Milling and Baking Qualities of Some Wheats Developed for Eastern or Northwestern Regions of the United States and Grown at Both Locations

CHARLES S. GAINES,[1,2] PATRICK L. FINNEY,[1] and GORDON RUBENTHALER[3]

ABSTRACT

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Nine soft wheats that were developed for the Eastern United States and six soft wheats developed for the Northwestern United States were each grown in the states of Michigan and Washington for two crop years. Wheats were analyzed for milling and baking qualities by two laboratories. Cultivar differences were observed relative to intended region of adaptation and to location of growth. Except for noodle color and texture, all quality tests could distinguish among cultivars on the basis of intended adaptation or location of growth. Cultivar differences due to region of adaptation were generally small but consistent for most milling and baking qualities. Northwestern-adapted wheats tended to have higher test weight, harder kernels, and to produce more flour than Eastern-adapted wheats. Northwestern-adapted wheat flours had higher amounts of ash and more damaged starch than did Eastern-adapted wheat flours. Eastern-adapted wheats were softer and their flour had less ash and less damaged starch than did Northwestern-adapted wheats. Eastern-adapted wheats absorbed less water and their flours baked larger sugar-snap cookies than did Northwestern-adapted wheats. Wheats grown in Washington were harder and produced more flour that had less ash and lower protein content than wheats grown in Michigan. Wheats grown in Michigan produced flours that had lower damaged starch, lower water absorption, larger sugar-snap cookies, larger Japanese sponge cakes, and better *udon* noodles than wheats grown in Washington. Wheats developed for both growing regions apparently have comparable genetic quality attributes. However, climatic conditions during growth apparently have greater influence over most quality traits than does genotype. The environment had strong influence on grain condition. Grain condition had the most influence on milling characteristics. The environment also had the most influence on baking characteristics, with softer kernels producing better end-use characteristics. Almost all of the commonly evaluated quality tests studied were sensitive to the wide range in qualities exhibited by the samples.

Both the unique genetics of wheat cultivars and their environment during growth have independent and interactive influences on all physical and biochemical quality attributes of wheat. Watson and Heyne (1977) observed that the weight distribution of individual wheat kernels was influenced by both genotype and environment, but more strongly by environment. Pomeranz et al (1985) observed that genotype had a larger influence on variability of wheat hardness than did location. Finney et al (1987) reported that mean differences in the ranges of kernel texture (break flour yield) that resulted from environmental influences were 1.5 times greater than genotypical differences. Huebner and Gaines (1992) noted that the hardness of individual wheat kernels was influenced by genotype, harvest date, and location of the kernels on the head spike.

Hong et al (1989) found that genotype variance was greater than environmental variance relative to the concentration of water-soluble pentosans. Fleming et al (1960) observed a larger effect of genotype than environment, with a significant genotype-to-environment interaction, on the α-amylase and protease produced among malted hard wheats. Fenn et al (1994) reported that genotype affected more of the quality traits of 1BL/1RS rye translocation containing wheats than did the environment. Some differences between the 1BL/1RS wheats and control wheats were exclusively due to genotype and other differences were exclusively due to environment.

Wheat breeders develop wheats that express both appropriate "growth habit" (disease resistance, field yield, etc.) and specific end-use qualities (milling and baking) for a relatively small, defined, and expected growth area for which the cultivar is intended. Rarely are wheats successful outside of that area, usually only when they continue to produce high grain field yield and test weight. A larger growing area places more diverse environmental pressure on the cultivar. In addition to lowered field performance, it is often observed that poorly adapted wheats produce poor end-use qualities when grown outside of their intended production area. Only if those wheats can produce sound unsprouted and unshrivelled kernels, can such cultivars be more widely successful.

In the continental United States, soft wheats are grown in most of the eastern half of the country (Eastern) and in specific regions of the northwestern United States (Northwestern), including the states of Washington, Oregon, and Idaho. Eastern soft wheat is much larger, has more year-round humidity, receives more rainfall, and has higher disease pressure than does the drier Northwestern soft wheat.

