling yield but not flour quality. Few reports link tempering effects to flour qualities such as ash content, farinograph, and extensigraph quality (Butcher and Stenvert 1973; Ibanoglu 2001). Ash content of flour has been used as an indicator for bran contamination but it is the measurement of inorganic compounds. Ash does not directly measure arabinoxylans, which are major functional flour components related to mixing and baking, and elevated by bran layers. Fuerst et al (2006) reported that most polyphenol oxidase (PPO) is located in bran; determination of PPO activity can be another valid indicator to measure bran contamination. For evaluating flour functionality, the solvent retention capacity (SRC) test is increasingly used to test the functional contribution of each flour component such as glutenins, damaged starch, and arabinoxylans (Guttieri et al 2001, 2002; Bettge et al 2002; Guttieri and Souza 2003; Ram and Singh 2004; Ram et al 2005; Roccia et al 2006; Xiao et al 2006). Water SRC is related to water absorption capacity for all flour components, lactic acid SRC to general gluten strength, sodium carbonate SRC to damaged starch, and sucrose SRC to arabinoxylans.

Despite several studies of tempering effects on flour functionality in hard wheats, few recent studies have reported tempering on soft wheat flour functionality. We tested initial wheat moisture (initial moisture of the grain), tempered wheat moisture (moisture level to which the grain was tempered), tempering temperature (temperature at which the tempering occurred), and tempering time (length of time for which the tempering occurred) in a factorial experimental design. Our goal was to seek treatment combinations that could elevate flour extraction, flour quality, or both as determined by flour yield on an experimental mill, softness equivalent (for predicting break flour yield), flour ash, PPO, and SRC testing.

MATERIALS AND METHODS

Materials

Based on historical milling quality data at Soft Wheat Quality Laboratory, three soft red winter (SRW) wheat cultivars (good milling Severn, average milling Cyrus, and poor milling Roane) were selected for the study. Samples were received from Purdue University, where they were grown together at West Lafayette, IN in 2004. All chemicals were reagent grade.

Tempering and Milling of Wheat

For an experimental design, initial wheat moisture, tempered wheat moisture, tempering temperature, and tempering time were chosen as factors, and two levels were selected for each factor: initial wheat moisture, ≈7 and 10.2%; tempered wheat moisture, 12 and 15%; tempering temperature, 25 and 45°C; and tempering time, 3 and 24 hr. For each wheat cultivar, tempering experiments were conducted by a full factorial design ($2^4 = 16$ runs) in random order. The wheat samples with 7% initial wheat moisture content were prepared by drying cleaned wheat berries (10.2% moisture content) at 43°C for approximately five days to reach the targeted weight. Cleaned wheat sample (200 g) weighed in a glass jar was mixed with tempering water and tempered at each tempering condition. The amount of tempering water was calculated according to initial wheat moisture (7 or 10.2%) and tempered wheat mois-

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ture (12 or 15%) contents. The tempered wheat sample was milled with an advanced Quadrumat Jr. mill (Brabender Instruments, South Hackensack, NJ) which consisted of two Quadrumat Jr. mill units. The first was a regular mill for break and the second was a modified mill for reduction. Tyler stainless steel bolting cloth 40 mesh (470 μm) and 94 mesh (180 μm) was used for sieving of the mill stream for the break mill, and 84 mesh (213 μm) was used for sieving of the further reduced stream of OV 94 mesh (<40 mesh and >94 mesh fraction) using the reduction mill. The flour streams <94 mesh from the first break mill and <84 mesh from the second reduction mill were blended well and used for further analysis. We anticipated that the particle size was relatively larger for the blended flour due to using a coarser sieving screen than the flour milled with long-flow experimental mill (Miag Multomat and Allis Chalmers) or commercial mill. The flour yield and softness equivalent (SE) were explained by Finney and Andrews (1986) and calculated as Yield = 100 × [1 – (Ov 40 mesh/wheat wt)] and SE = 100 × [1 – Ov 94 mesh/(wheat wt – Ov 40 mesh)], respectively, in this study.

