Evaluation of a Barrier to Inhibit Lesser Mealworm (Coleoptera: Tenebrionidae) and Dermestidae Movement in High-Rise, Caged-Layer Poultry Facilities

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ABSTRACT An evaluation of a mechanical barrier to prevent movement of adult and larval lesser mealworm, *Alphitobius diaperinus* (Panzer); larder beetle, *Dermestes lardarius* L.; and hide beetle, *Dermestes maculatus* De Geer was conducted in caged-layer poultry facilities in New York and Maine. The barrier, a plastic collar wrapped around building support posts, proved highly effective at preventing movement of adult lesser mealworms. Significantly more lesser mealworm larvae were recovered from cardboard collar beetle traps placed below both washed and unwashed barriers than from traps placed above washed and unwashed barriers. Similarly, significantly more adult *Dermestes* were recovered from traps placed below washed barriers than from above both washed and unwashed barriers. The level of fly specking on the barrier was found to have no significant impact on the numbers of adult lesser mealworms and adult and larval *Dermestes* recovered either above or below barriers. Fly specking level did significantly impact the numbers of lesser mealworm larvae recovered above the barrier. Although washed barriers provided the greatest deterrent to adult lesser mealworms, the presence of the barrier, regardless of the level of fly specking, provided a significant deterrent to beetle climbing success. Washed barriers further reduced climbing success by lesser mealworm larvae by 17%, *Dermestes* adults by 7–28%, and *Dermestes* larvae by 33–38%. The high level of climbing observed by adult lesser mealworms suggests that the impact of adult beetle movement toward birds should be considered in its importance in building damage, disease transmission, feed infestation, and bird productivity and health. Observations on cost and maintenance of the barrier are discussed.

KEY WORDS darkling beetle, *Alphitobius diaperinus*, litter beetle, poultry manure, integrated pest management

LESSER MEALWORM, *Alphitobius diaperinus* (Panzer), is a worldwide pest of poultry facilities (Axtell 1999). Although the primary habitat for the beetle is in the manure or litter, the larvae climb walls and support posts in caged-layer poultry facilities seeking pupation sites and causing extensive damage to insulation materials (Vaughan et al. 1984, Despins et al. 1987, Geden and Axtell 1987). Vaughan et al. (1984) also observed a preponderance of adult beetles in the tunnels of the insulation; however, the damage to insulation was not directly attributed to the adult stage. Additionally, the adult stage can become a very serious pest when manure is spread on fields during warmer months. The adult beetle is capable of flight and will move en masse toward artificial lights generated by residences near fields on which beetle-infested manure has been spread.

Furthermore, lesser mealworm importance as a reservoir of avian pathogens and parasites, including *Salmonella typhimurium*, *Escherichia coli*, tapeworms, avian leucosis virus, turkey coronavirus, and turkey enterovirus is well documented (Avincini and Ueta 1990, Axtell and Arends 1990, Despins et al. 1994, Goodwin and Waltman 1996, McAllister et al. 1996, Watson et al. 2000).

Two additional beetles are also pests of caged-layer facilities. The larder beetle, *Dermestes lardarius* L., and the hide beetle, *Dermestes maculatus* De Geer (Coleoptera: Dermestidae) feed on broken eggs and bird and rodent carcasses (Cloud and Collison 1986). Damage to wooden building support posts and joists has been reported from *Dermestes* larval activity as well (Cloud and Collison 1985, Stafford et al. 1988).

Chemical management of lesser mealworms in caged-layer facilities is particularly difficult because of

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long manure accumulation times and protected larval habitat. Pesticides are often effective only immediately after manure removal. Due in part to inconsistent results, biological control agents, including protozoans, fungi, nematodes, and mites, have not achieved widespread adoption by producers (Geden et al. 1987; Steinkraus et al. 1991, 1992; Steinkraus and Cross 1993). Calibeo-Hayes et al. (2005) documented the effectiveness of mechanical soil incorporation of manure containing lesser mealworms on reducing beetle emergence in North Carolina, whereas Kaufman et al. (2005) investigated soil incorporation on beetle emergence under New York conditions.

Geden and Carlson (2001) first reported on the successful use of mechanical barriers for protection of poultry facilities from the climbing activities of larval lesser mealworm and hide beetles. Their study, conducted in Florida caged-layer poultry facilities, examined the ability of larvae to cross the barrier under differing conditions of fly speck coverage and time. Our study was conducted to determine the impact of a barrier on restricting movement of both larvae and adult lesser mealworm and *Dermestes* beetles in northeastern caged-layer poultry facilities.

