Starch Damage in Soft Wheats of the Pacific Northwest

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ABSTRACT

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The effect of broad growing conditions in the Pacific Northwest and varietal differences on starch damage (191 samples) of soft white winter (SWW) and club wheat flours were investigated. Starch damage was measured enzymatically by the Megazyme method and iodometrically by a Chopin Rapid Flour Tester (RFT). The overall average of starch damage (cultivars, years, and locations) showed a comparable level in SWW and club wheat flours. The starch damage in club wheat flours was more stable over crop years than in SWW wheat flours. For individual cultivars, averaged over crop years and locations, the SWW cv. Madsen had the highest percentage of starch damage at 4.77%, while Lewjain and Dusty had the lowest percentage of starch damage among SWW wheats, at 3.19 and 2.76%, respectively. Among club wheats, Tres showed the highest percentage of starch damage at 4.03%, and Moro the lowest with 3.40%. The strong correlation between starch damage values measured enzymatically by the Megazyme method and the electric current reading (E_c) of the Chopin Rapid Flour Tester (RFT) for 191 Bühler milled soft wheat flours formed the basis for a calibration curve and respective equation. The equation was introduced into the Chopin RFT instrument and successfully used for predicting starch damage in three validation sets of samples (41 samples total) with excellent accuracy of 0.29% for soft white winter (SWW) wheat flours and 0.10% for club wheat flours. The equation could to be applicable to unknown commercial blends of soft wheat flours.

The level of starch damage is an important quality index for the evaluation of both hard wheat and soft wheat flours. Starch damage is unpreventable during the process of conversion of cereal grain to flour; it is a consequence of milling, rather than an objective (Evers and Stevens 1985). The amount of damage varies with the severity of the milling process and the hardness of the wheat kernel (Faridi 1990). Damaged starch granules absorb more water than nondamaged starch and are more susceptible to enzymatic hydrolysis (Evers and Stevens 1985, Bloksma and Bushuk 1988, Hoseney et al 1988, Pomeranz 1988, Faridi 1990). Both end-use and rheological properties of a flour dough are greatly influenced by the level of starch damage in the flour.

Starch damage is substantially and consistently lower in soft than in hard wheat flours (Pomeranz 1988). High starch damage is detrimental to soft wheat products, especially in cookies and cakes (Evers and Stevens 1985, Gaines et al 1988, Hoseney et al 1988, Faridi 1990).

Methods currently used for determination of starch damage are based on enzymatic and iodometric assays. Enzymatic methods require a long process and high operator skill (Rogers et al 1994). Chopin RFT combines the iodometric method with amperometric titration, which requires 10 min for each sample and less intensive operator skill. Other analytical methods, such as the near-infrared reflectance technique (Osborne and Douglas 1981, Finney et al 1988, Morgan and Williams 1995) and reversed-phase high-performance liquid chromatography (Sutton and Mouat 1990) have also been reported.

Several publications describing the comparison between Chopin RFT and enzymatic methods have recently been published (Ranhotra et al 1993, Rogers et al 1994, Morgan and Williams 1995). With a limited number of soft wheat samples, Morgan and Williams (1995) concluded that the Chopin RFT is not suitable for evaluation of starch damage in wheats other than hard wheats. Independent of the technique, research on starch damage of wheat was focused on samples including soft and hard cultivars differing widely in starch damage or intentionally damaged flours. The differences in kernel structure and milling performance between soft and hard wheats result in large differences in starch damage. These differences are easy to detect. On the other hand, the differentiation of starch damage in soft wheats, which have similar kernel structure and a narrow range of starch damage, represents a real challenge.

The Pacific Northwest (PNW) area of the United States is the largest producer of soft white wheats and the only place where the club wheats are grown. Growing conditions in the PNW area differ widely. These differences in growing conditions may have a detrimental effect on grain quality, such as elevated protein content, increased hardness, or impaired milling performance. No systematic information describing the effect of growing conditions and varietal differences on starch damage within PNW soft white wheats is available. Therefore, the objectives of this study were to investigate the effect of broad growing conditions and varietal differences on starch damage in SWW and club wheats grown in the PNW and to develop a calibration curve for the Chopin RFT to predict starch damage in those wheat flours.

