Effect of Sprout Damage on Durum Wheat and Spaghetti Quality[1]

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ABSTRACT

The falling number test is highly correlated to durum wheat α-amylase activity and is a good indicator of sprout damage in durum wheat. The critical factor affecting end-use quality is the level of α-amylase in the processed product. High amylolytic activity in spaghetti increases the amount of residue in the cooking water and the level of reducing sugars in both semolina and spaghetti and tends to give a slightly softer cooked spaghetti. Semolina proteins do not appear to be affected by field sprouting, as shown by a modified Osborne protein fractionation procedure and by gel filtration of acetic acid extracts. Semolina yield and spaghetti color are not affected by sprout damage.

Sprout damage in bread wheats has a marked influence on bread-making quality (Tipples et al 1966). The deleterious effects have been attributed to high levels of α-amylase. In their study of Japanese noodles, Bean et al (1974) found that sprout-damaged wheat caused stickiness in noodle doughs and stretching and breaking of the noodles during drying. Previous studies have not conclusively demonstrated whether sprout damage in durum wheat has a significant effect on pasta quality. Harris et al (1943) suggested that blight and similar forms of damage are more injurious to durum quality than is sprout damage. The Grain Research Laboratory (1944) investigated sprout damage on the quality of durum wheat and their findings concurred with Harris's. Dick et al (1974) reported that semolina milling yield and overall spaghetti quality were not significantly altered by sprouting, even when the falling number (FN) test indicated extensive sprout damage. Donnelly's (1980) results agreed with those of Dick et al (1974), but he did find that sprout damage adversely affected semolina speck count and spaghetti shelf stability. He concluded that "sprout damage levels higher than 4.0% or falling number values less than 120 can be expected to provide pasta products with a high potential for checking and cracking upon storage".

According to Maier (1980), sprout damage, even at the 1% level, can adversely affect the quality of durum products. He stated that sprout-damaged durum loses much of its elasticity in the dough; long goods break apart in the drying process and lack "al dente," or firmness, when cooked.

Kruger and Matsuo (1982) found that high amylolytic activity increases the amount of cooking water residue and the level of reducing sugars in laboratory-germinated samples of durum wheat. However, because germination under controlled conditions in the laboratory can be quite different from that in the field, a study was undertaken to investigate the effects of field sprouting on durum wheat spaghetti-making quality.

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MATERIALS AND METHODS

Approximately 50 samples with varying levels of sprout damage were obtained from new crop surveys from the past several years as well as from carlots unloaded at terminal elevators. Pure varieties with sprout damage ranging from 6 to 15% grown at one station were also studied. Sound samples served as controls.

In the Inspection Manual of the Canadian Grain Commission (Canadian Grain Commission 1980), sprouted kernels are defined as follows: "Kernels will be classed as sprouted when there is a clear evidence of growth in the germ area; the bran is noticeably split over the germ from apparent growth; the germ is removed and there is apparent discoloration normally attributable to sprouting; and to kernels with distinctly swollen germs caused by growth action even though the germ is intact. Kernels with slightly swollen germs or with the bran split with no apparent sprouting activity are not considered sprouted."

Milling

Samples were tempered overnight and milled at 16.5% moisture in an Allis-Chalmers laboratory mill in conjuction with a small-scale purifier (Black 1966). The mill room was controlled for temperature (22° C) and humidity (60% rh).

Physical Tests

Farinograms were obtained as described by Irvine et al (1961) at an absorption of 31.5% (14% moisture basis). FN (S.D. = 6.2) was determined on a 7-g sample of ground wheat by the method of Hagberg (1961) with modification in sample size as recommended by Tipples (1971). A sodium dodecyl sulfate (SDS)-sedimentation test (S.D. = 1.11) was performed as described by Axford et al (1978).

Sphaghetti Processing

Samples were processed into spaghetti by a micro process (Matsuo et al 1972). Samples were dried at 39° C with decreasing relative humidity over 28 hr (Dexter et al 1981b).

