EVALUATION OF METHODS TO PROTECT POULTRY HOUSE INSULATION FROM INFESTATIONS BY LESSER MEALWORM (COLEOPTERA: TENEBRIONIDAE)[1,2]

Joseph L. Despins[3], E. Craig Turner, Jr., and Douglas G. Pfeiffer
Department of Entomology, Price Hall,
Virginia Polytechnic Institute and State University,
Blacksburg, Virginia 24061

ABSTRACT

Insecticide sprays and paint barriers applied to the surface of extruded polystyrene, and different types of insulation, were evaluated for prevention of lesser mealworm, *Alphitobius diaperinus* (Panzer), infestations. In a laboratory study, tetrachlorvinphos 50 WP and pirimiphos-methyl 7E on extruded polystyrene produced > 90% mortality in larval and adult lesser mealworm populations 71 wk after application. These insecticide spray treatments, however, were not effective under conditions found in the manure pit of a high rise cage layer house. Our field study showed that Styrofoam BB™ and Ethafoam 220™, were resistant to lesser mealworm infestations. Super IQ™ paint, a latex paint impregnated with chlorpyrifos, was also effective in protecting extruded polystyrene from infestations under field conditions.

Key Words: Insecta, *Alphitobius diaperinus*, lesser mealworm, high rise cage layer house, poultry house insulation damage, Coleoptera, Tenebrionidae.

J. Agric. Entomol. 8(3): 209-217 (July 1991)

In high rise cage layer poultry houses, light, humidity and air quality, and ambient temperature are manipulated for a controlled environment to obtain optimal egg production. Maintenance of stable ambient air temperature throughout all seasons is facilitated by placing insulation in the ceiling and walls of the structure. The most common types of insulation in cage layer houses are polyurethane, extruded polystyrene, and fiberglass products (Vaughan 1982, Vaughan et al. 1984, Despins et al. 1987)

The controlled environment of the cage layer house is conducive to the development of certain arthropod populations in the lower story (manure pit) of the house, with the lesser mealworm, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae) being the most common beetle species at some times of the year (Pfeiffer and Axtell 1980). The lesser mealworm develops in the accumulated composting manure, where temperature is favorable (Armitage 1985). The larvae tunnel in manure and have a significant impact in house fly emergence, being predaceous on house fly larvae (Despins et al. 1988). Unfortunately, this beneficial behavior has been overshadowed by its status as a structural insect pest in poultry houses. The late instars begin tunneling activity for construction of pupation cells thereby reducing the insulation structural integrity, and increasing insulation

[1] Received for publication 1 November 1990; accepted 25 March 1991.

[2] Trade/Brand names for products are used for identification purposes only, and their mention in this publication does not represent a product endorsement.

[3] Present address: USDA, ARS, Tick Research Unit, P.O. Box 3008, Kingshill, St. Croix, U. S. Virgin Islands, 00851-3008.

thermal conductivity (Dale et al. 1976, Ichinose et al. 1980, Safrit and Axtell 1984, Vaughan et al. 1984, Despins et al. 1987).

Insulation materials commonly used in broiler houses and cage layer houses have been examined for resistance to lesser mealworm infestations under laboratory conditions with conflicting results (Ichinose et al. 1980, Le Torc'h and Letenneur 1983, Vaughan et al. 1984). Application of mechanical barriers onto various forms of insulation have been evaluated under laboratory conditions, but to date, no material has been completely resistant to penetration by these insects. Insecticide barriers have shown promise in protecting insulation under laboratory conditions (Vaughan and Turner 1984). Further information on the effectiveness of the mechanical and chemical barriers to field populations of lesser mealworms is needed. This study was conducted to compare various mechanical barriers, new types of insulation materials and insecticide sprays under laboratory and field conditions to reduce lesser mealworm damage.