Proximate Analyses and Total PPO Assay

Moisture content was measured with Approved Method 44-16 and ash content was determined with Approved Method 08-01 (AACC International 2000). Total PPO assay of milled flour samples was based on the modification of Approved Method 22-85 and the method used by Jukanti et al (2003). Flour (150 mg) was weighed into a 2-mL microcentrifuge tube, and 1.5 mL of 10 m*M* L-DOPA in 50 m*M* MOPS buffer with 50 m*M* SDS was dispensed into the tube. The tube containing flour slurry was placed on a rotating shaker immediately, rotated for 30 min, and centrifuged at 5,000 × *g* for 10 min using an Eppendorf centrifuge. The supernatant was measured its absorbance at 475 nm at 1 hr after adding L-DOPA solution, and the PPO results were expressed as ΔA_{475} hr^{-1} g $flour^{-1}$. The PPO assay was done in duplicate.

SRC Test

The standard SRC solvents (deionized water, 5% sodium carbonate, 5% lactic acid, and 50% sucrose) were prepared according to the Approved Method 56-11 (AACC International 2000). Flour (5 g) was suspended in 25 g of each solvent for 20 min with intermittent hand shaking at 5, 10, 15, and 20 min. Flour suspension was centrifuged at 1,000 × *g* for 15 min and drained for 10 min. The pellet was weighed and SRC value was calculated. The SRC assay was done in duplicate.

Statistical Analysis

Statistical software (JMP v.7.0; SAS Institute, Cary, NC) was used for analyzing the results of the factorial design, and the significant factors to each response were analyzed with analysis of variance using SAS software. The model's fixed effects were initial wheat moisture, tempered wheat moisture, tempering temperature, and tempering time. Cultivars were assumed to be random effects in this model. The three cultivars were not selected for specific milling and baking quality effects but, rather, to represent a sample of the cultivars milled in the eastern United States. As random effects, interactions between cultivars and the fixed effects of the study were not analyzed but, rather, pooled as an error estimate for the fixed effects of the model. For factorial analysis, estimates of main effects and interaction effects were evaluated and significant factors were decided by half-normal plot.

TABLE I
Analysis of Variance Mean Squares by General Linear Model Procedure for Milling Performance and Flour Functionality Responses with Various Tempering Conditions[a,b]

						SRC			
Source[c]	DF	Flour Yield	SE	Ash	PPO	Water	Lactic Acid	Na_2CO_3	Sucrose
Cultivar	2	136.96***	383.10***	0.00497***	0.0953***	19.36***	1197.97***	233.76***	352.53***
WM	1	6.02***	5.67***	0.00196***	0.0131*	2.71**	20.41	17.52***	13.34*
TM	1	212.52***	18.13***	0.05569***	0.4528***	1.40*	840.85***	23.24***	256.23***
TP	1	14.08***	0.02	0.00226***	0.0316**	0.00	9.81	1.33	40.15***
TT	1	19.76***	3.05**	0.0342***	0.0204**	1.76*	63.71**	19.76***	0.39
WM × TM	1	0.4	1.17	0.00149**	0.0002	0.80*	10.55	4.44*	0.11
WM × TP	1	0.37	0.68	0.00009	0.0019	0.33	0.13	0.75	4.50
WM × TT	1	1.84**	1.58**	0.00144*	0.0004	0.16	11.90	1.47	0.01
TM × TP	1	0.19	0.04	0.00054	0.0002	0.12	0.01	5.07**	1.37
TM × TT	1	0.44	1.58**	0.0443***	0.0290**	1.20*	34.85*	11.21***	0.73
TP × TT	1	2.80**	2.66**	0.00100**	0.0001	0.70	6.53	3.97*	4.26

[a] SE, softness equivalent; PPO, polyphenol oxidase; and SRC, solvent retention capacity.
[b] *, **, and ***, mean square term significant at $P < 0.05$, 0.01, and 0.001%, respectively.
[c] WM, initial wheat moisture; TM, tempered wheat moisture; TP, tempering temperature; and TT, tempering time.