In this study, several soft wheats that were developed for the Eastern and Northwestern growing regions were evaluated for milling and baking. Each group was grown in both Eastern and Northwestern growing regions for two years. The objective was to determine whether the wheats' intended adaptation (Eastern or Northwestern) or the actual Eastern or Northwestern location of growth caused greater differences in milling and baking qualities, and if so, which adaptation or location produced better qualities. Because quality testing is expensive and time consuming, another objective was to observe which common quality tests may be sensitive or insensitive to the wide range in qualities exhibited by the samples. The Eastern and Northwestern samples were tested within the same series by laboratories in both regions.

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[1] U.S. Department of Agriculture, Agricultural Research Service, Soft Wheat Quality Laboratory, Ohio Agricultural Research and Development Center, Ohio State University, Wooster, OH 44691.

[2] Corresponding author. Fax: 216/263-3658.

[3] Retired, U.S. Department of Agriculture, Agricultural Research Service, Western Wheat Quality Laboratory, Washington State University, Pullman, WA 99164-6394.

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MATERIALS AND METHODS

Wheats

All wheats were grown for two crop years (1987 and 1988) at the same locations in the states of Michigan and Washington. The 15 wheats consisted of nine developed for the Eastern region and six developed for the Northwestern region. The nine Eastern wheats were Arthur, Auburn, Augusta, Caldwell, Cardinal, Frankenmuth, Hillsdale, Pioneer 2550, and Tyler. The six Northwestern wheats were Crew, Daws, Hill 81, Lewjain, Nugaines, and Stephens. Wheats were aspirated to remove any severely shrivelled kernels that could adversely affect milling yield.

Analyses

Test weights were determined using AACC Method 55-10 (AACC 1995). All wheats were milled at both the USDA/ARS Soft Wheat Quality Laboratory (SWQL), Wooster, OH, and the USDA/ARS Western Wheat Quality Laboratory (WWQL), Pullman, WA. Some quality tests were accomplished at both laboratories and some at only one laboratory. The SWQL used an Allis-Chalmers mill using AACC Method 26-32. Break flour yield, endosperm separation index (ESI), number of reduction passes, and flour yield were determined as described by Yamazaki and Andrews (1982). The WWQL used a Buhler mill and AACC Method 26-31. The Buhler milling score was calculated as:

$$\text{Milling score} = 100 - ((80 - \text{flour yield}) + 50(\text{flour ash} - 0.30) + 0.48(\text{milling time} - 12.5) + 0.5(65 - \%\ \text{long patent}) + 0.5(16 - \text{first tempering moisture})$$

Flour ash was determined using AACC Method 08-01 (AACC 1995). SWQL flour protein contents were determined using AACC Method 46-12. WWQL flour protein contents were determined using a thermogravimetric method (Leco, model FP-428, St. Joseph, MI). MacMichael acidulated flour viscosity was determined using AACC Method 56-79. Alkaline water retention capacity (AWRC) of flour was determined using AACC Method 56-10. Cookie diameter was determined using AACC Method 10-52. Japanese sponge cakes and Japanese noodles were produced according to Nagao et al (1976) and Otsubo et al (1978). Mixograph type was determined using AACC Method 54-40A and Finney and Shogren (1972). Near-infrared reflectance (NIR) spectroscopy was used to determine wheat kernel texture according to AACC Method 39-70A. Flour starch damage was accomplished using the method of Donelson and Yamazaki (1962). Flour falling number determination was accomplished using AACC Method 56-81B. α-Amylase activity of flour was determined using AACC Method 22-06 (AACC 1995).

Statistics

Data were analyzed for descriptive statistics and analysis of variance (ANOVA) by the Winstar PC statistical software package (Anderson-Bell, Aurora, CO). The ANOVA model used adaptation, location, and year as fixed effects and cultivar within adaptation as a random effect. The location-by-adaptation interaction term was not statistically significant except for MacMichael viscosity. The error mean square for adaptation was cultivar within adaptation. The error mean square for location and for location-by-adaptation interaction was the location-by-cultivar within adaptation interaction. The error mean square for year and for year-by-adaptation interaction was the year-by-cultivar within adaptation interaction. There was no direct test for cultivar.