MATERIALS AND METHODS

The lesser mealworm colonies were obtained from field populations in cage layer houses in various locations in southwestern Virginia. They were reared on wood shavings in glass covered aquaria (19-liter) and placed in a controlled environment room at ca. 30°C. Relative humidity was maintained at no less than 60% by regular addition of a small amount (50-75 ml) of water. Soaked cracked corn was added as needed for food.

Insecticide Residual Experiment in the Laboratory

The insecticide treatments were applied to 0.09-m^2 panels of extruded polystyrene as follows:

(1) permethrin 25 WP, 0.05% AI, 0.0108 g/m^2 (ICI Americas Inc., New Murphy Road, Concord Pike, Wilmington, Delaware 19897);
(2) permethrin 5.7 EC, 0.05% AI, 0.0107 g/m^2 (ICI Americas Inc.);
(3) pirimiphos-methyl 7E, 0.25% AI, 0.0534 g/m^2 (ICI Americas Inc.);
(4) pirimiphos-methyl 7E, 0.50% AI, 0.1069 g/m^2 (ICI Americas Inc.);
(5) tetrachlorvinphos 50 WP, 0.50% AI, 0.1032 g/m^2 (Shell International Chemical Co., Ltd., Shell Centre, London SE1 7PG, England);
(6) chlorpyrifos-impregnated paint, 0.86% AI, 322 gm/m^2, Insectaway™ Anti-Insect Flat Latex Paint, (Universal Cooperatives, Inc.).

Insecticide solutions were prepared by mixing the amount of commercial product to give the desired concentration in 473 ml of distilled water. From this solution, 2 ml were placed into a 5-ml glass test tube and sprayed evenly over one side of a polystyrene panel using a glass chromatography type atomizer. The chlorpyrifos paint was applied to one side of the panel, and, as with the other treatments, left to air dry for 24 h before evaluation. Each treatment was replicated three times. Treated panels were aged at room temperature (21°C) for the length of the 71-wk experiment. Residual activity of the insecticides was evaluated with the method of Vaughan and Turner (1984). Adults and larvae were exposed to treated panels at specific post-treatment times from 48 h to 71 d. Ten adults and ten sixth to eighth instars were exposed under artificial light at room temperature for 1 h on each treated surface beneath an overturned plastic petri plate (14 by 2 cm). Treated insects were placed in recovery glass jars (473-ml) and maintained at room temperature for 48 h, at which time mortality, defined as inability to right or crawl after being prodded with forceps, was recorded. Data were corrected for natural mortality with Abbott's (1925) formula.

Laboratory Evaluations of Barriers and New Types of Insulations

Surface barrier treatments were evaluated in the laboratory for effectiveness to lesser mealworm penetration. These included a polyurethane varnish (Deft Defthane™ Polyurethane Finish) and an aluminum paint, (Rustoleum™ Silver Metallic 7715; Rustoleum Corp., 11 Hawthorn Parkway, Vernon Hills, Illinois 60061). Panels of extruded polystyrene were cut into 7.6- by 7.6- by 2.5-cm sections. A single coat of each material was applied to the insulation and allowed to air dry for 48 h.

Three products from Dow Chemical Co. (Granville Research Center, P.O. Box 515, Granville, Ohio 43023) were also tested for damage by lesser mealworm infestations. They were Styrofoam IB™, Styrofoam BB™ and Ethafoam 220™. Styrofoam IB™, is a low density (20.6 g/m^3) polystyrene foam board with a cell size of 0.6 mm; this product is primarily used as a plastering or stucco base. Styrofoam BB™ is a polystyrene foam buoyancy billet, with a density of 25.7 g/m^3 and 1.5-mm cell size. Ethafoam 220™ is a polyethylene foam product typically used for cushion packaging; it is characterized by having large cell size (1.5 mm) and has the highest density (29.5 g/m^3) of the three test materials. In comparison, the density and cell size of an extruded polystyrene insulation used in agricultural buildings such as poultry houses (e.g., Styrofoam TG™) is 25.7 g/m^3 and 0.35 mm, respectively. Panels of Styrofoam IB™ and Styrofoam BB™ were cut to 7.6- by 7.6- by 2.5-cm and Ethafoam 220™ panels cut to 7.6- by 7.6- by 3.8-cm.