TABLE II
Tempering Treatment Averages for Milling Performance and Flour Functionality[a]

						SRC (%)			
Factor[b]	Level	Flour Yield (%)	SE (%)	Flour Ash (%)	Flour PPO[c]	Water	Lactic acid	Na_2CO_3	Sucrose
TM	12%	72.21	59.03	0.345	0.674	52.62	98.00	69.38	92.85
	15%	68.00	60.26	0.286	0.531	52.28	106.38	67.99	97.48
TT	3 hr	69.47	59.90	0.326	0.655	52.25	103.34	68.05	95.25
	24 hr	70.75	59.40	0.343	0.696	52.64	101.04	69.33	95.08
TP	25°C	70.65	59.63	0.341	0.701	52.45	101.74	68.85	94.25
	45°C	69.57	59.67	0.328	0.650	52.45	102.64	68.52	96.08
WM	7.0%	69.75	59.99	0.328	0.659	52.21	102.84	68.08	94.64
	10.2%	70.46	59.30	0.341	0.692	52.68	101.54	69.29	95.69
Standard error		0.09	0.09	0.002	0.010	0.09	0.57	0.16	0.29

[a] SE, softness equivalent; PPO, polyphenol oxidase; and SRC, solvent retention capacity.
[b] WM, initial wheat moisture; TM, tempered wheat moisture; TP, tempering temperature; and TT, tempering time.
[c] Expressed as ΔA_{475}/hr/150 mg.

RESULTS AND DISCUSSION

Our primary interest was in single-factor and two-way interactions. In this study, two-way interactions were often significant (Table I). However, the three- and four-way interactions were nonsignificant for all response variables except flour ash. With flour ash, the significant *F* values were much smaller than the *F* values for the two-way interaction treatment effects on flour ash (data not shown). Fitting all three- and four-way interactions resulted in an R^2 value for the model of 97%. Reducing the model for treatment effects on flour ash to main effects and two-way interactions only reduced the R^2 to 95%. Therefore, we conclude that the reduced model for flour ash captures the most important model effects.

The tempered wheat moisture produced the largest differences in milling performance and flour functionality among the four tempering factors. Within the milling industry, the optimum milling moisture is 14–17% and the level of moisture added to the grain depends on wheat class, with hard wheats conditioned to 15.5–17% moisture content and soft wheats to 14–15.5% moisture content (Posner and Hibbs 1997). Expanding the range in tempering conditions cited by Posner and Hibbs (1997) produced significant differences in flour yield, ash, and PPO (Table I). The treatment effects on flour yield were greatest with tempered wheat moisture, followed by tempering time, tempering temperature, then initial wheat moisture (Table II). Generally, the magnitude of treatment effects on flour yield was reflected in the effect of the treatments on flour quality, with tempered wheat moisture having the greatest effect on the individual measures of wheat quality. The exception was water SRC, where initial wheat moisture treatments produced greater *F* values than tempered wheat moisture (Table I). The 15% tempered wheat moisture, 7% initial wheat moisture, 45°C tempering temperature, and 3-hr tempering time resulted in more reduced flour yield, reduced ash content, and reduced PPO activity than in each corresponding opposite condition (Table II).

Among interactions, tempered wheat moisture and tempering time affected most responses, such as SE, flour ash, PPO, water SRC, lactic acid SRC, and sodium carbonate SRC (Table I). Sucrose SRC was not influenced by any interactions between tempering conditions, whereas flour ash and sodium carbonate SRC were influenced by most tempering interactions. The treatment average values by interactions are presented in Table III. At 12% tempered wheat moisture, 10.2% initial moisture resulted in greater flour ash, water SRC, and sodium carbonate SRC than 7% initial moisture. Also, with 3 hr of tempering time, 10.2% initial wheat moisture resulted in greater flour yield and ash and less SE than 7% initial wheat moisture. In addition, 12% tempered wheat moisture generated more damaged starch than 15% tempered wheat moisture, as measured by sodium carbonate SRC. With 24 hr of tempering time, 25°C tempering temperature gave greater flour yield, ash, and sodium carbonate SRC and more reduced SE than 45°C tempering temperature. Rather than identifying large crossover effects of treatment interactions, statistical significance of the interaction effects derive from the accuracy of measurements detecting small changes in range for a single factor affected by the second factor.