RESULTS AND DISCUSSION

Analytical means are described as means for Eastern or Northwestern wheat adaptations and as means for location (wheats grown in Michigan or Washington) as presented in Tables I–III. For each laboratory, reported data are the means of both crop years, or are presented for individual crop years if the ANOVA test for differences between years was significant ($P < 0.05$). ANOVA mean squares and F-ratio probability levels for testing differences between means for Eastern or Northwestern wheat adaptations and location of growth (Michigan or Washington) are presented in the Tables I–III.

Milling Quality Predictive Tests

Compared to Michigan, the drier growing region in Washington produced higher mean test weights and wheats developed for that region had higher mean test weights from the 1987 crop (Table I). As would be expected, the greater differences among location means suggest that environment had greater effect on test weight than did cultivar adaptation. It is generally recognized that Northwestern grown wheats often have higher test weights and larger kernels than Eastern grown wheats.

Wheat kernel texture was estimated from Buhler long patent flour percentage, Allis-Chalmers break flour percentage, and NIR hardness values. Except for the 1987 Buhler long patent flour, wheat adaptation did not significantly influence kernel texture. Also, except for 1987 Buhler long patent flour, wheats grown in the more humid state of Michigan were softer, producing more break and patent flours than those grown in the dryer state of Washington. As would be expected, the softer Michigan grown wheats also had lower levels of damaged starch. ANOVA mean squares and probability levels suggest that location of growth had much more influence over kernel texture than did intended cultivar adaptation.

The number of reduction passes required during Allis-Chalmers milling represents how quickly reduction mill stock is reduced to flour. Reduction stock from wheats grown in Washington reduced to flour more quickly. Allis-Chalmers endosperm separation index (ESI) represents the ease with which endosperm is released from bran flakes. Lower ESI values are usually superior milling wheats. The Northwestern-adapted wheats grown in 1988 had better bran-endosperm separation. Allis-Chalmers total flour yield was slightly better among wheats grown in Washington. Buhler flour yield was better only for the Northwestern-adapted wheats from the 1987 crop. The Buhler milling score was better ($P < 0.05$) for the Eastern-adapted wheats from the 1988 crop and for wheats grown in Washington. Being a longer and nonautomated milling system, the Allis-Chalmers milling system differentiated better among cultivars on the basis of adaptation and location than did the fixed Buhler milling system.

Flour Quality Predictive Tests

Eastern-adapted wheats and wheats grown in Washington produced lower ash values (Table II). Wheats grown in Washington produced lower wheat and flour protein contents in the 1988 crop year. Marchylo et at (1990) noted that the environment did not influence gliadin and glutenin chromatograms, but that the environment could affect the quantitative analysis of those extracted proteins. Eastern- and Northwestern-adapted wheats had similar levels of protein content.

MacMichael acidulated flour-water viscosity values were lower for wheats grown in Michigan in 1987. AWRC values were lower among wheats grown in Michigan and among Eastern-adapted wheats, which may reflect the lower levels of damaged starch among those wheats.

End-Use Quality Predictive Tests

Sugar-snap cookie diameters were larger among wheats grown in Michigan and among Eastern-adapted wheats (Table III). Japanese sponge cake volumes, cake scores, and crumb grain values were better among wheats grown in Michigan. Sponge cake tex-

TABLE I

Laboratory, Year, Mean, Standard Deviation (SD), Analysis of Variance (ANOVA), Mean Square, and Probablity (*P*) that Adaptation or Location Means are Significantly Different for Various Soft Wheat Quality Evaluations for Wheat and Milling Properties of Eastern- and Northwestern-Adapted Soft Wheats Grown in Michigan and Washington

