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# Effect of Malting on Development of Rice Weevils in Barley[1,2]

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ABSTRACT

Barley was steeped, germinated, and kilned under laboratory conditions, and the effects of the various steps in the malting process and of adding gibberellic acid (to enhance enzyme synthesis) and gibberellic acid plus potassium bromate (to check proteolytic activity) on the oviposition and growth of *Sitophilus oryzae* (L.) were determined. High kilning of malt, and especially of barley, reduced number of progeny and increased development time. Gibberellic acid did not affect the number of progeny or their development time, but potassium bromate had an inexplicable effect in reducing progeny numbers. The main effects of barley processing on rice weevil development were from heat treatment.

Processing of grain affects susceptibility of finished products to insect attack. In studies with the maize weevil, *Sitophilus zeamaiz* Motschulsky, and the lesser grain borer, *Rhyzopertha dominica* (F.), on bulgar (a gelatinized wheat product), Robinson and Mills (1971) found that both insects developed faster in bulgar, especially at high humidities, than in nonprocessed wheat at similar humidities. Boles and Ernst (1972, 1973) demonstrated that WURLD Wheat,[5] another gelatinized product, would not support a population of the red flour beetle, *Tribolium castaneum* (Herbst), was not very attractive to the rice weevil, *Sitophilus oryzae* (L.), and developmental periods were longer and progeny emergence was lower on processed than on unprocessed wheats. Mills (1973) found similar results when he tested WURLD against the maize weevil. McGaughey (1974) reported that parboiled milled rice was less suitable than raw milled rice for progeny production by the rice weevil, the lesser grain borer, and 5 other stored product insects.

Barley is extensively processed and modified in malting (Kneen and Dickson 1967, Pomeranz 1975). In a survey of mites and insects in 60-malt-producing premises in England, Hunter et al. (1973) found over 100 species and showed that malting practices provide a variety of environments affecting insects and mites. Little published information is available, however, on the effects of barley modifications during malting on the susceptibility of the kernel to attack by storage insects.

Malting is a controlled, defined, germination process that liquefies high-molecular-weight components and modifies the physical properties of the barley kernel. Our purpose was to determine effects of malting on susceptibility of barley to oviposition and development of the rice weevil.

MATERIALS AND METHODS.—Barleys and malts were from 2 sources. 'Larker', a 6-rowed, white aleurone barley was malted under laboratory conditions according to Dickson et al. (1968). Gibberellic acid and potassium bromate were dissolved in water and added as a spray after steeping.[6] The test materials from the laboratory-malt series included the original barley, freeze-dried steeped barley, steeped barley kilned at a maximum of 85°C (high kiln), freeze-dried malted barley, malted barley kilned at a maximum of 65°C (low kiln), and malted barley kilned at a maximum of 85°C. The low-kiln barley malt also was pretreated with 2 ppm gibberellic acid or with 2 ppm gibberellic acid and 800 ppm potassium bromate ($KBrO_3$). In addition, a commercial malt from Larker barley was studied. The barleys and malts were analyzed according to Anon. (1958).

Following 4 wk of equilibration at 26.7±2°C and 60% RH, 5 replicate samples of each test material were prepared. Each replicate sample consisted of 100 uniform and whole kernels which were weighed and then placed into separate vials, screened on top and bottom.

Each replicate was infested with 6 female and 3 male rice weevils 14±7 days old, that were allowed to mate and oviposit for 7 days, and then removed. Beginning 25 days after the start of oviposition, kernels were examined for progeny every day for 35 days. Emerged progeny were removed from the vials on each count day. After emergence was completed, samples were weighed for weight loss determinations. Two separate tests, as described previously, were conducted with each material and the results were combined for reporting purposes.

RESULTS AND DISCUSSIONS.—Table 1 summarizes results of the weevil feeding tests. Steeping alone (treatment 2), as compared with no treatment, did not significantly affect the number of progeny or length of insect development. Kilning of the steeped barley (treatment 3) significantly reduced the num-

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[5] So named to indicate origin of its development, Western Research and Development Division of USDA, Albany, Calif.

[6] In malting, applications of exogenous gibberellic acid enhance the production of at least 6 hydrolytic enzymes in the aleurone cells of barley, potassium bromate (an oxidant) is added to prevent excessive proteolytic activity.