Effect of Tempered Wheat Moisture on Milling Performance

The flour yields with reduced tempered wheat moisture were greater than those with increased tempering moisture treatment, which is consistent with reports by Hook et al (1982a,b,c). The

TABLE III
Tempering Treatment Averages by Interactions for Milling Performance and Flour Functionality[a]

Interaction[b]	Level	Flour Yield (%)	SE (%)	Flour Ash (%)	Flour PPO[c]	SRC (%)			
						Water	Lactic Acid	Na_2CO_3	Sucrose
WM × TM									
7.0%	12%	71.77	59.53	0.357	0.754	52.25	99.13	68.48	92.18
	15%	67.74	60.45	0.300	0.564	52.17	106.56	67.69	97.10
10.2%	12%	72.66	58.53	0.381	0.791	52.98	96.88	70.29	93.53
	15%	68.27	60.45	0.301	0.593	52.38	106.19	68.29	97.85
TT × TM									
3 hr	12%	71.48	59.47	0.351	0.727	52.27	100.01	68.26	93.07
	15%	67.46	60.33	0.302	0.582	52.24	106.68	67.83	97.44
24 hr	12%	72.95	58.60	0.387	0.818	52.97	96.00	70.51	92.64
	15%	68.55	60.19	0.299	0.574	52.31	106.08	68.15	97.51
TP × TM									
25°C	12%	72.69	59.04	0.379	0.800	52.67	97.57	69.88	92.11
	15%	68.61	60.22	0.304	0.602	52.23	105.91	67.83	96.39
45°C	12%	71.73	59.03	0.358	0.745	52.57	98.44	68.89	93.60
	15%	67.40	60.31	0.297	0.554	52.33	106.84	68.15	98.56
WM × TT									
7.0%	3 hr	68.92	60.43	0.314	0.636	51.96	104.49	67.27	94.74
	24 hr	70.59	59.56	0.342	0.683	52.46	101.19	68.90	94.53
10.2%	3 hr	70.02	59.38	0.338	0.674	52.55	102.19	68.83	95.77
	24 hr	70.91	59.23	0.344	0.710	52.82	100.88	69.76	95.62
TP × TT									
25°C	3 hr	69.77	60.12	0.328	0.679	52.13	103.26	67.93	94.04
	24 hr	71.53	59.14	0.354	0.723	52.76	100.22	69.78	94.46
45°C	3 hr	69.17	59.68	0.324	0.631	52.38	103.43	68.17	96.47
	24 hr	69.97	59.65	0.332	0.669	52.52	101.86	68.88	95.69
WM × TP									
7.0%	25°C	70.21	60.09	0.333	0.680	52.13	102.44	68.13	93.42
	45°C	69.30	59.89	0.322	0.638	52.29	103.24	68.04	95.86
10.2%	25°C	71.09	59.17	0.349	0.723	52.77	101.03	69.58	95.08
	45°C	69.83	59.44	0.333	0.661	52.60	102.04	69.00	96.30
Standard error		0.13	0.13	0.003	0.015	0.12	0.81	0.23	0.41

[a] SE, softness equivalent, PPO, polyphenol oxidase, and SRC, solvent retention capacity.

[b] WM, initial wheat moisture; TM, tempered wheat moisture; TP, tempering temperature; and TT, tempering time.

