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LOW-PRESSURE VACUUM TO CONTROL LARVAE OF *HYLOTRUPES BAJULUS* (COLEOPTERA: CERAMBYCIDAE)

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Abstract Low-pressure vacuum applied to wood killed larvae of the old house borer, *Hylotrupes bajulus*. Mortality resulted from whole-body dehydration in the vacuum environment. Larvae were placed individually into sections of southern yellow pine (*Pinus* sp.) with MC of 12% and 23%, and low-pressure vacuum was achieved in a flexible, rubber container. Lethal vacuum time was directly related to larval weight; the lower the larval weight, the fewer hours were required for mortality. Limited data indicate that lethal vacuum time may increase with an increase in wood moisture content. Low-pressure vacuum may be an effective alternative to heat treatment and gas fumigants for controlling some wood-infesting beetles infesting pallets and wooden shipping containers.
Key Words Wood-infesting beetles, dehydration, water loss

INTRODUCTION

Several species of longhorned (Cerambycidae) beetles infest seasoned lumber with moisture content (MC) between 20-30%. Larvae of two pest species, the old house borer, *Hylotrupes bajulus* (L.), and the Asian longhorned beetle, *Anoplophora glabripennis* Motchlusky, are capable of surviving in seasoned timber, and wood used for commercial shipping containers and pallets. The old house borer is a pest of structural timber in eastern and southern United States, and in limited regions of the United Kingdom and Europe (Robinson, 2005). Larvae are capable of digesting cellulose, and feed on seasoned pine, spruce or fir lumber. Asian longhorned beetle larvae typically feed in living hardwood trees. This species is native to China and Korea, and is a forest pest in China. Recently, *A. glabripennis* was accidentally introduced into the United States and Canada in untreated wood used in packing materials and pallets (USDA, 1996).

Cerambycid larvae may feed within wood used for container shipping and may not be detected by conventional inspection methods. Spread of these and other wood-infesting insects in pallets and packing crates can lead to unwanted financial costs and may result in procedures that limit international movement of goods. International Standards for Phytosanitary Measures (2002) requires an insect-control treatment of wood used in all containers for imported or exported goods. Control methods include continuous heating for 30 min at 56˚C, which may not be suitable for all materials, or gas fumigation, which may be limited by product availability. United Nations Environment Program (UNEP, 1998) prohibits the use of the fumigant methyl bromide in developed countries by 2005. Low-pressure vacuum treatment is a nonchemical method for killing insects in wood packaging materials.

Challot and Vincent (1977) reported that pressures below 100 mm Hg were necessary to kill insects infesting stored food. The effect of low-pressure vacuum on insect pests of stored foods was investigated by Back and Cotton (1925), Bare (1948), and Calderon et al. (1966). Mbata and Phillips (2001) reported the effects of temperature and exposure time on mortality of insects maintained at low pressure. Calderon and Navarro (1968) and Navarro and Calderon (1972) proposed that insect death under low pressure is primarily a result of oxygen deficit and not the effect of physical pressure on the insect body. Navarro et al. (2001) used flexible storage facilities to maintain pressures of 25, 50, and 100 mm Hg. Rigaux et al. (2001) examined lethal water loss in adult *Tribolium castaneum* (Herbst).

The objective of this research was to evaluate the utility of using low-pressure vacuum to kill cerambycid larvae infesting wood packaging materials. *H. bajulus* was selected because it is physiologically adapted to living in seasoned wood, and the larval stages are tolerant of sustained low wood moisture, high and low temperatures, and other unfavorable environmental conditions Durr (1957). Given the range of wood-infesting beetle species that may infest the hardwood and softwood used in pallets and packing crates, *H. bajulus* represents one of the most difficult species to control.