		Wheat Adaptation						Location of Growth					
		Eastern		Northwestern		ANOVA		Michigan		Washington		ANOVA	
Analysis/ Laboratory[a]	Year	Mean	SD	Mean	SD	Mean Square	*P*	Mean	SD	Mean	SD	Mean Square	*P*
Test weight (lb/bu)													
WWQL	1987	60.0	2.48	61.4	2.67	15.20	0.007	58.4	1.81	62.7	1.02	131.24	0.000
WWQL	1988	61.8	1.58	62.3	1.03	1.80	0.198	61.1	0.92	62.9	1.16	21.36	0.000
SWQL	1987	60.0	2.80	61.3	2.94	12.48	0.014	58.1	1.85	63.0	0.91	172.87	0.000
SWQL	1988	62.5	2.16	62.9	1.52	1.28	0.271	61.1	0.97	64.2	1.14	65.28	0.000
Buhler patent flour (%)													
WWQL	1987	61.3	2.07	63.1	2.30	25.09	0.021	61.2	2.27	62.9	2.11	18.43	0.045
WWQL	1988	63.8	1.46	64.7	1.95	6.73	0.144	64.3	1.75	64.0	1.71	0.91	0.584
Allis-Chal. break flour (%)													
SWQL	1987	31.0	6.36	31.0	6.40	0.00	0.996	36.6	3.04	25.4	2.30	893.34	0.000
SWQL	1988	28.0	4.77	28.9	4.12	5.44	0.398	31.9	2.93	24.9	2.56	324.55	0.000
Wheat NIRS hardness													
WWQL	Both	28.7	7.33	28.5	6.57	0.70	0.874	24.7	6.29	32.5	5.34	898.61	0.000
Starch damage (%)													
SWQL	1987	2.5	0.54	2.5	0.43	0.00	0.861	2.1	0.21	2.8	0.46	3.23	0.000
Milling reduction passes													
SWQL	Both	7.3	0.47	7.5	0.83	0.34	0.325	7.6	0.77	7.2	0.38	2.40	0.007
Endosperm separation index													
SWQL	1987	10.3	0.86	9.6	1.56	3.47	0.122	10.4	1.35	9.7	1.01	3.70	0.111
SWQL	1988	10.7	0.73	9.7	1.42	7.86	0.010	10.6	1.09	10.1	1.18	3.20	0.088
Allis-Chal. flour yield (%)													
SWQL	Both	76.4	0.78	77.3	1.22	11.74	0.114	76.5	1.16	76.9	0.94	2.40	0.021
Buhler flour yield (%)													
WWQL	1987	71.0	1.28	72.4	2.23	14.22	0.035	71.1	2.10	72.1	1.39	6.73	0.137
WWQL	1988	72.3	0.90	72.9	1.65	2.74	0.207	72.7	1.31	72.4	1.24	0.39	0.629
Buhler milling score													
WWQL	1987	83.7	2.91	85.5	3.08	22.40	0.080	82.9	2.69	86.0	2.62	70.31	0.003
WWQL	1988	86.9	2.32	84.7	2.67	34.94	0.016	85.1	2.73	87.1	2.24	32.68	0.020
Buhler flour ash (%)													
WWQL	Both	0.34	0.037	0.37	0.044	0.015	0.026	0.37	0.045	0.33	0.030	0.023	0.000
Allis-Chal. flour ash (%)													
SWQL	1987	0.37	0.042	0.41	0.079	0.012	0.000	0.43	0.020	0.33	0.020	0.083	0.000
SWQL	1988	0.37	0.040	0.41	0.044	0.013	0.000	0.42	0.036	0.35	0.025	0.035	0.000
Wheat protein (%)													
WWQL	1987	11.1	0.92	11.4	0.48	0.75	0.170	10.9	0.76	11.5	0.70	1.42	0.063
WWQL	1988	10.8	1.11	10.8	0.67	0.00	0.967	11.6	0.58	10.1	0.53	14.62	0.000

[a] WWQL = USDA/ARS Western Wheat Quality Laboratory, Pullman, WA; SWQL = USDA/ARS Soft Wheat Quality Laboratory, Wooster, OH.