Table 1.—Development of rice weevil on steeped, malted, and kilned Larker barley.[a]

| Treatment | Moisture % | Protein % | Mean wt 10×100-kernel samples mg | Mean no. progeny produced[b] | Mean no. development days[b] | Wt loss per insect produced mg | Mean wt 1st 20 insects mg |
|---|---|---|---|---|---|---|---|
| 1. No treatment | 11.0 | 12.0 | 3965 | 28.2 a | 41.7 a | 14.18 | 1.93 |
| 2. Steeped, not malted | 12.0 | 12.7 | 3572 | 29.1 a | 42.7 a | 13.44 | 1.76 |
| 3. Steeped, high kiln | 10.0 | 12.8 | 3426 | 13.1 d | 48.2 bc | 17.71 | 1.68 |
| 4. Malted, freeze dried | 10.7 | 12.3 | 3426 | 25.3 a | 47.2 b | 15.69 | 1.80 |
| 5. Malted, low kiln | 10.7 | 12.5 | 3553 | 28.3 a | 47.9 bc | 17.36 | 1.90 |
| 6. Malted, high kiln | 10.6 | 12.5 | 3699 | 23.0 ab | 48.9 bc | 20.26 | 1.93 |
| 7. Malted gibberellic acid 2 ppm, low kiln | 10.9 | 12.3 | 3538 | 24.9 ab | 48.0 bc | 17.13 | 1.81 |
| 8. Malted gibberellic acid 2 ppm, $KBrO_3$ 800 ppm, low kiln | 10.5 | 12.6 | 3922 | 15.9 cd | 46.8 b | 17.10 | 1.99 |
| 9. Commercial malt | 10.8 | 12.8 | 3596 | 19.0 bc | 49.1 bc | 16.92 | 1.75 |

[a] Totals are for 2 tests, each with 5, replicated 100-kernel samples for each treatment; each sample infested for the oviposition period with 6 female and 3 male weevils.
[b] Means followed by the same letter do not differ significantly at the 5% level (Duncan's multiple range test).

ber of progeny and increased the length of development. The heat treatment apparently reduced substantially the nutritive value or availability of nutrients. Malting without kilning (treatment 4), as compared with no treatment, slightly affected the number of progeny, even though it apparently lengthened somewhat the development time.

The effects of heat treatment alone on the nutritive value can be demonstrated further by a comparison of results from treatments 3 and 4 with those from treatments 5 and 6. The number of progeny and development time for malted-low kiln, malted-high kiln (treatments 5 and 6) and malted-freeze dried (treatment 4) were not significantly different. However, treatment 3 reduced the number of progeny significantly without affecting development time differently from treatments 4, 5, and 6. Both in the steeped-high kiln and the malted-high kiln samples, weight loss per insect produced was slightly larger than in malted, freeze-dried samples (treatment 4). This indicates poorer utilization by the insect of the nutrients in the high-temperature-treated barley or malt.

Comparison of treatments 5 and 7 shows that gibberellic acid did not affect the number of progeny or their development time. The reason for the reduction in number of progeny when bromate was included in the treatment (treatment 8) is not known. It is rather unlikely that the oxidant survived the malting and kilning processes. The production of progeny might have been inhibited by organic compounds oxidized by the bromate. The reduced number of progeny and increased weevil development time in the commercial malt (treatment 9) likely resulted from the relatively high temperatures used in commercial malting.

As noted in the introduction, workers have found that when grown on heat-processed grains, insects develop more slowly than normal. No explanation was given as to why heat-processed grains were less suitable for weevils. They noted that the heat-treated grains equilibrated at lower moisture than the unprocessed grains, a condition noted to a rather limited extent with the barley samples used in our study.

The heat-treated barleys and malts showed stress cracks from the alternate wetting and drying. However, x-ray examination during insect development and final emergence counts showed that the cracks did not affect the larvae developing within the kernels.

Our study indicates that the rice weevil is highly sensitive to differences in nutrient contents or availability of nutrient contents resulting from grain processing. Since information on the nutritive requirements of *Sitophilus* species are particularly meager (Baker and Mabie 1973), more study is needed to delineate further the factors which are responsible for variations in the response of rice weevils to processed and unprocessed grains.

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