[c] Expressed as ΔA_{475}/hr/150 mg.

effect of the tempering moisture carried through to the flour moisture contents, where 12% tempering moisture treatment had flour moistures of 11.7–12.0% and the 15% tempering moisture treatment had 13.7–14.3% (Fig. 1). Softness equivalent was greater for the flour samples with the 15% tempering moisture than those with the 12% tempering moisture within same cultivar, which indicated that the kernels were moistened, softened, and then easy to mill (Fig. 1A). Gaines et al (2000) reported that SE is closely related to break flour yield obtained from Allis Chalmers milling.

Flour ash content is commonly requested in flour specification for milling and baking industries. Yet, it does not consistently give useful information on flour functionality because it is mineral content and depends on both flour extraction percentage and whole wheat ash. Variation in whole wheat ash is primarily contributed by growing environment rather than by intrinsic grain quality characteristics (Shuey 1976; Rharrabti et al 2003). To account for variation in whole wheat ash between the cultivars, we displayed both flour ash as a content within the flour (Fig 1B) and as a ratio of whole wheat ash (Fig 1D). Reduced ash ratios should indicate better separation of aleurone from the flour. For all cultivars, 15% tempered moisture reduced flour yield but improved flour quality as measured by less ash content and PPO activity due to less bran contamination, whereas 12% tempered moisture resulted in greater flour yield and higher ash ratio flour (Fig. 1B–D). The PPO profile had the same trend as ash ratio, in which the reduced tempered wheat moisture contains more bran and more PPO. Although flour PPO was generally correlated to flour yield within a cultivar, its correlation was poorer than flour ash (Fig. 1B and C). Within a cultivar, flour ash was correlated to PPO at $r > 0.91$.

Within each cultivar, treatment combinations with the 12% tempered wheat moisture treatment that increased flour yield consistently decreased in flour quality as measured by ash, ash ratio, or PPO (Fig. 1). Hatcher and Kruger (1993) reported similar results for the low tempered wheat treatment, observing that flour PPO activity and ash content increased with flour extraction rate. This generally was not the case for treatment combinations, including 15% tempered wheat moisture. Overall flour yield was less for the 15% tempered wheat moisture treatments than for paired treatments involving the 12% tempered wheat moisture treatments. However, the treatment combinations that increased flour yield within the 15% tempered wheat moisture treatments typically did not degrade flour quality, as measured by flour ash, ash ratio, or PPO (Fig. 1).

Effect of Tempered Wheat Moisture on Flour Functionality

Reducing the tempered wheat moisture greatly increased flour yield but also greatly increased sodium carbonate SRC (Table II). Similarly, treatments such as tempering temperature that only slightly changed flour yield caused negligible changes in sodium carbonate SRC. Generally, with increasing flour yield, lactic acid and sucrose SRC values decreased and sodium carbonate SRC increased (Fig. 2B–D). Tempered wheat moisture did not cause a significant change in water SRC (Fig. 2A). Water SRC values are related to water absorption capacity contributed by all flour functional components such as glutenins, damaged starch, and arabinoxylans, and represent combined contributions of lactic acid, sodium carbonate, and sucrose SRC values. Tempering treatments that improved flour yield caused off-setting effects of increased absorption due to glutenins and damaged starch (increased lactic acid SRC and sodium carbonate SRC), yet decreased sucrose SRC. Thus, the resulting water SRC showed convex shape curvature from the combination of all three SRC values.

For the flour samples with 12% tempered moisture, increased flour yield does not mean improved flour functionality, instead, it resulted in reduced lactic acid SRC. Therefore, gluten strength of