TABLE II

Laboratory, Year, Mean, Standard Deviation (SD), Analysis of Variance (ANOVA), Mean Square, and Probablity (*P*) that Adaptation or Location Means are Significantly Different for Various Soft Wheat Quality Evaluations for Flour Properties of Eastern- and Northwestern-Adapted Soft Wheats Grown in Michigan and Washington

		Wheat Adaptation						Location of Growth					
		Eastern		Northwestern		ANOVA		Michigan		Washington		ANOVA	
Analysis/ Laboratory[a]	Year	Mean	SD	Mean	SD	Mean Square	*P*	Mean	SD	Mean	SD	Mean Square	*P*
Flour protein (%)													
WWQL	Both	9.4	1.05	9.6	0.62	0.46	0.528	9.6	0.89	9.4	0.91	0.94	0.028
SWQL	1987	9.8	0.94	10.3	0.47	1.80	0.043	9.7	0.86	10.3	0.70	0.99	0.126
SWQL	1988	9.7	1.27	9.8	0.86	0.13	0.583	10.6	0.68	8.8	0.64	20.93	0.000
MacMichael viscosity (M)													
WWQL	1987	134.8	30.03	123.1	33.45	984.7	0.280	115.5	25.63	144.7	30.55	6636.9	0.008
WWQL	1988	114.6	26.61	104.4	19.54	748.3	0.216	117.1	22.10	103.9	25.12	616.05	0.261
AWRC (%)[b]													
WWQL	1987	55.6	3.54	58.8	3.76	77.36	0.007	54.8	4.46	58.9	1.67	112.02	0.002
SWQL	Both	51.2	2.27	52.4	2.42	19.65	0.139	50.0	2.05	53.4	1.17	173.06	0.000
Mixograph type													
WWQL	1987	3.7	1.74	3.0	1.04	3.76	0.158	4.1	1.51	2.7	1.22	11.76	0.016
WWQL	1988	2.4	0.92	2.5	0.67	0.02	0.850	2.7	0.96	2.2	0.56	1.42	0.139
Falling number (sec)													
WWQL	Both	437.0	72.80	432.0	57.90	326.80	0.773	451.0	71.90	418.0	57.80	16269	0.051
α-Amylase activity (abs)													
WWQL	1987	0.23	0.492	0.19	0.222	0.01	0.784	0.37	0.534	0.07	0.007	0.62	0.055
WWQL	1988	0.06	0.011	0.06	0.006	0.00	0.450	0.06	0.008	0.06	0.011	0.00	0.844

[a] WWQL = USDA/ARS Western Wheat Quality Laboratory, Pullman, WA; SWQL = USDA/ARS Soft Wheat Quality Laboratory, Wooster, OH.

[b] Alkaline water retention capacity.

TABLE III
Laboratory, Year, Mean, Standard Deviation (SD), Analysis of Variance (ANOVA), Mean Square, and Probablity (*P*) that Adaptation or Location Means are Significantly Different for Various Soft Wheat Quality Evaluations for End-Use Properties of Eastern- and Northwestern-Adapted Soft Wheats Grown in Michigan and Washington

