Effect of Smudge and Blackpoint, Mildewed Kernels, and Ergot on Durum Wheat Quality[1]

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Cereal Chem. 59(1):63–69

ABSTRACT

Farm samples from the 1979 and 1980 Canadian durum wheat crops were handpicked to yield a series of controls and samples enriched by varying degrees in smudge and blackpoint, mildewed kernels, and ergot bodies. The most important effect of smudge and blackpoint and of mildewed kernels was an undesirable increase in semolina speckiness. Spaghetti color also deteriorated slightly, particularly from mildewed kernels. Levels of ergot bodies within the legally tolerated limits for Canadian durum wheat caused an increase in semolina speckiness. At higher levels of ergot, spaghetti color deteriorated rapidly and milling yield decreased. Spaghetti cooking quality did not appear to be affected by any of the degrading factors examined.

Depending on weather conditions during the growth, maturation, and harvest of durum wheat, various microorganisms may inflict considerable damage. Some of the more common and widespread forms of damage from microorganisms associated with Canadian durum wheat are smudge, mildew, and ergot.

Smudge is a dark-brown or black discoloration of the kernel associated with fungal pathogens such as *Helminthosporium sativum* and *Alternaria alternata* and/or the reddish discoloration associated with various other fungi such as *Fusarium*. Smudge is particularly prevalent in wet seasons if airborne spores are abundant (Simmonds 1968). Durum wheats are more susceptible to smudge than common wheats (Machacek and Greaney 1938). Serious infections can result in discoloration penetrating and extending throughout the endosperm. More often, however, the infection is confined to the germ end of the kernel, a condition commonly referred to as blackpoint. Harris and Sibbitt (1942) have reported on the effect of blackpoint on semolina yield and spaghetti color, but no information has been published on the possible effects of smudge and blackpoint on spaghetti cooking quality.

When the crop lies in swath for prolonged periods of cool, damp weather, mildewed and moldy kernels may become principal degrading factors. Often other factors such as weathering and sprouting are also associated with mildewed samples. Although grain containing mildewed kernels is degraded depending on the incidence and severity of the damage, we are aware of no published information on the effect of mildewed kernels on durum wheat quality.

Ergot is a fungus, *Claviceps purpurea,* that grows parasitically on a wide variety of cereal crops and grasses. Although most often associated with rye, ergot occasionally can become a serious problem in durum wheat. The fungus produces sclerotia or "ergot bodies," which contain chemicals including alkaloids that are highly toxic (Young 1980). Ergot infection occurs during the flowering stage. The ergot body grows in place of the kernel and at harvest is collected with the crop. Because they are nearly the same size and as normal kernels, ergot bodies are difficult to clean out. Although ergot bodies are easily recognizable by their dark outer covering, they are less obvious when ground into feed or flour. Shuey et al (1973, 1975) have reported on the effect of ergot on the milling and baking properties of common wheats, but no published information is currently available on the effect of ergot on durum wheat quality.

In this investigation, we attempted to determine the type of quality effects associated with smudged, mildewed, and ergotic durum wheat. A series of samples from the 1979 and 1980 Canadian durum wheat crops were handpicked to achieve a series of samples with various degrees of damage. The effects of each degrading factor on wheat, semolina, and spaghetti characteristics were assessed.

MATERIALS AND METHODS

Sample Preparation

To determine the effect of smudged and mildewed kernels on durum wheat quality, samples were prepared such that quality differences could be attributed to the degrading factors rather than to environmental or varietal effects. Envelope samples from the 1979 and 1980 Canadian durum wheat crop survey were segregated according to the predominant degrading factor. For each degrading factor, each envelope sample was handpicked to yield two samples of equal weight: a control essentially free of the degrading factor and a sample enriched in the degrading factor. About 20 controls and corresponding enriched samples were bulked to make up a series of composite samples weighing at least 600 g each.

To determine the effect of ergot on durum wheat quality, a large ergot-free farm sample was blended in various proportions with ergot bodies that had been handpicked from ergotic durum wheat samples by the Grain Inspection Division of the Canadian Grain Commission.