Materials and Methods

Tests were conducted in four conventionally ventilated high-rise, caged-layer poultry facilities, as described by Kaufman et al. (2001), on two farms in New York and one farm in Maine. There were two facilities used on farm A in Wayne County, New York, whereas farm B in Onondaga County, New York and farm C in Kennebec County, Maine, each consisted of one facility. Manure was allowed to accumulate under normal farm practices and studies began after manure had been accumulating for a minimum of 4 mo. Insecticide use was limited to methomyl-based fly baits on the bird level and occasional pyrethrin house fly, *Musca domestica* L. spray applications in the manure pit.

Sampling at farm A, facility 1 (F1) occurred on five dates between July and September 2003, whereas in facility 2 (F2) sampling occurred on five dates between March and June 2004. Farm B sampling occurred on four dates between August and October 2003. Farm C sampling occurred on six dates between June and August in both 2003 and 2004.

Polyethylene terepthalate (PET) type D was obtained from AIN Plastics (Mount Vernon, NY) in rolls that were 115 m in length, 15.2 cm in width, and 0.25 mm in thickness. At each facility, barriers (PET strips) were installed using the same procedure. The PET was cut into 64-cm strips. Before installation, support posts in the facilities were measured and the PET strips were creased by hand according to the dimensions of the corresponding posts. A 1-cm bead of adhesive (Nail Pro, OSI Sealants, Inc., Mentor, OH) was applied 3 cm from the edge on the inner surface of each barrier. The barrier was then positioned on each post 1.5 m above ground, forming a collar around the post and stapled into place. After placement, the attachment of the barriers was examined and additional adhesive was applied to fill in any gaps at the wood–plastic interface. Barriers were installed on 15 October 2002 at farm C, 15 April 2003 at farm B, 18 April 2003 at farm A, facility 1 and 25 March 2004 in facility 2 on farm A.

In each poultry house, beetle traps, made of 81 by 15.2-cm corrugated cardboard strips (Brooder Guard, Beacon Industries, Westminster, MD), were placed for a 1-wk duration at a minimum of 3-wk intervals to determine the efficacy of the barriers. Corrugated cardboard in various forms had been effectively used in other studies as a trapping system for lesser mealworms (Safrit and Axtell 1984, Geden and Carlson 2001). Cardboard collars were positioned on 40 posts in 10 groups of four posts, which were preselected randomly in each facility. Each grouping of four posts consisted of four treatments: 1) cardboard collar placed above an unwashed barrier, 2) cardboard collar placed above a washed barrier, 3) cardboard collar placed below an unwashed barrier, and 4) cardboard collar placed below a washed barrier. All barriers where a cardboard collar was placed were first examined for fly specking. The percentage of each barrier covered in fly specks was recorded after visual inspection as one of five categories of 1–20, 21–40, 41–60, 61–80, and 81–100%.

To determine the impact of fly specking, at each sample date one-half of the 40 barriers to be used were washed to remove the accumulated fly specks. The two barriers in each of the 10 groups that were to be washed were wiped with a water-saturated sponge until the fly specks were removed. To complete the cleaning, each barrier was again wiped down with clean water. Cardboard collars were wrapped around the post, either above or below the barrier, as described previously. The cardboard collars were affixed with the corrugated side facing out, and stapled twice where the ends overlapped. After 1 wk, the cardboard collars were removed. In New York studies, this process involved placing an enamel pan against the post underneath the cardboard collar to catch fleeing insects. The cardboard collar and the contents of the enamel pan were placed in a sealable plastic bag. In Maine, insects on the cardboard collar surface were removed and the cardboard collars were placed into sealable plastic bags. In all cases, samples were frozen for a minimum of 24 h at −20°C. After freezing the cardboard collar was pulled apart and insects were identified and counted. Both *D. lardarius* and *D. maculatus* were present on all farms and are grouped as *Dermestes* for the purposes of this article.

In New York studies, at the beginning of sampling in each 2003 facility and at each sampling in 2004, manure cores were collected from the facilities to gauge relative beetle abundance in the manure. This was accomplished by taking two 400-ml manure cores with a bulb planter at a minimum of four sites in the facility (Geden and Stoffolano 1988, Kaufman et al. 2002). At each site, a sample was obtained one-third and two-thirds distance from the base to the peak of the pile. Live adult and larval lesser mealworm and *Dermestes* beetles were identified and counted.

