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Heating Poultry Houses with an Attic Ventilation System

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Abstract. *Fuel use constitutes a large percentage of the energy costs incurred by growers during winter flocks and increasing fuel costs have illustrated the need for alternative methods to reduce energy usage in broiler production. The objective of this study was to determine the feasibility of using the attic space of a broiler house as a source of pre-heated air to reduce energy usage during winter flocks. A series of air inlets were installed in the ceiling of a broiler house to supply pre-heated air during brooding. Inlets were installed in the peak of the ceiling and manually controlled with a curtain actuator. Temperature and relative humidity data were collected for the brood chamber, attic space, and outdoors. Heater, brooder, and fan run times were also monitored. Heating system run time was reduced for the house with the attic inlet system installed, with estimated gas savings of 128.8 l of LP gas over the first two weeks of a spring flock. Humidity was also reduced in the house with the system installed; the humidity ratio with the system installed was 0.0141 kg water / kg dry air versus 0.0155 kg water / kg dry air in a house with a traditional sidewall inlet system.*

Keywords. Broiler, energy efficiency, gas usage, heating

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Introduction

Recent increases in fossil fuel costs have illustrated the need to reduce energy usage and improve energy efficiency in poultry production. Using solar heat to reduce energy costs in livestock structures has received much attention, but application has been limited in broiler production.

Research efforts in using solar energy in various forms for poultry production dates from the late 1950's (Bressler and Walton, 1957). Rising fuel prices in the 1970's spurred further research into use of solar energy (Flood et al.,1979; Flood et al., 1981; Brewer et al., 1981; Reece, 1981). Reece (1981) developed a solar heating system to heat inlet air for use during the day and water to store heat for use at night in broiler houses capable of reducing liquid petroleum (LP) gas usage in broiler houses by 70%.

The simplest means of using solar energy is using attic spaces to temper inlet air, and this has traditionally been the method used in animal facilities (Hellickson et al., 1983). Attic inlets are typically found in swine and layer facilities located in areas which experience severe winters, but are virtually non-existent in broiler facilities. As such, little information exists on the utility of these systems in broiler housing. The objectives of this study were to determine the feasibility of using the attic space of a broiler house as a source of pre-heated air to reduce energy usage during winter flocks by: 1) characterizing the air temperature difference between the attic space and interior and exterior air temperatures and 2) compare gas usage between broiler houses with and without an attic inlet system.

Materials and Methods

This study was conducted on a four-house commercial farm in southeastern Mississippi. All four houses were identically constructed and equipped with the exception of the attic inlet system which was installed in only two houses. The houses measured 12.2 m × 152.4 m (40 ft. × 500 ft.) and were totally enclosed; both the ceiling and walls were insulated to 3.3 $m^2 \cdot °C \cdot W^{-1}$ (19 $ft^2 \cdot °F \cdot h \cdot BTU^{-1}$). The brood chamber of each house was equipped with ten 11.7 kW (40,000 $BTU \cdot h^{-1}$) radiant brooders and two 73.2 kW (250,000 $BTU \cdot h^{-1}$) forced air furnaces fired with natural gas.

Air movement and heat distribution data were collected between flocks in summer 2006. Temperature and heater operation data during the brooding period were taken during a winter flock (January 2007) and a spring flock (March 2007).

Attic Inlet System

Attic inlets consisted of a pair of 152.4 cm × 17.8 cm (60 in × 7 in) sidewall inlet vents mounted to a plywood chimney (Figure 1). The inlets were installed between trusses, slightly off-center as not to interfere with row of lights mounted at the peak of the ceiling (Figure 2); a total of nine inlets were installed in the house. A sidewall curtain actuator was mounted in the ceiling to control opening/closing of the inlets.

Figure 1. Construction of attic inlets.

Figure 2. Attic inlets installed in ceiling of broiler house.

Data Acquisition

Outside air temperature and relative humidity was measured using a compact battery-powered data logger (H08-003-02, Onset Computer Corp., Pocasset, Mass.). Internal air temperature and relative humidity were measured in the attic and at bird level directly beneath the attic measurement point using miniature dataloggers (DS1923, Dallas Semiconductor, Sunnyvale, Cal.) in the house with the attic inlet system installed; the attic measurement point was omitted in the house without the inlet system. Air temperature was measured in four additional locations at bird level in both houses using miniature dataloggers (DS1922L, Dallas Semiconductor, Sunnyvale, Cal.). All measurements were recorded on 5 min intervals. Surface temperature measurements were taken with an infrared thermal camera (S65HS, FLIR Systems, Boston, Mass.). Forced air furnace run time was measured using a motor activity logger (H06-003-02, Onset Computer Corp., Pocasset, Mass.); brooder run time was recorded on the houses' environmental controllers.

