Effect of Fusarium Head Blight on Semolina Milling and Pasta-Making Quality of Durum Wheat[1]

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ABSTRACT

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Ten durum wheat cultivars harvested in Manitoba in 1995, which were downgraded primarily because of fusarium-damaged (FD) kernels, were subjected to mycological tests and evaluated for semolina milling and pasta-making quality. *Fusarium graminearum* was the primary fungus infecting kernels. The ratio of FD to deoxynivlaenol (DON) level varied slightly among cultivars but was generally near unity. Retention of DON in semolina was about 50%. FD had a negative impact on kernel weight and test weight, resulting in lower semolina yield. Semolina ash content and bran specks were not affected by FD, but semolina became duller and redder. FD had no effect on protein content, but gluten strength was weaker probably due to a lower proportion of glutenins as shown by reversed-phase high-performance liquid chromatographic analysis of sequentially extracted gluten proteins. The influence of FD on gluten strength was not sufficient to alter pasta texture. FD had a strong adverse effect on pasta color. Even for the least damaged cultivars, which had FD levels near the limit of 2% established for the No. 3 and No. 4 Canadian Western Amber Durum (CWAD) grades, the deterioration in pasta color was readily discernible by eye, confirming that the strict FD tolerances for premium No. 1 CWAD (0.25%) and No. 2 CWAD (0.5%) grades are warranted.

Since 1984, fusarium head blight (or scab) has become increasingly common in southeastern Manitoba (Clear and Patrick 1990). In Manitoba, fusarium head blight is caused primarily by *Fusarium graminearum* Schwabe. Outbreaks are a concern because of loss of grain yield and quality and mycotoxin contamination.

Potential toxic effects of mycotoxins associated with fusarium head blight, particularly the trichothecene deoxynivalenol (DON, vomitoxin) have resulted in numerous investigations on levels in infected wheat, flour, and processed products (Pomeranz et al 1990). DON is stable during wheat milling, although it becomes partitioned in varying concentrations among screenings, mill feed, and flour streams (Scott et al 1983, 1984; Seitz et al 1985; Lee et al 1987; Tkachuk et al 1991) and is also stable during baking (El-Banna et al 1983, Young et al 1984, Tanaka et al 1986, Boyacioglu et al 1993). DON levels are reduced in cooked pasta and Asian noodles because of leaching into the cooking water (Nowicki et al 1988) and in alkaline products such as tortillas due to decomposition (Abbas et al 1988).

The effect of fusarium head blight on the processing quality of wheat has received less attention. Meyer et al (1986) reported that German wheat infected by *F. culmorum* (W.G. Smith) Sacc. exhibited inferior baking quality. It has been reported that scab levels up to 3% do not affect the baking quality of American hard red winter wheat (Seitz et al 1986). Dexter et al (1996) found that fusarium-infected hard red spring wheat from the 1994 Manitoba harvest exhibited poor flour color, weak dough properties, and unsatisfactory bread quality.

There is little information available on the processing implications of fusarium head blight on durum wheat quality, aside from a report by Moore (1994) that fusarium-infected durum wheat from North Dakota exhibited poor pasta color. This study reports on the implications of various levels of fusarium damage on semolina milling, gluten strength, and pasta-making quality of 10 durum wheat cultivars harvested in Manitoba in 1995. Such data are needed to verify that fusarium damage (FD) tolerances established for Canada Western Amber Durum (CWAD) grades correctly classify durum wheat according to processing potential.

MATERIALS AND METHODS

Wheat Samples

Ten durum wheat genotypes were grown near Portage La Prairie, Manitoba, in 1995 in a randomized complete block design with four replications, although only three of the replicates were tested for quality. Plots consisted of four rows, 3 m long. The genotypes comprised the current check cultivars for the Durum Cooperative Test, Hercules (Leisle 1970), Kyle (Townley-Smith et al 1987), Plenty (Knott 1991), and AC Melita; three U.S. semidwarf cultivars, Duraking, Durex, and Reva; and three advanced lines from the Semiarid Prairie Agricultural Research Centre durum breeding program, DT369 (McLeod et al 1991), DT666, and DT673.

