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Susceptibility of the Gelatinized Wheat Product Bulgur to *Sitophilus zeamais* Motsch. and *Rhyzopertha dominica* (F.)*

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Abstract—The development of *Sitophilus zeamais* and *Rhyzopertha dominica* was studied at relative humidities of 71, 58 and 43% in bulgur and wheat. Male and female adult weevils, introduced into 6 bulgur and 6 wheat media of different particle sizes, were allowed to oviposit for 7 days. Thirty *R. dominica* eggs were placed in each replicate of a similar set of bulgur and wheat media.

S. zeamais produced more adult progeny in whole kernels of bulgur and of wheat and in the larger-sized particles, and a high percentage of *R. dominica* larvae developed into adults in these media. *S. zeamais* progeny produced and *R. dominica* larvae surviving were fewer, and developmental periods for both species longer, the smaller the particles and the lower the relative humidity. Males and females collected from bulgur and wheat media of the same particle size tended to weigh the same; but the smaller the particle size, the less the weights.

INTRODUCTION

BULGUR, a gelatinized wheat product, has been a mainstay in the diets of people in Middle East countries for several hundred years (HALEY *et al.*, 1960). In the United States it is produced in several ways, but usually by soaking the wheat followed by cooking, drying and, after removing part of the bran, cracking (BROWN, 1962).

The purpose of this research was to determine whether either the maize weevil, *Sitophilus zeamais* Motsch., and the lesser grain borer, *Rhyzopertha dominica* (L.), could develop in whole and cracked bulgur and, if so, the lengths of their developmental periods and the weights of emerging adults.

MATERIALS AND METHODS

All test media were kept at −17°C for 1 week to destroy any existing infestation and then were stored at 4·4°C until used.

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Whole and cracked bulgur were obtained from a commercial processor, the whole bulgur from the processing line just prior to cracking and the cracked bulgur as a sample of the final product. The hard, red winter wheat used was of the same lot from which the test bulgur was made. Whole wheat was cracked with a coffee grinder set to give particles similar in size to those of the 'cracked bulgur'. Both cracked media ranged from a few whole kernels to many fine particles. These and the whole kernel forms were tested along with samples of cracked bulgur and wheat of four known particle sizes. These latter were obtained by passing portions of the cracked product through a stack of U.S. Standard Sieve Series sieves numbered 8, 10, 12, and 20 which allowed passage of particles of up to 2·36, 2·0, 1·65, and 0·83 mm, respectively. The material passing through the No. 20 sieve was discarded. The material held on the Nos. 8, 10, 12 and 20 sieves were designated >8, <8–>10, <10–>12, and <12, respectively. Six samples of each foodstuff were used for each test described below.

Saturated solutions of strontium chloride, sodium bromide, and potassium carbonate were used to obtain relative humidities of approximately 71, 58 and 43% in 29·5 × 19·5 × 10 cm^3 plastic containers (SOLOMON, 1951). A 1·27-mm hail-screen platform was installed in each container (humidity chamber) to support the test boxes. The containers were covered with well-fitting snap-on lids and placed in a room with temperature varying from 25° to 29°C. Containers were not air-tight and each was opened irregularly to check the saturated solution, then opened regularly after the beginning of adult emergence.

For the maize weevil tests, 8 g of each medium (particle size) were weighed and placed in small plastic boxes, 44 × 44 × 15 mm^3. Four-g samples were used in lesser grain borer tests. Each test-box lid contained a hole, 38 mm in dia., covered with 24-mesh/cm wire cloth.

The boxes of media were placed on hailscreen platforms in the humidity chambers for 2–4 weeks of moisture equilibration. There were sufficient chambers with each r.h. to permit test boxes to be placed in one layer. Extra samples were included in each chamber and subsamples from these were tested for moisture content by the air-oven method.

Each replicate was infested with 6 male and 10 female maize weevils 14 (±1) days old, allowed to mate and oviposit for 7 days, then were removed. In lesser grain borer tests, 30 1-day-old eggs were placed in each replicate.

Every other day, starting with first emergence, progeny of the weevils were aspirated from the media and counted. Each replicate containing lesser grain borers was examined every other day for emergence holes and the adults removed. Frequently this required their extraction from within kernels and the larger particles.

The first 10 male and 10 female adults of each species to emerge from whole and from <8–>10 media, and of lesser grain borers from <12 particles also, were weighed.

RESULTS AND DISCUSSION

Moisture contents of wheat and bulgur

In each of the three relative humidities, bulgur equilibrated at a moisture content of from 1·0 to 1·7% lower than that for wheat. FERREL *et al.* (1965) previously reported similar findings.

