End-Use Quality of Flour from *Rhyzopertha dominica* Infested Wheat

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ABSTRACT

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The objective of this study was to evaluate how *Rhyzopertha dominica* infestation of stored wheat grain affects the rheological and baking properties of bread made with the milled flour. Wheat samples were infested with *R. dominica* and stored for up to 180 days at room temperature. Every 45 days, samples of wheat were collected and evaluated for insect population and flour yield. Flour milled from these wheat samples was evaluated for color reflectance, pH, fat acidity, and rheological properties which were measured by a farinograph. Loaves of bread were baked using a straight-dough procedure. Volume, height, and weight of the loaves were evaluated. None of the analyses performed on the control wheat flours showed any changes during the storage period, and they were similar to the initial wheat. The insect population increased during storage of the wheat up to 90 days, and the flour yield decreased with the storage up to 180 days. Flours from insect-infested wheat absorbed more water than did flours from control wheat. Dough stability and dough development times of infested flours decreased. Bread volume showed a progressive decline throughout the storage experiment. In conclusion, flour from insect-infested wheat exhibited changes in rheological properties such as dough stability, dough development times, water absorption, and mixing stability; bread had an offensive odor; and volume and loaf characteristics were negatively affected.

Cereal grains are an important part of the diet for most of the people in the world. Among the cereals, wheat production is third in the world. Moreover, flour made from wheat is transformed to baked products such as breads, tortillas, and pastas that are staple foods in many countries.

Stored grain and processed foods, however, are subject to attack by pests. The presence of insects in stored products causes loss in quality and monetary value. Pushpamma and Reddy (1979) indicated food losses from 2 to 50%, depending on the grain, and period and method of storage and biological agents surrounding the grain.

Insects are the major problem in the storage of grain and seed. The USDA has estimated that monetary losses caused by insect infestation are more than $470 million per year (Hoseney 1994). Insects not only consume grain, but also contaminate it with their cast skins, excrement, fragments of immature insects, and other by-products (Smith et al 1971, Pedersen 1994). Chemical analysis of insect-infested grain has revealed significant effects on nutrients. Gluten, nonreducing sugars, sedimentation value, and protein quality decreased in wheat and corn infested with stored-product insects (Girish et al 1975, Sharma et al 1979, Jood and Kapoor 1992, Jood et al 1993).

Among insects infesting grain, the lesser grain borer, *Rhyzopertha dominica* Fabricius (Coleoptera: Bostrichidae) occurs widely in stored grains. However, relatively little has been published on the effects of insect infestation on the baking properties of flour ground from stored wheat infested with *R. dominica*. The objective of this study, therefore, was to determine the effect of *R. dominica* infestation of the wheat on the rheological and breadbaking properties of wheat flour.

MATERIAL AND METHODS

Raw Materials

Fresh wheat (*Triticum aestivum*) Oasis F-86 cultivar, commercially grown in 1992 in La Costa de Hermosillo, Sonora, Mexico, was obtained for this study. This is a hard wheat and its flour is commonly used for industrial bread production.

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Adult insects of *R. dominica* were obtained from the Entomology Laboratory of the University of Sonora. Insects were reared under laboratory conditions according to the USDA techniques (USDA 1969).

Storage and Infestation of Wheat Samples

Twenty concrete cylindrical silos of 40-kg capacity were used to store the grain. Wheat samples (15 kg) were deposited in each of the silos. Fifteen insects (one- to three-day-old adults) per kilogram of wheat sample were placed in 12 of the 20 silos (eight that were not infested were to be used as controls). Silos were covered with a stainless-steel bolting cloth (38SS) and stored at ambient conditions (28 ± 2°C and 65 ± 5% rh). Three infested and two control silos each were sampled at random after 45, 90, 135, and 180 days of storage.

Number of Insects

From each silo, a 1-kg homogenized sample was taken using the Boerner divider. The number of adult insects present in each sample was counted and reported per kilogram of sample. Wheat was cleaned by passing it over a 7/64" sieve to separate insects and dust from the grain. Controls were free from insects at all sampling periods.

Milling Procedure

Moisture content of cleaned wheat was determined using the Motomco moisture tester. Wheat was tempered by adjusting to 15% moisture according to Method 26-95 (AACC 1995). Tempered wheat samples were ground in a Brabender Quadrumat Sr. experimental mill. Flour yields were recorded. Flour was kept in plastic bags at 5°C for further analysis.

