Studies on the Improvement of Quality of Wheat Infected with Karnal Bunt. I. Milling, Rheological, and Baking Properties[1,2]

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ABSTRACT

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Studies were conducted with a view to developing treatments to overcome the adverse effects of Karnal bunt (*Neovossia indica*) disease on the quality of wheat and its products. Among various treatments tried, lye peeling and debranning followed by washing were found to be very effective. The flour yield and quality (i.e., ash content, milling value, and color grade value) of the Karnal-bunt-infected wheat were improved considerably by these treatments. The increase in proteolytic activity, total phenols, free fatty acids, and trimethylamine content due to bunt infection was reversed to an appreciable extent with the treatments. The deteriorated dough rheological characteristics and bread quality and acceptability of flour infected with Karnal bunt were also significantly improved. Bread prepared from 5% Karnal-bunt-infected wheat treated with either method was comparable to bread prepared from sound wheat.

Karnal bunt, a fungal disease of wheat caused by *Neovossia indica*, was reported for the first time in India (Mitra 1931) and has now spread to many countries (Duran 1972, CMI 1974). The disease has assumed great significance because of widespread inoculum and its adverse effect on grain quality (Bedi et al 1981). Wheat becomes unfit for human consumption beyond a 3% level of infection due to a fishy odor, perceptible blackening, and altered organoleptic attributes (Mehdi et al 1973; Sekhon et al 1980a,b). The infected wheat is also reported to have adverse biological effects such as reduced liver weight, white blood cell count, and monocyte count (El-Behadli et al 1978, Sharma et al 1982, Gopal et al 1988). The presence of diseased kernels in small proportions not only threatens the acceptability of the wheat, but the very cultivation of wheat in a particular area becomes questionable. The present study was undertaken to evaluate simple techniques for overcoming the adverse effects of the disease so that farming efforts may be optimized and the wheat produced could be utilized without adverse effects on human health.

MATERIALS AND METHODS

Preparation of Samples

Wheat infected with Karnal bunt (*Neovossia indica*), cv. WL-711, was obtained from the Regional Research Station, Kheri, of the Punjab Agricultural University from the 1986-87 harvest. Severely infected grains, which were partially black and separated by hand picking, were then added to sound wheat samples at 5 and 10% levels to constitute the study material.

Treatments

1. Washing. Samples were soaked in water for 20 min with stirring at intervals, then washed thoroughly and dried to the original moisture content in a forced-air laboratory cabinet drier at 35°C.

2. Debranning. Debranning was accomplished with a McGill polisher in two steps. The samples (900 g each) were abraded for 20 sec at each step after 10 min of tempering, by adding 4% water and then 1% water. The resultant grains were sieved and taken as debranned.

3. Debranning followed by washing. Debranning was done as described for treatment 2 followed by washing and drying as described for treatment 1.

4. Lye peeling. The samples were treated with 15% sodium hydroxide solution (lye), 30% by weight of sample at 65°C for 6 min, and were washed in running water. The residual alkali on the kernels was neutralized by dipping in 2.5% acetic acid, and the kernels were dried to the original moisture level as in treatment 1.

Conditioning and Milling

The samples were conditioned to 14% moisture and rested for 48 hr before milling in an experimental mill (Quadrumat Junior).

Physicochemical Properties

Grain hardness was tested by crushing 20 grains of each prepared sample on the grain hardness tester (OSK 8055, Kiya Seisqkusho Ltd., Japan).

Analytical methods for ash (08-01), protein (46-13), crude fiber (32-15), diastatic activity (22-15), proteolytic activity (22-60), falling number (56-81B), damaged starch (70-30A), dry gluten (38-10), and free fatty acids (58-16) were followed (AACC 1976). A milling value was calculated as flour yield/2 × ash. A color grade value was determined with the Kent-Jones and Martin color grader (Series III) as described by Amos et al (1973). Total phenols were extracted and estimated according to the method of Swain and Hillis (1959). Trimethylamine was estimated by the method of James and Critchfield (1961).

