The Effect of Field Sprouting on the Quality of Durum Wheat[1]

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ABSTRACT

Seven durum wheat varieties were sprouted under controlled field conditions in order to reveal the effect of sprouting on the milling and pasta-making quality of durum wheat. The degree of sprouting, as measured by the falling number test, ranged from sound wheat to severely sprouted wheat. Sprouting had an adverse effect on falling number, vitreous kernel content, and number of damaged kernels in the wheat. At the early stages of germination, wheat grade was not affected by sprouting. Furthermore, semolina milling yield and overall spaghetti quality were not significantly altered by sprouting, even when the falling number tests indicated extensive sprout damage.

Semolina milled from good-quality durum wheat is an essential ingredient for manufacturing high-quality pasta (macaroni) products. Quality of durum wheat, as reflected by grade, is important because the price of the wheat is set by the grade, whereas quality of pasta is important in marketing the final product to consumers. The concept of quality, however, is complex, because each segment of the durum industry has specific criteria to determine quality. Consequently, to define durum quality, the performance of the wheat and its products must be established at a number of processing stages.

Factors such as wheat variety and location of growth affect the quality of durum wheat and can be controlled to some extent. However, weather, which has an important influence on quality, remains beyond control.

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In 1965, 1968, and 1973, periodic rainfall during the wheat harvest season in North Dakota resulted in the sprouting of a large portion of the durum wheat crop. Consequently, in these years, it was difficult for millers to obtain top grade durum, and in many cases the sprouted durum was milled into semolina and processed into pasta products. Although semolina from sprouted durum wheat has been used in large quantities by the pasta processors, there is little agreement as to the effect of sprouting on pasta quality. Furthermore, very few research data have been published to resolve the questions concerning the effect of sprouting on spaghetti quality.

Experimental sprouting studies were reported by Harris et al. (1) in 1943 and by Leu (2) in 1970. Both studies showed that sprouting affected the physical properties of wheat, notably wheat grade and semolina yield, but the authors disagreed on the effect of sprouting on spaghetti color and cooking quality. In the present study, seven wheat varieties were sprouted under field conditions and tested in detail to determine the influence of sprouting on quality. In addition, a statistical analysis of the data revealed the significance of the quality data.

MATERIALS AND METHODS

Wheat Samples

Seven durum wheat varieties were grown comparably in 1969 at the North Dakota State University Langdon Branch Station. One third of each variety plot was harvested and threshed when dry to serve as an unsprouted control sample. The rest of the wheat in the plots was bundled and placed head down on earth-covered plastic and soaked with water to induce germination (aerobic). At 5-day intervals, bundles of each variety were removed, air-dried in the sun, and threshed.

Milling

Wheat samples (6,000 g.) were milled to semolina on a Buhler laboratory durum mill. The wheat was tempered to a 12.5% moisture content 72 hr. before milling, followed by a second temper to 14.5% moisture content 18 hr. before milling, and a final temper to a 17.5% moisture content 45 min. before milling. Semolina was purified with a Miag purifier (Model 7.5 D) and stored under refrigeration until used for spaghetti processing.

Spaghetti Processing

Spaghetti was processed on a semicommercial scale DeMaco (DeFrancisci Machine Co., 46 Metropolitan Ave., Brooklyn, N. Y. 11200) pasta extruder (Fig. 1). The control sample as well as sprouted materials were extruded under the optimum conditions for spaghetti, as described by Walsh et al. (3):

Temperature	49.5°C.
Extrusion Rate	12 r.p.m.
Absorption	30%
Vacuum	18 in. Hg

To process the pasta, 1,000 g. of semolina and water were premixed at high speed in a small Hobart mixer. The pasta was then transferred to the vacuum mixer

Fig. 1. Continuous press for extruding spaghetti on a semicommercial scale (25 lb. per hr.). Extrusion conditions can be controlled to produce spaghetti that is comparable to commercially processed products.