		Wheat Adaptation						Location of Growth					
		Eastern		Northwestern		ANOVA		Michigan		Washington		ANOVA	
Analysis/ Laboratory[a]	Year	Mean	SD	Mean	SD	Mean Square	*P*	Mean	SD	Mean	SD	Mean Square	*P*
Cookie diameter (cm)													
WWQL	1987	9.0	0.21	8.9	0.20	0.12	0.037	9.1	0.19	8.9	0.15	0.41	0.001
WWQL	1988	8.9	0.22	8.8	0.20	0.03	0.380	9.0	0.21	8.8	0.16	0.34	0.004
SWQL	1987	8.8	0.33	8.6	0.42	0.51	0.015	8.8	0.30	8.6	0.30	1.71	0.000
SWQL	1988	9.1	0.28	8.9	0.37	0.42	0.014	9.1	0.27	8.9	0.26	1.28	0.000
Sponge cake volume (cm^3)													
WWQL	1987	1,297	71.7	1,306	68.8	1,278	0.350	1,361	28.0	1,244	42.9	90,004	0.000
WWQL	1988	1,245	74.8	1,239	54.8	269	0.644	1,298	30.5	1,187	40.5	81,494	0.000
Sponge cake score													
WWQL	1987	75.7	5.71	75.0	6.13	0.63	0.825	80.2	3.14	71.0	3.68	574.22	0.000
WWQL	1988	71.7	5.02	72.0	3.41	0.80	0.782	74.8	2.68	68.8	3.65	231.20	0.000
Sponge cake crumb grain													
WWQL	Both	19.9	3.31	20.1	2.29	0.28	0.737	21.3	3.26	18.7	1.89	97.93	0.001
Sponge cake texture													
WWQL	Both	23.3	1.04	23.2	1.03	0.24	0.657	23.4	1.05	23.1	1.01	0.89	0.394
Noodle yield (%)													
WWQL	Both	17.7	0.78	17.4	0.76	0.96	0.328	18.2	0.54	17.2	0.65	13.57	0.000
Noodle score													
WWQL	Both	72.7	1.90	72.3	2.07	2.23	0.588	73.4	1.75	71.8	1.83	36.46	0.010
Noodle wt. increase (%)													
WWQL	Both	344.8	14.35	340.1	15.54	275.35	0.365	353.2	8.23	334.4	13.67	4956.5	0.000
Noodle color, uncooked													
WWQL	1987	14.0	1.19	14.4	0.74	0.78	0.362	14.6	0.67	13.7	1.16	2.53	0.108
WWQL	1988	15.0	1.19	15.4	0.51	1.25	0.279	15.1	1.13	15.2	0.86	0.01	0.942
Noodle color, cooked													
WWQL	1987	14.6	0.50	14.3	1.04	0.35	0.425	14.6	0.50	14.4	0.83	0.22	0.522
WWQL	1988	14.2	0.55	14.4	0.79	0.27	0.385	14.6	0.74	14.0	0.38	2.94	0.007
Noodle texture													
WWQL	1987	26.8	0.73	26.8	1.28	0.35	0.531	26.5	0.82	26.9	0.96	1.68	0.176
WWQL	1988	25.3	0.67	24.6	0.67	3.47	0.007	25.1	0.88	24.9	0.59	0.01	0.907

[a] WWQL = USDA/ARS Western Wheat Quality Laboratory, Pullman, WA; SWQL = USDA/ARS Soft Wheat Quality Laboratory, Wooster, OH.

ture was not significantly ($P \leq 0.05$) influenced by location or adaptation, suggesting that sponge cake texture may not be as sensitive to quality differences as are volume and crumb appearance.

Japanese *udon* noodle yield, noodle score, and cooked noodle weight (increase during cooking) were better among wheats grown in Michigan. Cooked noodle color was better among wheats grown in Michigan in 1988. Noodle texture was better among Eastern-adapted wheats from the 1988 crop. It is noteworthy that wheat adaptation did not significantly ($P < 0.05$) influence sponge cake and noodle characteristics, suggesting that environment of growth has an overwhelming influence over those quality tests, if not over actual genotypic expression of those qualities.

Mixograph mixing type was identified as stronger among wheats grown in Michigan in 1987. Falling number (FN) mean values were above those that would suggest field sprouting, indicating that the wheats were generally sound, based on adaptation and location. However, the mean α-amylase activity values for the 1987 Michigan-grown wheats reflect elevated values for Augusta, Frankenmuth, Daws, Hill 81, and Crew. Most likely, they experienced some field sprouting that was not evident in the FN values. α-Amylase analysis is generally considered to be the most sensitive method to detect low levels of field sprouting. Field sprouting is generally recognized to be a less persistent problem in the Northwestern growing region.