Maize weevil

At 71% r.h. as many progeny were removed from bulgur as from wheat of the same particle size. At 58 and 43% r.h. progeny were fewer from bulgur than from wheat (Fig. 1). Only 20 weevils emerged from the bulgur at 43% r.h., 5 from the cracked and 15 from the >8. Progeny from most media were fewer, the lower the relative humidity and the smaller the particles. Figure 1 indicates that the >8 media might have been exceptions, but they were composed of larger particles only, which had been screened from the cracked media; the latter included substantial amounts of finer particles. The average number of progeny per replicate at 71% r.h. ranged from

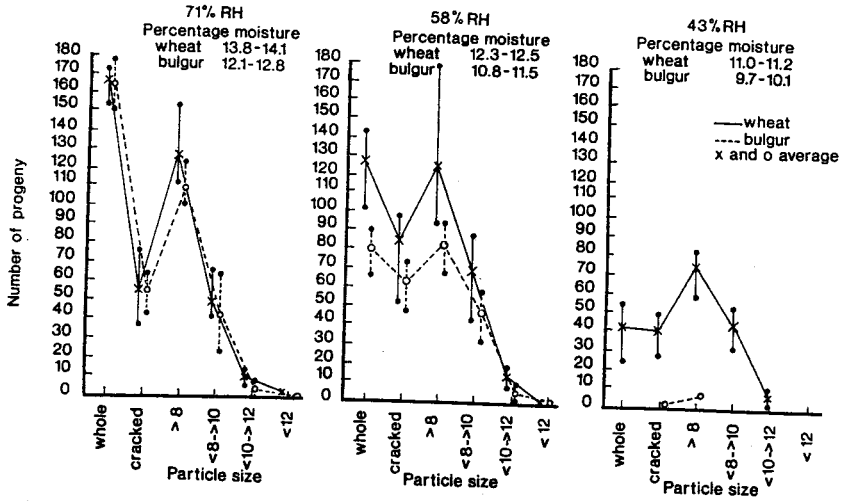

FIG. 1. Range and average numbers of progeny per replicate produced by maize weevils in bulgur and wheat of different particle sizes at 71, 58 and 43% r.h. (6 males and 10 females were placed in each of the six replicates of each particle size for a 7-day oviposition period). Total progeny from bulgur at 43% r.h. was 20:5 from cracked and 15 from > 8-mesh.

165·2 and 166·8 in whole bulgur and whole wheat to 0·0 and 1·0 in both bulgur and wheat of <12 particles. At 58% r.h. the range was from 81·8 per replicate in >8 bulgur and 127·8 per replicate in whole wheat to 0·17 in both bulgur and wheat of <12 particles. At 43% r.h. the range was from 74·7 in >8 wheat particles to 6·7 in <10–>12 wheat particles. The only progeny from bulgur at 43% r.h. were 0·8 per replicate in cracked, and 2·5 in >8 particles.

The developmental periods of maize weevils were longer in bulgur than in wheat, and were longer in both bulgur and wheat as the relative humidity was decreased (Fig. 2). At 71% r.h. the average developmental periods ranged from 35·7 and 32·9 (±4) days in whole bulgur and whole wheat, respectively, to 37·9 in <10–>12 bulgur and 36·7 in <12 wheat. At 58% r.h. the shortest average developmental period in bulgur was 40·6 (±4) days in whole kernels, and longest was 42·1 in <10–>12 (except for a single adult, from <12 bulgur, having a developmental period of 44 days). The shortest average developmental period in wheat at 58% r.h. was 35·6 days in <8–>10 particles (except for a single adult, from <12 particles,

having a developmental period of 35·0 days), and the longest was 37·0 in whole kernels. At 43% r.h. the developmental periods in wheat averaged from 50·9 (±4) days in whole to 48·4 in <10–>12 particles. Adults emerged from only two bulgur media at 43% r.h.; average developmental periods were 58·2 days in cracked and 58·6 days in >8 particles.