Each individual sample was divided into two equal portions. Foreign material, dockage, and FD were removed by hand-picking from one portion to give a “cleaned” (CL) portion. Foreign material and dockage only were removed from the other portion to give an “as is” (AS) portion.

Grading and Determination of Fusarium Damage

FD for each CL and AS sample and for the severely fusarium-damaged (SFD) kernels removed during hand-picking were determined according to the standard Canadian Grain Commission (CGC) procedure. The Official Grain Grading Guide (Canadian Grain Commission 1995) describes FD as “lifeless, thin, shrunken kernels affected by a whitish or pinkish fibrous mold.” The presence of the mold on individual kernels is confirmed using a 10 power magnifier.

A basic grade was assigned to each series exclusive of FD. The maximum FD tolerances for Canadian durum wheat milling grades are 0.25% in No. 1 CWAD, 0.5% in No. 2 CWAD, 2% in No. 3 and No. 4 CWAD, and 5% in No. 5 CWAD (a feed quality grade).

Mycological Evaluation

Fungal analysis was performed on each AS sample and SFD fraction. One hundred seeds per sample were chosen at random, surface disinfected by soaking in a 0.3% sodium hypochlorite solution for 1 min, and then air dried in a laminar flow cabinet. Dried seeds were placed onto cooled potato dextrose agar in 100-mm petri dishes, with 10 seeds per plate. The plates were incu-

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bated for five days at room temperature (21–28°C) under a cycle of 12 hr darkness and 12 hr of mixed UV and fluorescent light to induce sporulation of fusaria and other fungi for identification.

Wheat Tests

Wheat moisture content, test weight, and kernel weight were determined by the methods described by Dexter and Tipples (1987). SDS-sedimentation volumes were determined as described by Dexter et al (1980).

Milling

The samples were prepared for milling as described by Dexter and Tipples (1987) and were milled in 400-g lots in a five-stand mill (Allis-Chalmers) using an abbreviated version of the flow described by Dexter et al (1990). The flow comprised four break passages, three sizing passages, and six purification passages. Flour and semolina were combined, and yields were calculated as the proportion of wheat to first break on a constant moisture basis.

TABLE I
Properties of Severely Fusarium-Damaged Kernels Picked from Fusarium-Damaged Durum Wheat[a]

Cultivar	FD (%)	KW (mg)	PR (%)	SDS (mL)
Reva	76	32.0	13.5	56
DT 673	88	33.7	13.5	40
AC Melita	89	32.6	14.5	42
Durex	86	33.9	13.4	40
Hercules	87	36.6	14.5	31
DT666	68	35.9	14.8	47
Kyle	79	30.5	14.8	34
Plenty	87	29.7	15.2	32
DT 369	76	28.2	13.5	56
Duraking	74	33.9	13.8	40

[a] FD = Fusarium damage, KW = kernel weight, PR = protein, SDS = sodium dodecyl sulfate sedimentation volume. KW and PR expressed on 14% moisture basis. Mean values of duplicate analyses on composite samples.

Deoxynivalenol Determination

Deoxynivalenol (DON) was determined using Veratox enzyme-linked immunosorbent assay (ELISA) kits (Neogen Corporation, Lansing, MI) on 50-g samples of semolina or ground wheat. Wheat samples were ground in a Ditting coffee grinder (Elpack Ltd., Toronto, ON) at the 1.5 setting, which gives a grind in which 90% of ground material passes through a U.S. No. 20 mesh (850 µm) sieve. Extraction was at a 1:5 ratio with water at high speed in a blender, and after settling, 30 ml of aliquot was centrifuged for 5 min at 3,000 rpm. One hundred microliter aliquots were used for the ELISA test.

Past experience from CGC DON surveys has shown that the ELISA test results correlate strongly ($r > 0.8$) to the reference gas chromatograph-mass selection detection procedure described by Nowicki et al (1988). The ELISA results tend to be higher by up to 50%, particularly when DON levels are below 2 ppm.

Analytical and Color Tests

Moisture contents of ground wheat and semolina were determined with a Brabender rapid moisture tester (C.W. Brabender Instruments, South Hackensack, NJ) as outlined in the instruction manual. All wheat and flour analytical data are expressed on a 14% moisture basis.