Statistical Analysis

Data were analyzed using PROC GLM (SAS v8.0, SAS Institute, Inc., Cary, N.C.). Differences between least square means were separated with Fisher's LSD with significance considered at $P \leq 0.05$.

Results

Preliminary tests of the system focused on qualitatively determining the air distribution patterns from the vents using smoke as well as surface temperature distribution throughout the house, as surface temperatures will indicate the heat distribution patterns from the inlets. The movement of smoke from the inlets (with an inlet opening of approximately 3.5 cm) showed a jet which attached to the ceiling without an appreciable drop before contacting the sidewall. Anemometer readings indicated an average air velocity of the jet of 0.6 $m \cdot s^{-1}$ (120 $ft \cdot min^{-1}$) as it approached the sidewall with one 121.4 cm (48 in) fan operating.

Surface temperatures were recorded using an infrared thermal camera; a representative image of the east sidewall during operation of the attic inlet system is shown in Figure 3. The thermograph in Figure 3 shows heating of the ceiling and sidewall surfaces, as well as the litter where the jet of warm air travels down the sidewall.

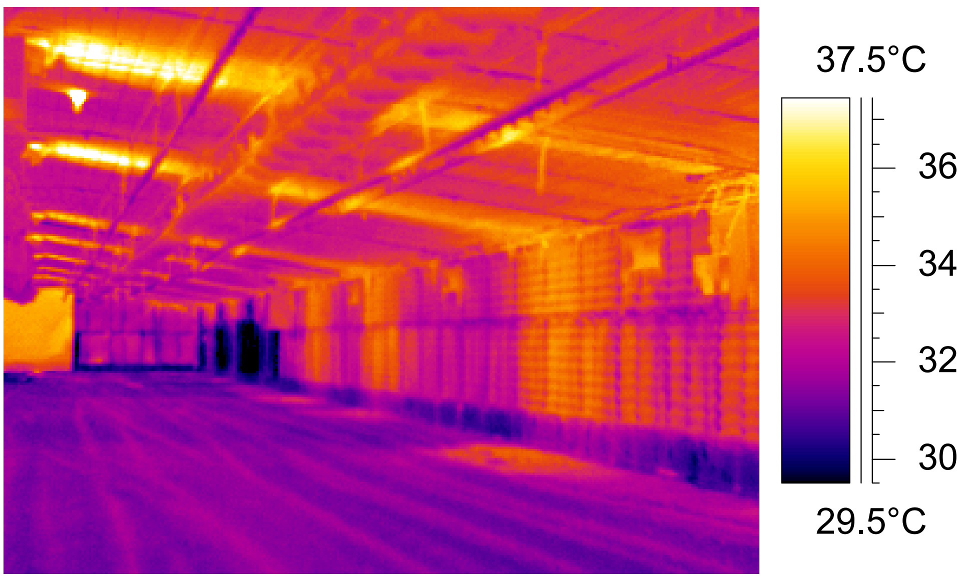

Figure 3. Example thermograph of east sidewall and ceiling (June 2006).

Data collected during brooding of a winter flock (January 2007) was used to characterize attic, outdoor, and indoor air temperatures and is shown for the first week (Figure 4) and for the second week (Figure 5). Attic temperature is significantly elevated over outdoor air temperature ($P \leq 0.0001$), with a difference of 6.9 °C. Histogram analysis was used to determine the frequency with which attic temperature exceeded ambient temperature over the initial two week brooding period (Figure 6). The attic temperature was at least 6 °C warmer than the outside air 86.6% of the time during this period, indicating that the attic space can be relied upon as a source of supplemental heat under typical winter conditions in Mississippi.