Table 1. Mean number of lesser mealworm adults and larvae and dermestid adults and larvae recovered from cardboard collar traps placed either above or below plastic barriers installed on wooden support posts in the manure pit of three New York caged-layer poultry facilities

Species	Life stage	Treatment	n	Mean (SE)[a]	% reduction in climbing success[b]		ANOVA
					Washed	Unwashed	
Lesser mealworm[c]	Adult	Washed above	10	29.2 (7.78)a	94.9		$F = 45.25, P < 0.001$
		Unwashed above	9	40.8 (11.2)a		92.8	
		Unwashed below	10	567.0 (206.5)b			
		Washed below	10	571.5 (140.9)b			
	Larva	Washed above	10	0.1 (0.04)a	90.0		$F = 7.55, P < 0.003$
		Unwashed above	9	0.3 (0.2)a		72.7	
		Unwashed below	10	1.1 (0.4)b			
		Washed below	10	1.0 (0.3)b			
Dermestes[d]	Adult	Washed above	14	0.6 (0.2)a	66.7		$F = 8.06, P < 0.001$
		Unwashed above	13	0.8 (0.4)a		38.5	
		Unwashed below	14	1.3 (0.4)ab			
		Washed below	14	1.8 (0.3)b			
	Larva	Washed above	14	0.2 (0.1)a	92.9		$F = 20.73, P < 0.001$
		Unwashed above	13	0.9 (0.3)a		55.0	
		Unwashed below	14	2.0 (0.5)b			
		Washed below	14	2.8 (0.8)b			

[a] Within species and life stage, means followed by the same lowercase letter are not significantly different ($\alpha = 0.05$; lesser mealworm df = 3, 15; *Dermestes* df = 3, 23; Tukey's multiple range test). Unwashed above treatment not included in the initial sampling at each farm.

[b] Washed indicates (beetles below washed barrier − beetles above washed barrier) /beetles below washed barrier. Unwashed indicates (beetles below unwashed barrier − beetles above unwashed barrier)/beetles below unwashed barrier.

[c] Mean (SE) fly specking scores of unwashed above and unwashed below barriers were 3.3 (0.52) and 3.2 (0.51), respectively.

[d] Mean (SE) fly specking scores of unwashed above and unwashed below barriers were 3.8 (0.42) and 3.7 (0.42), respectively.

Data Analysis. As a result of differing behavioral patterns and study methods, data were analyzed separately by life stage and state. The mean of each of the four treatments (washed below, washed above, unwashed below, and unwashed above) was obtained from each study date. All means were log $(x + 1)$ transformed for analysis and untransformed means are presented in tables. Due to extremely low numbers of lesser mealworm larvae present on cardboard collars at farm C (Maine), an analysis was performed only on the adult lesser mealworm data. Additionally, because of a more recent manure cleanout in 2004 versus 2003, no lesser mealworm adults were recovered in 2004 sampling at farm C; therefore, an analysis was performed only on 2003 adult lesser mealworm data.

The level of fly specking on the barriers was ranked in severity using a scale of 0–5 where a score of 0 was assigned for washed barriers, a score of 1 was assigned to the 0–20% coverage category, and a score of 5 was assigned to the 81–100% fly speck coverage category. The fly specking mean from each treatment was obtained as described previously. Data were first analyzed using a multi-factorial analysis of variance (ANOVA) with level of fly specking, cardboard trap placement, and study as random effects in the model (PROC GLM, SAS Institute 1996). The fly specking variable was a quantitative parameter and the interactions fly specking*trap placement and fly specking*study number were included in the model. A Tukey's comparison was used to separate significant differences among trap placement means.

To assess the impact of increasing level of fly specking on beetle success in crossing the barrier, an analysis of the data categorized by the placement of the cardboard traps, either above or below the barrier, was performed. Data were analyzed separately by trap placement above or below the barrier using a multifactorial ANOVA (PROC GLM, SAS Institute 1996). Fly specking score was held as a quantitative parameter in the analysis and the model statement also included study and washing regime (washed or unwashed) and the interaction of washing regime and fly specking.

Results

The New York manure core sampling in 2003 revealed very few lesser mealworm adults and larvae at farm A (mean of 4.8 adults and 29.2 larvae per sample) and almost no lesser mealworms at farm B (0.1 adults and larvae per sample). In 2004, considerably more lesser mealworms were recovered from manure cores at farm A (65.3 adult and 63.6 larvae per sample).