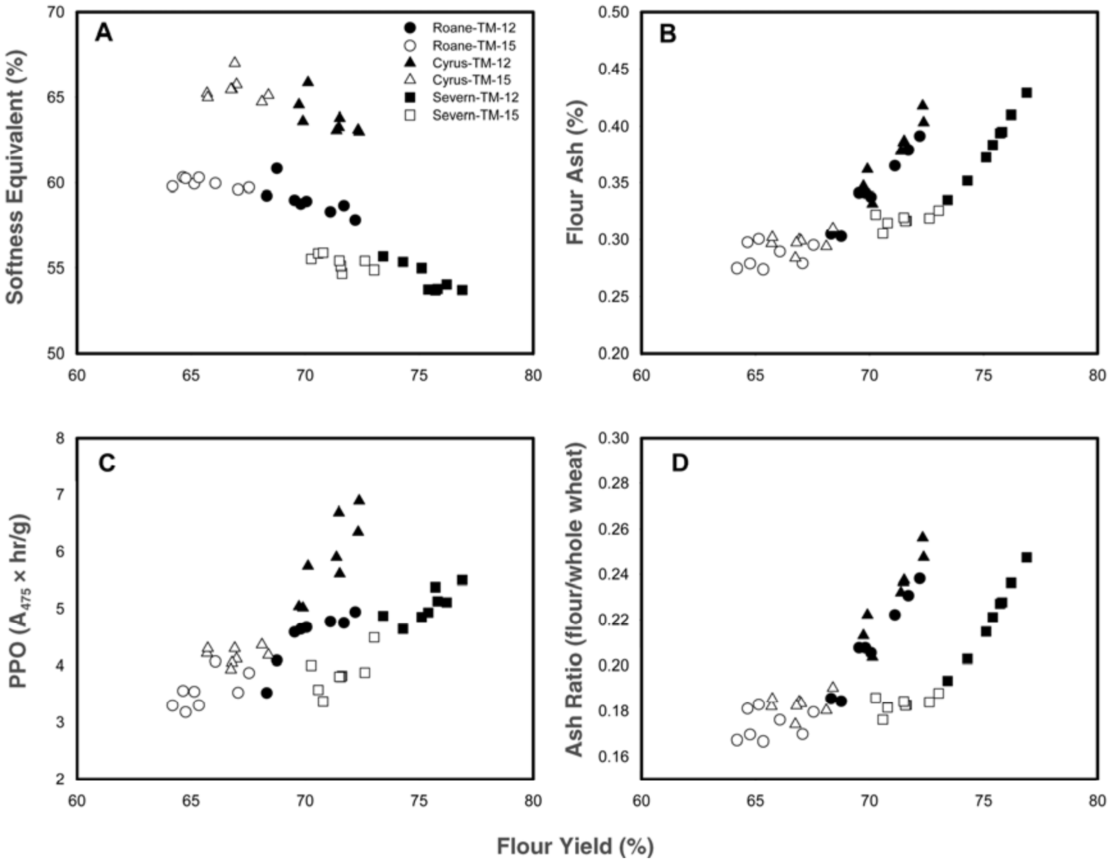

Fig. 1. Effect of tempered wheat moisture (12 and 15%) on flour yield, ash, and polyphenol oxidase (PPO) activity. **A,** Softness equivalent; **B,** ash content; **C,** PPO activity; and **D,** ratio of flour ash to whole wheat ash.