Ash content, Agtron color, yellow pigment content, wet gluten, and gluten index and mixograph curves were obtained by AACC standard methods (AACC 1995).

Semolina Falling Number was determined as described by Hagberg (1961). Protein content (N × 5.7) was determined by the Kjeldahl procedure as modified by Williams (1973). Semolina specks were determined by the imaging technique of Symons et al (1996).

TABLE II
Properties of Fusarium-Damaged Durum Wheat[a]

Cultivar	Treatment	FD (%)	DON (ppm)	TW (kg/hL)	KW (mg)	PR (%)	SDS (mL)	SY (%)
Reva	As is	9.2	6.2	76.1	38.3	14.2	62	68.6
	Clean	0.1	2.2	77.7	39.0	14.3	71	68.9
DT 673	As is	7.8	6.9	78.3	44.1	14.1	46	70.6
	Clean	0.2	3.7	79.5	45.0	14.1	49	70.8
AC Melita	As is	5.2	3.4	77.8	40.5	15.0	56	69.2
	Clean	0.1	1.1	79.0	41.1	15.1	62	69.7
Durex	As is	4.6	6.0	78.4	43.7	14.2	54	70.2
	Clean	0.2	3.3	79.3	45.7	14.1	63	71.1
Hercules	As is	3.8	3.9	78.4	44.5	15.2	41	71.3
	Clean	0.2	1.2	78.9	45.2	15.2	49	71.7
DT 666	As is	2.8	1.8	78.6	43.8	14.8	62	68.9
	Clean	0.3	0.8	79.1	43.7	14.8	66	69.0
Kyle	As is	2.4	2.1	78.8	39.7	15.2	42	68.7
	Clean	0.04	0.7	79.3	39.8	15.1	42	69.8
Plenty	As is	2.3	2.2	79.4	38.5	14.9	32	69.2
	Clean	0.02	0.6	79.7	38.7	14.9	38	69.8
DT 369	As is	2.1	2.4	76.8	37.8	13.8	62	68.3
	Clean	0.03	1.0	77.9	39.6	14.0	66	69.3
Duraking	As is	1.7	3.4	79.9	39.7	14.5	45	69.9
	Clean	0.1	0.9	81.1	42.0	14.5	53	71.0
P values:								
Rep		0.018	0.002	0.50	0.0.23	0.85	0.0001	0.006
Cultivar (C)		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Treatment (T)		0.0001	0.0001	0.0001	0.12	0.69	0.0001	0.002
C*T		0.0001	0.016	0.80	0.99	0.99	0.80	0.96
LSD (0.05):								
Cultivar		1.3	0.82	0.93	2.7	0.34	4.8	0.91
Treatment		0.59	0.36	0.41	1.2	0.15	2.2	0.41

[a] FD = Fusarium damage, DON = deoxynivalenol, TW = test weight, KW = kernel weight, PR = protein, SDS = sodium dodecyl sulfate sedimentation volume, SY = semolina yield. DON, KW, and PR expressed on 14% mb. SY expressed as proportion of clean wheat on constant moisture basis. Mean values for three replications.

Tristimulus color coordinate measurements were performed with a Minolta CM-525i Spectrophotometer (Minolta Canada Inc., Mississauga, ON) on semolina and spaghetti strands. Color readings were expressed by Judd-Hunter values for L^* (lightness), a^* (red-green chromaticity), and b^* (yellow-blue chromaticity) (Francis 1983).

Protein Characterization

Samples of ground grain (0.5 g) were extracted by the sequential extraction procedure described by Marchylo et al (1989). The protein fractions were separated by reversed-phase high-performance liquid chromatography (RP-HPLC) using a Waters HPLC and Waters Millennium 2010 software (Waters Associates Inc., Milford, MA). Analyses were performed using a Zorbax SB300-C18 HPLC column (C18, 300 Å pore size, 3.5 µm particle size, 15cm × 4.6 mm i. d.) as described by Marchylo et al (1996) with a column temperature of 50°C and using a liner gradient extending from 24 to 50% acetonitrile. The ratio of gliadins to glutenins was determined as noted previously (Dexter et al 1994).

