APPLICATION OF VACUUM TO CONTROL POSTHARVEST INSECT PESTS

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Low pressure, achieved by applying vacuum to a system, reduces atmospheric gases and imposes a controlled atmosphere. Atmospheres at 5% of ambient are sufficiently low in oxygen to kill insects in a matter of hours to days. Vacuum usually can not be applied effectively in structures other than specialized pressure chambers, but flexible storage structures provide the potential to apply vacuum to a commodity for insect disinfestation without chemical pesticides. Laboratory and field experiments were conducted with stored-product insects held at low pressure under various conditions. Laboratory studies were conducted with adults and immature life stages of the red flour beetle, *Tribolium castaneum* (Herbst), the lesser grain borer, *Rhyzopertha dominica* (F.) and the Indian meal moth, *Plodia interpunctella* (Hubner) exposed to 32.5 mm Hg at 25, 33, 37 and 40°C. Adults of the three species were found to be very susceptible to low pressure and complete mortality was obtained within three 3 h exposure at 25°C. More extensive studies were continued with one-day old eggs, one-day old larvae and one-day-old pupae of the three species. Probit analyses were performed and lethal dose exposure time values (in hours) for LD_{50}, LD_{90} and LD_{99} were calculated. Lethal doses were compared among the nine species-life stages tested at each of the four temperatures and also across the four temperatures for each species-life stage. In all cases the lethal dose value was significantly decreased with each successive increase in temperature. Lesser grain borer eggs required the longest exposure times to achieve a given level of kill among the nine insect types tested, with LD_{99} values of 176.5 h at 25 and 11.2 h at 40 . Since lesser grain borer is predominantly a pest of small cereal grains compared to other stored products, information on Indian meal moth and red flour beetle more relevant to protection of higher value commodities such as cocoa, dried fruits, nuts and processed foods. Of these two pests, eggs of red flour beetle were the most tolerant of vacuum treatment and required 10.1 h to achieve LD_{99} at 25 C and 1.9 h for the same level of kill at 40 C. Thus treatment times between 2 and 10 hours, depending on temperature, should be effective for controlling common pests of commodities that might be treated with a pressure of 32.5 mm Hg or below. Additional research with eggs of moths and beetles found that effective levels of kill can be achieved at pressures up to 200 mm Hg given adequate time and heat.

A unique field application of low pressure was realized and validated using a flexible PVC hermetic storage container, known commercially as the Volcani Cube and

the GrainPro Cocoon. The field trial used a 3 HP, 45 cfm rotary vane vacuum pump connected to a 10 T capacity flexible structure and maintained a vacuum of 25-29 mm Hg. The pump load was relieved by partial venting with a valve actuated by a programmable vacuum controller and pressure sensor. Upon attaining the set-point pressure of 25 mm the controller triggered a solenoid to open and let air pass into the pump until pressure in the structure reached 29 mm, at which point the valve closed and pressure returned to 25 mm. Vacuum was applied for several hours to several days in repeated studies. The flexible structure proved particularly suited to this application because the PVC walls were drawn tight against the commodity and held the vacuum efficiently. Pressure increased slowly during pump-relief times due to membrane permeability and small leaks. Larger leaks were easily detected by sound and effectively repaired with silicone caulk. Insect bioassays confirmed insecticidal efficacy and the commodity was well preserved at the end of the longest treatment time. Ventilated containers with live insects of different species and life stages were placed within the bag stacks and removed at 3, 10 and 17 days after the start of the treatments. Survival of these insects was compared with those of insects held in an untreated bag-stack. All almond moth pupae were dead (no adult emergence) in both treatments after three days. Vacuum treatment killed 100% of Indian meal moth eggs and pupae at 3 days. Mixed cultures of red flour beetle eggs and larvae required 10 days to achieve 99.0% mortality in vacuum. Essential oils and other volatiles released during evacuation of commodities like cocoa can impair pump operation if not effectively pre-filtered or trapped. Additional studies with application of low pressure to wheat, which releases low levels of volatiles, experienced no pumping problems.

Conclusions from this work are as follows.

- Low pressure of 200 mm Hg or less from application of vacuum can kill tolerant postharvest insects given adequate time and temperature. Successful treatments can be accomplished in less than a day at typical warehouse storage temperatures using pressures of 25-50 mm Hg.

- Flexible PVC hermetic storage structures can be used as vacuum chambers for bagged or packaged durable commodities. The combination of the PVC structures with a vacuum pump represents a low-cost, non-chemical, relatively simple alternative to methyl bromide for many applications.