Chemical Analysis

Moisture content of milled insect-infested and control samples was determined by Method 44-15, ash content was determined by Method 08-01, and nitrogen was determined by Method 46-16 (AACC 1995). Protein conversion was N × 5.7.

Color, pH, and Fat Acidity

Flour color was determined using an Agtron M-500-A reflectance spectrophotometer, using the blue and green modes (Method 14-30, AACC 1995). Determination of flour pH was done with a 1:10 mixture of flour and water using a buffer solution of pH 7 at

25°C to calibrate the potentiometer as described in Method 02-52 (AACC 1995). Fat acidity of the flours was determined according to Method 02-01A (AACC 1995). KOH required to neutralize the free fatty acids in mg/100 g were reported.

Farinograms

Flours were analyzed in a Brabender Farinograph-Resistograph using the constant flour weight procedure (Method 54-21, AACC 1995). Flours were evaluated for water absorption, time of development, and mixing stability.

Baking

Bread was baked using the straight-dough procedure (Method 10-10B, AACC 1995) with flour from insect-infested and control wheat. The formula, based on 300 g of flour, contained 225 g of sugar, 4.5 g of salt, 5.1 g of dry yeast, and 9 g of shortening. The flour and ingredients were mixed at low speed for 30 sec in the farinograph. Water was added and the speed of the farinograph blades was increased to full speed and stopped at the predetermined optimum mixing time. After mixing, doughs were fermented for 2 hr at 30°C and 70% rh. The doughs were punched through an opening of 9/32" and 3/16" at 30 and 60 min, respectively. Doughs were scaled, divided into three equal parts, molded, proofed for 60 min, and baked at 250°C for 10 min. The bread loaf volume was measured 30 min after baking by rapeseed displacement. Bread was weighed and cut in half for height measurements.

Experimental Design

A completely randomized design was used to estimate the variation among the treatment means (three replicates of each storage period [0, 45, 90, 135, and 180 days]). All the analyses were done in triplicate. Data were analyzed using the general linear model; means of treatments were compared by Tukey's test (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

Number of Insects

The insect population showed a slight increase at the end of the first sampling period (45 days). At other sampling periods, insect populations showed a rapid increase to a constant level. *R. dominica* requires ≈45 days to complete its life cycle. The population density changed (Table I); it followed the sigmoid curve (figure not shown), indicating that the rate of population was controlled by insect density, not lack of food or limitations of the environment. The insect population growth rate observed was unusual. The number of the insects grew rapidly in the 45–90 day storage period. This could be due to little insect competition and abundant food availability. In addition, from the statistical analysis of the data, we observed that the standard deviations were ±5 and ±25 with means of 45 and 571 insects/kg, for the 0–45 and 45–90 day periods, respectively. From these observations, we believe supplementary entomological studies should be done to further understand the behaviors observed.

Flour Yield

Flour yields were significantly lower ($P \leq 0.05$) in infested wheat samples than in the controls (Table I). Flour yield of uninfested samples did not change significantly ($P \geq 0.05$) in 180 days. Samples with the largest insect populations tended to give the lowest flour yields ($r^2 = -0.61$). This reduction in flour yield represented a 2–9% point loss. Our results are similar to those of Liscombe (1962), who reported that wheat infested with 41 internal forms/100 g lost 1.1% of weight due to insect feeding in a storage period of 11 weeks, which represented 5% less flour.

Chemical Analyses

Chemical analyses (protein, ash, fat acidity, and pH) for control wheat samples were not significantly affected by storage time ($P \geq 0.05$). The means obtained for these analysis were similar to the initial time (zero storage days) values.

Moisture contents of control wheat lots did not change (data not shown), whereas the insect-infested wheat lots showed a moisture gain of 1–2% (Table I). These increases in moisture contents may have been due to the insect metabolism. Pant and Susheela (1977), Pushpamma and Reddy (1979), and other authors have reported that the moisture contents of insect-infested flours and cereal grains increased with infestation.