A panel of each treatment, replicated 10 times, was placed on the wood shaving litter of a lesser mealworm colony for 21 d. Panels were observed periodically to ensure that they did not become buried as a result of beetle activity. Evaluation of beetle damage on the panels was performed by counting the number of penetrations on the surface of each panel. For comparison purposes, this number was divided by the total surface area of the respective treatments to yield a common measure (i.e., average number of holes per cm^2).

Field Evaluations of Chemical Barriers and New Types of Insulation

Field evaluation of insecticides, paint treatments and new types of insulation for prevention of lesser mealworm damage was done by exposing treated panels in the manure pit of a cage layer house having a heavy natural infestation. The insecticide formulations, and their diluted dosages were: (1) pirimiphos-methyl 7E, 0.25% AI; (2) pirimiphos-methyl 7E, 0.50% AI; (3) tetrachlorvinphos 50 WP, 0.25% AI; (4) tetrachlorvinphos 50 WP, 0.50% AI; (5) permethrin 25 WP, 0.05% AI, and (6) permethrin 5.7 EC, 0.05% AI. The insecticide solutions were applied to extruded polystyrene panels (10.2 by 10.2 by 2.5 cm) by immersing each panel in a solution for 60 seconds.

Two brands of insecticide-impregnated paint were also evaluated: (1) Insectaway™ Anti-Insect Flat Latex Paint (0.86% chlorpyrifos by weight) and (2) Super IQ™ Paint (Biochemico Dynamic Americas Corporation), (0.90% chlorpyrifos by weight). A single coat of both chlorpyrifos-impregnated latex paint formulations was applied to the same size polystyrene panel. All panels were air dried for 24 h.

The experiment was arranged in a randomized block design, with five replications. Panels were placed on plastic petri dish covers (14.0 cm diam) and set on the surface in the trough which exists between the cones of accumulating poultry manure. They were inspected monthly to ensure that they had not become buried by accumulating manure. After 150 d exposure time, the number of surface penetrations in each panel of insulation was counted and the average number of penetrations per square centimeter of surface area was computed.

Statistical Analysis

Percentage mortality data were transformed using the arcsine-square root function (Zar 1984). Data obtained from the insecticide residual experiment and laboratory test of barriers and new types of insulation were analyzed using analysis of variance (PROC ANOVA, SAS Institute 1987); data obtained from the field test of barriers and new types of insulation were analyzed using analysis of variance (PROC GLM, SAS Institute 1987). Treatment means were separated using Duncan's (1955) multiple range test.

RESULTS

Insecticide Residual Experiment in the Laboratory

Adult mortality from 1 h exposure to treated panels was 90% or greater at 48 h post-treatment (Table 1). Both concentrations of pirimiphos-methyl, and tetrachlorvinphos produced greater than 95% mortality throughout the 71-wk test. Permethrin WP treatment also resulted in 95% mortality from 2-5 wk post-treatment and was more toxic than the EC formulation of permethrin from 2-23 wk post-treatment. Chlorpyrifos paint killed greater than 90% of the adults at 48 h post-treatment but less than 5% at 1-wk post-treatment. Mortality gradually decreased to zero after 3 wk.

Trends of insecticide toxicity to larvae (Table 2) were similar to those which occurred in the adult trial. Nearly 100% mortality was observed in the tetrachlorvinphos and both concentrations of pirimiphos-methyl treatments throughout the 71-wk test. Permethrin WP killed greater than 90% of the larvae, and was more toxic than the permethrin EC formulation, from weeks 2-4 post-application. Chlorpyrifos paint produced greater than 90% mortality at 48 h post-treatment, but dropped to about 20% at 1-wk post-treatment, and to 0% at 2 wk post-treatment.