TABLE I
Description of Damage for One Series of Samples and Analytical Data

Sample	Grade	Damage[a]	Wheat Protein (%)	Wheat Ash (%)	1,000-Kernel Weight (g)	SDS Sedimentations Volume (ml)	Vitreous Kernels (%)	Test Weight (kg/hl)	Semolina Yield (%)	Semolina Protein (%)	Falling Number (sec)
Control	1		13.7	1.48	44.0	38.5	94.0	81.8	69.8	12.8	360
1	2	1.3% SP, 1%MIL	13.2	1.49	46.0	36.0	70.0	81.8	70.9	12.4	251
2	2	1.3% SP, 2%MIL	15.4	1.62	38.2	48.0	65.0	81.0	68.5	14.6	174
3	2	2.2% SP, 8% MIL, 6% FR	14.3	1.38	41.6	49.0	60.0	80.0	68.6	13.2	216
4	2	3.5% SP, 16%MIL	15.3	1.56	41.4	50.0	60.0	80.9	68.9	14.3	116
5	3	3.5% SP, 8% MIL, 2% SM 2% BP	13.5	1.81	40.0	42.0	40.0	78.8	67.8	12.5	196
6	3	6.2% SP, 7% MIL, 2%FR	14.2	1.58	46.3	34.0	42.0	81.0	68.2	13.1	128
7	3	6.7% SP, 5% MIL, 18% FR 12% GR	13.3	1.41	41.9	38.5	50.0	80.0	66.5	12.3	109
8	3	7.0% SP,13% MIL, 1% SM	14.9	1.63	40.6	46.0	50.0	80.1	67.8	14.1	179
9	4	2.8% SP,31% MIL, 10% FR	12.0	1.51	45.0	41.0	18.0	80.0	67.8	11.3	96
10	4	4.0% SP,39% MIL, 15% FR	12.2	1.86	43.2	35.0	22.0	78.0	66.1	11.2	97
11	4	6.6% SP,14% MIL, 17% FR 1.5%SM	12.6	1.47	46.0	30.0	40.0	82.0	67.6	11.8	94
12	4	10.4%SP, 38% MIL, 6% FR	12.0	1.51	45.3	43.0	12.0	80.3	67.7	11.2	101
13	4	10.5%SP, 54% MIL, 26% FR	12.7	1.44	46.3	34.0	5.0	76.8	65.6	11.5	80
14	4	12.0%SP, 46% MIL, 22% FR	10.6	1.56	45.9	28.5	8.0	79.9	67.1	9.8	124

[a]SP = sprout; MIL = mildew; FR = frost, SM = smudge; BP = black point; and GR = green.

Spaghetti Quality

Spaghetti color was determined on whole strands of spaghetti mounted on white cardboard, and reflectance was measured with a Beckman Color DBG spectrophotometer (Beckman Instruments, Inc., Fullerton, CA) as described by Dexter and Matsuo (1977a). Dominant wavelength (S.D. = 0.11), brightness (S.D. = 0.13), and purity (S.D. = 0.40) were determined by the ten selected ordinates method (Hardy 1936).

The cooking quality of spaghetti was determined as described by Matsuo and Irvine (1969, 1971). Tenderness index (S.D. = 1.4) is a measure of the shear rate; compressibility (S.D. = 3.5) a measure of the deformation under constant load; and recovery (S.D. = 2.9) a measure of the resilience. Residue in the cooking water, ie, cooking loss (S.D. = 0.4), was determined as previously described (Dexter and Matsuo 1979a).

Fractionation of Semolina Proteins

The proteins from twelve sprouted and several sound samples were quantitatively fractionated according to their solubilities by the modified Osborne method of Chen and Bushuk (1970). The nitrogen content of the soluble fractions was determined colorimetrically (Williams 1964), and that of the insoluble fraction by the Kjeldahl method (N × 5.7) as modified by Williams (1973). Total recoveries of semolina nitrogen ranged from 95 to 99%. Reproducibility of duplicate determinations was about 5% for all protein solubility fractions.

