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Yang Zhao
Iowa State University, yangzhao@iastate.edu

Hongwei Xin
Iowa State University, hxin@iastate.edu

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Roof Insulation in Laying-hen Houses to Ease Summer Heat

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Yang Zhao, Post-doctoral Research Associate;
Hongwei Xin, Professor, Department of Agricultural and Biosystems Engineering, Iowa State University

Summary and Implications

Use of roof insulation in laying-hen houses to reduce heat transfer through the roof in summertime in Iowa was assessed through modeling and field measurement. The results indicate that roof insulation is effective to reducing heat transfer through the roof, thus may help to relieve hen heat stress. One inch-thick polystyrene board (R5) is sufficient to prevent majority of the roof heat transfer.

Introduction

A typical air inlet system of US hen houses is shown in Figure 1, where fresh air enters the attic through the eve inlets and is distributed into the hen area via ceiling inlets. The roof line of the hen house is normally not insulated, making the solar radiation energy easily pass through the roof and enter the attic space. During heat waves, this heat transfer may aggravate hen heat stress. Hence adding roof insulation may reduce heat transfer into the hen house.

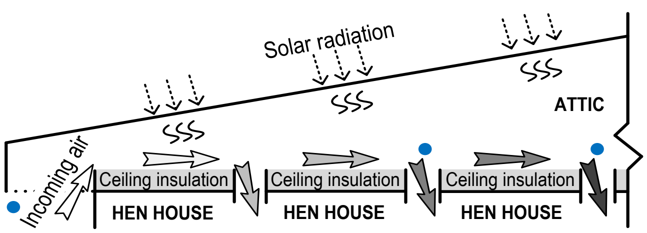

Fig 1. Illustration of heat transfer in roof system of hen house.

The purpose of this study was to 1) investigate the temperature increase of incoming air in the attic of an aviary hen house in Iowa in summertime, 2) develop a model to simulate heat transfer through the roof in summertime as affected by roof-line insulation level.

Materials and Methods

The aviary house with 100,000 hens had dimensions of 495×70×10 ft (L×W×H) and was oriented north-south. The roof was made of non-insulated sheet metal (R value≈0) with a slope of 18.4° (1:3). The ceiling was insulated with 8-inch blown-in insulation. There were six rows of box inlets across the width of the building. From 7/17/2011 to 8/15/2011, ambient temperature (T_{amb}) and air temperature (T_a) and black globe temperature (T_b) near the second and the third ceiling inlets (fig 1, round dots) were continuously measured for 2 hours at noontime.

A model was developed based on heat transfer theory. The inner roof surface temperature (T_{is}) was calculated using energy balance (Eq.s 1 and 2). Heat transfer to the house (H) was then calculated using Eq 3.

$$S_r \cdot A_b = h_u \cdot (T_{us} - T_{amb}) + (T_{us} - T_a)/(R_r + R_{ia}) + \varepsilon \cdot \sigma \cdot (T_{us}^4 - T_s^4) \quad (1)$$

$$T_{is} = T_{us} + [R_r/(R_r + R_{ia})] \cdot (T_a - T_{us}) \quad (2)$$

$$H = h_i \cdot (T_{is} - T_a) \cdot A_r + \varepsilon \cdot \sigma \cdot (T_{is}^4 - T_c^4) \quad (3)$$

where S_r is noon solar radiation; A_b is roof absorbance; h_u, h_i are the convection coefficients of the outer and inner roof surfaces; T_{us}, T_{amb}, T_a, T_s, T_c are temperatures of the outer roof surface, ambient air, attic air, sky and upper ceiling surface, respectively; R_r, R_{ia} are the R-values of roof insulation, air film at inner roof surface, respectively; ε is the roof emissivity; σ is the Stephan-Boltzmann constant.

Results and Discussion

Temperature rise of incoming air averaged 1.9 – 2.6°F during the monitoring period, but was as high as 3.7°F. The temperature rise of black globe averaged 3.5°F with a maximum of 5.0°F. These temperature rises are quite significant, considering that even 1°F increase could be rather detrimental to the hens when temperature exceeds the upper limit of the thermoneutral zone.

Table 1. Temperature increase (°F) of incoming air and black globe in the laying-hen house attic during 7/11 – 8/15, 2011.

	T_{amb}	2nd ceiling inlet		3rd ceiling inlet	
		$T_a - T_{amb}$	$T_b - T_{amb}$	$T_a - T_{amb}$	$T_b - T_{amb}$
Mean±SD	85.5±6.6	1.9±0.6	3.5±0.8	2.6±0.6	3.5±0.7
Max	96.6	2.7	5.0	3.7	4.8

At 1% summer design temperature (93°F) in Iowa and with the noon solar radiation at 40° on June 21 (279 btu/ft^2-hr), the heat transfer rate through a non-insulated roof was 1142 btu/h, equal to 44.6% of the heat production by 100K hens kept in this house. This heat transfer would result in a 1.9°F air temperature elevation in the attic. Roof-line insulation will reduce the heat transfer, although its additional reduction effect diminishes above R value of 4-5 (fig. 2). In conclusion, roof-line insulation is effective to reducing heat transfer to the hen house in summer, thus help to relieve hens of heat stress. One inch-thick polystyrene board (R5) would be sufficient under the Iowa conditions.

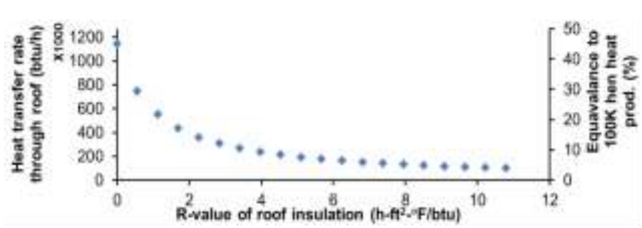

Fig 2. Heat transfer rate through the roof of the hen house with 100K hens as affected by roof insulation.

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