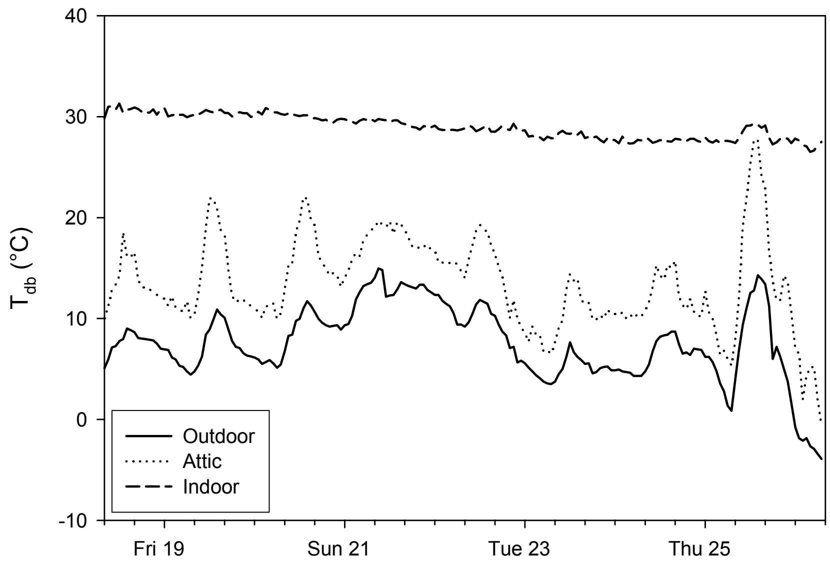

Figure 4. Air temperatures during the first week of the flock.

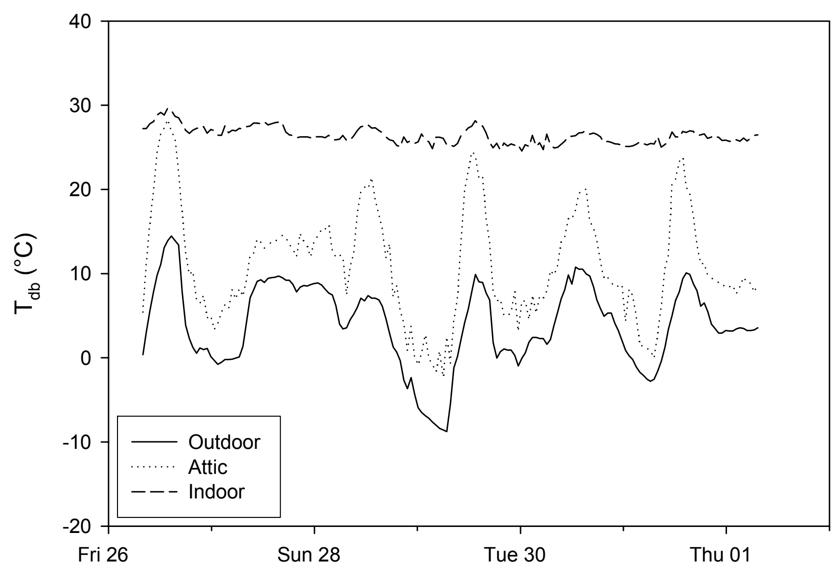

Figure 5. Air temperatures during the second week of the flock.

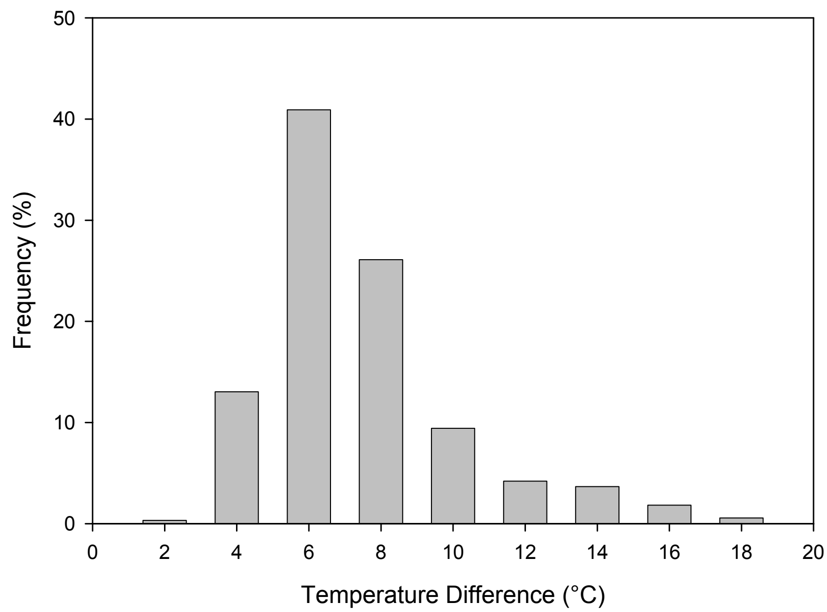

Figure 6. Overall frequency of temperature difference between attic space and outdoor temperature during the first two weeks of a winter flock.