MATERIALS AND METHODS

Low-pressure Vacuum Equipment

A vacuum pump (Mink, MI #2122) with a 7.5 HP, two-stage rotary, dry claw motor was used for all evaluations. The pump creates a vacuum to 8 mm Hg with a capacity of 1.6 cubic meters per minute at atmospheric pressure. An air cooled, cold-trap condenser (Nestlab CC-55) was used to collect the water vapor from the wood. The condenser is a mechanical refrigeration system employing a single motor stage with one compressor; the temperature range was from –20 to –55˚C, with a capacity of about 120 watts of heat at –20˚C. A control switch (HPM 760 Plus Controller, Teledyne and Hastings Co.) was used to maintain the absolute pressure in the flexible container between 25-29 mm Hg. A rubberized fabric container was used for the vacuum treatment. These containers can withstand temperature of 150˚C and pressures of 241.5 kPa.

Procedures

Wood samples were prepared from southern yellow pine dimension lumber at MC of 12% (3.8 x 10 x 76 cm) and 22% (14 x 8.9 x 91 cm). MC of the pine was determined with moisture meter. *H. bajulus* larvae were selected randomly from a laboratory colony of the European biotype in Bundesanstalt fur Materialforschung und –prufung, Unter den Eichen, Berlin, Germany. Larvae were maintained individually in nutrient-impregnated pine blocks with a MC of about 12% prior to use, and were alive when inserted into the test wood. Two larval weight categories were used: larvae >100 mg, and larvae < 100 mg.

Larvae were removed from their wood-block substrate and placed in holes drilled in the wood samples. The hole diameter was selected to provide the larva space to move, holes were plugged with a dowel to a depth of about 1 cm. Vacuum treatment began within 1 hr of placing larvae in the test wood pieces. Pressure was controlled at 20 mm Hg and temperature at 20˚C for all experiments.

Evaluations

Percentage of weight loss was determined by the difference in the weight divided by the original weight of larva. Mortality was determined by observing the movement of larvae after the removal from wood, if larvae were alive after the treatment, they were placed back in the original hole in the wood for further vacuum treatment.

RESULTS

Exposure of *H. bajulus* larvae to low-pressure vacuum resulted in mortality when their percentage body weight loss exceeded 40%. There was no consistent value of percentage of weight loss at which *H. bajulus* larvae were killed; it ranged from about 20% to more than 60%. Mortality for large (114-229 mg) larvae generally occurred within 48 hr exposure (Table 1), and mortality for small (43-100 mg) larvae generally occurred within 66 hr of exposure (Table 2). The correlation between lethal percentage weight-loss for small larvae was –0.43, indicating that with higher larval body weight, the lower the value of lethal percentage weight loss. Larval death was directly linked to loss in water content, which was indicated by a percentage weight loss. Larval death is not attributed to anoxia. Larvae consistently survived 48-hr exposure to low pressure and presumably a low-oxygen environment in the wood.

Large Larvae

Mortality of large (114-229 mg) larvae in 12% and 23% MC southern yellow pine occurred within 48 hr of exposure, with one exception (Table 1). The 184 mg larva (No. 4) in 23% MC wood was dead at 53 hr exposure. Mean percentage weight loss for large larvae at 24 hr exposure was 22.7%, and ranged from 8.7% (larva 4, Table 1) to 47.3% (larva 3, Table 1), the latter resulted in mortality at 24 hr. Mean percentage weight loss at 48 hr was 37.4%, and ranged from 23.3% in larva 4 to 52.4% in larva 1. All large larvae were dead when their percentage weight loss exceeded 29%. A mean percentage loss of 2.7% in wood moisture occurred in the 23% MC wood during the exposure to low-pressure vacuum.

Table 1. Large (114-229 mg) *H. bajulus* larvae in 12% and 23% moisture content (MC) southern yellow pine wood and exposed to low-pressure vacuum conditions for 24-48 hr.

		Body weight (mg) [percentage weight loss, *mortality]		
		Low-pressure vacuum time (hr)		
Larva	**Wood MC**	**0**	**24**	**48**
1	12%	114	60 [47.3*]	
2	12%	145	117 [19.3]	69 [52.4*]
3	12%	179	----	114 [36.3*]
4	23%	184	168 [8.7]	141 [23.3][1]
5	23%	229	193 [15.7]	142 [37.9*]
x		170.2	134.5 [34.5]	116.5 [37.5]

[1]Mortality occurred at 53 hr exposure and 29.3% weight loss.