Grading

Each composite was graded by the Grain Inspection Division according to the Official Grain Grading Guide (Canadian Grain Commission 1980). Where possible, the extent of the predominant degrading factor was quantitated.

Table I lists the quality tolerances for the grades of Canada Western (CW) amber durum wheat pertinent to the current study. Weight per hectoliter was determined with an Ohaus 0.5-L measure and cox funnel (standard deviation, based on 10 single determinations of a representative sample, was 0.11 kg). Hectoliter weight, gives a general indication of the soundness of the wheat.

Definite tolerances for smudge and blackpoint are specified for the top three grades of Canadian amber durum wheat (Table I). However, tolerance for blackpoint may be increased or reduced in the judgment of the inspector according to the severity of the stain and in consideration of the overall visual quality of the sample. Separate strict tolerances are maintained for red smudge because some importers of Canadian durum wheat are concerned about *Fusarium* mycotoxin. However, so far as we are aware, *Fusarium* mycotoxin has never been detected in significant levels on Canadian durum wheat or any other grain grown in Western Canada.

Assessment of mildew damage is fairly subjective, based on the judgment of an experienced inspector, and no definite tolerances have been established. Samples containing mildewed kernels will be degraded depending on the incidence and severity of the mildew on otherwise sound kernels. For kernels that are severely mildewed, ie, blackened throughout, the tolerances for "severely binburnt" kernels are applied (Table I).

[1]Paper 481 of the Canadian Grain Commission, Grain Research Laboratory Division, Winnipeg, Manitoba, R3C 3G9.
[2]Unpublished data.

0009-0352/82/01006307/$03.00/0

Maximum tolerances of ergot are expressed on the basis of kernel-size pieces in 500 g, except grade 5 CW amber durum, for which the maximum allowed is 0.25% (Table I). Samples containing ergot in excess of 0.25% are degraded to sample grade. Such samples are normally blended off with essentially ergot-free samples, usually at the country elevator level, although occasionally ergotic grain is received at terminal elevators.

Wheat and Semolina

Kernel weights (SD = 0.96 g) were determined by counting 1,000 unbroken kernels on a kernel counter (Labtronics Manufacturing, Winnipeg, Canada) in duplicate. Ash (SD = 0.012%) and yellow pigment contents (SD = 0.16 ppm) were performed as described by Dexter and Matsuo (1978). Protein contents (SD = 0.16%) were determined in triplicate by the Kjeldahl method (N $\times$ 5.7) as modified by Williams (1973). Gluten strength was estimated in duplicate on ground whole wheat by the sodium dodecyl sulfate (SDS)-sedimentation test (SD = 1.1 ml) of Axford et al (1979). α-Amylase activity (SD = 5 iodine-dextrin color units per gram) was determined in triplicate by the method of Briggs (1963) as modified by MacGregor et al (1971).

Each composite sample was milled in a three-stand Allis-Chalmers laboratory mill as described by Matsuo and Dexter (1980a). Milling yield (SD = 0.42%) was based on recovery of granulars (semolina and clear flour), but for simplicity the product is referred to as semolina. Dark specks (SD = 5.9 specks per 250 cm^2) were measured in duplicate by pouring semolina between two sealed glass plates and counting the number of dark specks in a 250-cm^2 area. Light bran specks that would not be conspicuous in the spaghetti were not counted. Semolina particle size distribution (SD = 0.5% for each fraction) was determined as described by Matsuo and Dexter (1980a).

Pasta dough mixing properties were determined in a Brabender farinograph (C. W. Brabender Instruments, South Hackensack, NJ) at 31.5% absorption in a 50-g bowl, using the rear sensitivity (1:5) setting. Mixing time (SD = 0.29 min) is the time to reach peak consistency; tolerance index (SD = 4.8 BU) is the decrease in consistency 4 min past the peak; and band width (SD = 4.7 BU) is the width of the curve 4 min past the peak.

Amylograph peak viscosities (SD = 20 BU) were determined in a Brabender amylograph on 65 g of semolina in 450 ml of water. When peak viscosity was reached, the run was terminated.