Laboratory Evaluations of Barriers and New Types of Insulations

Styrofoam™ BB and Ethafoam 220™ insulations, Defthane™ finish and Rustoleum™ paint had significantly fewer surface penetrations than the standard extruded polystyrene insulation (Table 3). Styrofoam BB™ insulation was the most resistant to lesser mealworm damage.

Field Evaluations of Chemical Barriers and New Types of Insulation

When compared to the extruded polystyrene standard, Styrofoam BB™, Ethafoam 220™ insulation and Super IQ™ chlorpyrifos-impregnated paint significantly reduced damage by lesser mealworm (Table 4). The two concentrations of pirimiphos-methyl, permethrin (WP formulation), Defthane™ finish, and Styrofoam IB™ insulation also had fewer surface penetrations than the standard extruded polystyrene. Rustoleum™ paint, both concentrations of tetrachlorvinphos, permethrin (EC

Table 1. Average corrected percent mortality* of adult lesser mealworm following a 1-h exposure to insecticide-treated extruded polystyrene panels.

			Weeks post-treatment									
Treatment	% AI	g/m²	48 h	1	2	3	4	5	6	23	61	71
Permethrin 25 WP	0.05	0.0108	100.0 a†	76.7 a	100.0 a	100.0 a	96.6 a	96.6 a	86.7 a	73.3 a	30.0 b	26.7 b
Permethrin 5.7 EC	0.05	0.0107	90.0 a	66.7 a	41.4 b	33.3 b	68.9 b	28.5 b	30.0 b	26.7 b	20.0 b	20.0 b
Pirimiphos-methyl 7E	0.25	0.0534	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Pirimiphos-methyl 7E	0.50	0.1069	100.0 a	100.0 a	100.0 a	96.7 a	100.0 a	100.0 a	100.0 a	96.7 a	100.0 a	100.0 a
Tetrachlorvinphos 50 WP	0.50	0.1032	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	96.7 a	96.7 a	100.0 a
Chlorpyrifos paint	0.86	0.322	93.3 a	3.3 b	2.3 c	0 c	-‡	-	-	-	-	-
		F =	1.37	7.50	12.21	33.63	20.05	15.96	5.56	7.63	12.47	15.16
		df =	5, 12	5, 12	5, 12	5, 12	4, 10	4, 10	4, 10	4, 10	4, 10	4, 10
		p =	>0.30	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.01	<0.01	<0.01

* Mortality data corrected for natural mortality using Abbott's (1925) formula.

† Data transformed before analysis (arcsine square root x); means within columns followed by the same letter are not significantly different (alpha = 0.05; Duncan's [1955] multiple range test).

‡ Treatment removed from evaluation.

Table 2. Average corrected percent mortality* of late instar lesser mealworm following a 1-h exposure to insecticide-treated extruded polystyrene panels.

			Weeks post-treatment									
Treatment	% AI	g/m²	48 h	1	2	3	4	5	6	23	61	71
Permethrin 25 WP	0.05	0.0108	100.0 a†	83.3 a	100.0 a	100.0 a	96.7 a	96.7 a	96.7 a	90.0 a	16.7 b	30.0 b
Permethrin 5.7 EC	0.05	0.0107	82.8 b	83.3 a	46.7 b	46.7 b	66.7 b	50.0 a	76.7 a	66.7 b	20.0 b	36.7 b
Pirimiphos-methyl 7E	0.25	0.0534	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Pirimiphos-methyl 7E	0.50	0.1069	100.0 a	100.0 a	100.0 a	96.7 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
Tetrachlorvinphos 50 WP	0.50	0.01032	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	96.7 a	96.7 a
Chlorpyrifos paint	0.86	0.322	93.1 a	23.3 b	0 c	0 c	-‡	-	-	-	-	-
		F =	6.56	6.52	17.63	61.18	10.73	2.95	2.56	1.86	14.22	4.79
		df =	5, 12	5, 12	5, 12	5, 12	4, 10	4, 10	4, 10	4, 10	4, 10	4, 10
		p =	<0.01	<0.01	<0.01	<0.01	<0.01	<0.05	<0.10	>0.10	<0.01	<0.05

* Mortality data corrected for natural mortality using Abbott's (1925) formula.