The protein content increased only in the whole wheat flour from insect-infested lots (Table I). It might be partly the result of proteolysis. Also, *R. dominica* reduces the carbohydrate content by eating starch, so the percent of protein content increases. El-Dessouski and El-Kifl 1976, Salunkhe et al 1985, and Girish et al 1975 have noted this previously. In the milled flour, the protein content tended to decrease. Correlation coefficient between the

TABLE I
Results of Analysis from Stored Wheat Infested with the Lesser Grain Borer *Rhyzopertha dominica*

Storage Days	No. of Insects/kg	Flour Yield	Moisture	Protein[a]		Ash	pH	Fat Acidity
				Whole Flour	Flour			
0	0a[b]	70.9a	8.0a	11.3a	8.4a	0.48a	6.2a	23.5a
45	45b	67.2a	9.8b	12.6b	8.3a	0.40a	5.9a	23.9a
90	571c	69.4a	10.7c	10.7c	8.0a	0.45a	6.0a	29.8b
135	571c	62.1b	10.0b	12.9b	7.1b	0.40a	6.0a	36.2c
180	551c	61.2b	10.0b	11.8b	7.6b	0.42a	5.5b	40.7c

[a] N × 5.7.
[b] Values followed by the same letter in a column are not significantly different at 5% level.

TABLE II
Color Reflectance, Farinograph, Amylograph, and Bread Results Obtained from Flour Milled from Stored Wheat Infested with the Lesser Grain Borer *Rhyzopertha dominica*

Storage Days	Color		Temp. of Gelatinization	Viscosity (BU)	% Water Absorption	Development Time (min)	Mixing Stability (min)	Loaf Height, cm	Loaf Volume (cm^3)
	Grain	Flour							
0	45.3a[a]	54.5a	59a	1,873a	51a	3.2c	15.2b	6.6b	568b
45	44.8a	54.2a	59a	1,887a	52b	3.0b	14.5b	6.9b	516b
90	48.3b	52.5a	59a	1,711b	53b	3.0b	10.1a	7.0b	521b
135	50.1b	58.9b	59a	1,942a	50a	2.2a	11.5a	5.6a	407a
180	60.9c	56.1b	62b	1,935a	51a	2.3ab	10.1a	5.6a	407a

[a] Values followed by the same letter in a column are not significantly different at 5% level.

number of insects and flour protein content was r = –0.804. This probably indicates that the insect excreta is mostly deposited in the outer layers of the grain, which are removed during the milling process. Ash contents were not different ($P \geq 0.05$) (Table I).

pH and Fat Acidity

The pH value decreased in flour from insect-infested wheat over storage time (Table I), which could be attributed to the presence of uric acid in flour samples. Fat acidity of flour from infested wheat increased significantly ($P \leq 0.05$). This increase correlated with the increase in insect population (r = 0.847) and can be attributed to lipid hydrolysis. We presume this is due to the lipase action on the triacylglycerides and other acylated lipids and production of free fatty acids. *R. dominica* makes holes in the kernels, and thus oxygen may be in contact with the interior of the grain causing rancidity and off-flavors.

Color

Color of whole wheat flour gradually brightened as the insect population increased with time (Table II). This brightening may be caused by insect-damaged kernels. Linear correlation coefficient showed a highly significant relationship between wheat brightening and number of insects (r = 0.892 for the blue mode). The green mode was not significant. In white flour, the brightening may have been due to insect excreta, cast skins, body fragments, and other insect contaminants that could not be removed by cleaning because they were inside the wheat and, therefore, remained in the flour after milling.

Farinograms

Water absorption showed small but significant variation ($P \leq 0.05$). Development time and dough mixing stability were significantly affected by insect infestations ($P \leq 0.05$, r = –0.75 and r = –0.968, respectively) (Table II). The values were lower in all the insect-infested samples than in the control samples. This indicates that the insects affected the protein quality and reduced the ability of the gluten to form a strong and continuous microstructural network in the dough.

Baking

The height and volume of bread loaves decreased considerably over the time of storage in infested wheat (r = –0.52 and r = –0.73, respectively) (Table II). Bread loaf volume from infested flour decreased when compared with the control. This probably can be attributed to the poorer dough-making properties of flour from infested grain. All the breads made with flour from insect-infested grain had an off-odor. The source of this odor was probably the insect excreta and other body secretions left on the surface or inside of the infested kernels. Color of bread loaves made with flour from insect-infested grain darkened at the later sampling time (data not shown). Venkatrao et al 1960, Jood et al 1993, and Smith et al 1971 reported that insect infestation affected the baking quality of flour. The loaf volume of bread baked from insect-infested flour was low, and the crumb was dense and had no elasticity when compared with bread from the controls.

CONCLUSIONS

Flour obtained from insect-infested wheat showed changes in rheological properties such as development time, water absorption, and mixing stability. Bread prepared from this flour showed a variety of negative trends, including darker color, reduced loaf volume and poor crumb characteristics, and a distinct, offensive odor. Farinograms and baking tests provided good information about quality deterioration caused by *R. dominica* infestation in wheat.

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