Spaghetti Processing and Texture Analysis

Spaghetti was processed by the micro procedure of Matsuo et al (1972) using the 70°C drying cycle described by Dexter et al (1981). Firmness of the cooked pasta was determined using a TA-XT2 texture analyzer (Texture Technologies Corp., Scarsdale, New York) and conformed to AACC Method 16-50 (AACC 1995) with some modifications. Spaghetti was cooked according to the method of Matsuo and Dexter (1977) and then 10 strands of cooked spaghetti were sheared crosswise and peak force (shear force) was determined. The 10 strands were cut five times in rapid succession at separate sites. The mean peak force was calculated and reported as firmness (kg/10 strands).

Experimental Design and Statistical Analysis

Testing of AS and CL samples was performed in block design using replicates as blocks. Testing within each block was randomized with the exception of milling where samples were milled in ascending order of FD to prevent spurious semolina DON results that could arise because of cross-contamination of stocks from successive millings.

All testing of SFD was performed in duplicate on composites. HPLC analyses were performed on duplicate extracts of AS and SFD composites.

Statistics for AS and CL data were calculated using general linear models procedures of the SAS (SAS Institute, Cary, NC) software system v6.08 for Windows. The data were analyzed as a factorial experiment. The analysis of variance (ANOVA) sources of variation (with degrees of freedom in parentheses) were as follows: reps (2), treatment (1), cultivar (9), cultivar × treatment (9), and error (38) for a total of 59 degrees of freedom.

RESULTS AND DISCUSSION

Wheat Physical Condition

All cultivars met visual requirements for the No. 2 CWAD grade exclusive of FD. The SFD kernels were shriveled, as evident from low kernel weight (Table I). As a result, the CL samples exhibited significantly higher test weight than did the corresponding AS samples (Table II) and a weak but consistent trend to higher kernel weight.

All samples were sound as indicated by semolina Falling Number values, which ranged from about 300 to 500 sec, depending on cultivar (results not shown). FD did not affect Falling Number values.

Mycology, Fusarium-Damaged Kernels, and DON Levels

Fungal species representing 18 genera were recovered from the AS samples. *A. alternata* and *F. graminearum* accounted for 60% of all fungal isolations from AS samples and 92% of those from SFD fractions. The same two species were dominant in a previous study of common wheat containing FD (Dexter et al 1996). *A. alternata* was the most frequently recovered fungus

TABLE III
Refinement and Color Indices of Semolina from Fusarium-Damaged Durum Wheat[a]

Cultivar	Treatment	DON (ppm)	Ash (%)	AC (%)	Minolta L^*	a^*	b^*	YP (ppm)	Specks (50 cm^2)
Reva	As is	3.9	0.90	40	86.2	–2.3	27.8	7.8	86
	Clean	1.0	0.89	48	86.9	–2.5	28.6	7.4	84
DT 673	As is	4.4	0.74	37	86.1	–2.7	31.2	9.5	120
	Clean	1.8	0.73	43	86.5	–2.9	31.5	9.5	109
AC Melita	As is	2.2	0.82	47	86.8	–2.7	28.8	7.5	70
	Clean	0.5	0.80	56	87.4	–2.8	29.3	7.3	52
Durex	As is	3.6	0.73	49	86.9	–2.7	28.4	7.4	98
	Clean	1.5	0.73	53	87.0	–2.9	29.1	7.3	76
Hercules	As is	2.1	0.76	48	87.1	–2.4	25.4	5.8	66
	Clean	0.6	0.76	51	87.1	–2.5	25.3	5.7	69
DT 666	As is	1.0	0.79	49	86.5	–2.6	29.0	7.3	72
	Clean	0.2	0.78	52	86.8	–2.7	29.3	7.2	62
Kyle	As is	1.2	0.75	43	86.3	–2.7	27.5	6.9	103
	Clean	0.5	0.73	44	86.6	–2.7	27.5	6.9	121
Plenty	As is	1.1	0.70	49	86.7	–2.6	28.1	7.1	89
	Clean	0.4	0.69	50	86.7	–2.7	28.1	6.9	96
DT 369	As is	1.6	0.78	45	86.5	–2.5	28.7	7.7	71
	Clean	0.5	0.78	49	86.6	–2.5	28.6	7.4	66
Duraking	As is	1.7	0.75	45	86.6	–2.7	27.7	7.2	95
	Clean	0.5	0.73	53	87.1	–2.7	27.7	7.1	92
P values									
Rep		0.12	0.0001	0.74	0.15	0.37	0.0001	0.0018	0.0001
Cultivar (C)		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Treatment (T)		0.0001	0.16	0.0001	0.0004	0.0001	0.055	0.044	0.35
C*T		0.0011	0.99	0.58	0.49	0.086	0.6036	0.98	0.75
LSD (0.05)									
Cultivar		0.57	0.034	4.2	0.33	0.099	0.46	0.28	21.2
Treatment		0.25	0.015	1.9	0.15	0.044	0.20	0.13	9.5

