End-Use Quality of Hard Red and Hard White Spring Wheat Contaminated with Grain of Contrasting Classes

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ABSTRACT

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Short growing seasons and lack of water limit the number of crops that can be productively grown in the Northern Great Plains, but wheat is uniquely adapted to the region. Growers interested in diversification of their operations are growing more than one class of wheat to target different markets. This has led to the challenge of maintaining class purity, in that contamination with alternate classes results in lower prices to the farmer. The primary rationale is that mixtures may have poor end-use quality. In these experiments, we tested hard red spring wheat and hard white spring wheat contaminated with different levels of soft white spring wheat, durum wheat, hull-less barley, and the hard wheat of the alternate kernel color for milling and baking quality. Our results showed that contamination of hard red and hard white spring wheat with soft white wheat and hull-less barley often influenced end-use quality in that flour yield was negatively affected at relatively low levels. Loaf volume was normally only affected at higher levels. Durum wheat contamination caused fewer quality problems at generally higher levels of contamination. Contamination of hard red or hard white wheat by hard wheat of the alternate color class rarely affected quality, and effects were both positive and negative, depending on quality attributes of the pure samples. Growers wishing to diversify by growing both hard red and hard white wheat would benefit if buyers and end users were willing to accept higher levels of contamination for alternate classes that are unlikely to cause problems in eventual end use.

Several classes of wheat are produced in many areas of the Pacific Northwest. For example, Montana produces soft white spring wheat, durum wheat, and hard white spring wheat in addition to the predominate hard red spring wheat. Production of hard white spring wheat is projected to increase as markets continue to develop, while production of durum wheat in Montana is increasing because of disease in the more easterly areas of traditional durum production. The production in a single area, and often on a single farm, of multiple classes of wheat leads to potential for inadvertent mixing of grain of different classes. This is problematic for growers, as the price received for grain at the elevator is lower if the wheat contains grain of contrasting classes. As little as 1% contamination of hard red spring wheat by wheat of alternate classes decreases the grade from U.S. No. 1 to U.S. No. 2. Ten percent contamination leads to classification as U.S. sample grade. Each decline in grade results in lower price received by the grower. Thus, growers wishing to diversify their farming operations face a substantial risk due to inadvertent mixing of classes of wheat.

Wheat is separated by class because different classes of wheat have different end uses. Hard red spring (HRS) wheat generally has high protein and strong gluten, and is used for making bread. Hard white spring (HWS) wheat is similarly used in the domestic market, with additional opportunity for use in making noodles in Asian countries. Durum wheat is largely used for making pasta. Soft white spring (SWS) wheats generally have lower protein and gluten strength, and are used primarily in making cookies and cakes.

Changes in end-use properties are expected to be more readily apparent at low levels of contamination when the contaminating class has been selected for a different end use. Conversely, when the two classes have similar targeted end-uses, such as with HRS and HWS wheat, low levels of contamination maybe relatively nonconsequential. There is little empirical data regarding the level at which contamination causes perceptible changes in end use properties. Morris (1992) evaluated the impact on milling and baking quality of the addition of two SWS wheat cultivars to three lots of HWS 'Klasic'. The impact on milling was inconsistent, depending on the properties of the specific sample of Klasic tested. Impact on baking quality was more consistent, with soft white wheat causing declines in dough water absorption, bake mixing time, and final loaf volume. Ten percent contamination often caused a dramatic reduction in baking quality, while the decline in quality continued at a slower pace with increasing levels of contamination. There were different effects seen with the two soft white wheat cultivars tested. Boyacioglu and D'Appolonia (1994) found that blending of bread wheat flour with durum wheat flour caused different levels of quality deterioration, depending on the specific durum cultivar tested.

For the present study, we evaluated breadmaking quality of HRS and HWS wheat contaminated by different levels of four different grains. Our objective was to obtain empirical data to address the impact of contamination on end use quality, and to determine whether all contaminating classes should be treated the same in assessing prices received by growers.