TABLE I. SPAGHETTI MOISTURE OBTAINED UNDER VARIABLE CONDITIONS IN SHATTERING STUDY

Day Conditions Employed	Environmental Temperature (dry bulb) °C.	Relative Humidity %	Moisture at Beginning of Period %
Initial storage	24	63	6.7
0	32	68	6.7
3	24	65	7.7
6	32	74	6.6
9	24	64	8.7
12	32	81	6.4
15	24	63	9.7
18	32	87	6.7
21	24	65	11.9
24	32	90	6.6
27	24	64	13.4
30 (last day)	24	63	6.7

of the press and extruded through an 84-strand 0.157-cm. diameter Teflon spaghetti die. A jacketed extrusion tube (24.13 cm. long × 4.44 cm. i.d.) was attached to the semicommercial pasta press to allow more time for hydration of the semolina and to minimize the number of white specks (unhydrated semolina) in the spaghetti. Extrusion temperature was controlled (±1°C.) by a circulating water bath.

Spaghetti Drying

Spaghetti was dried in an experimental dryer (4) with an 18-hr. cycle. During the drying period, the humidity of the dryer was decreased linearly from 95% to 60% r.h. and the temperature was held constant at 38°C.

Wheat Quality Testing

The wheat samples were graded by a licensed inspector according to methods described in the *Official Grain Standards of the United States* (5). Thousand-kernel weight was measured by counting 10 g. of unbroken kernels on an automatic seed counter. Data were converted to express the weight in grams of 1,000 wheat kernels.

The falling number method described by Medcalf et al. (6) was used to detect sprout damage in the wheat.

Semolina Quality Testing

The semolina from each sample was inspected for the concentration of bran specks by placing a dark glass plate with a 2.54-sq.-cm. (1 sq. in.) window onto the surface of the semolina. Three such measurements were made for each thoroughly mixed sample and the resulting total of bran specks was multiplied by 3.33 to give the total number of bran specks per 25.4 sq. cm. (10 sq. in.) of surface area. The standard deviation for the test was approximately two specks per 25.4 sq. cm.

Spaghetti Quality Testing

The spaghetti color scores were determined according to the method of Walsh (7) on a Model D 25 Hunter color difference meter (Hunterlab, 9529 Lee Highway, Fairfax, Va. 22030) equipped with a D 25 A optical unit.

Spaghetti shattering was judged visually. Samples of spaghetti made from the sprouted wheat, in addition to two commercially processed spaghetti samples, were placed in commercial spaghetti boxes (1-lb. size) and stored under changing temperature and relative humidity conditions. The following procedure was used to induce shattering in the samples. The temperature was varied from 24° to 32°C. in 3-day intervals over a 30-day period. Concomitantly the relative humidity was alternated from approximately 64% r.h. at 24°C. to a progessively increasing relative humidity at 30°C. in the 3-day cycles (Table I). Every 3 days during the 30-day storage period, the spaghetti samples were examined for shattering under a constant light source. Shattering was defined as any visible crack, fracture, or breakage of a single spaghetti strand. After each examination, the samples were given a score (0 = no shattering, 1 = slight shattering, 2 = approximately 25% shattered, 3 = approximately 50% shattered, 4 = approximately 75% shattered, 5 = 100% shattered), which expressed the amount of apparent shattering of the samples. At the end of the 30-day period, the sum of the shattering scores for each individual sample was calculated and reported as the final shattering score. The shatter score value of each sample represents a measurement of the relative degree of susceptibility to induced shattering.