Spaghetti

Spaghetti samples were processed by a micromacaroni method (Matsuo et al 1972). Pigment loss (SD = 2.5%) was computed from the yellow pigment content of the dried spaghetti compared to that of the semolina on a constant moisture basis. Spaghetti color was determined on whole strands of spaghetti in a Beckman Color DB-G spectrophotometer (Beckman Instruments, Inc., Fullerton, CA). Dominant wavelength (SD = 0.11 nm), purity (SD = 0.04%), and brightness (SD = 0.13%) were determined by the 10 selected ordinates method of Hardy (1936) as modified by Daun (1978). Dominant wavelength is the wavelength of the pure spectrum color that, in combination with a tungsten lamp source, produces the color. The desirable color for pasta products, amber yellow, is characterized by a dominant wavelength of about 577 nm; brownish pasta is characterized by a dominant wavelength greater than 578 nm. Brightness is a measure of the amount of light reflected by a sample relative to the amount of light reflected by a near-perfect white surface. Purity is an indication of color intensity and thus is related to pigment content.

Spaghetti was cooked as described previously (Dexter and Matsuo 1977), and cooked spaghetti texture was determined on the Grain Research Laboratory spaghetti tenderness apparatus (Matsuo and Irvine 1969, 1971) at optimal time (12 min) and after overcooking for 10 min. Tenderness index (SD = 1.4×10^{-3} mm/sec) indicates firmness, whereas compressibility (SD = 3.5%) and recovery (SD = 2.9%) indicate elasticity. These variables may be combined into a cooking score (SD = 1.8×10^3 sec/mm) by finding the ratio of recovery to the product of compressibility and tenderness index. Elasticity of overcooked spaghetti was derived using a lighter compression weight than for optimally cooked spaghetti because many of the overcooked samples were completely compressed and exhibited no recovery under the heavier weight.

RESULTS AND DISCUSSION

Smudge and Blackpoint

Five pairs of controls and smudge-enriched samples were prepared (Table II). The fifth smudge-enriched sample contained only red smudge, whereas the other smudge-enriched samples were visually free of red smudge. The difference in grade between each pair of samples was entirely due to smudge and/or blackpoint.

Test weight was not affected greatly by smudge (Table II). This was true even for the fourth pair of samples, in which about 85% of the kernels were infected to some extent in the smudge-enriched sample. Kernel weight also was not affected greatly. Some workers have previously reported that smudged wheat kernels are larger than healthy kernels (Machacek and Greaney 1938, Waldron 1934), whereas others have reported a decrease in kernel size due to smudge and blackpoint (Huguelot and Reisling 1973, Russell 1943), particularly when infection was due to *H. sativum*. Russell (1943) suggested that the stage of kernel ripeness at the time of infection may explain this apparent discrepancy. Waldron (1934) stated that at least part of the weight difference he observed could be attributed to the fact that heavy midspike kernels have a greater tendency to become infected than do kernels in other spike positions. Huguelet and Kiesling (1973), who observed a decrease in kernel size with blackpoint infection in greenhouse tests, pointed out that, in the field, the wet conditions under which blackpoint is usually severe also afford favorable growing conditions for the host and may result in the production of large kernels.

Test weight and kernel weight are two of the most important factors determining durum wheat milling yield (Matsuo and Dexter 1980b). Because test weight and kernel weight were not affected to any great extent, the absence of any pronounced effect of smudge on milling yield was to be expected (Table II).

Wheat protein and ash were not influenced greatly by smudge (Table II). Although protein and ash in the smudged samples appeared slightly higher, in many cases the differences were insignificant. Similarly, wheat yellow pigment remained unchanged by smudge (results not shown).

TABLE I
Quality Tolerances for Hectoliter Weight, Smudge and Blackpoint, Severely Binburnt Kernels, and Ergot Bodies for Canada Western (CW) Amber Durum Wheat Grades[a]

Grade	Minimum Hectoliter Weight (kg)	Smudge: Penetrated	Smudge: Red	Smudge: Total Including Penetrated	Total Including Blackpoint	Binburnt Kernels	Ergot Bodies
1 CW	80	3K	30K	30K	10%	2K	3K
2 CW	78	0.5%	1%	1%	15%	4K	6K
3 CW	76	1.0%	1.5%	3%	35%	6K	12K
4 CW	71	AP	AP	AP	AP	2%	24K
5 CW	NL	AP	AP	AP	AP	10%	0.25%

[a] AP = no limit but overall appearance is considered, K = kernels or kernel-size pieces in 500 g. NL = no limit.