MATERIALS AND METHODS

Grain harvested from Montana field trials were combined or collected to make up pure lots of HRS (1998 and 1999) and HWS (1999) wheat to be used as the bases for the contamination study. Samples of soft white spring (SWS) wheat, durum wheat, and hull-less barley were also collected from Montana field trials and used as contaminants. Samples for analysis were created by blending each of the contaminant grains by weight with the two lots of HRS and HWS wheat at levels of 0, 1, 5, 10, and 25%. Base wheat was replaced with increasing levels of contaminant grain at ratios (contaminant to pure lot) of 0:400, 4:396, 20:380, 40:360, 100:300. Four replicates were created for each class of wheat per crop year, and sample numbers were randomized.

TABLE I
Quality Characteristics of Hard Red Spring (HRS) and Hard White Spring (HWS) Wheat Base Flours

		1999	
Traits	1998 HRS	HRS	HWS
Wheat protein (%)	14.3	14.9	15.4
Flour yield (%)	69.5	71.8	66.4
Flour ash (%)	0.435	0.458	0.470
Flour protein (%)	12.7	13.3	13.6
Mixograph mixing tolerance	4.75	1.75	3.75
Bake water absorption (%)	74.5	73.2	77.2
Bake mixing time (min)	4.1	1.8	6.3
Loaf volume (cm^3)	1,095	1,048	1,171

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Grain samples were analyzed using Approved Methods (AACC 2000). Whole grain protein (N × 5.70, 12% moisture basis) and moisture were determined on the blended samples by near-infrared transmittance using an Infratec 1225 grain analyzer (Foss North America, Silver Springs, MD) (Approved Method 39-21). Subsamples of the contaminant grains were ground on a laboratory mill (model 3303, Perten Instruments, Springfield, IL). Grain protein was determined as N × 5.7 for all classes of wheat and N × 6.25 for hull-less barley by a combustion method using a Leco FP-528 (Leco Corp., St. Joseph, MI) (Approved Method 46-30). Moisture was determined by oven method (Approved Method 44-15A) and results were adjusted to a 12% moisture basis. A Brabender Quadromat Senior mill (C.W. Brabender Instruments, South Hackensack, NJ) was used to obtain white flour. Wheat was tempered to 15.5% moisture before milling (Approved Method 26-10A). Flour yield was calculated by dividing the flour by the total product (flour, bran, and shorts). Flour moisture and protein (14% moisture basis) were determined by near-infrared reflectance (InfraAlyzer 400, Technicon Industrial Systems, Tarrytown, NY) (Approved Method 39-11). Ash content was determined according to Approved Method 44-15A. Dough properties were measured using the mixograph (Approved Method 54-40). A standard bake test methodology was used to measure breadmaking properties (Approved Method 10-10B).

Data for each trait were analyzed by analysis of variance separately for each year-class combination. The 5% least significant difference was computed to compare means. Observed trait means were regressed against level of contamination to determine significance of the linear trend using the residual mean square to test significance of the regression coefficient.

RESULTS AND DISCUSSION

The HRS and HWS wheat lots chosen as the bases for the contamination studies both had good baking properties (Table I). The HWS wheat sample in 1999 had higher protein, higher bake water absorption, longer bake mixing time, and greater loaf volume than the other flours. The HRS wheat samples had higher flour yield than the other flours, in both years. These differences are specific to these samples and are not indicative of a general difference between these two classes of wheat. Cultivars and environments both affect the end-use qualities of both HRS and HWS wheat (McGuire and McNeal 1973; Lang et al 1998). The contaminating lots of SWS wheat, durum wheat, and hull-less barley had grain protein levels of 11.4, 16.2, and 13.4%, respectively, in 1999. Protein percent of these contaminating samples were not determined in 1998.

Tables II and III shows the results of contamination of the HRS and HWS wheat samples with increasing levels of SWS wheat, durum wheat, hull-less barley, and the alternate color hard wheat class (i.e., HRS wheat in HWS wheat). Hull-less barley and SWS wheat reduced wheat protein content, flour yield, and mixing time of 1998 HRS (Table II). In addition, hull-less barley also reduced loaf volume. Durum wheat contamination at the 25% level significantly increased flour ash and reduced bake water absorption, dough mixing time, and loaf volume. There was no effect with other levels of durum contamination. There was no significant effect of HWS wheat contamination in HRS on any trait measured.