Rheological and Baking Properties

The constant flour method 54-21 was used for farinographic characteristics of flours, and the straight dough method 10-10 was used for test baking (AACC 1976). Volumes were determined by the rapeseed displacement method. Breads were evaluated by a semitrained panel and scored as follows: maximum score, 100; volume, 10; symmetry, 5; break and shred, 5; crust color, 10; grain quality, 10; crumb texture, 15; crumb color, 10; taste, 15; aroma, 10; and mouthfeel, 10. The results were analyzed by analysis of variance as described by Steel and Torrie (1960) using two factors in a randomized block design. Least significant differences were calculated as reported in the tables. The data reported represent the average of three replications.

RESULTS AND DISCUSSION

Physicochemical Characteristics of Grains

As expected, Karnal bunt infection resulted in a decrease in 1,000-kernel and test weights: 1,000-kernel weight by 3.4 and 5.0%; test weight by 5.4 and 9.0% in 5 and 10% infected samples, respectively (Table I). Debranning of wheat samples diminished the 1,000-kernel weights but increased the test weights. The decrease in 1,000-kernel weight was due to the removal of outer layers from the kernels; the increase in test weight was due to loss of outer layers, which were lighter in weight than the inner endospermic tissues. The higher test weight of infected samples was probably due to the removal of infected light-weight grains by

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the treatments. The lye-peeling treatment produced similar effects.

In general, all treatments resulted in loss of grain weight to some extent. The loss due to washing was 0.1, 0.8, and 1.5% for 0, 5, and 10% infected samples, respectively. Debranning reduced the weight 7.3–8.8%, the lowest for the control and the highest for 10% infected samples (Table I). Washing of debranned samples caused an additional loss of 0.4–0.6%, while lye peeling caused a loss of 5.8% in the control and 7.2 and 10.0% in 5 and 10% infected samples, respectively.

The average grain hardness decreased significantly with the increase in infection. The decrease in the average hardness index of infected samples may be due to reduction in cohesive binding between endosperm fractions.

The protein, ash, crude fat, and crude fiber content (Table I) increased significantly with the increase in bunt infection as reported by Bedi et al (1981) and Gopal and Sekhon (1988). Debranning and lye peeling significantly reduced the protein, ash, and crude fiber content of sound and infected samples, but crude fat content was significantly reduced in infected samples only. The results are in agreement with Morgan et al (1966), Wasserman et al (1970), Fellers et al (1976), and Obuchowski and Bushuk (1980).

TABLE I
Effect of Pretreatments on Physicochemical Properties of Sound and Bunted Wheat

Infection Level (%)	Characteristics[a]	Control		Debranned		Lye Peeled
		Unwashed	Washed	Unwashed	Washed	
0	1,000-kernel weight, g	39.50	39.45	36.50	36.25	37.10
	Test weight, kg	81.80	81.80	84.80	84.80	82.70
	Grain hardness, kg	10.40	9.90	8.20	8.30	8.20
	Grain yield, %	100.00	99.90	92.80	92.30	94.20
	Protein (N × 5.7), %	9.36	9.36	9.10	9.00	8.80
	Crude fat, %	1.70	1.70	1.66	1.65	1.68
	Crude fiber, %	2.90	2.90	1.86	1.75	2.12
	Ash, %	1.42	1.40	1.25	1.12	1.33
5	1,000 kernel weight, g	38.15	38.60	36.15	36.10	37.00
	Test weight, kg	77.40	77.60	83.80	83.10	82.10
	Grain hardness, kg	9.60	9.80	8.10	8.50	8.20
	Grain yield, %	100.00	99.20	92.00	91.40	92.80
	Protein (N × 5.7), %	9.50	9.47	9.14	9.00	8.87
	Crude fat, %	1.80	1.80	1.72	1.69	1.74
	Crude fiber, %	3.00	3.00	1.95	1.85	2.20
	Ash, %	1.68	1.62	1.32	1.25	1.45
10	1,000 kernel weight, g	37.20	37.60	36.10	36.00	36.80
	Test weight, kg	74.40	75.00	82.80	82.90	82.10
	Grain hardness, kg	9.10	9.50	8.00	8.30	8.20
	Grain yield, %	100.00	98.50	91.20	90.80	90.00
	Protein (N × 5.7), %	9.60	9.58	9.18	9.10	8.95
	Crude fat, %	1.88	1.88	1.74	1.72	1.75
	Crude fiber, %	3.30	3.25	1.97	1.90	2.25
	Ash, %	1.94	1.90	1.40	1.30	1.50

[a] Least significant differences (0.05): 1,000-kernel weight, 0.60; test weight, 1.04; grain hardness, 0.50; grain yield, 0.66; protein, 0.11; crude fat, 0.05; crude fiber, 0.14; ash, 0.04.