[a] AC = Agtron color, YP = yellow pigment. Ash and YP expressed on 14% mb. Mean values for three replications.

from all AS samples, averaging 77% recovery, followed by *F. graminearum* at 29%.

Mycology analyses verified that infection by fusaria was the primary causal agent of damage in the SFD kernels hand-picked from the AS samples. In all SFD fractions, *F. graminearum* was the most common fungus (87%) followed by *A. alternata* (13.7%). The level of seed infection by fusaria in the AS fraction ranged from 15 to 59%, with an average of 39%. In the SFD seeds, infection levels by fusaria ranged from 84 to 99%, with an average of 92%. *F. graminearum* was the most frequently recovered *Fusarium* species. Seventy-five percent of fusaria from the AS samples and 95% from the SFD were *F. graminearum*.

There was a wide range of FD among cultivars for the AS samples (Table II). Duraking was the only cultivar that did not exceed the limit of 2% FD for the No. 3 CWAD grade. Among the remaining cultivars AC Melita, DT 673, and Reva exceeded the 5% limit for feed grain (No. 5 CWAD).

Confirmation of FD with a magnifier was too tedious to be practical during the hand-picking, so the CL samples still contained some FD when officially graded by Canadian Grain Commission grain inspectors, and the SFD composites were less than 100% FD (Tables I and II). Although the CL samples were virtually free of FD, all had significant levels of DON, and for the most severely infected cultivars some CL samples had values in excess of 2 ppm (Table II). The presence of DON in the cleaned samples (Table II) is attributable, in large part, to seeds infected by *F. graminearum* but without visible symptoms. In some samples, the symptomless seeds contained over half of the DON detected.

FD wheat is sometimes cleaned on specific gravity tables prior to marketing (Tkachuk et al 1991, Trigo-Stockli et al 1995). Results from the current study indicate that intensive cleaning does not guarantee that the wheat will meet DON guidelines, which vary among markets and often depend on the intended end use. For example, FDA (1993) advisory levels for DON are 1 ppm for finished wheat products intended for human consumption, and 5–10 ppm for products destined for feed use.

All samples exhibited a DON retention in semolina near 50% (Table III), consistent with previous reports for common wheat flour (Pomeranz et al 1990 and references therein) and durum wheat semolina (Nowicki et al 1988).

Semolina Milling Performance

Semolina milling yield differed among cultivars and consistently showed moderate improvement when SFD kernels were removed (Table II). The lower yields observed for the AS samples were consistent with a strong relationship between durum test weight and kernel size and semolina milling performance demonstrated previously (Dexter et al 1987). When marketing semolina, millers generally must meet semolina refinement indices, most commonly ash content, number of bran specks, and color (brightness and yellowness) (Feillet and Dexter 1995). Semolina ash content and number of bran specks were not significantly affected by removal of SFD kernels (Table III). Previous reports