A modification of the method of Sheu et al. (8) was adapted to determine cooking quality of spaghetti used in this study. Spaghetti (10 g.), which had been broken into lengths of approximately 5 cm., was cooked for 20 min. in 300 ml. of boiling distilled water. The samples were then rinsed thoroughly with distilled water in a Buchner funnel, allowed to drain for 2 min., and weighed. Cooking loss was

TABLE II. THE EFFECT OF SPROUTING ON WHEAT QUALITY

Variety	Sprouting Condition	Test Weight lb./bu.	1,000-Kernel Weight g.	Vitreous Kernel Content %	Damaged Kernels %	Grade U. S.	Protein Content[a] %	Falling Number[b] sec.
Leeds	Unsprouted	61.8	35.2	93	0.2	2 HAD	15.0	467
	Sprouted	60.8	35.1	88	0.4	1 HAD	15.0	166
	Sprouted	58.9	36.9	92	2.4	2 HAD	14.8	135
	Sprouted	58.8	35.0	78	3.3	3 HAD	14.4	90
Wells	Unsprouted	59.7	27.9	90	0.5	2 HAD	14.9	459
	Sprouted	58.7	27.5	70	1.0	3 AD	14.6	222
	Sprouted	58.0	29.4	68	4.9	4 AD	14.8	190
	Sprouted	57.9	27.9	52	3.2	S. G.	14.0	150
Hercules	Unsprouted	60.4	38.2	91	0.2	3 HAD	14.5	474
	Sprouted	58.6	36.9	70	2.0	3 AD	14.2	204
	Sprouted	59.4	36.2	85	1.7	2 HAD	14.4	170
	Sprouted	58.8	39.1	95	0.5	2 HAD	14.3	127
Stewart-63	Unsprouted	57.0	28.9	92	0.2	2 HAD	16.3	499
	Sprouted	56.9	28.4	88	0.4	3 HAD	16.3	232
	Sprouted	57.1	28.6	87	0.7	3 HAD	16.2	216
	Sprouted	57.1	28.5	91	0.8	3 HAD	15.6	169
Mindum	Unsprouted	55.8	26.6	91	0.3	4 HAD	15.8	488
	Sprouted	56.2	24.5	87	0.6	3 HAD	14.8	226
	Sprouted	55.5	22.4	88	0.6	4 HAD	14.7	217
	Sprouted	55.9	26.2	93	0.2	4 HAD	15.4	151
Yuma	Unsprouted	56.6	25.8	90	0.3	3 HAD	16.7	462
	Sprouted	56.4	25.4	86	0.8	3 HAD	16.2	156
	Sprouted	56.3	27.9	78	2.9	3 HAD	15.1	97
	Sprouted	55.5	24.6	84	1.4	4 HAD	16.2	81
Golden Ball	Unsprouted	58.7	35.5	93	0.8	2 HAD	16.6	494
	Sprouted	58.7	35.6	86	2.9	2 HAD	15.3	155
	Sprouted	58.7	35.2	83	0.7	2 HAD	15.6	145
	Sprouted	57.9	34.6	88	2.3	2 HAD	15.8	141

[a]14% m.b.

[b]15% m.b.

determined by the AACC Approved Methods (9).

Spaghetti firmness was measured by shearing two strands of cooked spaghetti at a 90° angle with a special Plexiglas tooth that has been described by Walsh (10). A continuous recording of distance versus force was made by the instrument (Instron, 2500 Washington St., Canton, Mass. 02021) during the operation. An automatic integrator was used to calculate the area under the curve (g. cm.), which was the amount of work required to shear a single strand of cooked spaghetti.

Chemical Analysis

Protein, ash, and moisture contents of the samples were determined according to AACC Approved Methods (9) and reported on a 14% moisture basis.

RESULTS AND DISCUSSION

Table II shows the effect of sprouting on quality of the wheat varieties. The

TABLE III. ANALYSIS OF VARIANCE OF WHEAT QUALITY DATA

	Mean Squares							
	Degrees of Freedom	Test weight	1,000-Kernel weight	Vitreous kernel content	Damaged kernels	Grade U.S.	Protein content	Falling number
Treatment (sprouting)	3.0	1.4	0.6	249.6*	4.2	2.1	0.9**	172,737.6**
Varieties	6.0	10.2**	105.6**	187.9*	1.9	4.4	2.1**	3,355.2
Error	18.0	0.4	1.4	36.0	0.9	1.0	0.1	1,122.2