SWS wheat and hull-less barley also had the greatest effect on end-use quality in 1999 HRS (Table II). Both contaminants significantly reduced wheat protein content, flour yield, and loaf volume. Durum wheat reduced flour yield and significantly increased flour ash. Increasing levels of HWS contamination significantly increased wheat protein content and loaf volume. There was a trend toward lower flour yield with increasing levels of HWS wheat contamination. The lot of HWS used as the contaminant had relatively low flour yield (Table I).

HWS wheat was similarly tested for the 1999 crop year (Table III). Hull-less barley significantly reduced wheat protein content, flour yield, and loaf volume, while SWS wheat significantly reduced wheat protein content and loaf volume of 1999 HWS. Increasing levels of durum wheat significantly increased flour ash and mixing tolerance, but reduced loaf volume. Contamination with HRS wheat

TABLE II
Contaminants in Hard Red Spring Wheat Resulting in Significant ($P < 0.05$) Changes in End-Use Quality Performance[a]

	1998				1999			
Traits	**SWS**	**D**	**HB**	**HWS**	**SWS**	**D**	**HB**	**HWS**
Wheat protein (%)	25	ns	**1**	ns	5	ns	25	**25**
Flour yield (%)	10	ns	5	ns	5	5	5	1
Flour ash (%)	ns	25	ns	ns	ns	X	ns	ns
Flour protein (%)	25	ns	25	ns	5	ns	5	ns
Mixograph mixing tolerance	25	ns	25	ns	ns	**10**	ns	ns
Bake water absorption (%)	X	X	ns	ns	1	ns	ns	ns
Bake mixing time (min)	5	25	ns	ns	ns	ns	ns	ns
Loaf volume (cm^3)	ns	25	25	ns	X	ns	25	**25**

[a] Level of soft white spring wheat (SWS), durum wheat (D), hull-less barley (HB), and hard white spring wheat (HWS), with least significant difference (LSD) for control (noncontaminated) sample; ns indicates no differences among samples for any level of contamination (0–25%). X indicates significant differences among levels of contaminants ($P < 0.05$), though no level of contaminant showed LSD with control. Bold values indicate contaminant improved quality.

TABLE III
Contaminants in Hard White Spring Wheat Resulting in Significant ($P < 0.05$) Changes in End-Use Quality Performance[a]

	1999			
Traits	**SWS**	**D**	**HB**	**HRS**
Wheat protein (%)	10	ns	10	25
Flour yield (%)	5	ns	1	**25**
Flour ash (%)	ns	25	ns	ns
Flour protein (%)	10	25	25	25
Mixograph mixing tolerance	ns	X	ns	ns
Bake water absorption (%)	ns	ns	ns	ns
Bake mixing time (min)	ns	25	5	25
Loaf volume (cm^3)	25	10	5	ns

[a] Level of soft white spring wheat (SWS), durum wheat (D), hull-less barley (HB), and hard red spring wheat (HRS), with least significant difference (LSD) for control (noncontaminated) sample; ns indicates no differences among samples for any level of contamination (0–25%). X indicates significant differences among levels of contaminants ($P < 0.05$), though no level of contaminant showed LSD with control. Bold values indicate contaminant improved quality.

reduced wheat protein content, mixing tolerance, and bake mixing time. Impact of HRS wheat contamination could be positive or negative, depending on characteristics of pure lots of the two classes of wheat (Table I).

The trait most influenced by contamination in this study was flour milling yield. Contamination with hull-less barley reduced flour yield in both base flours by ≈0.5% for each percentage increase in contaminant (Table IV). One explanation is that the barley was simply lost in the milling process. Contamination with SWS wheat also consistently reduced flour yield, but to a lesser extent than hull-less barley and the linear trend was not significant with the 1999 HWS wheat.

Flour yield was slightly affected by contamination with the hard wheat of the alternate color class. However, addition of HWS wheat with lower flour yield properties (Table I) to HRS wheat did cause a significant reduction in flour yield in 1999.