Gel Filtration

Gel filtration of 0.05 *M* acetic acid extracts of semolina proteins was performed on a 2.5 × 29-cm bed of Sephadex G150 with an upward flow rate of 7 ml/hr as described by Dexter and Matsuo (1979b).

Alpha-Amylase Activity

α-Amylase activity was assayed by the method of Briggs (1963) as modified by MacGregor et al (1971). Results are expressed in iodine-dextrin color (IDC) units per gram of sample. Reproducibility of the assay is about 5%.

Reducing Sugars

For reducing-sugar determination, 5 ml of 95% ethanol was added to 500 mg of finely ground sample and immersed in a boiling water bath for 5 min to eliminate amylolytic activity. Twenty ml of distilled water was then added and the sample extracted on a rotating wheel (60 rpm) for 1 hr. After centrifugation, the supernatant solution was diluted 1:10 with distilled water, and the reducing sugar content was determined by the method of Dygert et al (1965). Results on duplicate determinations are reported as milligrams of maltose per gram of sample (S.D. = 0.8 mg/g).

TABLE II
Falling Number and α-Amylase Activity of Hand-Picked Sprouted and Sound Durum Wheats

Sample	Falling Number (sec)	α-Amylase Activity[a]
Undamaged, sound, control	425	75
Natural, 5% sprout (visual)	121	1,248
Undamaged, sound, segregated from natural sample	249	315
Sprung, slightly swollen germ, not classed as sprouted	100	1,637
Sprouted	60	9,599

[a]Expressed in iodine - dextrin units per gram of sample.

RESULTS

Characteristics related to sprout damage of one series of wheat samples investigated are presented in Table I. The levels of sprout-damaged kernels allowed in Canadian Western Amber Durum (CWAD) grades are 1% in 1 CWAD, 5% in 2 CWAD, 8% in 3 CWAD, and 12% in 4 CWAD.

Wheat protein content, ash content, 1,000-kernel weight, and test weight fall in the range that is normal for Western Canada. Both vitreous kernel content and semolina yield decrease with the severity of the damage. SDS-sedimentation volume, a measure of protein quality (Dexter et al 1980a), does not appear to be affected by sprout damage. For the samples in Table I, the correlation for SDS versus FN was 0.21 and for SDS versus wheat α-amylase was −0.36, neither of which is statistically significant.

FN values decrease with increasing sprout damage, as assessed visually. Although the correlation coefficient ($r = -0.65$, $P = 0.05$) is statistically significant, visual assessment is not a good indicator of the level of enzyme activity. For example, sample 5, with 3.5% sprouted kernels, has a slightly lower FN value than sample 14, with 12.0% sprouted kernels. This was also found for another series of samples on which both tests were done (results not shown).

To explain the inconsistency in relationship between visual sprout damage and FN, a sample that was visually assessed to contain 5% sprout damage was hand-picked, and sound, sprung, and sprouted kernels were sorted. "Sprung" refers to kernels that have a slightly swollen germ and are sometimes slightly starchy around the germ. A top-quality, fully sound sample served as control. FN and α-amylase activity were determined for each sample. As shown in Table II even the sound kernels hand-picked from the 5%-sprouted sample, although visually undamaged, yielded a lower FN value and had slightly higher α-amylase activity than the sound control. Therefore, the germination process appears

to have been initiated in the visually sound kernels. Furthermore, the sprung kernels, although classed as undamaged, have an even lower FN value and much higher α-amylase activity. These data demonstrate the inadequacy of visual assessment in judging the actual degree of sprout damage.

The relationship of FN to wheat α-amylase activity in 32 samples is shown in Fig. 1. This type of curvilinear relation has often been shown in reports for common wheats (eg, Corr and Spillane 1969, Kruger and Tipples 1979). Hlynka (1968) showed that a plot of the reciprocal of the FN or amylograph viscosity versus α-amylase gave a straight-line relationship. The reciprocal of the FN plotted against α-amylase yielded a correlation coefficient of 0.95, but a plot of FN versus log of α-amylase yielded a slightly higher correlation coefficient (−0.97).