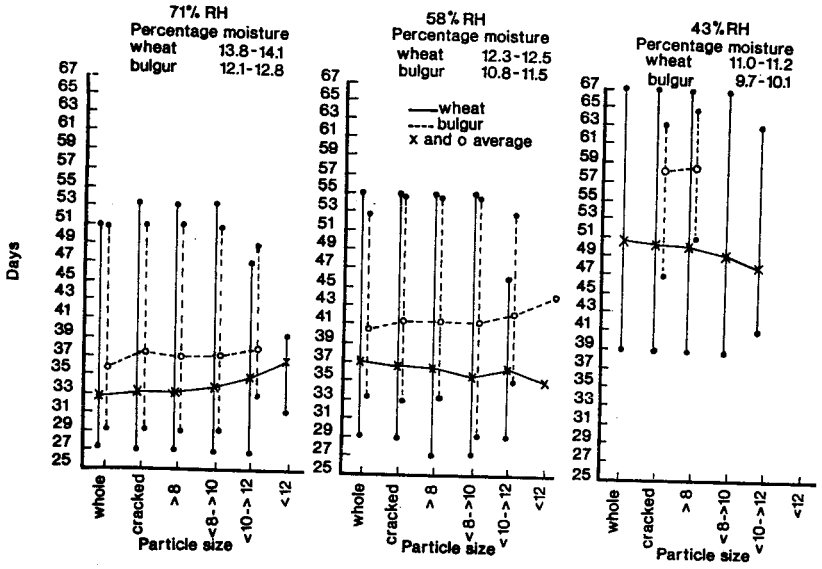

FIG. 2. Range and average of developmental periods (oviposition to adult emergence in days ± 4) of maize weevils in bulgur and wheat of different particle sizes at 71, 58 and 43% r.h. (6 males and 10 females were placed in each of the 6 replicates of each particle size for a 7-day oviposition period).

At 71% r.h. adults from whole bulgur weighed approximately the same as those from whole wheat; at 58% r.h. those from the whole bulgur kernels weighed more. No adults emerged in whole bulgur at 43% r.h. (Table 1). Table 1 shows that the smaller the particle sizes of both bulgur and wheat, the less the weights; but individuals from the same medium in different relative humidities weighed approximately the same.

TABLE 1. AVERAGE WEIGHTS (mg) OF THE FIRST 10 MALE and 10 FEMALE MAIZE WEEVILS TO EMERGE FROM BULGUR AND WHEAT MEDIA AT 71%, 58% AND 43% r.h.

Medium	71% r.h.		58% r.h.		43% r.h.	
	Male	Female	Male	Female	Male	Female
Whole bulgur	2·64	2·65	2·77	2·73	No emergence	
Whole wheat	2·64	2·68	2·42	2·55	2·21	2·26
<8–> 10 bulgur	1·32	1·40	1·42	1·38	No emergence	
<8–> 10 wheat	1·43	1·26	1·31	1·24	1·27	1·24

Lesser grain borer

Approximately 70 per cent of the lesser grain borer eggs hatched (from 60 to 80 per cent per replicate). Survival rate in bulgur and wheat was inconsistent but differed little, regardless of particle size or relative humidity. Lesser grain borers survived at all three relative humidities in bulgur and wheat of all particle sizes, but survival was much less in smaller particles (Fig. 3). In bulgur at 71% r.h., survival was highest in whole kernels (av. 89·6 per cent per replicate) and lowest in <12 particles (31·0 per cent per replicate). In wheat at 71 per cent r.h., highest survival was in $<8->12$ particles (92·4 per cent) and lowest in <12 (39·0 per cent).

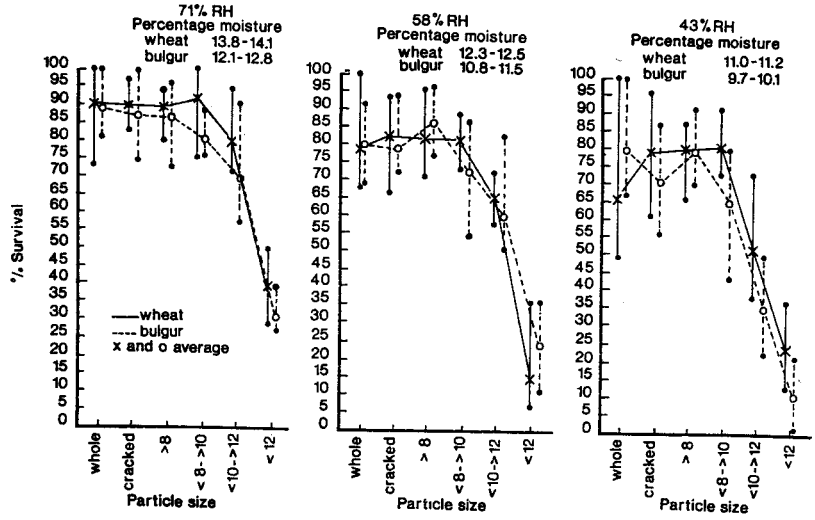

FIG. 3. Range and average survival (per cent of hatched larvae) of lesser grain borers in bulgur and wheat of different particle sizes at 71, 58 and 43% r.h. (30 eggs were placed in each of the 6 replicates of each particle size).