Dermestes are most commonly found at the manure pile periphery where protein-rich eggs and feathers accumulate. Therefore, as would be expected given our sampling protocol, adult and larval *Dermestes* were not recovered in appreciable numbers from manure core samples.

Impact of Washing Barriers. *New York Studies.* Significantly more lesser mealworm adults and larvae and *Dermestes* larvae were recovered from cardboard collars placed below barriers than above barriers (Table 1). Significantly more *Dermestes* adults were recovered from cardboard collars placed below washed barriers than were collected above both washed and unwashed barriers. However, differences were not

Table 2. Mean number of lesser mealworm adults and dermestid adults and larvae recovered from cardboard collar traps placed either above or below plastic barriers installed on wooden support posts in the manure pit of a Maine caged-layer poultry facility

Species	Life stage	Treatment[a]	n	Mean (SE)[b]	% reduction in climbing success[c]		ANOVA
					Washed	Unwashed	
Lesser mealworm	Adult	Washed above	3	0.9 (0.6)a	97.6		$F = 72.92$; df = 3, 3; $P < 0.003$
		Unwashed above	3	1.9 (0.9)a		81.3	
		Unwashed below	3	10.2 (3.7)b			
		Washed below	2	37.0 (6.5)c			
Dermestes	Adult	Washed above	6	0.6 (0.4)a	74.0		$F = 12.18$; df = 3, 12; $P < 0.001$
		Unwashed above	6	0.4 (0.2)a		66.7	
		Unwashed below	6	1.2 (0.6)b			
		Washed below	5	2.3 (0.4)c			
	Larva	Washed above	5	4.3 (1.2)a	73.8		$F = 12.25$; df = 3, 9; $P < 0.002$
		Unwashed above	5	8.2 (3.6)ab		41.0	
		Unwashed below	5	13.9 (5.0)bc			
		Washed below	4	16.4 (8.2)c			

[a] Mean (SE) fly specking scores of unwashed above and unwashed below barriers were 4.2 (0.17) and 4.4 (0.16), respectively.
[b] Within species and life stage, means followed by the same lowercase letter are not significantly different ($\alpha = 0.05$; Tukey's multiple range test). Washed below treatment not included in the initial sampling. Due to the absence of beetles on cardboard collars, data were not analyzed for three lesser mealworm adult dates and one *Dermestes* larvae date.
[c] Washed indicates (beetles below washed barrier − beetles above washed barrier)/beetles below washed barrier. Unwashed indicates (beetles below unwashed barrier − beetles above unwashed barrier)/beetles below unwashed barrier.

detected with *Dermestes* adults between the unwashed below treatment and either above-barrier treatment.

Maine Studies. Significantly more lesser mealworm and *Dermestes* adults were recovered from cardboard collars placed below washed barriers than all other treatments (Table 2). Furthermore, the unwashed below barrier treatment had significantly more beetle adults, of both species, than either the washed or unwashed above-barrier treatments.

Significantly more *Dermestes* larvae were recovered from cardboard collars placed below washed barriers than above washed and unwashed barriers (Table 2). Additionally, cardboard collars placed below unwashed barriers were only found to have significantly more larvae than traps placed above washed barriers.

Impact of Fly Specking Level. *New York Studies.* Mean (SE) fly specking scores of unwashed above and unwashed below barriers used in lesser mealworm analysis were 3.3 (0.52) and 3.2 (0.51), respectively, whereas the mean (SE) fly specking scores of unwashed above and unwashed below barriers in the *Dermestes* analysis were 3.8 (0.42) and 3.7 (0.42), respectively. The level of fly specking on the barriers was found to have no significant impact on the numbers of lesser mealworm adults or *Dermestes* adults recovered above the barriers. However, the level of fly specking did significantly impact the number of lesser mealworm larvae recovered above the barriers, but it did not significantly impact the number of *Dermestes* larvae recovered either above or below the barriers.

Maine Studies. Mean (SE) fly specking scores of unwashed above and unwashed below barriers were 4.2 (0.17) and 4.4 (0.16), respectively. Level of fly specking did not affect lesser mealworm adult or *Dermestes* larval and adult abundance above or below the barriers.