The level of α-amylase in wheat, semolina, and spaghetti, the level of reducing sugars in semolina and spaghetti, and the proportion of solids lost to the cooking water are shown in Table III. The amount of α-amylase lost during milling varies widely, ranging from 20% in sample 10 to 70% in sample 3. Kruger and Tipples (1979) reported a wide variation in the percentage of α-amylase activity lost in milling hard red spring flour. On the average, α-amylase activity in the flour was 40–50% of that in the wheat, but the range was 10–90%. Under our laboratory conditions, α-amylase activity lost during spaghetti processing varies from 0 to 23%. The level of reducing sugars in semolina and spaghetti and the amount of residue in the cooking water appear to be related to the level of enzyme activity. This was shown by Kruger and Matsuo (1982) for laboratory-germinated samples. For the data in Table III, the correlation coefficient for spaghetti α-amylase activity and reducing sugar is 0.95 ($P = 0.01$), and that for spaghetti α-amylase and cooking water residue is 0.88 ($P = 0.01$). A similar relation between α-amylase activity and cooking water residue was found for 12 pure varieties grown at one station (results not shown). For 27 samples, the correlation coefficient between α-amylase and cooking water residue was 0.85 ($P = 0.01$).

The effect of sprout damage on durum wheat proteins does not appear to be very great. Results of protein fractionation by a modified Osborne procedure on pure varieties (sound and field-sprouted, Fig. 2A) and on graded samples with varying levels of field-sprout damage (Fig. 2B) show a slight increase in the acetic acid-soluble fraction and a decrease in the alcohol-soluble fraction. The other fractions appear to be unaffected. These slight changes, although significant in some cases, did not alter the gel filtration elution profiles of acetic acid protein extracts of sound and sprouted samples (Fig. 3). In particular, no noticeable increase in low molecular weight material occurred, even at 46% sprouted level, as would be expected if proteolytic damage had occurred. Hwang and Bushuk (1973) showed a great increase in low

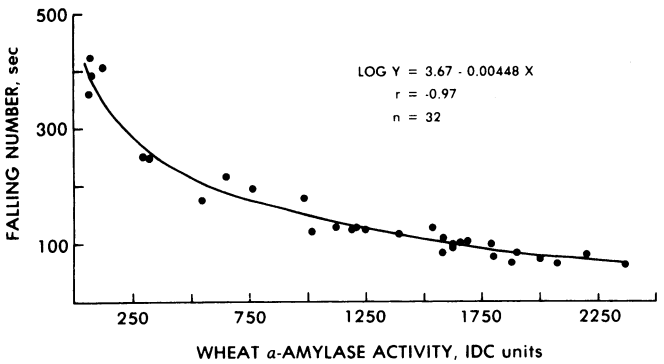

Fig. 1. Relationship of falling number and wheat α-amylase activity.

TABLE III
α-Amylase Activity of Wheat, Semolina, and Spaghetti, Level of Reducing Sugar in Semolina and Spaghetti, and the Solids Lost on Cooking Spaghetti for 15 Samples[a]

	α-Amylase Activity[b]			Reducing Sugar (mg/g of Sample)		Cooking Water Residue
Sample	Wheat	Semolina	Spaghetti	Semolina	Spaghetti	(%)
Control	54	34	52	7.0	11.0	6.20
1	287	144	214	13.0	11.6	5.94
2	543	318	326	10.4	12.0	5.82
3	647	193	205	14.4	15.0	5.64
4	1,380	720	577	17.0	16.8	6.20
5	755	350	384	21.4	21.6	6.46
6	1,111	470	497	20.6	20.0	6.56
7	1,577	852	701	25.0	25.8	6.76
8	985	402	430	19.4	20.4	6.29
9	1,629	933	785	22.8	26.6	6.52
10	1,629	1,334	1,167	27.6	31.6	7.54
11	1,792	1,193	928	23.2	24.6	7.68
12	1,682	876	845	22.8	21.4	6.92
13	2,219	1,363	1,181	30.4	28.4	7.97
14	1,527	736	715	26.2	23.8	7.48

[a] Samples described in Table I.
[b] Expressed in iodine-dextrin color units per gram of sample.