The SDS-sedimentation volumes were not affected by smudge (results not shown). The SDS-sedimentation test is an excellent predictor of gluten strength (Dexter et al 1980). Therefore these data suggested that gluten properties were not affected adversely by smudge and blackpoint.

In all but one case, the smudged wheat samples exhibited more α-amylase activity than did the respective controls (Table II). The tendency toward higher amylase activity in smudged samples probably reflects the prevalence of smudge in wet conditions, which might also cause some sprouting. Retention of wheat α-amylase in durum wheat semolina can vary from 20 to 70%.[2] Nevertheless, semolina amylograph peak viscosity results confirmed the tendency for increased amylolytic activity in the presence of smudge (Table III). These data offer an explanation for the increased tolerance index and reduced band width observed for each smudged pasta dough (Table III) except the red smudge-enriched sample. Increased tolerance index suggests that the water retention ability of the dough may be lessened, and decreased band width reflects an increase in dough stickiness. Damage to starch resulting from amylolytic activity is a possible cause for both effects. Farinograph mixing time, a measure of the rate of water uptake, was not affected significantly. This was consistent with the observation that semolina granulation, which has a strong influence on farinograph mixing time (Dexter and Matsuo 1978), was not influenced by smudge and blackpoint (results not shown).

With the exception of the red smudge-enriched sample, the smudged semolina samples tended to have a slightly higher protein content (Table III). Although the increased protein could be a result of nitrogen contributed by smudge, it likely reflects an environment conducive to smudge infection. Based on wheat protein data (Table II), the higher protein levels in smudged semolina appear to be related to lower protein loss during milling as well as to differences in wheat protein. We were not able to establish a definite effect of smudge on semolina yellow pigment (results not shown) or ash (Table III). However, except for that of the red smudge-enriched sample, semolina speckiness substantially increased (Table III). Because a low speck count is normally mandatory for top-quality semolina, the importance of increased speckiness in the smudged semolina should not be underestimated.

Spaghetti color characteristics appeared to be slightly influenced by smudge and blackpoint (Table IV). The smudged samples seemed to have a slightly lower color intensity, as measured by purity, although in most cases differences in spaghetti yellow pigment and pigment loss were not significant. Some of the

TABLE II
Effect of Smudge and Blackpoint on Durum Wheat Properties

Sample	Grade[a]	Smudge (%)	Blackpoint (%)	Test Weight (kg/hl)	1,000-Kernel Weight[b] (g)	Protein[b,c] (%)	Ash[b] (%)	α-Amylase Activity (IDC[d] units per gram)	Milling Yield (%)
Control I	2 CW	0	0	83.2	42.7	13.3	1.54	45	69.1
Smudged I	3 CW	2	4	83.0	44.1	13.5	1.54	75	69.0
Control II	2 CW	0	0	83.9	44.8	13.3	1.47	35	68.7
Smudged II	4 CW	3	7	83.0	43.7	13.5	1.52	55	69.1
Control III	1 CW	0	0	83.5	43.6	13.3	1.55	45	69.5
Smudged III	3 CW	3	8	83.2	44.5	13.5	1.58	43	68.3
Control IV	2 CW	0	0	84.5	50.3	14.0	1.74	23	71.5
Smudged IV	5 CW	20	65	83.2	51.2	14.5	1.76	218	70.2
Control V	1 CW	0	0	84.8	43.2	13.9	1.56	38	70.8
Red smudge V[e]	4 CW	10	0	84.8	44.7	14.0	1.59	74	69.9

[a] CW = Canada Western.
[b] Expressed on a 14% moisture basis.
[c] N × 5.7.
[d] Iodine-dextrin color.
[e] This sample contained red smudge only. Other smudged samples were essentially free of red kernels.

