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ABSTRACT: House mice (*mus musculus*) cause a variety of problems with livestock, feed, and structures. Researchers have yet to discover an insulative material that is not susceptible to house mouse damage. In this study, house mice caused significant ($P < 0.01$) increases in the thermal conductance of 10.2-cm thick wall panels, insulated with cellotex, fiberglass, rockwool, styrofoam, and vermiculite. Mouse populations increased 3-to 4-fold inside the insulated panels during the 6-month study period.

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INTRODUCTION

House mice (*Mus musculus*) are a common pest in both rural and urban areas. They are perceived as a problem by farmers because they cause damage, by consuming and contaminating livestock feed, degrading buildings and equipment, and transmitting diseases to livestock and humans. In 1987, Johnson and Timm estimated that house mice and Norway rats cause $16.4 million damage to agriculture in Nebraska annually. In a survey of 275 Nebraska pork producers, 92% reported that house mice were present on their farms (Timm et al. 1983). Fifty-five percent reported having at least one insulated livestock confinement building and 67% experienced structural damage caused by house mice and Norway rats (*Rattus norvegicus*).

House mice often tunnel and nest in insulation within wall spaces and ceilings. These activities result in the compaction, destruction, and removal of insulation. In a confined experiment, house mice caused significant damage ($P < 0.1$) to 4 types of insulation: cellulose, fiberglass batt, fiberglass batt with fiberboard sheathing, and fiberglass batt with styrofoam sheathing (Fisher 1984, Timm and Fisher 1986b). The resultant heat loss in insulated livestock confinement buildings can result in higher heating costs and may necessitate costly reinstallation of insulation (Timm 1983, Vansickle 1983, Timm and Fisher 1986a).

Timm and Fisher planned to continue studying the impact of house mice on insulation at the University of Nebraska-Lincoln (UNL), but before experiments were initiated, job opportunities lured them to California and Kansas, respectively. With their encouragement I continued the study. My objectives were to: 1) determine the impacts of house mouse activity on 5 different types of insulation, and 2) examine the changes in house mouse populations after a 6-month confinement period.

MATERIALS AND METHODS

The study was conducted at the UNL Veterinary Science Research Facility (VSRF) in Lincoln, Nebraska. Four rodent-proof rooms were subdivided by 5 enclosures, 2 m x 1 m x 60 cm high, made of 0.76-mm (22-gauge) galvanized sheet metal. I installed the enclosures to maintain 20 separate mouse populations.

One insulated wall panel (1.2 m x 1.2 m x 10.2 cm) was placed in each enclosure. I built the panels to simulate the wall of an environmentally-controlled livestock facility. Frames were made of 5.1-cm x 10.2-cm x 125-cm wooden studs, spaced at 40.6-cm intervals (wooden 2 x 4 construction on 16-inch centers). A 0.6-cm plywood sheet was nailed to the "inside" face of each frame and corrugated steel siding was nailed to the "outside" face of each frame. Foam tape (Macklanburg-Duncan Co.) was attached to the inside top and bottom of the siding to prevent airflow into or out of the panels. I filled the cavities of 16 panels with insulation. Four sets of 4 panels were each filled with 1 type of insulation, including: 1) extruded polystyrene (Styrofoam Brand, Dow Chemical Co., Inc.), 2) fiberglass batt (Owens-Corning Fiberglass Corp.), 3) rockwool (American Rockwool Corp.), and 4) vermiculite (W. R. Grace Co., Inc.). I insulated a fifth set of 4 panels with sheets of 2.5-cm Cellotex Tuff-R (Cellotex Co., Inc.), attached just inside the plywood sheet. One of each of the 5 types of insulated panels was randomly assigned to an enclosure in each of the 4 rooms.

I installed a 45-cm high mouse guard around the bottom of each panel to prevent mice from climbing. Mouse guards consisted of 0.76-mm galvanized sheet metal. Three holes, 1.9 cm in diameter, were drilled through the bottom of the "inside" face of each panel to provide the mice access to the panel cavities. Two 2.5-cm x 15.2-cm x 30.4-cm boards were nailed to the bottom of each panel for vertical support.

I released 2 male and 3 female house mice into each enclosure on 10 April 1989 and maintained them for 6 months. House mice were obtained from a commensal population at the Purina Mills Inc. Lab Farm near St. Louis, MO. All released mice were ear-tagged for individual identification. During the first 14 days, I replaced 15 dead mice with live mice of the same sex. After day 14, I allowed each population to fluctuate without additions, other than births and without removal, other than deaths or escapes. Mice were provided ad lib food (Wayne Rodent Lab-blocks) and water throughout the experiment. Enclosures were vacuumed twice each week to remove discarded insulation, waste food and dead mice. Dead mice were identified and recorded throughout the 6-month period. Occasional escaped mice were captured in live-traps and returned to their respective panels. I followed UNL Institutional Animal Care and Use Committee protocol and recommendations throughout the study.

I removed all mice from the enclosures using live-traps on 10-12 October 1989 at the end of the 6-month period. Mice were identified as tagged individuals or untagged, counted, and euthanized with carbon dioxide gas. Two mice from each insulation type were examined for internal and external lesions or abnormalities.