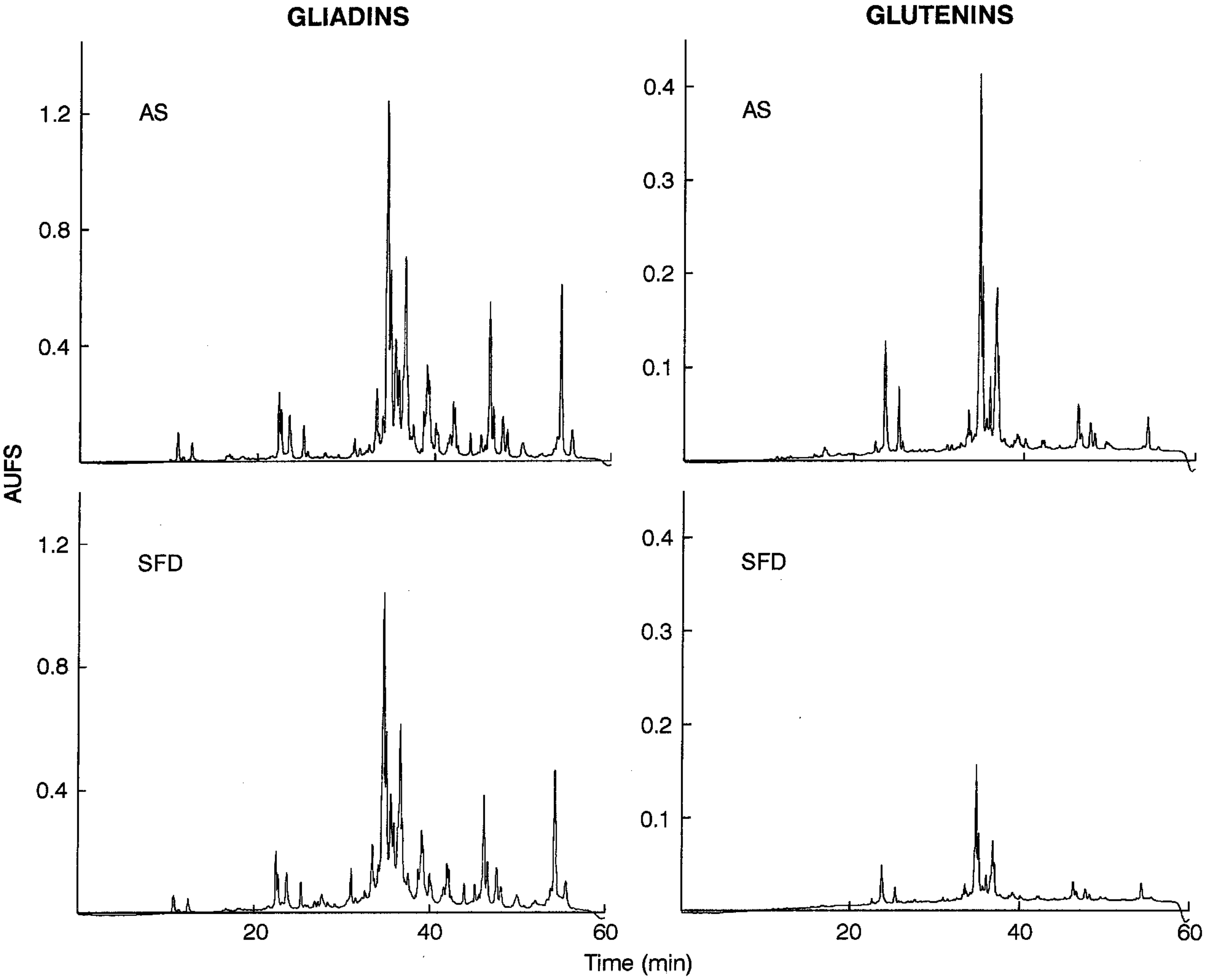

Fig. 1. Comparison of reversed-phase high-performance liquid chromatograms of gliadin and glutenin protein extracted from severely fusarium damaged (SFD) wheat (cv. Reva) removed from a wheat sample containing 3.9% fusarium damaged kernels (AS).

have associated FD with poor color in common wheat flour (Tkachuk et al 1991, Dexter et al 1996), and in the current study semolina color-related parameters also showed strong effects attributable to FD (Table III). The most notable effect was an improvement in semolina brightness when SFD were removed, as denoted by consistently higher Agtron color. Tristimulus color values for dry semolina showed that removal of SFD kernels resulted in marginal improvements in brightness (*L**) for some cultivars. In addition, where differences attributable to removal of SFD kernels were apparent, semolina hue and intensity were generally better due to less redness, as indicated by slightly lower *a**, and slightly higher yellow pigment content and associated *b** values for CL samples.