† Data transformed before analysis (arcsine square root x); means within columns followed by the same letter are not significantly different (alpha = 0.05; Duncan's [1955] multiple range test).

‡ Treatment removed from evaluation.

Table 3. Twenty-one day exposure of styrofoam panels treated with paint-like barriers or different formulations in lesser mealworm colonies.

Treatment	Damage (holes/cm² surface area)	
	Mean*	SD
Styrofoam BB™	0.006 a	0.008
Defthane™ painted on extruded polystyrene	0.081 ab	0.125
Ethafoam 220™	0.107 ab	0.096
Rustoleum™, paint on extruded polystyrene	0.168 ab	0.274
Styrofoam IB™	0.232 c	0.274
Extruded polystyrene	0.418 bc	0.355

* F = 4.15; df = 5, 54; means followed by the same letter are not significantly different (alpha = 0.05), Duncan's [1955] multiple range test.

Table 4. Effectiveness of barrier paints and insecticide sprays applied on extruded polystyrene panels, and other insulation types to natural populations of lesser mealworms in the manure pits of a high rise cage layer house for 150 days.

Treatment	Holes/cm² surface area	
	Mean*	SD
Styrofoam BB™	0.008 a	0.008
Ethafoam 220™	0.010 a	0.010
Super IQ™ paint	0.021 a	0.041
Pirimiphos-methyl 7E, 0.50% AI spray	0.234 ab	0.276
Pirimiphos-methyl 25WP, 0.25% AI spray	0.494 ab	0.637
Defthane™ finish	0.540 ab	0.186
Styrofoam IB™	0.574 ab	0.468
Insectaway™ paint	1.147 abc	2.059
Permethrin 5.7EC, 0.05% AI spray	1.537 abc	1.849
Tetrachlorvinphos 50 WP, 0.50% AI spray	1.894 abc	1.744
Tetrachlorvinphos 50 WP, 0.25% AI spray	2.508 abc	2.648
Rustoleum™ paint	3.066 c	2.377
Extruded polystyrene	3.305 c	2.095

* F = 2.71; df = 13, 47; alpha = 0.05; means followed by the same letter are not significantly different (Duncan 1955).

formulation) and Insectaway™ chlorpyrifos-impregnated paint, containing a lesser concentration of chlorpyrofos than Super IQ™, were not as effective.

DISCUSSION

Under laboratory conditions, the organophosphate class of insecticides (tetrachlorvinphos and pirimiphos-methyl) showed extremely long acute residual activity against both larvae and adults, however, these results were not duplicated under field conditions. For example, the chlorpyrifos-impregnated paint treatment, Super

IQ™ paint, did not produce significant adult or larval mortality after 1 wk post-application in laboratory tests, but the paint performed well in protecting standard extruded polystyrene from lesser mealworm infestations under field conditions and provided the best results of the insecticidal treatments evaluated in the field trial. The alkaline environment (from dust and poultry waste) to which these treatments were exposed probably contributed to the decomposition of the insecticides. It is obvious that conclusions based on laboratory tests alone should be made with care.

The two most resistant insulation materials, Styrofoam BB™ and Ethafoam 220™, could serve as an alternative choice for use in poultry house construction. These insulation materials should be examined further for their chemical and physical properties to determine factors which contribute to resistance to lesser mealworm infestation.