TABLE IV. CORRELATIONS BETWEEN FALLING NUMBER AND WHEAT QUALITY

Variable X	Variable Y	Correlation Coefficient r
Falling number	Damaged kernels	−0.51**
Falling number	Semolina bran specks	−0.38*
Falling number	Vitreous kernel content	0.37*
Falling number	Protein content	0.31
Falling number	Test weight	0.19
Falling number	Grade	−0.17

data show that a dramatic drop in falling number values occurred with sprouting for all varieties. Falling number can be used as an index of sprout damage. It can therefore be used to correlate sprout damage with chemical and physical data determined on the wheat. Although all of the quality factors tested showed some variation, only the falling number, vitreous kernel content, and damaged kernels showed marked changes with sprouting. Falling numbers decreased and indicated that amylolytic activity of the wheat increased rapidly with sprouting. Vitreous kernel content decreased and the amount of damaged kernels increased as sprouting progressed.

To aid in identifying the effects of sprouting on quality, an analysis of variance (AOV) of the data was performed (Table III). In the AOV the randomized complete block design for four levels of sprouting (treatment) and seven varieties was used. The results confirmed earlier observations and showed that sprouting had a highly significant influence on the falling number and the protein content of the wheat and had a significant (5% level of confidence) influence on vitreous kernel content. Furthermore, wheat variety was a highly significant (1% level of confidence) source of variance for test weight, 1,000-kernel weight, and protein content of the wheat, and a significant source of variation for the vitreous kernel content of wheat.

To further characterize the effect of sprouting on quality, a correlation matrix was computed. Of particular interest were the correlations between falling number and each of the durum quality characteristics (Table IV). Falling number showed significant negative correlations with damaged kernels and semolina bran specks and positive correlations with vitreous kernel content. Notably, as sprouting increased, vitreous kernel content decreased, whereas the percentage of damaged kernels and the number of bran specks increased. Interestingly enough, the overall wheat grade was not correlated with falling number values even though the grading factors

TABLE V. MILLING AND SPAGHETTI QUALITY DATA FOR SPROUTED DURUM WHEAT

Variety	Falling Number[a] sec.	Purified Milling Yield[b] %	Semolina: Specks/ 25.4 sq. cm.	Semolina: Ash %	Spaghetti: Color units	Spaghetti: Cooked weight g./10 g.	Spaghetti: Cooking loss %	Spaghetti: Cooked firmness g. cm.	Spaghetti: Shatter score units
Leeds	467	52.0	13	0.70	10.0	36.0	5.0	5.7	28
	166	52.2	20	0.69	10.0	37.5	6.0	5.7	24
	135	52.3	23	0.82	10.0	37.7	6.0	5.4	25
	90	52.3	17	0.75	9.5	38.2	5.0	5.1	23
Wells	459	51.7	13	0.74	10.0	38.0	5.0	5.8	25
	222	51.3	13	0.71	10.0	40.6	6.0	4.9	29
	190	51.7	23	0.79	10.0	39.4	5.0	4.8	28
	150	51.6	23	0.76	10.0	37.4	5.0	5.1	29
Hercules	474	52.6	20	0.72	10.5	36.2	5.0	6.0	25
	204	52.3	13	0.69	10.0	37.9	5.0	5.8	19
	170	52.0	17	0.73	10.0	37.3	5.0	5.9	15
	127	52.4	20	0.78	10.0	35.3	5.0	5.6	22
Stewart-63	499	51.6	17	0.77	9.5	38.4	6.0	4.9	25
	232	51.1	17	0.77	9.5	36.3	5.0	5.7	13
	216	50.8	20	0.75	10.0	37.0	6.0	5.2	21
	169	51.8	17	0.77	10.0	39.0	6.0	5.5	17
Mindum	488	49.3	17	0.75	10.0	39.3	6.0	5.4	31
	226	49.8	17	0.71	10.0	36.2	5.0	5.0	32
	217	49.6	17	0.73	10.0	37.9	6.0	5.3	31
	151	50.2	23	0.79	10.0	36.4	5.0	5.6	28
Yuma	462	50.7	20	0.69	10.0	37.0	5.0	6.5	23
	156	51.6	20	0.73	9.5	36.4	5.0	6.3	44
	97	52.3	30	0.74	9.5	36.9	6.0	6.3	33
	81	50.0	23	0.74	10.0	36.0	5.0	6.0	22
Golden Ball	494	50.8	13	0.78	8.5	36.5	5.0	5.7	28
	155	52.5	13	0.80	8.5	36.5	7.0	5.2	24
	145	52.0	10	0.84	8.5	36.5	6.0	5.3	29
	141	50.9	23	0.96	8.0	37.5	5.0	5.5	32