Small Larvae

Mortality for small (43-100 mg) larvae in 23% MC southern yellow pine occurred within 66 hr of exposure, with two exceptions (Table 2). The 67 mg larva (No. 7, Table 2) and 43 mg larva (No. 8, Table 2) were both dead at 84-hr exposure and about 55% weight loss. Mean percentage weight loss for small larvae at 24-hr exposure was 14.5%, and ranged from 1.5% in larva No. 9 to 27.3% in larva No.5. Mean percentage weight loss at 48 hr was 31.5%, with a range of 25.2% for larva No. 1, which resulted in mortality, to 37.3% in larva No. 7. Mean percentage weight loss at 66 hr was 40.4%, which resulted in mortality in all but two larvae (Nos. 7, 8).

Table 2. Small (43-100 mg) *H. bajulus* larvae in 23% moisture content (MC) southern yellow pine wood and exposed to low-pressure vacuum conditions for 24-66 hr.

	Body weight (mg) [percentage weight loss, *mortality]			
	Low-pressure vacuum time (hr)			
Larva	**0**	**24**	**48**	**66**
1	91	79 [13.1]	68 [25.2*]	----
2	75	60 [20.0]	55 [26.7]	35 [53.3*]
3	49	37 [24.5]	36 [26.5]	33 [32.6*]
4	76	64 [15.8]	53 [30.2]	47 [38.1*]
5	33	24 [27.3]	22 [33.3]	14 [57.5*]
6	100	87 [13.0]	66 [34.0]	56 [44.0*]
7	67	60 [10.5]	42 [37.3]	30 [55.2][1]
8	43	38 [11.6]	25 [41.8]	19 [55.8][2]
9	67	66 [1.5]	50 [25.3]	42 [37.3*]
10	98	90 [8.1]	64 [34.7]	53 [45.9*]
x	69.9	60.5 [14.5]	48.1 [31.5]	41.1 [40.4]

[1]Mortality occurred at 84 hr exposure and 61.1% weight loss.
[2]Mortality occurred at 84 hr exposure and 62.8% weight loss.

Lethal Vacuum Time

The lethal vacuum time (LVT) for *H. bajulus* larvae in southern yellow pine is expected to be 66 hr. This would provide for the presence of large (114-229 mg) larvae, which would be killed within 48-hr exposure (Table 1), and for the presence of small (43-100 mg) larvae, which would be killed within 66 hr of exposure (Table 2). Although the data is limited to tests on a small number of larvae, the LVT tends to increase with larvae averaging about 70 mg. The influence of wood moisture content on the LVT is unclear, since mortality for one of the large larvae required more than 48 hr. In the 12% MC wood there was no change in the moisture content following the low-pressure vacuum treatments, in the 23% MC wood the moisture content decreased a maximum of 2.2%.

DISCUSSION

The results obtained here are consistent with the mortality obtained by Rigaux et al. (2001) in adult *Tribolium* beetles exposed to diatomaceous earth. The tenebrionid beetles died when their body water content was between 33 and 37% of their total weight. The cerambycid larvae exposed to low-pressure vacuum died when their loss of body water content was about 40%. The *H. bajulus* larvae are expected to have 50 to 53% of their total weight as water, and a loss that approaches this percentage is expected to be lethal.

Species in the family Cerambycidae are generally adapted to feeding in wood with moisture content above 25%, and typically in living hardwood and softwood trees. Larvae and pupae of these species remain in the wood during their development and are usually not exposed to fluctuations in wood moisture content. However, some species may survive in wood with moisture content below 25%. For example, the Asian longhorned beetle, *Anoplophora glabripennis*, is a native forest pest in China, but has spread to other regions in lumber used for shipping containers. Low-pressure vacuum treatment may provide economical and nonchemical control of wood-infesting beetles in pallets and other wooden crates used for international shipping.