TABLE III
Effect of Smudge and Blackpoint on Durum Wheat Semolina Properties

Sample	Protein[a,b] (%)	Ash[a] (%)	Farinograph: Mixing Time (min)	Farinograph: Tolerance Index (BU)	Farinograph: Band Width (BU)	Black Specks (per 250 cm²)	Amylograph Viscosity (BU)
Control I	12.7	0.71	4.75	70	120	81	210
Smudged I	12.9	0.73	4.5	90	80	120	80
Control II	12.6	0.68	5	80	80	55	375
Smudged II	13.0	0.70	5	100	70	124	175
Control III	12.5	0.71	5	60	100	48	355
Smudged III	12.9	0.71	4.75	100	70	79	215
Control IV	13.7	0.73	4	60	120	104	210
Smudged IV	13.9	0.73	4	90	80	208	0
Control V	13.4	0.69	3.5	100	60	101	260
Red smudge V[c]	13.4	0.68	3.75	100	70	119	160

[a] Expressed on a 14% mositure basis.
[b] N × 5.7.
[c] This sample contained red smudge only. Other smudged samples were essentially free of red kernels.

smudged samples were slightly duller (lower brightness) and slightly browner (longer dominant wavelength) than their respective controls. One of the samples contained 85% smudged or blackpointed kernels, and therefore we were somewhat surprised that a greater effect on color was not observed. Harris and Sibbitt (1942) reported that as little as 5% heavily smudged kernels seriously lowered macaroni color scores. However, they also found that color and speck count were not seriously affected by up to 50% light smudge.

Spaghetti cooking quality was not related to smudge damage (Table IV). In every case the elasticity and firmness of smudge-enriched cooked spaghetti were not significantly different from those of their respective controls. Based on previous studies on the effect of sprouting on spaghetti quality (Dick et al 1974, Donnelly 1980), the increased levels of amylolytic activity in the smudged-enriched samples (Tables II and III) were not expected to significantly alter spaghetti cooking quality.

Mildew

Three pairs of controls and mildew-enriched samples were prepared (Table V). Each pair exhibited a two-grade difference based solely on the presence and degree of damage from mildewed kernels. Degrading of samples because of mildew is subjective and normally very difficult to quantitate. However, based on visual assessment, mildewed II (a "good" 3 CW) did not contain as many severely damaged kernels as mildewed I and mildewed III (each a "poor" 3 CW).

Despite a significantly larger kernel weight, the mildewed samples were significantly lower in test weight than their respective controls (Table V). This was somewhat surprising because a positive correlation between test weight and kernel weight would normally be anticipated (Matsuo and Dexter 1980b). However, as pointed out by Hlynka and Bushuk (1959), other factors such as heterogeneity of kernel size, density, and packing factor sometimes outweigh kernel weight in determining test weight.

Wheat ash levels did not appear to be related to mildew damage (Table V). Similarly, gluten properties, as measured by the SDS-sedimentation test, were not affected (results not shown). However, all mildewed samples tended to have significantly increased protein levels and α-amylase activities and significantly lower pigment contents (Table V). The reason for most of these trends is not clear. Perhaps they are related to environmental conditions promoting mildew infection and/or a greater tendency for heavier midspike kernels to become infected, as postulated by Waldron (1934) in the case of blackpoint and smudge infection. The mildew may also contribute significantly to wheat nitrogen content. Certainly the cool damp conditions conducive to mildew damage would be expected to promote sprouting, resulting in the increase in the α-amylase observed for all the mildewed samples.

No effect on milling yield was found for any of the mildewed samples (Table V). This was anticipated because any negative effect on milling yield due to the slight decrease in test weight of the

TABLE IV
Effect of Smudge and Blackpoint on Durum Wheat Spaghetti Characteristics