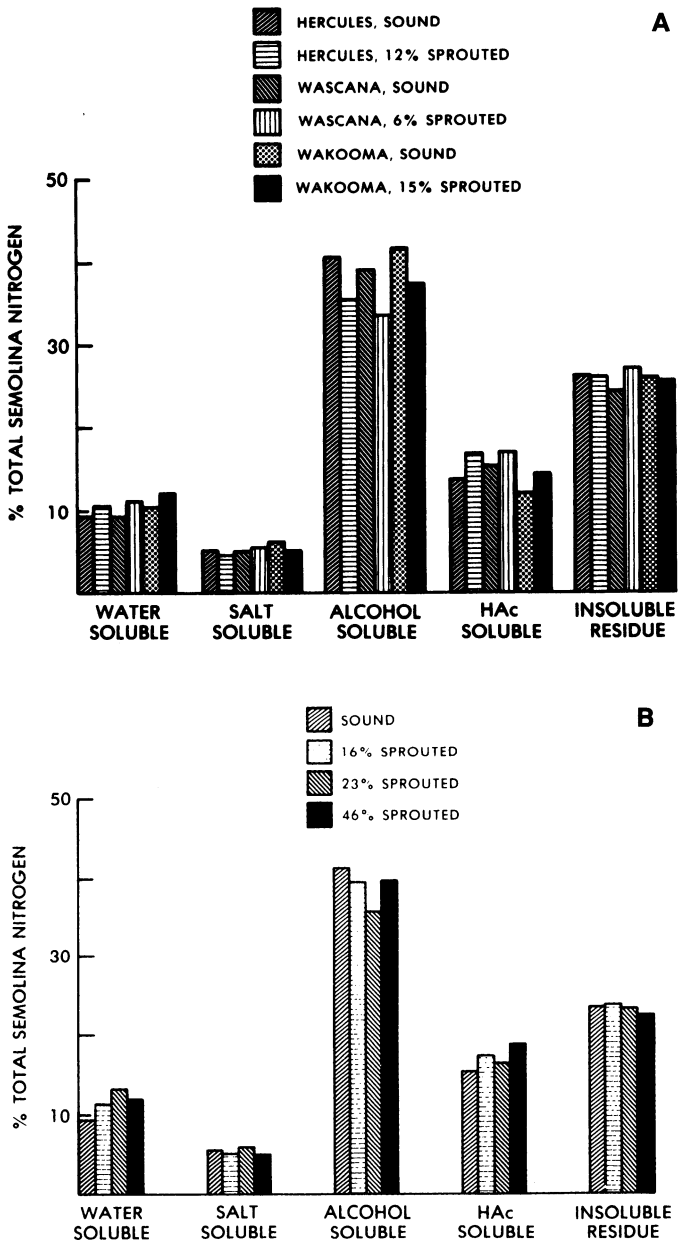

Fig. 2. Effect of sprout damage on the Osborne protein solubility distribution for **(A)** pure durum varieties and **(B)** grade samples with various levels of sprout damage.

molecular weight material in laboratory germinated samples of bread wheats. However, although they found high α-amylase activity (low amylograph viscosity) in a sample steeped for two days, they also found only a slight increase in low molecular weight material. In a study on storage protein hydrolysis, Preston et al (1978) found no increase in total free amino acids and peptides in sound wheat steeped for 24 hr. Conditions in the field that lead to germination are, of course, vastly different and are much more variable than carefully controlled laboratory germination conditions. Based on results of the current study, the proteolytic activity of field-sprouted samples appears similar to that of steeped samples and seldom approaches the level attained in laboratory-germinated samples.