TABLE II
Effect of Pretreatments on Milling Characteristics of Sound and Bunted Wheat

Infection Level (%)	Characteristics[a]	Control		Debranned		Lye Peeled
		Unwashed	Washed	Unwashed	Washed	
0	Flour yield,[b] %	65.60	65.70	67.00	67.20	68.00
	Flour yield,[c] %	65.60	65.70	62.80	62.80	64.50
	Color grade value	3.94	3.80	3.10	2.00	2.80
	Milling value[b]	72.90	74.70	83.80	90.80	81.00
	Milling value[c]	72.90	74.70	78.50	84.90	76.80
	Ash, %	0.45	0.44	0.40	0.37	0.42
5	Flour yield,[b] %	64.20	64.30	66.80	67.10	68.10
	Flour yield,[c] %	64.20	64.30	62.00	62.20	63.30
	Color grade value	>20	>20	8.50	5.00	4.00
	Milling value[b]	64.20	65.60	83.50	88.30	81.10
	Milling value[c]	64.20	65.60	77.50	81.80	75.40
	Ash, %	0.50	0.49	0.40	0.38	0.42
10	Flour yield,[b] %	63.30	64.80	66.60	67.00	68.20
	Flour yield,[c] %	63.30	64.80	61.50	61.60	62.20
	Color grade value	>20	>20	14.20	10.00	7.10
	Milling value[b]	58.60	61.00	74.00	79.80	75.80
	Milling value[c]	58.60	61.00	68.30	73.40	69.10
	Ash, %	0.54	0.53	0.49	0.42	0.45

[a] Least significant differences (0.05): Flour yield,[b] 0.44; flour yield,[c] 0.41; milling value,[b] 4.10; milling value,[c] 4.00; ash, 0.04.
[b] Expressed on recovered-contents basis.
[c] Expressed on original-grain-weight basis.

Milling Characteristics

Flour yield and quality deteriorated progressively with the increase in bunt infection (Table II). A reduction of 1.3 and 2.8% in flour yield was observed in 5 and 10% infected samples, respectively. A reduction in flour yield due to bunt infection was also observed by Singh and Tyagi (1982) and Gopal and Sekhon (1988). Debranning and lye peeling of samples showed an increase in flour yield on the basis of recovered content basis; however, this is a decrease of the original grain weight basis, as a portion of grain was lost during these treatments. Flour yield was reduced by 2.8 and 1.1% in sound, 3.6 and 2.3 in 5%, and 4.1 and 3.4% in 10% infected samples by debranning and lye peeling, respectively. Comparatively higher flour yield obtained with the lye peeling than with debranning treatment was due to smaller grain losses during the former treatment.

Milling quality, as judged from the ash content, color grade value, and milling value, deteriorated with the increase in bunt infection. The color grade values for both infection levels were more than 20 compared to 3.94 for the control flour. Debranning markedly improved the color grade values of the flour produced from infected samples, which was further improved significantly by washing. Lye peeling improved color grade value to an even higher degree, and the values for the 5% infected samples approached the value of the control. The higher color grade values of infected flour samples were a consequence of the admixture of the black fungal mass and the higher content of phenols (Table IV) and ash.