MATERIALS AND METHODS

Materials

This study investigated a total of 240 soft wheat samples and was conducted in two parts. Part 1 used 191 soft wheat samples, including 123 SWW and 68 club wheats harvested in 1988, 1990, and 1993. SWW wheat included cvs. Hill81, Lewjain, Nugaines, Daws, Dusty, Madsen, and Stephens. Club wheats included Moro, Tres, Crew, and Hyak. The samples were provided by C. J. Peterson (USDA-ARS), and were collected from seven locations (Pullman, Pomeroy, Ritzville, Walla Walla, Cunningham, Coulee City, and Cavendish) in the PNW. Each cultivar was planted in every location in four replicates. Part 2 included a second set of 41 samples from seven commercially blended soft wheat flours provided by Fisher Mill Corp. (Seattle, WA) and 34 samples obtained from the USDA Western Wheat Quality Laboratory (Pullman, WA), representing 17 SWW wheats, and 17 club wheats.

Methods

Samples used in Part 1 of the study were laboratory milled on a Bühler experimental mill to 60% flour extraction by the approved method 26-31 (AACC 1995). In Part 2 of the study, samples were commercially or laboratory (Bühler and Miag) milled. Flour

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moisture content was measured by the standard AACC method 44-15. Protein content (N × 5.7) was determined by a Leco FP-428 N-analyzer (Leco Corp., St. Joseph, MI). Starch damage was analyzed iodometrically by a Chopin RFT (Seedburo Equipment Co., Chicago, IL) with the original calibration curve provided by Chopin Co., and enzymatically by Megazyme method (AACC 76-31). The operation procedures for the RFT were applied according to the user's manual. The E_c and predicted AACC starch damage value (RFT-AACC) were recorded. E_c is the current flow between the platinum electrodes as detected by the instrument. Higher E_c resulting from the free iodine ions indicate that a less damaged starch was present in a sample that absorbed iodine ions. Therefore, E_c is negatively correlated with starch damage. The E_c can be converted to any applied starch damage index (determined by a selected method) by the internal equation of the instrument. The RFT-AACC value of starch damage is predicted by the calibration equation, based on the AACC 76-30A method and built into the Chopin RFT instrument. The conversion of the E_c reading to starch damage values can bias the results (Ranhotra et al 1993). In this study, the E_c readings were used. A calibration curve for predicting starch damage in the PNW soft wheats was constructed based on the correlation between E_c and Megazyme value for the first set of 191 samples, and was introduced to the instrument. The second set of 41 samples was used for the validation of the calibration curve.

Statistical Analysis

All tests were run at least in duplicate. Correlation analysis between the two methods, analysis of variance (ANOVA) and least significant difference (LSD) were performed using the Statistical Analysis System, Version 6.08 (SAS Institute, Cary, NC.)

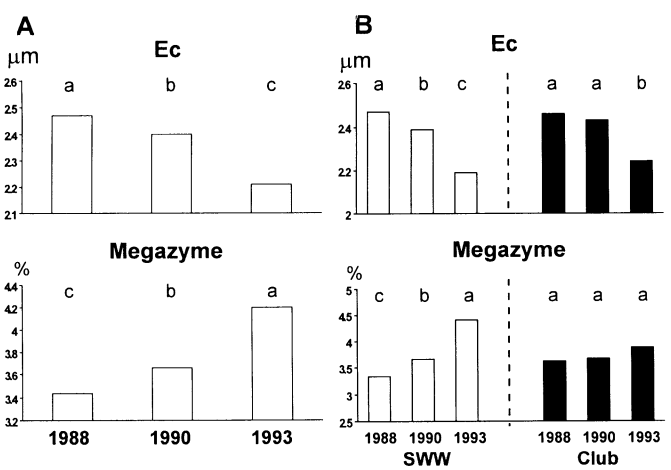

Fig. 1. Electrical current (E_c) readings and Megazyme starch damage values representing each crop year for combined soft white winter (SWW) and Club wheats averaged over cultivars and locations (**A**) and representing each crop year for SWW and club wheats separately, averaged over cultivars and locations (**B**). Bars annotated with the same letter denote mean values that are not significantly different ($P < 0.05$).