Farinograph mixing characteristics of the samples studied differed widely (results not shown). Most had normal dough development time, tolerance index, and bandwidth. Maximum consistency varied with the protein content. In samples in which kernels were damaged by other degrading factors (eg, frost, immaturity, mildew) in addition to sprout damage, mixing time was prolonged from 4 min to about 7 min. These curves tend to be wider with lower tolerance index. Sprout damage, as such, does not appear to affect mixing characteristics. This is expected, in view of the results in protein fractionation and gel filtration, in which very little effect on protein properties was detected for sprouted samples.

Color and cooking quality characteristics are presented in Table IV. In most of the samples, the lowering of brightness values can be attributed to damage such as immaturity, and frost (Dexter and Matsuo 1981) or smudged and mildewed kernels (Dexter and Matsuo 1982) rather than sprout damage. In agreement with the results of Dick et al (1974) and Donnelly (1980) for samples with no appreciable degrading factor other than sprout damage, spaghetti color was not affected. The poor cooking quality of samples 9 to 14 (100% compressibility and 0% recovery) can be attributed to low protein content.

A textural characteristic of cooked spaghetti that appears to be influenced by sprout damage is the tenderness index. Tenderness index, a measure of firmness derived from the shear rate, is not necessarily related to the resilience of the cooked sample. Samples can be firm without being elastic, such as the texture of boiled potato. For 15 samples, higher tenderness index (loss of firmness) correlated with higher α-amylase activity in spaghetti ($r = 0.74$, $P = 0.01$). Protein content may be a factor in these samples, as low protein samples yield high tenderness index values. However, in a recent study involving 30 durum cultivars grown at two stations for two years ($n = 120$), Matsuo et al (1982) showed that the correlation coefficient between tenderness index and semolina protein was not significant. The shear rate of cooked spaghetti (tenderness index) appears to be influenced by starch gel properties. The higher the level of α-amylase in the spaghetti, the more likely would be the breakdown of starch gel structure, resulting in a softer cooked product.

Compressibility and recovery, on the other hand, measure the resilience of the sample, a property that is influenced not only by the quality of gluten (Feillet et al 1977) but also by the quantity (Dexter and Matsuo 1977b). Results of this study indicate that the protein functionality is not significantly affected by sprout damage,

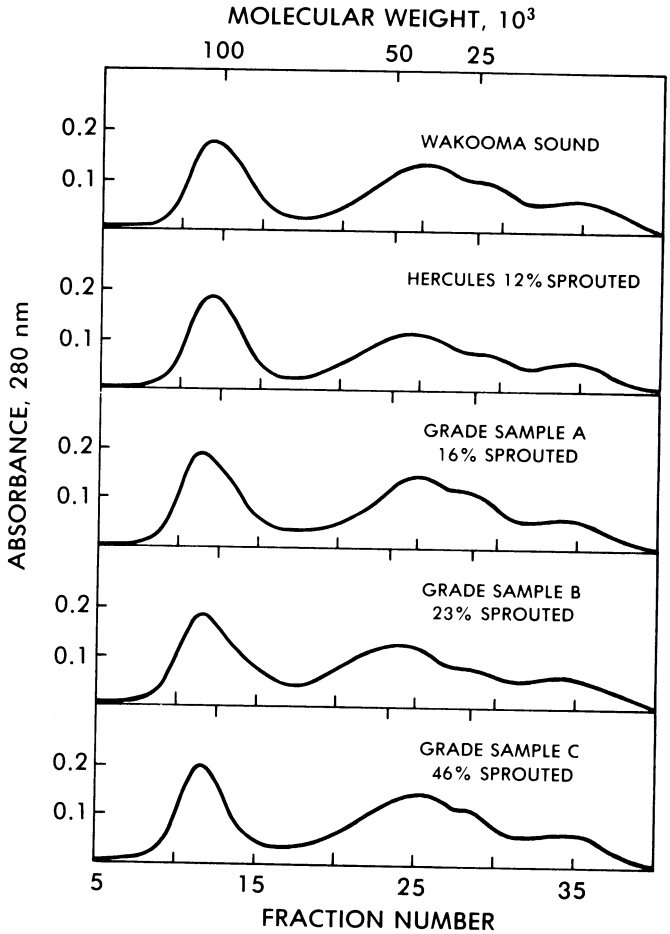

Fig. 3. Effect of sprout damage on gel filtration elution profiles of acetic acid protein extracts.