Gas usage was estimated for one spring flock (March/April 2007) by monitoring brooder and furnace run time; these results are shown in Table 1. Total energy use estimated from run time was calculated assuming that all brooders and furnaces were operating properly. The house with the attic inlets installed had fewer hours of heating system run time. The estimate of energy consumed during the first two weeks of the flock for the house with the attic inlets was 897 kW·h less than the house without it.

Table 1. Brooder stage and furnace run times during the first two weeks of a spring flock.

	Attic Inlets		**Sidewall Inlets**	
	Run Time (h)	**Energy Use (kW·h)**	**Run Time (h)**	**Energy Use (kW·h)**
Brooder Stage	27.9	981	45.5	1598
Brooder Stage	4.4	154	1.7	59
Brooder Stage	23.0	1075	19.4	911
Furnace 1	0.1	4	2.8	201
Furnace 2	8.8	642	13.4	984
Total		2856		3753

House conditions were also compared between the two houses. Mean air temperature was not different between the houses, however dewpoint and humidity ratio were significantly higher in the house equipped only with traditional sidewall vents; mean house conditions for both houses are shown in Table 2.

Table 2. Mean conditions for each measurement location during the first two weeks of a spring flock. Means within a column with different superscripts are different at $P \leq 0.05$.

Location	t_{db} (°C)	t_{dp} (°C)	W kg_{water} / kg_{da}
Attic Inlet House	31.0 [a]	19.2 [b]	0.0141 [b]
Attic	26.4 [b]	13.8 [c]	0.0101 [c]
Sidewall Inlet House	30.8 [a]	20.8 [a]	0.0155 [a]
Outdoor	19.5 [c]	11.9 [d]	0.0088 [d]

Discussion

Both the brooder and furnace run time were reduced for the house with the attic inlet system, operating 17% and 45% less time than the house with traditional sidewall vents. Gas usage was estimated from the heat production ratings for the brooders and furnaces and their associated operating times. The house with the attic inlet system used an estimated 410 l of LP gas as compared with 539 l for the house with traditional sidewall vents. The difference of 129 l of LP would result in a savings of $51.60 per house over the first two weeks of this flock, based on a price of $0.40 / l LP gas.

The difference in moisture within the house also illustrates the benefit of using preheated inlet air. Moisture in the house, specifically in the litter, can lead to a host of problems, most notably increased ammonia production (Elliot and Collins, 1982; Carr et al., 1990). The effects of ammonia exposure on health and production efficiency of broilers is well documented (Anderson et al., 1964; Reece et al., 1980; Reece et al., 1981; Kristensen and Wathes, 2000; Miles et al., 2004), and any means to reduce ammonia production would be beneficial for improving production efficiency and reducing emissions. Humidity ratio in the house with traditional sidewall vents was significantly higher when compared to the house with attic inlet vents. Under a typical minimum ventilation scenario with one 91.4 cm and one 121.9 cm fan running every 30 s per 5 min, the house with the attic vents and the house with the sidewall vents will exhaust 1989 and 2197 kg $H_2O \cdot d^{-1}$, respectively, based on the average humidity ratio in those houses. The estimated energy required to reduce the moisture in the sidewall vented house down to the moisture levels of the attic vented house is 520 $MJ \cdot d^{-1}$ (493673 $Btu \cdot d^{-1}$), which equates to 20.8 l (5.5 gal) of LP gas. At $0.40 / l LP gas, the cost to reduce the moisture level will be 8.23\cdot d^{-1}$.

Conclusion

The results show that the attic space of a broiler house can be successfully used as a source of pre-heated air. Surface heat distributions from the attic inlets show that warm air can be evenly distributed throughout the brooding area of a typical broiler house. Attic temperatures are also significantly warmer (6.9 °C, $P \leq 0.0001$) than ambient temperatures for long periods of time. Reductions in brooder and furnace run time of 17% and 45%, respectively, indicate that gas savings are indeed possible; however, further research is necessary to accurately determine the amount of gas savings possible from use of such a system.

Additional benefits may be realized from this system, most notably improved air quality due to increased fan run time to offset the increased inlet air temperature. While primarily intended as a means to reduce fuel usage during brooding, the system could potentially provide a means of inexpensively heating the house between flocks to dry litter and reduce ammonia.

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