Loaf volume was generally affected only at high levels of contamination (Tables II, III, and V). Hull-less barley caused a significant decline in loaf volume (>3 cm^3 for each percentage of contamination) for all base flours (Table V). Durum wheat and SWS wheat also reduced loaf volume in HWS but to a lesser extent than hull-less barley. The linear trend was not significant for 1998 HRS wheat contaminated with SWS wheat or 1999 HRS wheat contaminated with durum wheat. In no case did contamination with the

TABLE IV
Flour Yield (%) of Hard Red Spring Wheat (HRS) and Hard White Spring Wheat (HWS) After Contamination by Soft White Spring Wheat (SWS), Durum (D) Wheat, Hull-less Barley (HB), and Contrasting Color Class

Crop and Year	Level of Contamination (%)	Contaminant SWS	D	HB	Contrasting Color Class HWS	HRS
HRS 1998	0 (69.53)					
	1	69.83	69.78	69.70	69.28	
	5	69.10	69.89	67.70	69.63	
	10	68.40	69.80	64.70	69.30	
	25	67.70	69.68	55.98	69.45	
b value[a]		–0.09**[b]	ns[c]	–0.54**	ns	
LSD_{05} 0.70						
HRS 1999	0 (71.80)					
	1	71.25	70.95	70.50	70.73	
	5	70.83	70.15	68.63	70.90	
	10	70.40	70.23	66.43	70.60	
	25	69.03	69.68	59.05	69.83	
b value		–0.07**	–0.05*	–0.47**	ns	
LSD_{05} 0.80						
HWS 1999	0 (66.40)					
	1	65.80	66.36	65.60		66.18
	5	65.60	65.53	63.70		66.70
	10	65.25	65.60	61.58		67.03
	25	65.25	65.68	54.85		67.08
b value		ns	ns	–0.45**		0.06*
LSD_{05} 0.69						

[a] Regression slope.
[b] * and ** = significant at $P < 0.05$ and < 0.01.
[c] Not significant.

TABLE V
Final Loaf Volume (cm^3) of Hard Red Spring Wheat (HRS) and Hard White Spring Wheat (HWS) After Contamination by Soft White Spring Wheat (SWS), Durum (D) Wheat, Hull-less Barley (HB), and Contrasting Color Class

Crop and Year	Level of Contamination (%)	Contaminant SWS	D	HB	Contrasting Color Class HWS	HRS
HRS 1998	0 (1,095)					
	1	1,060	1,094	1,104	1,089	
	5	1,084	1,083	1,106	1,091	
	10	1,093	1,048	1,063	1,059	
	25	1,054	1,028	1,009	1,090	
b value[a]		ns[b]	–2.8*[c]	–3.05**	ns	
LSD_{05} 51						
HRS 1999	0 (1,048)					
	1	1,048	1,073	1,068	1,091	
	5	1,058	1,053	1,043	1,071	
	10	1,061	1,068	1,070	1,106	
	25	1,010	1,034	973	1,111	
b value		–2.15*	ns	–3.33**	2.03*	
LSD_{05} 62						
HWS 1999	0 (1,171)					
	1	1,144	1,140	1,156		1,150
	5	1,160	1,160	1,113		1,139
	10	1,139	1,115	1,121		1,138
	25	1,101	1,115	1,064		1,151
b value		–1.78*	–1.64*	–3.41		ns
LSD_{05} 43						

[a] Regression slope.
[b] Not significant.
[c] * and ** = significant at $P < 0.05$ and < 0.01.

hard wheat of the alternate color class negatively affect loaf volume. However, addition of HWS to 1999 HRS increased loaf volume ≈2 cm^3 for each percentage of contamination. This reflects the fact that the HWS wheat sample produced relatively high loaf volume (Table I).

CONCLUSIONS

Our data have implications regarding the necessity for segregation of grain of alternative classes by farmers and elevators before grain reaches end users. Certain contaminants, such as SWS wheat and hull-less barley, appear to have a serious effect on milling and breadbaking quality. Conversely, contamination of HRS by HWS, or vice versa, is likely to be inconsequential to eventual baking quality. In fact, contamination with the alternate color class was as likely to result in a positive change in quality as in a negative change. HWS wheat has potential to complement HRS wheat production in the Northern Great Plains, leading to increasing challenges in keeping the two classes separate. Our results suggest that the end users of HRS and HWS wheat may be able to accept relatively high levels of contamination by the alternate color class without negatively affecting end-use quality. Such acceptance would make the production of HWS wheat a more attractive option for wheat growers in the region.

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