RESULTS AND DISCUSSION

The protein content, Megazyme value of starch damage, RFT-AACC value, and E_c for the first set of samples (n = 191) and for SWW and club wheat flours considered separately are summarized in Table I. The overall average for each of the above measurements for cultivars, years, and locations covers a broad range of values. The SWW and club wheat flours considered separately show comparable levels of protein and starch damage, the latter being similar within each of the applied methods.

The E_c and Megazyme values for each crop year for all 191 samples are presented in Figure 1. Both methods, for the SWW and club wheats considered jointly, show the same trend in changes of starch damage over the three-year period. When the individual crop year is considered, statistically significant differences appear. Samples from 1993 had the highest starch damage, followed by samples from 1990 and 1988. The same order was obtained by both methods. This indicates that differences in growing conditions between crop years have great influence on starch damage in wheat flours and that these differences can be measured by both methods.

Figure 1 also shows that for SWW and club wheats, there are significant differences in starch damage between each crop year in SWW wheat flour as measured by both methods, whereas there is no difference in starch damage in club wheat flour between crop years. Only 1993 is higher in starch damage, as measured by Chopin RFT. This indicates that starch damage in club wheat flours is more stable over crop years than in SWW wheat flours.

Starch damage levels determined by the Megazyme method in each individual cultivar averaged over crop years and locations is shown in Figure 2. Madsen had the highest level of starch damage (4.77%) among all cultivars used in this study. Dusty and Lewjain had significantly lower percentages of starch damage than other cultivars (2.76 and 3.19%, respectively). Tres showed the highest and Moro showed the lowest levels in starch damage among club

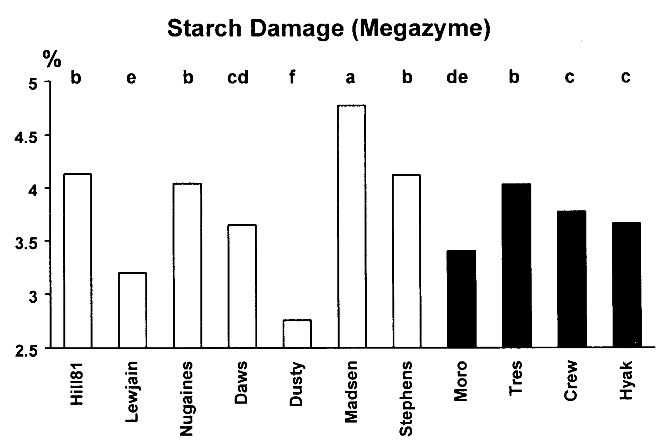

Fig. 2. Megazyme starch damage values representing each cultivar averaged over crop years and locations. Bars annotated with the same letter denote mean values that are not significantly different ($P < 0.05$).

TABLE I
Protein and Damaged Starch Content of Samples in Part 1 of Study

			Damaged Starch Values[b]					
	Protein (%)		Megazyme (%)		RFT-AACC (%)		E_c	
Samples[a]	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
All (191)	6.70–15.01	10.57 ± 1.60	1.92–6.80	3.23 ± 0.67	5.15–10.10	7.16 ± 0.86	1.70–2.85	2.36 ± 0.21
SWW (123)	7.00–15.01	10.58 ± 1.64	1.92–5.24	3.25 ± 0.67	5.15–9.50	7.18 ± 0.85	1.80–2.85	2.36 ± 0.21
Club (68)	6.70–13.94	10.55 ± 1.53	2.22–6.80	3.21 ± 0.64	5.60–10.10	7.12 ± 0.88	1.70–2.75	2.37 ± 0.21

[a] Soft white winter (SWW) and club wheats. Sample number indicated in parentheses.
[b] Predicted value using AACC 76-31 method for Chopin Rapid Flour Tester (RFT); E_c = electrical current of Chopin RFT.

wheats. Similar order was observed in each crop year (data not shown). This indicates that varietal differences contribute significantly to the amount of damaged starch in wheat flours, and that the varietal contribution can be observed over crop years.