Protein Composition

Protein content differed significantly among cultivars, but slight differences in protein content between SFD kernels and healthy kernels were not sufficient to induce a significant effect of FD on wheat protein content (Tables I and II). Similarly, semolina protein content, wet gluten, and dry gluten values differed among cultivars but showed no effect due to FD (results not shown).

There have been several reports that FD in common wheat results in reduced gluten strength due to a decline in the proportion of glutenins (Boyacioglu and Hettiarachchy 1995; Dexter et al 1996). No qualitative differences in protein composition were observed. Similarly, in the current study major qualitative differences in chromatograms were not evident even for severely damaged samples (Fig. 1). A decrease in the proportion of glutenins also was obtained for all durum cultivars in this study. RP-HPLC analysis showed that SFD kernels had a much higher ratio of gliadins to glutenins (Table IV). The higher ratio was attributable to a significant decrease in the amount of glutenin concomitant with only slightly depressed amounts of gliadins in SFD as compared to healthy kernels.

Bechtel et al (1985) showed that *F. graminearum* is an aggressive invader of wheat kernels, destroying starch granules, storage proteins, and cell walls. It has been speculated that degradation of gluten protein by *F. graminearum* is the primary cause of gluten composition differences (Meyer et al 1986). If that is the case, then degradation by the fungus must be specific to glutenins. Alternately, Dexter et al (1996) suggested that immaturity, brought on by incomplete development of the seeds due to premature death of infected spikelets, may influence gluten composition. According to Simmonds (1968), in a SFD kernel, development of the seed is halted by fungal invasion at about the early milk to early dough stage, depending on the time of initial infection. Glutenins are synthesized more rapidly than are gliadins during the later stages of the kernel maturation process (Huebner et al 1990), which could account for less glutenins in SFD kernels.

Gluten protein weakness associated with FD was evident from SDS-sedimentation volumes (Tables I and II). With the exception of Kyle, CL samples gave consistently higher SDS-sedimentation volumes than corresponding AS samples, and SFD kernels exhib-

TABLE IV
Effect of Severe Fusarium Damage on Gliadin-to-Glutenin Ratio of Fusarium-Damaged (FD) Durum Wheat[a]

Cultivar	As Is	Severely FD
Reva	4.6	7.5
DT673	3.8	5.4
AC Melita	3.7	6.1
Durex	3.8	5.4
Hercules	5.0	8.1
DT 666	3.7	5.3
Kyle	3.8	5.9
Plenty	4.1	6.0
DT 369	4.0	6.2
Duraking	3.7	5.3

[a] Mean values from duplicate extracts of composites of as is and severely FD samples.

TABLE V
Falling Number and Gluten-Related Semolina Properties of Fusarium-Damaged Durum Wheat[a]

Cultivar	Treatment	GI (%)	MDT (min)	MPH (mm)
Reva	As is	76	4.25	74
	Clean	83	5.08	77
DT 673	As is	51	4.33	66
	Clean	53	4.08	67
AC Melita	As is	68	4.42	74
	Clean	74	4.50	80
Durex	As is	82	4.58	70
	Clean	83	5.08	77
Hercules	As is	30	3.25	65
	Clean	28	3.50	70
DT 666	As is	80	4.67	79
	Clean	73	4.67	80
Kyle	As is	26	3.42	64
	Clean	24	3.50	67
Plenty	As is	7	3.17	50
	Clean	5	3.42	53
DT 369	As is	77	4.33	70
	Clean	72	4.25	72
Duraking	As is	53	4.25	66
	Clean	49	4.33	70
P values				
Rep		0.0001	0.0001	0.0001
Cultivar		0.0001	0.0001	0.0001
Treatment		0.34	0.081	0.0027
C*T		0.89	0.36	0.94
LSD (0.05)				
Cultivar		8.3	0.27	4.8
Treatment		3.7	0.12	2.2

[a] GI = gluten index, MDT = mixograph development time, MPH = mixograph peak height. Mean values for three replications.