At 58 per cent r.h. highest survival in bulgur was 87·1 per cent in >8, and lowest was 24·3 per cent in <12 particles; in wheat the highest was 83·3 per cent in cracked, and lowest was 14·9 per cent in <12 particles. At 43 per cent r.h. highest survival in bulgur was 80·7 per cent in >8 particles, and lowest was 11·0 per cent in <12 particles; in wheat the highest was 81·6 per cent in $<8->10$ particles, and lowest was 23·6 per cent in <12 particles. Survival in whole kernels of wheat was less than in the coarser cracked wheat media. This may have been due to greater resistance to larval entry. This was not true of the bulgur media, possibly due to the rougher surface of the whole kernels of bulgur. Some of the bran was removed during processing, leaving an unevenness which may have rendered the whole kernels as susceptible to larval entry as the cracked kernels.

The average developmental periods of the lesser grain borers in bulgur media were consistently longer than in corresponding wheat media at each of the three relative humidities; in both bulgur and wheat, the periods generally were longer the smaller the particles and the lower the relative humidity (Fig. 4). The effects of particle size and relative humidity were slightly greater in the bulgur than in the wheat. At 71%

r.h. average developmental periods in bulgur ranged from 47·0 days in whole kernels to 54·6 days in < 12 particles; in wheat the range was small, 42·6–44·0 days. At 58% r.h. developmental periods in bulgur ranged from 50·8 days in whole kernels to 61·6 days in < 12 particles; in wheat the range was from 46·2 in < 8–> 10 particles to 50·5 in < 12 particles. At 43% r.h. the range in bulgur was from 62·5 in whole kernels to 68·7 in < 8–> 10 particles; in wheat, from 51·7 in whole kernels to 55·7 in < 12 particles.

Adults emerging from wheat generally weighed about the same as, or slightly more than, those emerging from bulgur, in corresponding treatments (Table 2). The weights in both bulgur and wheat were less in the smaller particle sizes, and tended to be less as the relative humidity decreased.

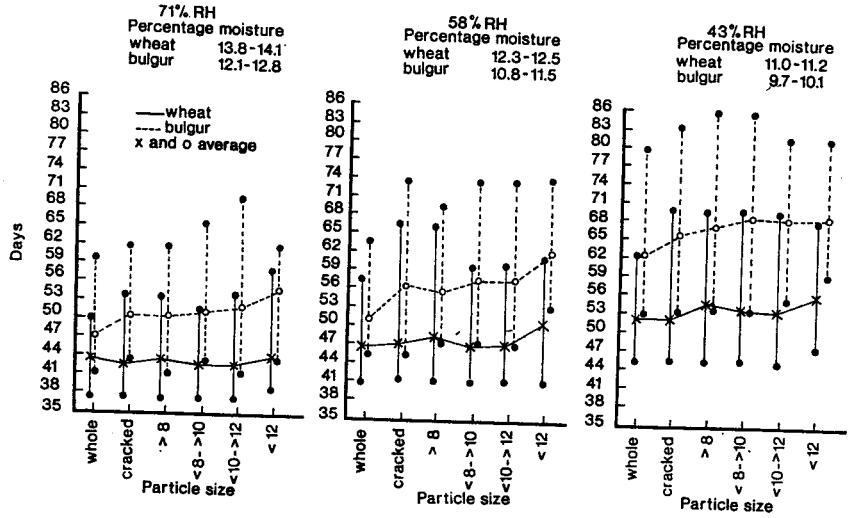

FIG. 4. Range and average of developmental periods (from oviposition to adult emergence in days ± 0·5) of lesser grain borers in bulgur and wheat of different particle sizes at 71, 58 and 43% r.h. (30 eggs were placed in each of the 6 replicates of each particle size).

TABLE 2. AVERAGE WEIGHTS (mg) OF THE FIRST 10 MALE AND 10 FEMALE LESSER GRAIN BORERS TO EMERGE FROM BULGUR AND WHEAT MEDIA AT 71%, 58% AND 43% r.h.

Medium	71% r.h.		58% r.h.		43% r.h.	
	Male	Female	Male	Female	Male	Female
Whole bulgur	1·18	1·23	1·15	1·25	1·04	1·07
Whole wheat	1·15	1·20	1·33	1·27	1·22	1·13
< 8–> 10 bulgur	0·99	0·96	0·91	0·89	0·82	0·83
< 8–> 10 wheat	1·15	1·20	0·98	0·99	0·86	0·92
< 12 bulgur	0·82	0·86	0·77	0·78	0·68	0·67
< 12 wheat	0·84	0·85	0·86	0·80	0·72	0·92

This study has shown that the maize weevil and the lesser grain borer developed successfully in bulgur, especially at higher humidities. But development was slower in bulgur than in wheat held at the same relative humidity. It is not known to what extent the development in bulgur is affected by the lower equilibration moisture content and by the physical and chemical changes wrought by processing.

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