The effect of growing location on starch damage averaged over cultivars and crop years is shown in Figure 3. Samples grown in Pullman and Cunningham had the highest percentage of starch damage (4.09–3.94%), followed by Ritzville (3.85%), Cavendish (3.73%), and Walla Walla (3.67%). Pomeroy and Coulee City produced wheat flours with the lowest starch damage (3.38 and 3.41%, respectively). The effect of growing location for each crop year is also shown in Figure 3. The level of starch damage for individual crop years did not follow the same order as did the average over crop years. However, significant differences existed in starch damage between wheat flour samples grown in different locations for each year. This indicates that not only differences in soil, but also differences in climatic condition and cultural practice between growing locations may have strong influences on starch damage in wheat flours.

Examples of the effect of growing locations over crop years on a single cultivar is demonstrated in Figure 4. None of the selected three SWW cultivars (Hill81, Daws, Dusty) showed a significant difference in starch damage between growing locations, except Pomeroy. However, each cultivar showed levels of starch damage distinctly different from other cultivars. The highest percentage of starch damage (3.5–4.6%) characterized Hill81, while Dusty

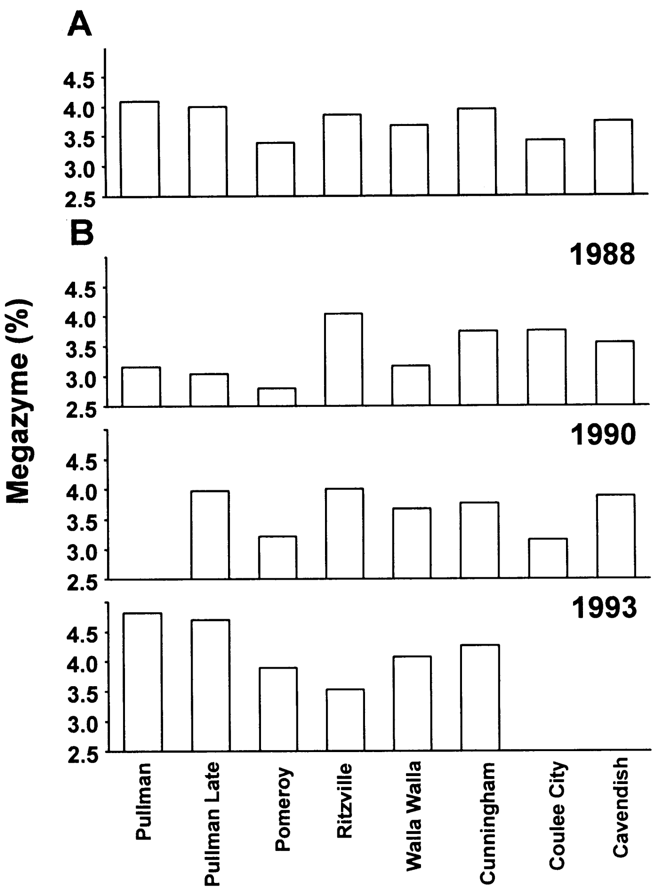

Fig. 3. Megazyme starch damage values representing each location averaged over crop years and cultivars (**A**) and representing each crop year for each location averaged over cultivars (**B**).

