EFFICACY OF A STRUCTURAL HEAT TREATMENT AGAINST *Tribolium castaneum* LIFE STAGES

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The Hal Ross flour mill, a pilot mill at Kansas State University, was subjected to heat treatment during May 13-15, 2009 using forced air gas heaters. Strategically placed fans facilitated distribution of heated air within the mill floors. The Hal Ross flour mill has five floors and the total volume is about 49,611 cubic meters. Tests were conducted during May to compare the effectiveness of methyl bromide (MB), sulfuryl fluoride (SF), and heat treatment for managing eggs, larvae, pupae, and adults of the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)—a pest that is commonly associated with food-processing facilities. The results on the efficacy of MB and SF against life stages of *T. castaneum* are reported separately at this conference. In this paper, we report on the efficacy of heat treatment against the life stages of *T. castaneum.* In order to determine the efficacy of the heat treatment, five bioassay boxes were placed in different locations (within and outside equipment) on each of the five mill floors. The bioassay box had 12 smaller compartments with lids. Two depths of flour were used to represent two levels of sanitation: “good” sanitation was represented by dusting of flour in six of the compartments and “poor” sanitation was represented by 2 cm deep flour in the other six compartments. In five compartments with dusting and 2-cm deep flour, 50 eggs, 50 young larvae, 50 old larvae, 50 pupae, and 50 adults were introduced from cultures. The remaining two compartments had temperature sensors (SmartButton, ACR Systems Inc., Surrey, Canada) to measure temperatures every two minutes. In addition, 48 HOBO® data loggers (Onset Computer Corp., Pocasset, MA) were placed at floor level among the five mill floors; the first floor had eight and the other floors had 10 data loggers each. These data loggers were placed in a grid fashion on each floor, with one data logger being placed near the staircase, outside of each mill floor. These data loggers were launched by computer to record

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temperatures every minute during the heat treatment.

On each floor of the Hal Ross flour mill, we placed 10 food-baited pitfall traps with a lure for *Tribolium* spp. (Trécé, Adair, OK) in October 2008. Ten traps were also placed on the outside perimeter of the mill. These traps were checked biweekly to determine insect populations present inside and outside the mill. There were two HOBO® data loggers outside the mill and one on each floor of the mill to record hourly temperature and relative humidity throughout the trapping period.

In another experiment, the effect of sanitation on the mortality of *T. castaneum* eggs and adults was verified. Different sanitation levels were simulated in 15 cm high and 20 cm internal diameter PVC rings. During August 25-26, 2009 second heat treatment, 24 rings were placed on the first floor and 24 on the third floor of the mill. Another set of 24 rings placed on the fourth floor of the old flour mill in the Department of Grain Science and Industry served as the control treatment (unheated). The six treatments that included different flour depths (and weights) of wheat flour with 5% yeast used for rearing *T. castaneum* in the laboratory were: 0.1 cm (15 g), 0.2 cm (38 g), 1.0 cm (109 g), 3.0 cm (388 g) cm, 6.0 cm (937 g) and 10.0 cm (1,645 g). In the laboratory, either 100 eggs or 100 adults were placed on the flour in glass jars and brought to the mill. At the mill site, the jar contents were emptied into the rings. Each ring had a SmartButton to measure temperatures every minute. There were two rings per treatment for eggs and two for adults. The contents of one half of the rings (12) were carefully collected at 12 hours into the heat treatment and placed in polyethylene bags and transported to the laboratory. Contents of another 12 rings were collected at the end of the heat treatment (24 hours). In the laboratory contents from bags were placed in glass jars with lids and incubated at 28°C and 65% RH. Adult mortality was checked 24 hours after collection, whereas the egg mortality was determined by rearing eggs to the adult stage. Only the adult mortality data are available at this time. The controls were handled similarly to determine natural mortality.

RESULTS

Psocids were the predominant species soon after trapping was initiated. A few economically important stored-product insects were captured in traps placed indoors and outdoors, but the densities were too low to be of any practical concern. Psocids were captured in traps between MB, SF, and heat treatments. The effectiveness of the three treatments in suppressing resident populations of insects cannot be ascertained based on trap captures.

The outside temperature on the day of heat treatment (May 13, 2009) was on an average 22°C and the ambient mill temperature was 24°C. Temperatures within the mill based on the 48 data loggers attained a maximum temperature that varied from 50-74°C; in two locations on the first floor temperatures did not reach 50°C. The time to reach 50°C was considerably slow and among the 48 locations this time ranged from 1-22 hours. The time to reach 50°C during an “effective” heat treatment should be around 6-8 hours. Only in five locations did temperatures reach 50°C within this time period. In all other locations the time to reach 50°C ranged from 10-22 hours, indicative of a slow heating rate. The maximum temperatures attained varied considerably and ranged from 44-74°C.

The maximum temperatures within the bioassays varied from 51-67°C. In one bioassay box on the first floor the maximum temperature never reached 50°C and was 42°C. In another box on the first floor, only the compartment with flour dust had a maximum temperature of 51°C while the one with 2-cm deep flour recorded a maximum of 49°C. These two boxes were placed inside a roller mill.

In the compartments with flour dust, the time to reach 50°C was 9-22 hours, whereas in compartments with 2-cm deep flour 12-22 hours were necessary to reach 50°C. In general, at every location, compartments with 2-cm deep flour took 1 to 5 hours longer than those with flour dust to reach 50°C. In compartments with flour dust , the maximum temperatures attained ranged from 42-67°C; in 2-cm deep flour compartments the maximum temperatures attained were 43-63°C.

In bioassay boxes, there was 100% mortality for all life stages except for insects in boxes in few locations. . The mortality can be related to how quickly temperatures reached 50°C and how long temperatures were maintained above 50°C. Despite the slow rate of heating to 50°C, in a majority of locations temperatures did reach 50°C and were maintained above 50°C for several hours, which was long enough to kill 100% of the insects.

During the August heat treatment, on first floor, maximum temperatures at 12 hours in the rings with various flour depths ranged from 35-45°C. After 24 hours it was still 43-49°C. On the third floor, maximum temperatures in the PVC rings ranged from 44-47°C at 12 hours and 57-58°C at 24 hours. Adult mortality in untreated PVC rings (control treatment) was 0-4%. On the first floor, the mortality of adults in various sanitation levels was 0-3% after 12 hours, whereas on the third floor the mortality ranged from 0-100%. After 24 hours, on the first floor mortality ranged from 2-89% while corresponding mortality on the third floor was 100%. Unlike the May treatment, during the August treatment temperatures reached 50°C within 10 hours in a majority of locations. The issues with heat distribution during the May heat treatment helped in modifying the August treatment to achieve the desired results.