TABLE VI
Minolta Color Values and Firmness (Peak Force) of Spaghetti from Fusarium-Damaged Durum Wheat[a]

		Minolta			Firmness
Cultivar	Treatment	*L**	*a**	*b**	(kg/10 strands)
Reva	As is	66.3	11.8	56.8	1.30
	Clean	70.5	6.4	55.0	1.27
DT 673	As is	66.3	11.7	61.9	1.30
	Clean	68.8	8.5	63.2	1.26
AC Melita	As is	69.6	6.9	58.0	1.25
	Clean	73.0	4.0	59.0	1.28
Durex	As is	69.1	8.8	60.6	1.28
	Clean	71.0	6.2	59.3	1.28
Hercules	As is	70.4	7.5	56.5	1.12
	Clean	72.1	5.1	55.1	1.12
DT 666	As is	70.6	6.1	58.5	1.29
	Clean	71.8	4.8	57.7	1.26
Kyle	As is	68.7	6.7	55.7	1.23
	Clean	69.4	6.0	55.7	1.22
Plenty	As is	71.0	5.6	56.2	1.10
	Clean	71.1	5.4	56.0	1.14
DT 369	As is	70.6	8.1	58.5	1.29
	Clean	70.5	6.2	61.1	1.16
Duraking	As is	69.5	6.9	54.1	1.25
	Clean	71.8	4.6	52.8	1.23
P values					
Rep		0.099	0.78	0.0001	0.0001
Cultivar (C)		0.0001	0.0001	0.0001	0.0001
Treatment (T)		0.0001	0.0001	0.37	0.52
C*T		0.12	0.0001	0.69	0.97
LSD (0.05)					
Cultivar		1.3	0.92	1.8	0.067
Treatment		0.60	0.41	0.83	0.030

[a] Mean values for three replications.

ited even lower values. However, with the exception of consistently lower Mixograph peak height for AS samples, other tests related to gluten quality were comparable for corresponding AS and CL samples. Gluten index values and Mixograph mixing time showed highly significant differences among cultivars but were not affected consistently by removal of SFD kernels (Table V).

Pasta Properties

FD gave highly significant effects on pasta color (Table VI). Most CL samples were brighter than corresponding AS samples. A tendency for less redness in the CL samples was readily discernible by eye. A significant cultivar to treatment effect reflected different degrees of increased redness among cultivars, but the trend was evident in all cases. Reva and DT 673, the most heavily damaged samples, showed particularly strong trends to greater redness, but the trend was still apparent for the least damaged cultivars, DT 369 and Duraking.

It is well established that protein content is the primary factor associated with pasta texture, and gluten strength is a secondary factor (Feillet and Dexter 1995). Cooked pasta firmness differed significantly among cultivars, reflecting intrinsic differences among cultivars in protein content and gluten strength (Table VI). FD had no effect on pasta texture because, as discussed previously, FD had no effect on protein content, and at most a weak effect on gluten strength.

CONCLUSIONS

FD, within the levels encountered commercially in southeastern Manitoba in 1995, had significant durum wheat processing quality implications. Semolina yield was reduced, and semolina became duller and more red. Gluten functionality (strength) was also reduced because glutenin concentration was less. Pasta texture was not affected by FD, but FD made pasta duller and redder. Pasta yellowness was not affected by FD.

The least damaged cultivars in this study had values near the limit of 2% set for the No. 3 and No. 4 CWAD grades. In every case, the effect of FD on pasta color was sufficient to cause concern commercially. These results confirm that the strict tolerances for FD in the premium durum wheat grades, No. 1 CWAD (0.25%) and No. 2 CWAD (0.5%), are warranted because demand for bright yellow pasta with no evidence of redness is a primary quality determinant in many high-quality markets (Feillet and Dexter 1995).

In terms of food safety, these studies confirm that visual inspection for FD gives a rough indication of DON levels. The ratio of DON to FD for AS samples was variety specific but was generally near unity. However, the retention of relatively high DON values in CL samples from the more heavily infected cultivars demonstrates that rigorous cleaning to remove FD, which is commonly practiced commercially, is not a guarantee that heavily infected wheat will meet DON level guidelines for food use after cleaning.

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