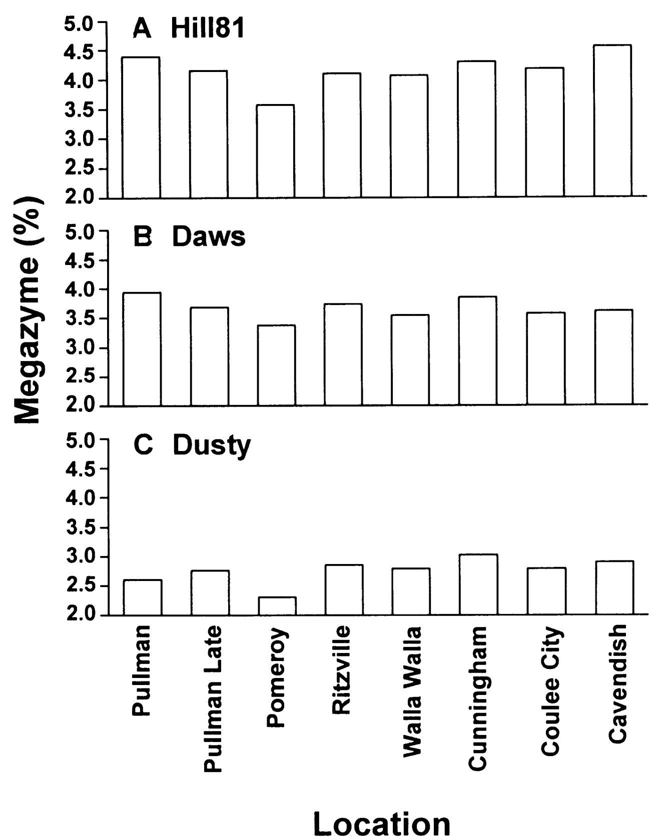

Fig. 4. Megazyme starch damage values representing three soft white winter cultivars Hill81 (**A**), Daws (**B**), and Dusty (**C**) averaged over crop years for each location.

TABLE II
Analysis of Variance for Megazyme Starch Damage

Source of Variation[a]	Megazyme df	Mean Square	F^b
All			
Cultivar	10	7.3449	25.87***
Location	7	2.7485	9.68***
Crop year	2	8.4290	29.69***
SWW			
Cultivar	6	9.6683	54.79***
Location	7	1.8187	10.31***
Crop year	2	8.8608	50.22***
Club			
Cultivar	3	2.9623	5.66**
Location	7	1.0393	2.19*
Crop year	2	0.8663	1.82

[a] All, combined soft white winter (SWW), and club wheats.
[b] *, **, *** = significant at $P < 0.05$, $P < 0.01$, $P < 0.001$, respectively.

TABLE III
Correlation Coefficients Between Megazyme Value and Electrical Current (E_c) of Chopin Rapid Flour Tester (RFT)

Cultivar[a]	R ($P < 0.01$)
SWW	
Hill81 (21)	–0.91
Lewjain (21)	–0.87
Nugaines (19)	–0.93
Daws (21)	–0.97
Dusty (15)	–0.85
Madsen (13)	–0.98
Stephens (13)	–0.91
Club	
Moro (17)	–0.92
Tres (18)	–0.91
Crew (20)	–0.86
Hyak (13)	–0.78

[a] Soft white winter (SWW) and club wheats. Sample number indicated in parentheses.

showed nearly two times lower starch damage (2.3–3.0%) than Hill81, Daws represented the intermediate values. These results indicate that varietal differences have a strong influence on starch damage. The effect of cultivar, location, and crop year on starch damage in the PNW soft wheat flours is summarized in Table II.

Correlation coefficients between starch damage determined by enzymatic Megazyme assay and Chopin RFT methods for individual cultivars (years and locations) are listed in Table III. The correlation coefficients for 11 cultivars range from –0.78 to –0.98, indicating that the relationship between these techniques of determination of starch damage is affected by different cultivars.

The effects of crop year on correlation between Megazyme starch damage value and Chopin RFT E_c reading for combined SWW and club wheat flours and for each of these classes are summarized in Table IV. For combined samples harvested in 1988, $R = -0.77$. For those harvested in 1990, $R = -0.69$, while for samples harvested in 1993, $R = -0.82$. Club wheats in these three crop years gave stronger correlations (–0.83 to –0.95) than did SWW wheats, which had correlation coefficients from –0.62 to –0.74.

The correlation coefficients between Megazyme value and E_c for each class separately are statistically significant for each crop year. However, the growing conditions (weather, fertilizer, etc.) in each crop year have a strong effect on this correlation.

The relationship between Megazyme value and E_c for all 191 samples used in the first part of this study and for the 123 SWW and 68 Club wheat flours considered separately are presented in Figure 5. In each set of samples, there is an even distribution of readings along the regression line. The correlation coefficients of $R = -0.80$ for the combined 191 samples, $R = -0.77$ for SWW wheats, and $R = -0.87$ for club wheats are statistically significant at the 0.01% level. These strong correlations for the large number of soft wheats grown under diverse conditions indicate that E_c readings can be used for prediction of Megazyme starch damage.