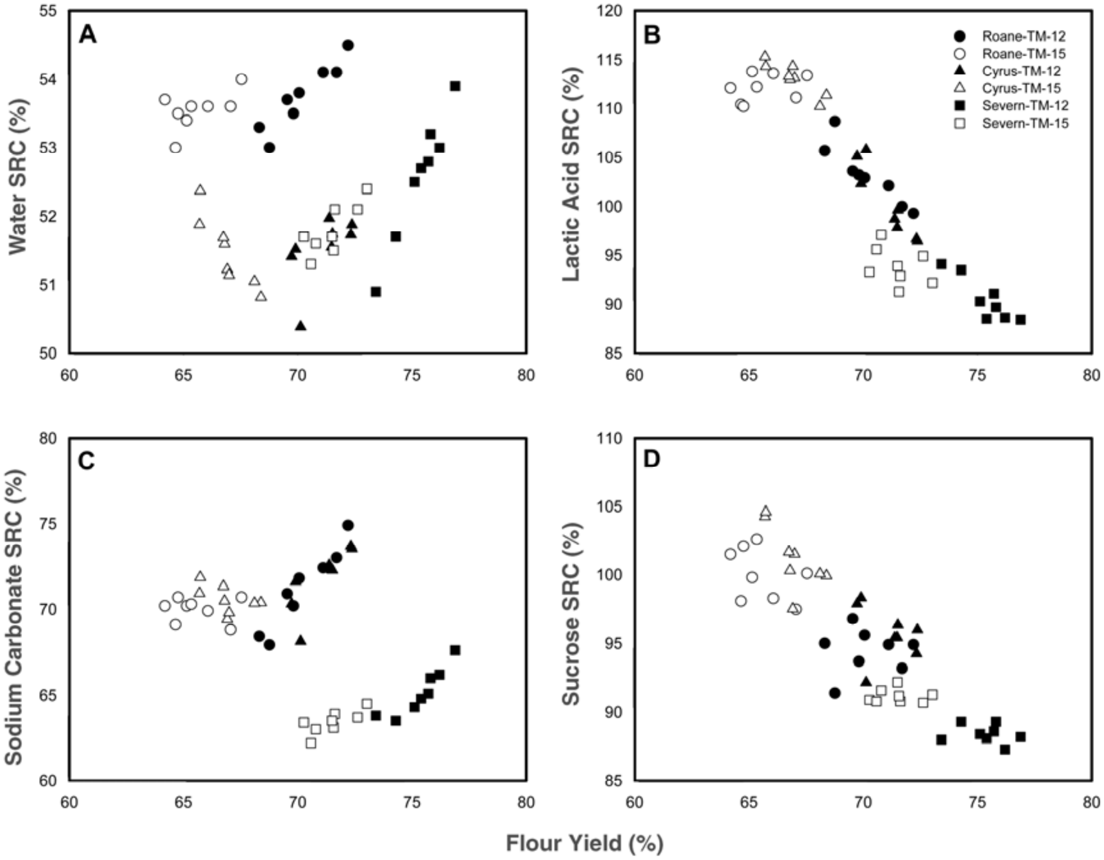

Fig. 2. Effect of tempered wheat moisture (12 and 15%) on flour functionality. **A,** Water; **B,** lactic acid; **C,** sodium carbonate; and **D,** sucrose. SRC = solvent retention capacity.

flour samples with 12% tempered moisture is weaker than samples with 15% tempered moisture. Generally, improved flour quality means an increase in lactic acid SRC and a decrease in sodium carbonate SRC and sucrose SRC. In genetic studies across different cultivars of wheat, changes in sodium carbonate SRC are typically positively correlated to changes in sucrose SRC (Guttieri et al 2001; Guttieri and Souza 2003). By contrast, within a cultivar, treatments that increased flour yield decreased sucrose SRC while increasing sodium carbonate SRC (Table II). The wheat kernels with 12% tempered moisture may have more starch granule fracture, causing increased damaged starch, and also have increased bran fracture. The increased bran facture may result in increased flour yield with more small bran particles. Those bran particles would contain relatively greater amounts of pericarp. As a result, the flour samples would contain more mineral, PPO, and water-unextractable arabinoxyans (only partially accessible to solvent) but less major solvent-accessible arabinoxylans. Correlations of flour PPO to sucrose SRC within a cultivar ranged from *r* = –0.73 to –0.86 while flour ash was correlated to sucrose SRC at only *r* = –0.68 to –0.82. This suggests that PPO is a slightly better proxy than flour ash to predict the elevation of flour arabinoxylans, as measured by sucrose SRC, because more of the bran enters the flour streams with increased flour yield. Jensen et al (1982) reported that fluorescence spectra of pericarp, aleurone, and endosperm were different, and a large correlation existed between pericarp and fiber but a smaller correlation between aleurone and ash. Symons and Dexter (1996) confirmed that pericarp fluorescence appears to exhibit universally strong relationships to flour ash content but the aleurone fluorescence does not relate strongly to flour ash.