Flour Composition

Protein and crude fat content of flour increased significantly with the increase in bunt infection, which was reversed by the debranning and lye-peeling treatments (Table III). The dry gluten content of infected wheat flour was lower than that of sound wheat flour. Debranning and lye peeling had a negligible effect on the gluten content of sound wheat flour but improved it in infected wheat flour. Gopal and Sekhon (1988) also observed

TABLE III
Effect of Pretreatments on Physicochemical Properties of Sound and Bunted Wheat

Infection Level (%)	Characteristics[a]	Control Unwashed	Control Washed	Debranned Unwashed	Debranned Washed	Lye Peeled
0	Protein (N × 5.7), %	8.60	8.60	8.55	8.53	8.50
	Crude fat, %	0.45	0.45	0.41	0.38	0.42
	Dry gluten, %	10.90	10.90	10.80	10.80	10.70
	Damaged starch, %	10.30	9.80	9.50	9.50	9.00
	Diastatic activity, mg of maltose/10 g	280	290	250	240	230
	Falling number, sec	440	435	470	480	495
	Proteolytic activity, HU/g[b]	0.30	0.30	0.23	0.22	0.20
5	Protein (N × 5.7), %	8.80	8.76	8.65	8.60	8.65
	Crude fat, %	0.52	0.50	0.43	0.40	0.42
	Dry gluten, %					
	Damaged starch, %	10.7	10.5	9.7	9.3	9.5
	Diastatic activity, mg of maltose/10 g	260	270	250	240	225
	Falling number, sec	480	470	475	480	490
	Proteolytic activity, HU/g[b]	0.45	0.42	0.25	0.22	0.20
10	Protein (N × 5.7), %	8.95	8.90	8.70	8.65	8.60
	Crude fat, %	0.53	0.53	0.43	0.41	0.45
	Dry gluten, %					
	Damaged starch, %	11.0	10.5	9.8	9.3	9.7
	Diastatic activity, mg of maltose/10 g	245	265	245	240	225
	Falling number, sec	500	480	475	485	500
	Proteolytic activity, HU/g[b]	0.52	0.50	0.28	0.25	0.22

[a] Least significant differences (0.05): Protein, 0.06; crude fat, 0.02; dry gluten, 0.17; damaged starch, 0.35; diastatic activity, 0.56; falling number, 8.80; proteolytic activity, 0.06.
[b] HU = hemoglobin units.

TABLE IV
Effect of Pretreatments on Total Phenols, Free Fatty Acids, and Trimethylamine Content of Sound and Bunted Wheat Flours

Infection Level (%)	Characteristics[a]	Control Unwashed	Control Washed	Debranned Unwashed	Debranned Washed	Lye Peeled
0	Total phenols, mg/100 g	92.0	94.0	74.0	67.0	80.0
	Free fatty acids, %	0.008	0.007	0.007	0.007	0.007
	Free fatty acids, g/100 g of fat	1.77	1.65	1.70	1.85	1.82
	Trimethylamine, meq/100 g	...	...	...	...	...
5	Total phenols, mg/100 g	117.5	110.5	79.70	69.50	90.00
	Free fatty acids, %	0.045	0.040	0.020	0.010	0.010
	Free fatty acids, g/100 g of fat	8.65	8.00	4.65	2.50	2.50
	Trimethylamine, meq/100 g	3.80	3.80	0.50	0.35	0.20
10	Total phenols, mg/100 g	160.00	138.50	102.50	76.50	92.00
	Free fatty acids, %	0.052	0.047	0.025	0.013	0.011
	Free fatty acids, g/100 g of fat	9.45	8.85	5.80	3.15	2.45
	Trimethylamine, meq/100 g	9.80	9.75	0.95	0.60	0.40

[a] Least significant differences (0.05): free fatty acids, 0.015; total phenols, 3.50.

TABLE V
Effect of Pretreatments on Farinographic and Baking Characteristics of Sound and Bunted Wheat

Infection Level (%)	Characteristics[a]	Control Unwashed	Control Washed	Debranned Unwashed	Debranned Washed	Lye Peeled
0	Water absorption, %	58.40	56.20	54.2	55.6	52.0
	Dough development time, min	1.50	1.50	1.75	1.75	2.00
	Dough stability, min	18.00	17.20	18.00	18.00	15.00
	Degree of softening, BU	30	55	20	40	40
	Loaf volume, cm^3	485	545	500	510	510
	Specific loaf volume, g/cm^3	3.50	4.00	3.60	3.60	3.75
	Total scores, 100	81.40	84.9	80.0	82.8	80.0
5	Water absorption, %	60.00	59.00	55.00	54.50	53.00
	Dough development time, min	1.75	1.75	1.50	1.50	1.50
	Dough stability, min	7.20	10.00	18.00	18.00	14.50
	Degree of softening, BU	70	65	20	45	50
	Loaf volume, cm^3	540	545	515	525	515
	Specific loaf volume, g/cm^3	3.75	3.90	3.60	3.90	3.80
	Total scores, 100	54.3	55.5	70.0	81.5	78.1
10	Water absorption, %	65.5	59.50	55.20	54.60	53.00
	Dough development time, min	2.00	2.00	1.50	1.50	2.00
	Dough stability, min	5.00	7.50	15.00	14.50	12.50
	Degree of softening, BU	105	100	50	70	60
	Loaf volume, cm^3	570	560	520	530	520
	Specific loaf volume, g/cm^3	4.15	4.10	3.60	3.95	3.80
	Total scores, 100	37.5	39.9	63.0	73.6	72.8