Discussion

That 81–98% more lesser mealworm adults were recovered below barriers, regardless of washing, suggests that although washed barriers provided the greatest deterrent to adult lesser mealworm climbing, the mere presence of a barrier, regardless of the level of fly specking, provided a significant deterrent to climbing success (Tables 1 and 2). The barrier also deterred climbing by lesser mealworm larvae, although as fly specking increased, more larvae succeeded in crossing the barrier.

Barriers also had a similar deleterious impact on *Dermetes* success in crossing barriers. However, it seems that to a limited extent, *Dermestes* were more adept at using fly specks to cross barriers. We observed that with *Dermestes* adults and larvae, there was a 7–28 and a 33–38% further reduction in climbing success, respectively, by washing the barrier to remove the fly specks.

Dermestes adults, in both New York and Maine studies, demonstrated greater success at crossing barriers than lesser mealworm adults. However, Geden and Carlson (2001) reported that barriers were highly effective with up to 40% fly speck coverage and moderately effective when coverage was 40–80%; however, when fly speck coverage exceeded 80%, barriers only prevented 40–55% of hide beetle larvae from crossing. Our results showed that the numbers of *Dermestes* larvae successfully crossing barriers did not increase at increasing levels of fly specking. These results further support our contention that barriers covered with fly specks serve as a deterrent to beetle passage, albeit at a level <100%.

Larvae of lesser mealworms and *Dermestes* are considered the predominant climbing and damaging stage (Ichinose et al. 1980, Geden and Axtell 1987). However, during this study, we observed considerably greater movement up support posts by lesser mealworm adults compared with larvae. Indeed, adult lesser mealworm climbing behavior was so prolific that while installing barriers it was not uncommon to return to the barriers within hours of installation and find dozens of beetles on support posts directly below barriers. That manure core beetle counts documented similar levels of adult and larval lesser mealworm in the manure pile while such a large number of adults was observed climbing the support posts suggests that the impact of adult beetle movement toward rafters or even movement into the bird level of the facility should be considered in its importance in building damage, disease transmission, feed infestation, and bird productivity and health. Many studies document the impact of birds feeding on lesser mealworms and the ability of lesser mealworms to serve as vectors of a variety of pathogens to broiler chickens and turkeys (Despins and Axtell 1994, 1995; Despins et al. 1994; McAllister et al. 1994, 1996; Goodwin and Waltman 1996). Preventing birds from feeding on lesser mealworms in these broiler chicken and turkey facilities is nearly impossible given animal management practices where birds are always in direct contact with the litter-containing beetles. However, caged-layer facilities are very different in that birds are held well above the manure pit, creating a spatial separation of bird and insect, thereby greatly reducing this interaction. In addition, the impact of lesser mealworm adult presence on adult, egg-laying, and possibly naïve birds has not been studied. We observed a >90% reduction in beetle presence above barriers that had not been washed and that were heavily covered with fly specks. Therefore, the barrier may prove to be a useful tool to deter large numbers of beetles from reaching rafters and birds, even if producers are unwilling or able to clean them regularly.

For barrier technology to be most effective, producers must be willing to wash them after house fly populations subside and most likely wash the barriers several times during the flock cycle. This is because barriers can rapidly become covered with fly specks during the typical fly outbreak that occurs after facilities are repopulated. In the larger New York facilities, this would involve ≈100–150 posts. An additional challenge to the use of barriers includes the duration of manure accumulation. The longer the manure remains in the facilities, the higher and wider the pile becomes which, in turn, contributes to increased inaccessibility to the barriers for the purpose of cleaning. At a certain point, maintaining/cleaning the barriers will become cost prohibitive. It is also critical that producers understand that this technology will not decrease beetle numbers in the facility. The barrier is solely a tool for preventing damage to the structural posts and possibly protecting bird health. Although not evaluated in this study, the inner foundation of a manure pit can easily be wrapped in plastic barrier to prevent beetles from crawling up the walls and reaching building insulation.

Geden and Carlson (2001) described the durability and maintenance efforts associated with the utilization of the barrier. Our estimate of the cost to install the barrier onto 100 posts include $133.00 for one roll of PET, $27.00 for 35 tubes of generic adhesive, and $400.00 for labor (26-h effort). The resultant primary installation costs totaled $560.00. The PET material is very durable and although it is likely that a number of posts will require repair after each cleanout, producers can expect several years of use after the installation of this mechanical barrier. This system provides producers with another cost-effective tool to add to their integrated pest management program.

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