[a]15% moisture basis.

[b]Calculated on a cleaned and tempered wheat basis.

(vitreous kernel content and percentage of damaged kernels) were significantly correlated. Apparently the grade was not affected until long after the falling number test had detected an increase in amylolytic activity of the sprouted wheat.

Table V shows milling and spaghetti quality data for durum samples at four levels of sprouting. Inspection of the data revealed no obvious trends relating sprout damage to durum milling or spaghetti quality characteristics of the samples. Moreover, no significant effects of sprouting on quality were revealed by an AOV (randomized block design) and regression analysis of the data. Although the data revealed no significant effects of sprouting on quality, there is the possibility that more deleterious effects of sprout damage might be detected in semolina of higher extraction.

AOV of the spaghetti quality data showed that sprouting treatments did not significantly influence spaghetti color, cooked spaghetti weight, cooking loss, cooked spaghetti firmness, and shatter scores. None of the samples exhibited unusual handling properties during processing, and there was no problem with spaghetti falling off the rods during the drying cycle, even with a single-strand length of approximately 100 cm.

Finally, to seek specific relations between sprouting and quality, linear correlation coefficients were calculated between falling number values and the major durum milling and spaghetti quality factors (Table VI). Of the various quality determinations, only semolina bran speck count showed a significant correlation with falling number. Apparently when durum is sprouted, the bran of the seed coat becomes friable, crumbles during milling, and causes an increase in semolina bran specks which are not removed by purification.

TABLE VI. LINEAR CORRELATIONS BETWEEN FALLING NUMBERS AND SEMOLINA MILLING AND SPAGHETTI QUALITY

Variable X	Variable Y	Correlation Coefficient r
Falling number	Ash	−0.2755
Falling number	Semolina yield	−0.1812
Falling number	Semolina speck content	−0.3801*
Falling number	Spaghetti color	0.1231
Falling number	Cooked spaghetti weight	0.0820
Falling number	Cooking loss	−0.1093
Falling number	Cooked spaghetti firmness	0.0982
Falling number	Shatter score	0.0200

SUMMARY AND CONCLUSIONS

Research was conducted to establish the influence of sprouting on durum wheat and spaghetti quality. In the study, seven durum wheat varieties were sprouted to four levels of germination in the field. In an effort to reveal the influence of germination on quality, the samples were analyzed to determine chemical and physical properties of the wheat. Notably, as sprouting increased, vitreous kernel content decreased, whereas the percentage of damaged kernels and the number of bran specks increased. However, when the sprouted wheat was milled, there was no significant decrease in semolina yield. A large increase in amylolytic activity with sprouting was detected by the falling number test. When semolina was processed into spaghetti, no unusual processing characteristics were noted for the sprouted samples. Furthermore, spaghetti color, cooked spaghetti weight, cooking loss, cooked spaghetti firmness, and shatter scores were not significantly affected by sprouting of the durum wheat.

In the past, sprout-damaged durum wheat has been used primarily for livestock feed. According to the results of this research, good-quality spaghetti can be milled and processed from durum wheat that has been sprouted. This is not to say that sprouting has no deleterious effect on durum quality. It does, however, lead to the conclusion that the degree of sprouting and conditions under which sprouting occurs may influence durum quality more than is indicated by the total number of sprouted kernels or the falling number value of the wheat.

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