Relative Sensitivity of Quality Tests to Adaptation and Location

Given that a wide range in genotypic expression of qualities was evident in this sample population, it was desirable to observe which quality tests were able to produce statistical differences for adaptation and for location. For each crop year, or both, cultivars were differentiated based on intended adaptation by the Buhler milling score and Buhler flour ash, by Allis-Chalmers flour ash, and by cookie diameter (SWQL). For one crop year, Buhler patent flour and flour yield, Allis-Chalmers endosperm separation index, flour protein, wheat test weight, cookie diameter (WWQL), and AWRC also differentiated cultivars based on intended adaptation. In contrast, many more differences among cultivars could be discerned based on location of growth. For each crop year, or both, the cultivars could be differentiated by analyzing for wheat test weight; Allis-Chalmers break and flour yields; starch damage; milling reduction passes; Buhler milling score; Buhler and Allis-Chalmers flour ash; flour protein content (WWQL); AWRC; cookie diameter (both WWQL and SWQL); sponge cake grain, volume and score; and noodle yield, score, and weight increase. For one crop year, cultivars could be differentiated by Buhler patent flour yield, wheat protein, flour protein (SWQL), MacMichael viscosity, cooked noodle color, and mixograph type.

Among the milling parameters (break-patent flours, flour yield-score, and ash), the Allis-Chalmers results appeared statistically superior (lower levels of probability). Location of growth was more influential on baking test results than was the intended wheat adaptation. In general, better baking results can be expected from softer textured kernels, such as those produced at the Michigan location.

CONCLUSIONS

Dryer climates should favor the production of larger, better filled, and harder kernels that tend to produce superior milling characteristics (e.g., faster flow, more flour). More moist environments should produce softer kernels that generally produce less damaged starch during milling, perhaps lower levels of cell-wall constituents (hemicellulose, pentosans), lower water absorption, and bigger, less dense baked products. In general, the Washington location produced higher test weights that produced slightly more straight-grade flour. However, milling quality and flour quality are often influenced by kernel hardness. The Michigan location produced wheats that had softer kernel texture and lower levels of flour ash, damaged starch, and AWRC, reflecting the softer kernels produced at that location.

All wheats were typical in protein content. The Michigan location produced lower levels of protein in one crop year and the Washington location produced lower levels of protein in the other crop year.

In general, the Michigan location produced larger sugar-snap cookies. The Michigan location produced better Japanese sponge cakes and *udon* noodles. Overall, Washington-grown wheats produced better looking, higher test weight wheats that tended to mill a little better than the softer Michigan-grown wheats. The softer Michigan-grown wheats were somewhat better at baking test products, even the cakes and noodles that are popular in Japan. To our knowledge, Japanese millers purchase no soft wheat of eastern United States origin. Only noodle color and texture could not differentiate among means for either wheat adaptation or location of growth.

Compared to location of growth, there were fewer statistical differences between the mean values for Eastern- and Northwestern-adapted wheats. Even though the wheats developed for Washington had higher test weights, generally there was no statistical difference in the milling quality between Eastern- and the Northwestern-adapted wheats. Eastern-adapted wheats tended to have lower AWRC values and lower flour ash. In general, Eastern-adapted wheats produced larger sugar-snap cookies (SWQL, two crop years; WWQL, one crop year).

There was no statistical difference between the Japanese sponge cakes and *udon* noodles produced by Eastern- and Northwestern-adapted cultivars. All other quality tests could statistically differentiate the means for either adaptation or location of growth for at least one crop year. Location was more easily identified by most tests. That indicates that these commonly used tests for flour quality have obvious utility in quality testing and predictions of end-use qualities.

Wheat cultivars and even wheat classes may have ideal growing regions where they produce the best milling quality or the best end products. Relative to the common cultivars evaluated in this study, the best possible milling quality soft wheats and the best possible baking soft wheats may not be produced within the same growing region. These observations suggest the need for soft wheat breeders in the eastern United States to place greater emphasis on milling quality and soft wheat breeders in the northwestern United States to place greater emphasis on kernel softness and baking quality.

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