TABLE IV
Color and Cooking Quality Parameters for Sprout-Damaged Samples

Sample	Spaghetti Yellow Pigment (ppm)	Spaghetti Color				Cooking Quality			
		Pigment Loss (%)	Brightness (%)	Purity (%)	Dominant Wavelength (nm)	Compressibility (%)	Recovery (%)	Tenderness Index (nm/sec)	CQI[a]
Control									
1	4.62	30.4	45.0	57.8	577.9	81	30	37	10.0
2	4.43	25.3	41.9	57.1	578.3	74	43	34	17.1
3	4.26	39.3	44.7	56.6	577.8	78	41	37	14.2
4	4.70	22.7	44.4	57.5	577.9	80	31	36	10.8
5	4.17	25.3	42.2	55.5	578.3	80	31	38	10.2
6	3.78	30.5	42.9	55.0	578.0	76	39	40	12.8
7	3.51	36.6	43.6	52.5	577.9	78	36	43	10.7
8	4.23	27.9	41.1	55.8	578.3	74	49	38	17.4
9	3.91	19.9	42.7	53.8	578.1	100	0	53	0.0
10	3.74	24.6	39.7	52.6	578.5	100	0	47	0.0
11	3.26	29.6	43.1	51.6	577.8	100	0	47	0.0
12	4.00	18.9	43.7	55.4	577.7	100	0	46	0.0
13	4.36	23.1	41.6	55.7	577.9	100	0	50	0.0
14	3.74	21.4	42.9	53.2	578.0	100	0	56	0.0

[a]CQI = cooking quality index: recovery/compressibility × tenderness index.

so that any tendency to poorer cooking quality due to sprout damage is likely related to α-amylase degradation of starch.

Recently, Dexter et al (1981a) showed that α-amylase activity during spaghetti drying can have an influence on cooking quality. They reported that high-temperature (80° C) drying of spaghetti greatly reduced enzyme activity compared to conventional drying temperatures (less than 65° C), thereby decreasing the amount of reducing sugars in the spaghetti dried at high temperature. Results of the present study using a conventional drying cycle indicate that α-amylase activity is related to the amount of residue in the cooking water, to the level of reducing sugars in dried spaghetti, and possibly to the tenderness index. If a high-temperature cycle had been used in drying the spaghetti, much of the α-amylase might have been inactivated, thereby counteracting some of the deleterious effects of sprout damage.

Donnelly (1980) reported that severe checking and cracking of spaghetti samples processed from severely sprouted wheat occurred after one month of storage. In the present study, samples were not stored to determine shelf stability. In the past, we noticed that some spaghetti samples processed from sprouted wheat and stored in unsealed plastic bags did check and crack after storage. However, for those samples listed in Table I, none of the samples checked, even after six months. Possibly, the levels of enzyme activity (α-amylase as well as proteases) were higher in the severely sprouted samples studied by Donnelly (1980) than in samples in the present study. Checking may be related to a threshold level of enzyme activity. The effect of sprout damage on checking requires further study.

CONCLUSIONS

The variability of the effect of sprout damage on spaghetti quality noted in the numerous samples studied in the past can probably be attributed to the level of α-amylase activity in the processed product. The amount of α-amylase activity lost in milling appears to vary among samples which further leads to a variability in the α-amylase activity in the dried spaghetti. Thus, a sample with a low FN in the wheat does not necessarily have high α-amylase activity in the processed product.

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