The calibration curves and the respective equations of the combined, SWW, and club sets of wheat flour samples are shown in Figure 6. Because the three regression lines are nearly overlapping, the prediction equation for soft wheat flours was based on all 191 samples. This calibration curve was then built into the Chopin RFT instrument and used for predicting Megazyme starch damage of the three validation sets of samples used in the second part of

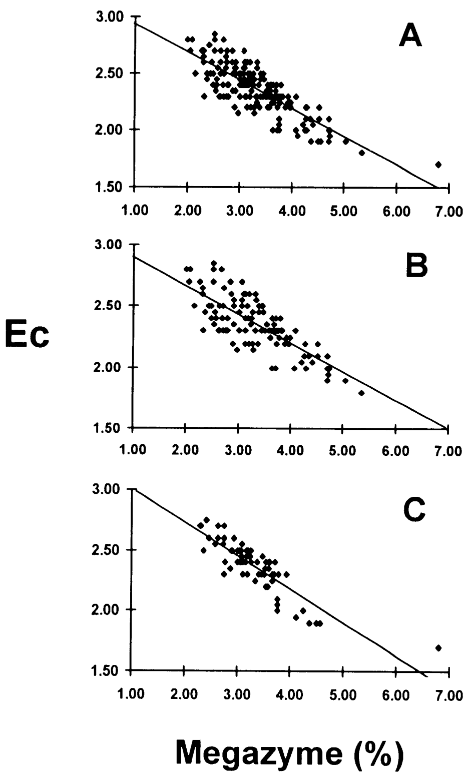

Fig. 5. Plots of electrical current (E_c) readings vs. Megazyme starch damage values. **A,** combined 191 soft white winter (SWW) and club wheats ($R = -0.80$, $P < 0.01$); **B,** 123 SWW wheats ($R = -0.77$, $P < 0.01$); **C,** 68 club wheats ($R = -0.87$, $P < 0.01$).

TABLE IV
Correlation Coefficients Between Megazyme Value and Electrical Current (E_c) of Chopin Rapid Flour Tester (RFT)

Year	Sample[a]	R ($P < 0.01$)
1988	All (60)	–0.77
	SWW (38)	–0.62
	Club (22)	–0.95
1990	All (72)	–0.69
	SWW (49)	–0.67
	Club (23)	–0.83
1993	All (59)	–0.82
	SWW (36)	–0.74
	Club (23)	–0.95

[a] Soft white winter (SWW) and club wheats. Sample number in parentheses.

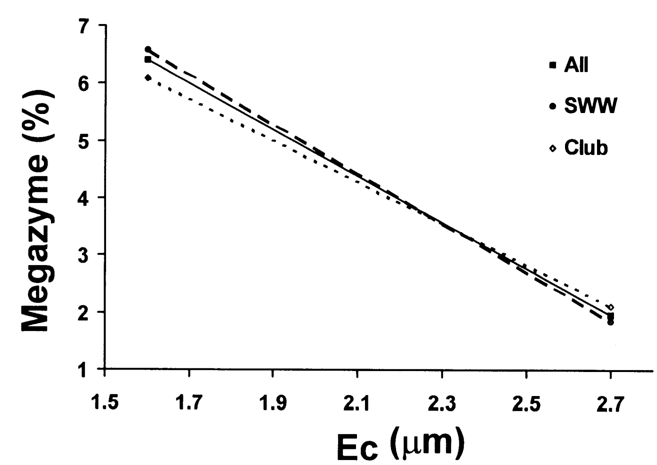

Fig. 6. Calibration curves represented all samples ($n = 191$, Megazyme % = $-4.0364\ E_c + 12.858$), soft white winter (SWW) wheats ($n = 123$, Megazyme % = $-4.2909\ E_c + 13.445$) and club wheats ($n = 68$, Megazyme % = $-3.6182\ E_c + 11.879$). E_c is electrical current reading.

TABLE V
Protein Content, Megazyme, and RFT-MEGA[a] Values of the Validation Sample Sets

	Protein Content (%)		Damaged Starch Values: Megazyme (%)		Damaged Starch Values: RFT-MEGA (%)	
Samples[b]	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
SWW (17)	9.50–11.67	10.71 ± 0.55	2.52–4.61	3.67 ± 0.53	2.75–4.85	3.96 ± 0.58
Club (17)	7.15–11.52	9.50 ± 1.35	2.84–4.79	3.95 ± 0.52	2.87–4.77	4.05 ± 0.55
Commercial (7)	8.72–12.03	10.61 ± 1.25	4.11–5.45	4.85 ± 0.53	3.21–4.50	3.94 ± 0.46

[a] Predicted value using AACC 76-31 method for Chopin Rapid Flour Tester (RFT); E_c = electrical current of Chopin RFT.
[b] Soft white winter (SWW) and club wheats. Sample number indicated in parentheses.