In summary, we observed no insecticidal, physical, or alternative insulation material treatment which was completely resistant to lesser mealworm damage, however, some treatments could be used in poultry houses to protect extruded polystyrene already in place from damage. Alternative insulation materials could be used in new poultry house construction provided they are not too costly. Perhaps even these costly materials, treated occasionally, could be justified in light of the present expense involved in replacing damaged panels.

ACKNOWLEDGMENT

This research was supported by a grant (No. 82-1332-05) from the Virginia Agricultural Council, and a grant-in-aid from Dow Chemical U.S.A. We are greatly indebted to Koichi Ono, Felicia Johnson, and Annick Mikailoff for the translation of the Japanese and French journal articles. We thank Andy Walters and Dale Mounce, of Glenwood Farms, and C. J. Martin and James R. (Peanut) Smith, of Brickland Breeder Farm, Inc. for their cooperation during the treatment field evaluation. We acknowledge Ken Franklin, and Dow Chemical U.S.A. for providing technical assistance, and donating insulation materials used in this study. We acknowledge Biochemico Dynamic Americas Corporation for providing their product, Super IQ Insecticide Coating.

REFERENCES CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

Armitage, D. M. 1985. Environment of deep-pit poultry houses: survey of air and manure temperatures in British houses. Br. Poultry Sci. 26: 275-280.

Dale, P. S., J. C. Hayes, and J. Johannesson. 1976. New records of plant pests in New Zealand. N. Z. J. Agric. Res. 19: 265-269.

Despins, J. L., E. C. Turner, Jr., and P. L. Ruszler. 1987. Construction profiles of high rise caged layer houses in association with insulation damage caused by the lesser mealworm, *Alphitobius diaperinus* (Panzer) in Virginia. Poult. Sci. 66: 243-250.

Despins, J. L. J. A. Vaughan, and E. C. Turner, Jr. 1988. Role of the lesser mealworm, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae), as a predator of the house fly, *Musca domestica* L. (Diptera: Muscidae), in poultry houses. Coleopt. Bull. 42: 211-216.

Duncan, D. B. 1955. Multiple range and multiple *F* tests. Biometrics 11: 1-42.

Ichinose, T., S. Shibazaki, and M. Ohta. 1980. Studies on the biology and mode of infestation of the tenebrionid beetle, *Alphitobius diaperinus* Panzer, harmful to broiler-chicken houses. Jpn. J. Appl. Entomol. Zool. 24: 167-174 (in Japanese with English abstract).

LeTorc'h, J. M., and R. Letenneur. 1983. Laboratory tests of resistance of different thermic insulators to the boring of the tenebrionid *Alphitobius diaperinus*, (Col. Tenebrionidae). Comptes Rendus des Seances de l'Academie d'Agriculture de France 69: 188-200 (in French, with English abstract).

Pfeiffer, D. G., and R. C. Axtell. 1980. Coleoptera of poultry manure in caged-layer houses in North Carolina. Environ. Entomol. 9: 21-28.

Safrit, R. D., and R. C. Axtell. 1984. Evaluations of sampling methods for darkling beetles (*Alphitobius diaperinus*) in the litter of turkey and broiler houses. Poult. Sci. 63: 2368-2375.

SAS Institute 1987. SAS/STAT applications guide, version 6 ed. Cary, North Carolina, 252 pp.

Vaughan, J. A. 1982. Biology and control of the lesser mealworm: *Alphitobius diaperinus* a structural pest in poultry houses. M. S. thesis, Va. Polytech. Inst. and State Univ., Blacksburg, 114 pp.

Vaughan, J. A., and E. C. Turner, Jr. 1984. Residual and topical toxicity of various insecticides to the lesser mealworm (Coleoptera: Tenebrionidae). J. Econ. Entomol. 77: 216-220.

Vaughan, J. A., E. C. Turner, Jr., and P. L. Ruszler. 1984. Infestation and damage of poultry house insulation by the lesser mealworm, *Alphitobius diaperinus* (Panzer). Poul. Sci. 63: 1094-1100.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey, 718 pp.