A heat flow probe (HFP-20, Concept Engineering) was used to collect data on heat flow through the panels before and after they were subjected to house mouse activity. Cold air from a 1,465-watt air conditioner was blown though a 1.2-

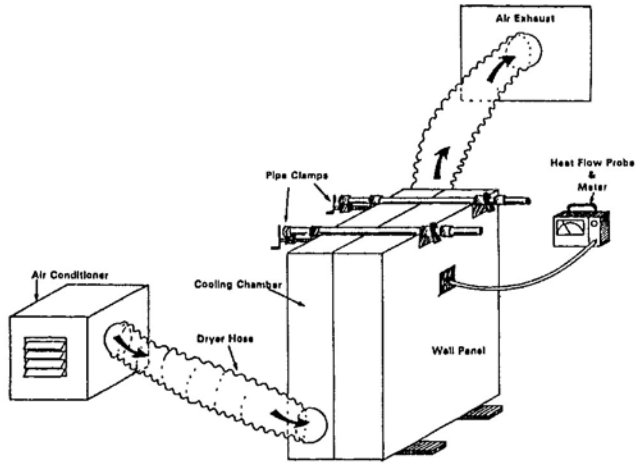

Figure 1. Configuration of equipment used in measuring the heat flow through wall panels.

m x 1.2-m x 15-cm cooling chamber, that was attached with pipe clamps to the "outside" corrugated steel face of each panel (Fig. 1). The cooling chamber was attached for about 2 hrs to allow the system to reach equilibrium and establish a temperature gradient between the cold "outside" face (1.7 to 4.4°C) and the warm "inside" face (18.3 to 21.1°C). Temperatures were measured at the centers of each panel face with an indoor-outdoor thermometer. The sensor of the heat flow probe was held against the "warm" inside face at 24 predetermined points. I measured the heat flow (watts) at each point after a 30-second stabilization period. The mean thermal conductance (TC) of each panel was calculated using the following equation: TC = HF/ (IT - OT), where HF is the mean heat flow, IT is the "inside" temperature, OT is the "outside" temperature, and TC is measured in watts/°C (MacDonald and Burns 1975).

I analyzed the impact of the house mice on insulation by conducting individual t-tests on the differences of the dependent TC means (after - before) for each insulation type. The individual TC values were normally distributed. Differences in TC and house mouse population levels among the insulation types were analyzed by Analysis of Variance (ANOVA). Individual variances were homogeneous.

RESULTS AND DISCUSSION

House mouse activity during the 6-month period increased HF and resultant TC through all 5 types of insulated panels tested (Fig. 2). The t-tests of the mean TC differences were highly significant (Cellotex: $t_3 = 4.77$, $P = 0.01$; fiberglass: $t_3 = 5.05$, $P = 0.01$; rockwool: $t_3 = 12.44$, $P = 0.005$; styrofoam: $t_3 = 7.14$, $P = 0.005$; vermiculite: $t_3 = 4.84$, $P = 0.01$). These results are similar to those of Timm and Fisher (1986b) who reported significant levels of damage ($P < 0.05$) to cellulose, fiberglass, fiberglass and styrofoam, and fiberglass and fiberboard subjected to house mouse activity under the same conditions.

The damage appears to be equally severe among the 5 types of insulation tested as the ANOVA revealed no significant differences among the mean TC differences (F_4, 15=.03, $P > 0.1$). This result differs slightly from Timm and Fisher (1986b) who reported that cellulose was damaged significantly more ($P = 0.002$) than the 3 other types of insulation.

The number of house mice in all panels combined increased from 100 to 399 during the 6-month period. I found 172 dead mice during the study and live-trapped 227 mice at the end of the study. There appear to be no significant differences (F_4, 15 = 0.08, $P > 0.1$) in the mean numbers of house mice found among the 5 types of insulation tested (Table 1).

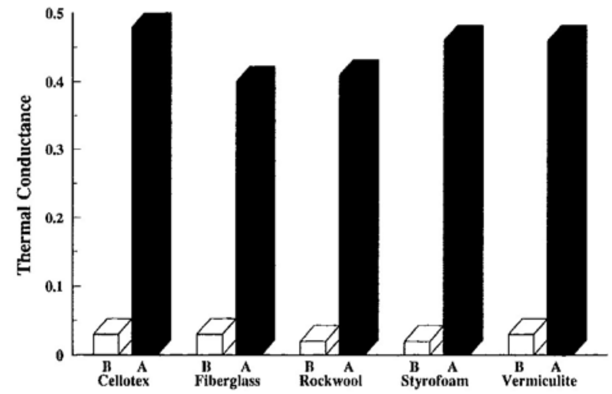

Figure 2. Mean thermal conductance of insulated panels (n = 4) before and after a 6-month occupation by house mice.

Table 1. Number of house mice live-trapped and found dead in insulated panels (n=4) during a 6-month period, after 5 mice (2M, 3F) were released at the start.

Insulation	Mean	Range
Cellotex	17.8	6-27
Fiberglass	17.0	9-22
Rockwool	24.3	18-29
Styrofoam	21.3	9-33
Vermiculite	19.5	15-23

Of the 100 ear-tagged mice that were released into the panels initially, 13 survived the 6-month period and 26 were found dead. The 61 marked mice that were unaccounted for likely lost their eartags (several unmarked mice had torn ears) or died and were mistakenly removed by vacuuming. Five marked and 45 unmarked mice were live-trapped outside of their enclosures, in the escape-proof rooms containing their respective enclosures. I returned the marked mice to their panels and the unmarked mice were removed from the study. Movements of mice among panels is assumed to be low, as only 1 marked mouse was captured and 1 found dead in panels that they were not originally assigned. None of the 10 mice that were examined displayed any internal or external lesions or physical abnormalities.

To date, all insulation materials tested in Nebraska have been susceptible to damage by house mice. In addition, Suss and Mittrach (1982) reported that house mice destroyed all 12 types of German insulation tested, including: expanded polystyrenes, extruded polystyrenes, loose-fill perlite, mineral fiber, polyurethanes, pressed sawdust, and spun glass. Research should be conducted to develop insulative materials that are less attractive to house mice or less susceptible to house mouse activity.

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