Responses of Red Flour Beetle Life Stages to Elevated Temperatures

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Abstract

Eggs, younger instars, older instars, pupae, and adults of the red flour beetle, *Tribolium castaneum* (Herbst), were exposed to constant temperatures ranging from 42-60ºC. Mortality of each stage increased with temperature and exposure time. Our data indicated that 120 min are required to kill 95% of exposed *T. castaneum* life stages at ≥50ºC. These data can be used to develop a degree-minute approach for predicting mortality under field conditions.

Introduction

Disinfesting food-processing facilities by heating to a threshold temperature of 50ºC for 24-36 h (Fields 1992, Dowdy and Fields 2002, Roesli *et al.* 2002) is a viable alternative to methyl bromide, an ozone depleting space fumigant. Very little is known about the impact of high temperatures on life stages of the red flour beetle, *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), a common insect pest associated with food-processing facilities worldwide (Mills and Pedersen 1990). Experiments were conducted in laboratory growth chambers to establish time-mortality relationships for life stages of *T. castaneum* exposed to six constant temperatures between 42 and 60ºC at 20-25% RH.

Methods

Eggs (2-d old), younger instars (6-d old), older instars (22-d old), pupae (26-d old) and adults (2-wk old) from cultures were held in plastic boxes (Figure 1A) with 305 mg of bleached wheat flour. The mean ± SE (n =15) weight of younger and older instars was 0.12 ± 0.01 mg and 3.59 ± 0.11 mg, respectively.

For each temperature-time combination, five boxes with 20 individuals each were exposed. Adults exposed to high temperatures were kept at 28ºC and 42% RH for an additional 24 h before assessing mortality. Pupae were kept until adult emergence. Eggs, and younger and older instars were held in separate 150-ml plastic containers (Figure 1B) containing 40 g of whole-wheat flour plus yeast. For eggs, larvae, and pupae, mortality was based on those that failed to develop into adults. Natural mortality was monitored in boxes kept at 28ºC and 42% RH.

Data Analyses

Mortality of insects exposed to high temperatures was not corrected for natural mortality (<10%). Data were subjected to probit analysis to estimate lethal times (LT_{95}s). For each combination of insect stage and temperature, probit time-mortality lines were back transformed to linear scale. To show differences among stages, the equation $Y^1 = a + bx^2$ was fit to the LT_{95} (y) and temperature data (x). LT_{95} values at 50-60ºC were expressed in degree-minutes above a base temperature of 48ºC as follows: (Temp.ºC – 48ºC)·LT_{95}. Slopes of linear regressions fit to these data were tested for departure from zero. The base temperature chosen was based on an unpublished degree-minute model by the second author. Statistical analyses were performed using SAS and TableCurve 2D.

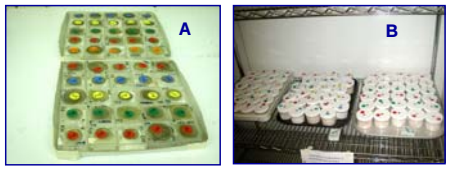


Figure 1. A; Plastic boxes used in tests. B; Plastic containers (150 ml) used for rearing immature stages after high temperature exposure.

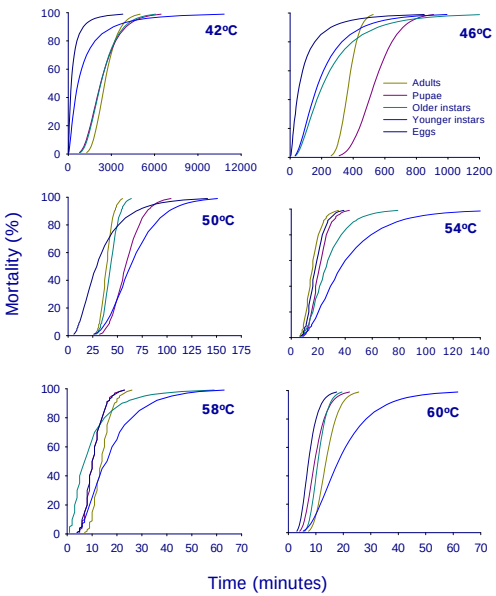


Figure 2. Predicted mortality of *T. castaneum* life stages at six constant temperatures. Each line is based on 1000-1400 insects observed at 10-14 different occasions over time. Independent samples were used for each occasion. **NOTE:** The x-axis scale is different for different temperatures.

Results

Mortality of *T. castaneum* life stages increased with increasing temperature and exposure time. At 42ºC, 95% of the exposed individuals were killed in 60 h; at 50ºC it was about 120 min (Figure 2). All eggs, older instars, and adults were killed within 60 min at 50ºC, whereas only 65% of pupae and 50% of younger instars were killed. At 60ºC, all stages were killed within 60 min. At 50-60ºC, younger instars were the most tolerant stage followed by mature instars (Figure 3). Eggs, pupae, and adults were similar in their responses at 54-60ºC. The degree-minutes versus temperature regression slopes for each life stage, except for adults (Figure 4), were not significantly different from zero (P > 0.05), indicating that this approach may be suitable for predicting mortality under field conditions.

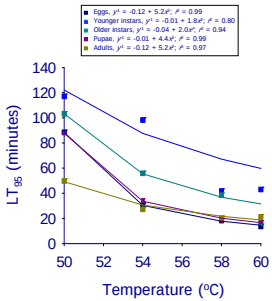
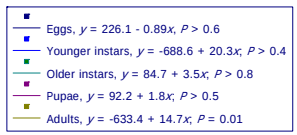


Figure 3. Observed LT_{95} values and fitted lines describing responses of *T. castaneum* life stages at 50-60ºC.



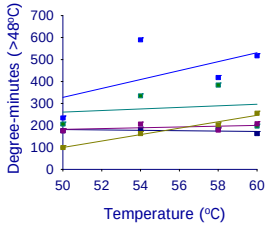


Figure 4. Linear regressions showing relationship between degree-minutes and temperature.

Conclusions

Heat disinfestation treatments that target younger instars will control all other stages. At temperatures ≥50ºC, a minimum of 120 min exposure kills 95% of all life stages. A degree-minute approach may be useful in predicting mortality of immature stages under field conditions. These data form the basis for successful use of high temperatures for *T. castaneum* management in food-processing facilities.

References

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