Although the overall trend for the data confirms that treatments that elevate flour yield also generally degrade the quality of flour, it may be possible to manipulate the degree of relationship. The interaction of tempered wheat moisture with the other treatment factors causes the increase in damaged starch to be much greater in treatment combinations of the 12% tempered moisture treatments than in the combinations of the 15% tempered moisture treatments (Table III). As described with milling effects, in this study, using increased tempering time or increased initial wheat moisture in combination with the 15% tempered wheat moisture could effectively increase flour yield without significant change in sodium carbonate SRC. Similarly, these treatments collectively improved flour yield within the 15% tempered moisture treatment without causing a decrease in lactic acid or increase sucrose SRC when compared within cultivars (Fig. 2B and D).

Milling and baking industries making crackers and tortillas with soft wheat typically use flour with greater than average gluten strength. Although SRC values with different solvents can give information on each functional component's contribution, all values are convoluted with each other due to all being water-basis solvents. To deconvolute gluten strength from damaged starch and arabinoxylans, the SRC ratio of lactic acid to sodium carbonate + sucrose is plotted in Fig. 3. Within each cultivar, we found an optimum flour extraction for the SRC ratio. As flour extraction increased the ratio increased for approximately one third of the range in flour yield, then decreased sharply as lactic acid SRC declined and damaged starch as measured by sodium carbonate SRC increased (Fig. 3). This suggests that millers seeking to elevate gluten strength while minimizing overall water absorption could use tempering as a tool to manipulate the ratios of flour functionality.

CONCLUSIONS

Four factors (initial wheat moisture, tempered wheat moisture, tempering temperature, and tempering time) tested the effect of

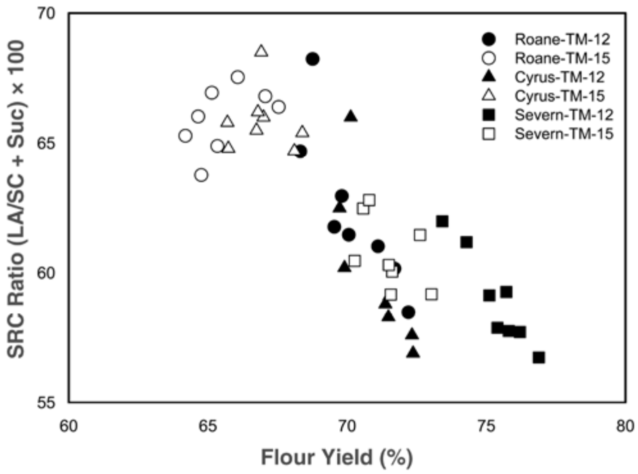

Fig. 3. Effect of tempered wheat moisture (TM 12 and 15%) on the ratio of solvent retention capacity (SRC) lactic acid to combined SRC sodium carbonate and sucrose.

tempering condition on milling characteristic and flour functionality for three SRW cultivars. Flour yield for the wheat tempered at 15% moisture was smaller than that for the wheat tempered at 12% moisture, but flour quality of the former was better with decreased flour ash and PPO activity. Lactic acid SRC values were increased for the milled flour tempered at 15% moisture, suggesting a better separation of mellowed endosperm from toughened bran and increased gluten strength. The two-way treatment combinations suggest methods for tempering to meet specific milling targets for flour. If flour specifications are minimal or the intrinsic flour quality of the cultivars being milled is very good, reduced tempered wheat moisture treatments could elevate flour extraction while meeting the specifications for flour functionality. This effect would be enhanced by increasing tempering time and initial wheat moisture. However, if superior quality flour is required to meet specifications for a product, it may be more important to reduce extraction and improve quality. If the increase of tempered wheat moisture is used to improve quality, overall flour extraction could still be elevated significantly (2–5% flour yield in this study) by increasing tempering time or by increasing initial wheat moisture, perhaps through a stage tempering or management of grain storage before milling.

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