			Color			Cooking Quality[b]				Overcooking Quality[b]			
Sample	Yellow Pigment[a] (ppm)	Pigment Loss (%)	Brightness (%)	Purity (%)	Dominant Wavelength (nm)	C (%)	R (%)	TI (mm/sec × 10^{-3})	Score[c]	C (%)	R (%)	TI (mm/sec × 10^{-3})	Score[c]
Control I	4.20	24.2	46.8	57.4	577.6	74	34	39	12	68	44	58	11
Smudged I	4.06	25.5	46.2	56.7	577.7	71	35	41	12	72	46	61	9
Control II	4.14	28.6	47.1	57.7	577.6	71	35	40	12	68	46	50	13
Smudged II	3.98	29.6	44.3	56.4	577.9	71	31	38	12	69	45	52	12
Control III	3.95	30.6	45.4	57.9	578.0	73	33	38	12	72	38	51	10
Smudged III	3.93	29.9	45.1	57.0	578.0	75	29	43	9	72	38	52	10
Control IV	4.20	23.8	45.7	58.1	577.7	66	44	37	18	67	40	57	10
Smudged IV	4.09	26.6	42.1	57.1	578.1	66	45	34	20	64	48	53	14
Control V	4.93	22.7	46.4	61.2	577.7	68	43	37	17	72	40	61	9
Red smudge V[d]	4.88	23.6	46.3	60.7	577.9	69	39	37	15	68	43	58	11

[a] Expressed on a 14% moisture basis.
[b] C = compressibility, R = recovery, TI = tenderness index.
[c] Score = R/(C × TI).
[d] This sample contained red smudge only. Other smudged samples were essentially free of red kernels.

TABLE V
Effect of Mildewed Kernels on Durum Wheat Characteristics

Sample	Grade[a]	Degree of Damage	Test Weight (kg/hl)	1,000-Kernel Weight[d] (g)	Protein[b,c] (%)	Ash[b] (%)	Yellow Pigment[b] (ppm)	α-Amylase Activity (IDC[d] units per gram)	Milling Yield (%)
Control I	1 CW	Trace	83.0	43.8	13.7	1.49	6.80	61	69.6
Mildewed I	3 CW	Light to severe	82.5	48.3	14.3	1.54	6.63	122	69.5
Control II	1 CW	Trace	83.0	44.4	14.2	1.54	7.00	69	68.9
Mildewed II	3 CW	Light to fairly heavy	82.0	48.3	14.5	1.55	6.64	143	69.3
Control III	1 CW	Trace	83.0	44.3	13.8	1.55	6.83	75	69.2
Mildewed III	3 CW	Light to severe	82.7	48.0	14.2	1.52	6.43	107	69.9

[a] CW = Canada Western.
[b] Expressed on a 14% moisture basis.
[c] N × 5.7.
[d] Iodine-dextrin color.

mildewed samples would be offset by their greater kernel weight (Matsuo and Dexter 1980b).

Table VI shows the effect of mildewed kernels on semolina characteristics. No definite trend could be established between mildew and semolina ash, but significantly higher protein and significantly lower pigment content and amylograph viscosity were found for each mildewed sample. These results were exactly as would be predicted from the wheat ash, protein, pigment, and α-amylase activity data (Table V).

Semolina granulation was not influenced by the presence of mildewed kernels (results not shown), but each mildewed sample had definitely weaker pasta dough mixing properties (Table VI). As seen in Table III for smudged samples, each mildewed semolina exhibited a greater tolerance index (more dough breakdown) and a narrower band width (stickier dough) than the corresponding control (Table VI), possibly because of enhanced α-amylase activity in the mildewed samples. In contrast to the smudged samples, the mildewed samples exhibited significantly shorter pasta dough mixing times than their respective controls did. This is probably a result of the slightly higher protein content of the mildewed semolina samples (Table VI) compared to that of their respective controls (Dexter and Matsuo 1977), although the possibility remains that enhanced enzymatic activity associated with mildewed samples also may be partly responsible.

In each case, the mildewed samples tended to yield undesirably high speck counts (Table VI). This was particularly true of mildewed I and mildewed III, presumably because they contained a greater proportion of severely damaged kernels (Table V).