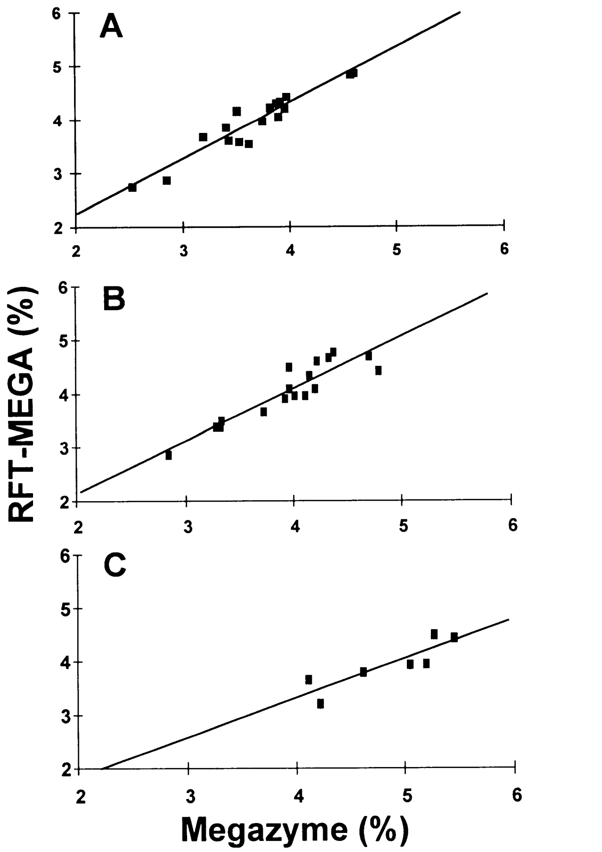

Fig. 7. Plots of measured and predicted Megazyme starch damage values for the validation sets of samples. **A,** 17 SWW wheats ($R = 0.95$, $P < 0.01$); **B,** 17 club wheats ($R = 0.91$, $P < 0.01$); **C,** seven commercial blends ($R = 0.87$, $P < 0.01$). RFT-MEGA is predicted value using AACC 76-31 method for Chopin Rapid Flour Tester (RFT).

this study. The validation sets included SWW wheat flours, club wheat flours, and commercially milled blends of soft wheat flours.

The protein content, Megazyme starch damage values, and the Megazyme values predicted by the Chopin RFT (RFT-MEGA) for the validation sets of samples are listed in Table V. Protein content and Megazyme starch damage for each set of samples fit in the range of calibration set of samples. The set of SWW and club wheat flours had comparable values of Megazyme starch damage. The starch damage in commercial blends was on average 1% higher than in SWW and club wheat flours. On average, the Megazyme and the RFT-MEGA starch damage values of SWW and club are in excellent agreement. The differences in percentage of starch damage between actual and predicted values are 0.29 and 0.10% for SWW and club wheat flours, respectively. However, the differences in percentage of starch damage between Megazyme and RFT-MEGA values for commercial blends are 0.91%. This may have been caused by different treatments (enrichment, bleaching, etc.) or different milling processes of the commercial blends. The good agreement between measured Megazyme and predicted RFT-MEGA values for all three validation sets is evident in Figure 7.

Summary

The SWW and club wheat flours show a broad range of starch damage resulting from different growing conditions (soil, climatic, and cultural practice) and varietal differences. However, on the average, the starch damage for both classes is comparable. Varietal differences have consistent strong effects on starch damage in wheat flours, which is likely under genetic control.

The calibration equation for Chopin RFT has been successfully attained for prediction of starch damage in flours from soft wheat grown in the PNW which were laboratory milled on Bühler or Miag mill. The equation could also be used to estimate starch damage in flours milled commercially.

ACKNOWLEDGMENT

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