[a] Least significant differences (0.05); water absorption, 0.75; dough development time 0.22; dough stability, 0.60; degree of softening, 6.05; loaf volume, 13.40; specific loaf volume, 0.12; total scores, 1.85.

a reduction in gluten content in infected wheat flour.

Damaged starch content of flour increased with the increase in level of infection in wheat. Debranning and lye peeling reduced the damaged starch content of both sound and infected wheat flours. Diastatic activity of bunt-infected wheat flours was significantly lower than that of their sound counterparts. Debranning and lye peeling invariably reduced the diastatic activity of the infected as well as the sound samples. The falling number results are in conformity with those of the diastatic activity; falling number increased significantly with the decrease in the diastatic activity. Proteolytic activity of the flours increased significantly with the increase in the incidence of bunt, which was reversed by debranning and lye peeling. The reduction in proteolytic activity in infected wheat flour by debranning and lye peeling might be due to removal of fungal mass.

Total phenols and free fatty acids also increased significantly with the increase of infection and were reduced significantly by debranning and lye peeling (Table IV). Trimethylamine imparts a fishy odor, which increases with an increase in infection. Debranning of infected wheat was effective in reducing the level of trimethylamine in flour; washing reduced it further. The effect of lye peeling was even more beneficial (Table IV).

Farinographic Characteristics

Farinograph water absorption and degree of softening increased, whereas dough stability decreased with the increase in bunt infection (Table V). Debranning and lye peeling reduced the water absorption of various samples. The higher farinographic water absorption in infected wheat flours may be due to higher protein and damaged starch (Greer and Stewart 1959, Moss 1961, Meredith 1966, Farrand 1969). Dough development time did not vary significantly with the increase in infection or with various treatments. The stability of infected flours significantly improved, and the degree of softening decreased with the treatments.

The decrease in stability of the infected samples, which is indicative of earlier breakdown of the gluten, might be the result of high water absorption coupled with higher proteolytic activity and low gluten content.

Baking Characteristics

Flours milled from infected samples produced higher loaf volume than did sound wheat flour (Table V). Washing of sound wheat further improved loaf volume. Debranning and lye peeling brought about an improvement in the volume of the loaves produced from sound wheat flour but had a depressing effect on the loaves produced from infected wheat flour. A higher loaf volume recorded for infected wheat compared to that of sound wheat samples might be due to improvement in the proteolytic activities of the otherwise deficient wheats, together with higher protein and damaged starch contents. The earlier work of Singh et al (1978) showed a similar effect.

Bread produced from infected wheat was inferior to that of the control (Table V). Total scores diminished with the increase in infection, except for loaf volume. Bread produced from infected wheat flours exhibited more break and shred, dark crust and crumb color, harder crumb texture, coarser grain, and bitter taste. Washing did not bring about any significant improvement in any of the traits. However, debranning of the infected wheat before milling significantly improved all bread attributes, which were further improved by washing of the debranned wheat prior to milling. The effect of lye peeling was comparable to that of debranning followed by washing. Overall, the flour milled from 5% infected wheat after debranning followed by washing or lye peeling produced breads of a quality comparable to those baked from sound wheat flour.

CONCLUSION

Debranning followed by washing or lye peeling of wheat infected with Karnal bunt significantly improved grain flour as well as dough rheology and bread quality. Either of these treatments can produce good-quality bread from wheat with 5% Karnal bunt infection. However, debranning followed by washing is commercially more feasible.

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