No evidence was found of a significant effect by mildew damage on spaghetti cooking quality either at optimum cooking time or at

TABLE VI
Effect of Mildewed Kernels on Durum Wheat Semolina Characteristics

Sample	Protein[a,b] (%)	Ash[a] (%)	Yellow Pigment[a] (ppm)	Farinograph Mix Time (min)	Farinograph Tolerance Index (BU)	Farinograph Band Width (BU)	Black Specks (per 250 cm²)	Amylograph Viscosity (BU)
Control I	13.2	0.69	6.07	5.5	50	115	47	130
Mildewed I	13.6	0.70	5.83	5	70	90	117	100
Control II	13.3	0.72	6.19	5.75	40	120	65	170
Mildewed II	13.9	0.74	5.93	5.5	60	95	83	70
Control III	13.2	0.69	6.13	5.5	50	105	37	230
Mildewed III	13.6	0.69	5.91	4.75	80	95	105	125

[a] Expressed on a 14% moisture basis.
[b] N × 5.7.

TABLE VII
Effect of Mildewed Kernels on Durum Wheat Spaghetti Characteristics

Sample	Yellow Pigment[a] (ppm)	Pigment Loss (%)	Color: Brightness (%)	Color: Purity (%)	Color: Dominant Wavelength (nm)	Cooking Quality[b]: C (%)	Cooking Quality[b]: R (%)	Cooking Quality[b]: TI (mm/sec × 10⁻³)	Cooking Quality[b]: Score[c]	Overcooking Quality[b]: C (%)	Overcooking Quality[b]: R (%)	Overcooking Quality[b]: TI (mm/sec × 10⁻³)	Overcooking Quality[b]: Score[c]
Control I	4.41	27.3	44.9	60.0	577.8	70	38	36	15	68	44	51	13
Mildewed I	4.14	29.0	43.7	58.8	577.9	66	42	36	18	64	50	47	17
Control II	4.47	27.8	45.6	60.0	577.8	66	42	34	19	65	45	48	14
Mildewed II	3.99	32.7	43.2	57.5	578.0	66	44	34	20	67	43	45	14
Control III	4.56	25.6	45.6	60.2	577.8	67	40	33	18	68	46	46	15
Mildewed III	4.33	26.7	43.3	59.0	577.9	70	40	36	16	63	52	48	17

[a] Expressed on a 14% moisture basis.
[b] C = compressibility, R = recovery, TI = tenderness index.
[c] Score = R/(C × TI).

TABLE VIII
Effect of Added Ergot on Durum Wheat and Semolina Characteristics

Sample	Grade[a]	Ergot Level[b]	Wheat: Test Weight (kg/hl)	Wheat: Protein[c,d] (%)	Wheat: Ash[c] (%)	Wheat: Milling Yield (%)	Semolina: Protein[c,d] (%)	Semolina: Ash[c] (%)	Semolina: Black Specks (per 250 cm²)
Control	1 CW	0	83.5	12.8	1.51	70.2	12.2	0.68	42
Ergot									
I	3 CW	11K	83.2	12.9	1.51	70.4	12.5	0.70	69
II	4 CW	22K	83.5	13.1	1.52	69.6	12.4	0.67	122
III	5 CW	0.25%	83.6	13.2	1.52	70.8	12.3	0.71	159
IV	sample	0.5%	83.4	13.0	1.54	70.4	12.6	0.71	218
V	sample	1.0%	83.1	13.2	1.53	70.0	12.6	0.70	320
VI	sample	2.0%	83.0	13.3	1.53	69.9	12.7	0.73	559
VII	sample	5.0%	82.1	13.4	1.58	68.0	12.7	0.75	1,000

[a] CW = Canada Western.
[b] K = kernel-size pieces in 500 g.
[c] Expressed on a 14% moisture basis.
[d] N × 5.7.

TABLE IX
Effect of Added Ergot on Spaghetti Characteristics

Sample	Color			Cooking Quality[a]				Overcooking Quality[a]			
	Brightness (%)	Purity (%)	Dominant Wavelength (nm)	C (%)	R (%)	TI (mm/sec $\times 10^{-3}$)	Score[b]	C (%)	R (%)	TI (mn/sec $\times 10^{-3}$)	Score[b]
Control	43.2	53.4	578.0	72	32	44	10	72	44	54	11
Ergot											
I	43.4	54.0	578.0	72	30	47	9	73	41	61	9
II	43.6	54.5	578.0	75	28	46	8	71	39	60	9
III	41.2	52.5	578.3	73	32	39	11	68	43	54	12
IV	40.4	52.3	578.5	71	38	40	13	70	40	58	10
V	37.4	50.7	578.9	73	36	44	11	70	40	60	10
VI	31.8	47.6	579.9	73	36	44	11	69	42	59	10
VII	22.7	41.0	582.0	75	31	48	9	70	44	60	11

[a] C = compressibility, R = recovery, TI = tenderness index.
[b] Score = R/(C × TI).

