VACUUM FOR CONTROLLING STORED-PRODUCT INSECTS: EFFECTS OF PRESSURE, TEMPERATURE AND LIFE STAGE

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Low pressure creates a low oxygen atmosphere that is toxic to insects. Eggs, larvae and pupae of the red flour beetle, *Tribolium castaneum*, the Indian meal moth, *Plodia interpunctella* and the lesser grain borer, *Rhyzopertha dominica* were exposed in the laboratory to 32.5 mm Hg in glass chambers at 25, 33, 37 and 40°C for times ranging from 30 min to 144 h. Time-mortality data were subjected to probit analyses and lethal dose ratios were computed to determine differences in lethal time (LT) values among all species-life stage combinations across the four temperatures. Eggs of each species were the life stage most tolerant to low pressure. Pupae of *T. castaneum* and *R. dominica* were more tolerant to low pressure than larvae. In all cases, mortality increased with increasing exposure time to low pressure and also with increasing temperature. Immature stages of *R. dominica* were more tolerant to low pressure than immature stages of the other two species. The LT_{99} for *R. dominica* eggs was 176.32 h at 25°C and that for *P. interpunctella* eggs was 28.35 h at the same temperature. An increase in temperature to 33°C resulted in a LT_{99} of 85.98 h for *R. dominica* and 6.21 h for *P. interpunctella*. Higher temperatures resulted in further significant reduction in lethal time values.

Subsequent studies focused on eggs of moths and beetles. We found a curvilinear mortality response to a pressure of 50 mm Hg at 30°C among eggs of different ages in both Indian meal moth and lesser grain borer. For both species the youngest eggs (3 h and 12 h, respectively) and the oldest eggs (48 h and 120 h, respectively) were most susceptible to low pressure, while eggs of intermediate ages were more tolerant. A comparison of mortality in the Indian meal moths, almond moth, *Cadra cautella*, lesser grain borer, and red flour beetle was conducted at pressures of 50, 75, 100, 200 and 300 m Hg and temperatures of 5, 15, 22.5, 30 and 37.5°C. Shortest exposures times estimated to elicit 99% mortality occurred at the lowest pressures and highest temperatures for all insects tested. Conversely, LT_{99} could be achieved at pressures up to 100 mm Hg and temperatures as low as 22.5°C in 72 to 120 h, depending on the species. Practical applications of the vacuum method should be performed above 22.5 C at pressures lower than 100 mm Hg for periods of at least 72 h. Successful pilot-scale applications were conducted in commercial settings with bag stacks of cocoa and coffee using flexible PVC hermetic storage structures.