Larvae of *H. bajulus* naturally feed in pine, spruce or fir lumber with moisture contents between 10-20%. Adaptations to feeding in seasoned wood may include seasonal fluctuations in body water as the wood substrate looses moisture during winter months (Bois, 1959). Fluctuation in wood moisture content is primarily due to changes in relative humidity of ambient air (Bois, 1959). *H. bajulus* larvae become inactive and cease feeding when wood moisture decreases below about 10% (Cannon and Robinson, 1981). Thus, the lethal vacuum time for *H. bajulus* may not be representative of the time required to kill larvae of the majority of other cerambycid species. Preliminary tests with larvae of the ribbed pine borer, *Stenocoris lineatus*, indicate that 24 hr exposure may be sufficient for control. Large (114-229 mg) larvae of *S. lineatus* in 30% MC southern yellow pine lost 51.9% body weight and were killed in 24 hr. (unpublished data). Tests with other cerambycid beetles may demonstrate that a lethal vacuum time of about 24 hr is sufficient to control the beetle species likely to infest dimension lumber used in pallets and shipping containers.

REFERENCES CITED

Back, E. A. and R. T. Cotton. 1925. The use of vacuum for insect control. J. Agric. Res. 31: 1035-1041.

Bare, C. O. 1948. The effect of prolonged exposure to high vacuum on stored tobacco insects. J. Econ. Entomol. 41: 109-110.

Bois, P. J. 1959. Wood moisture content in homes, seasonal variations in the southeast. For. Prod. J. 9: 427 - 430.

Calderon, M. and S. Navarro. 1968. Sensitivity of three stored-product species exposed to different low pressures. Nature (Lond.) 218: 190.

Calderon, M., S. Navarro and E. Donahaye. 1966. The effect of low pressures on the mortality of six stored-product insect species. J. Stored Prod. Res. 2: 135-140.

Cannon, K. F. and Wm. H Robinson.1981. Old house borer larvae: Factors affecting wood consumption and growth. Pest Control 49 (2): 25, 27-28

Challot, F. and J.C.Vincent. 1977. Stockage du cacao sous vide dans des conteneurs en polyethylene. Café Cocoa Thé, vol. XXI (2), 129-136.

Durr, H.J. R. 1957. The morphology and bionomics of the European houseborer, *Hylotrupes bajulus* (Coleoptera: Cerambycidae). Dept. Agricult. Entomol. Mem. 4, Part 1.

International Standard for Phytosanitory Measure. 2002. Guideline for regulating wood packaging material in standard trade publication No. 15. March 2002. IPPC Food and Agriculture Organization, Rome, Italy.

Mbata, G. N. and T.W. Phillips. 2001. Effects of temperature and exposure time on mortality of three stored product insects exposed to low pressure. J. Econ. Entomol. 94:1302-1307.

Navarro, S. and M. Calderon. 1972. Exposure of *Ephestia cautella* (Wlk.) (Lepidoptera, Phycitidae) to low pressures: effects on adults. J. Stored Prod. Res. 8: 209-212.

Navarro, S., E., R., D. Donahaye, A. Azrieli, M. Rindner, T. Phillips, R. Noyes, P.Villers, T. de Bruin, R. Truby and R. Rodriguez. 2001. In, Donahaye, E.J., S. Navarro, and J. Leesch (eds.). Application of vacuum in transportable system for insect control. Proc. Int. Conf. On Controlled Atmospheres and Fumigation in Stored Products, Fresno, CA.

Rigaux, M., E. Haubruge and P.G. Fields. 2001. Mechanisms for tolance of diatomaceous earth between strains of *Tribolium castaneum*. Entomol. Experimentalis et Appl. 101: 33-39.

Robinson, W. H. 2005. Urban Insects and Arachnids. Cambridge Univ. Press, Cambridge, UK

UNEP 1998. United Nations Environment Programme, Montreal Protocol on Substances that Deplete the Ozone Layer, 1998:Assessment of Alternatives to Methyl Bromide. Methyl Bromide Alternatives Committee. Nairobi, Kenya

USDA. 1966. Animal, Plant Protection and Quarantine. New Pest Advisory Group Rpt. September 25, 1996 Riverdale, MD