10 min beyond optimum time (Table VII), a result similar to that observed for the smudged series (Table IV).

Mildew appeared to influence spaghetti color in a manner similar to that of smudge, although the effect of mildew on spaghetti pigment and brightness was somewhat greater. Spaghetti from the mildewed samples (Table VII) was significantly duller (low brightness) and also lower in yellow pigment content, which resulted in less intense spaghetti color (lower purity). The lower pigment level in the mildewed spaghetti was probably the result mainly of lower pigment in the semolina (Table VI). Although pigment loss was higher during processing for the mildewed samples (Table VII), in all but one case the difference was not significant. Similarly, although each mildewed spaghetti appeared to be slightly browner (longer dominant wavelength) than the corresponding control, the differences were not significant.

Ergot

The effect of ergot bodies on durum wheat and semolina characteristics is shown in Table VIII. The most obvious effect was an increase in protein content as the level of ergot increased. This was consistent with a report by Pomeranz et al (1975) that ergot bodies tended to be higher in nitrogen than cereals were, although a large proportion of ergot nitrogen was nonprotein nitrogen. Test weight, wheat ash, and milling yield were not greatly affected by ergot until levels in excess of 2% were present, far in excess of the levels normally encountered commercially. This was in agreement with a report by Shuey et al (1975) on the effect of ergot on hard red spring wheat properties.

The presence of ergot had no influence on semolina granulation (results not shown). This was somewhat surprising because Shuey et al (1975) pointed out that the ergot bodies had a padding effect that minimized the grinding action on endosperm chunks between rolls for hard red spring wheat. No effect on pasta dough properties could be detected at any of the levels of ergot contamination (results not shown).

As would be anticipated from the wheat ash data, semolina ash remained relatively unaffected for levels of ergot contamination below 2% (Table VIII). With increased ergot levels, semolina protein showed a steady increase similar to the effect observed on the wheat, demonstrating that a considerable proportion of ergot found its way into the final milled product.

Because of its dark color, ergot had a pronounced effect on semolina speckiness (Table VIII); a level of 0.25% resulted in a fourfold increase. Examination of the color characteristics of spaghetti (Table IX) showed that ergot levels of 0.25% (as found in sample ergot III) or greater had a significant deleterious effect on brightness and color hue (longer dominant wavelength). Those samples containing large amounts of ergot assumed a "muddy" complexion, resulting in greatly reduced color intensity (lower purity). Yellow pigment levels and pigment loss were not determined because interference by compounds in the ergot made the results meaningless.

Ergot did not appear to have an effect on spaghetti cooking quality (Table IX). Even at a level of 5% added ergot (ergot VII), cooking quality was indistinguishable from that of the control. However, at levels of 0.25% (ergot III) and greater, the cooking water began to become highly colored from ergot contamination.

These results demonstrate that, except for an increase in speckiness, within the amount (24 kernels per 500 g) legally allowed for even the fourth grade of Canadian durum wheat (Table I), ergot exerted very little effect on durum wheat end-use quality. In addition, we had made no attempt to clean the ergot out of the wheat. Ergot is difficult to remove from durum wheat on the basis of size. However, because of its low specific weight, up to 95% of ergot can be removed with the screenings by means of modern cleaning equipment (Lippuner 1978). Thus, under commercial milling conditions, the effects of ergot would be expected to be even less than those observed in the current study.

ACKNOWLEDGMENTS

We thank E. L. Seguin and P. Edwards for their helpful advice during sample preparation and for grading the samples. The technical assistance of R. W. Daniel, J. W. Bradley, B. C. Morgan, and J. J. Lachance is gratefully acknowledged.

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[Received May 11, 1981. Accepted September 11, 1981]