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Laboratory-scale evaluation of incandescent and compact florescent lamps for poultry house lighting

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ABSTRACT

This laboratory-scale study compared 1000- and 2000-h rated 60W incandescent lamps and 6000-h rated 60W-equivalent compact florescent lamps over 6000 h of simulated broiler-house operation. The four original 1000-h incandescent lamps were replaced 22 times and the four 2000-h incandescent lamps were replaced 14 times. None of the four compact florescent lamps failed during the 6000-h experiment, although one was broken due to human error. Both types of incandescent lamps had significantly higher ($p < .0001$) mean illuminance (lx) than did the compact florescent lamps. The compact florescent lamps used significantly less ($p < .0001$) power (W) and had significantly higher ($p < .0001$) efficiency (lx/W) than the incandescent lamps. Despite a higher initial purchase price, the total cost (purchase + replacement + electrical) of operating compact florescent lamps was approximately 36% lower than the total cost of operating either type of incandescent lamp over the 6000 h period. The results of this study indicate that even at a least-cost price for electricity ($0.04/kW/h), growers can reduce total broiler-house lighting costs by replacing incandescent lamps with compact florescent lamps.

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† Donald M. Johnson, faculty sponsor, is a professor in the Department of Agricultural and Extension Education.

MEET THE STUDENT-AUTHOR

Leanne M. Gabriel

I was born in Yellville, Arkansas, and graduated from Yellville-Summit High School in 1997. I attended North Arkansas College in Harrison, where I received my A.A., A.S., and A.S. in agriculture from the Dale Bumpers College of Agricultural, Food and Life Sciences. My husband and I both transferred to the University of Arkansas in fall 2000, he as a mechanical engineering major and I as an agricultural education, communication, and technology major. During fall 2002, I decided to pursue a minor in agricultural systems technology management to better supplement my degree. We had our first child in spring 2001.

I have received several scholarships while at the University of Arkansas including the Romeo E. Short Scholarship, the Triangle Cooperative Scholarship, and numerous departmental scholarships. I have had the opportunity to join several student organizations at the university. I am a member of the Golden Keys Honor Society, The National Society of Collegiate Scholars, Gamma Sigma Delta Agricultural Honorary Society, Alpha Tau Alpha, and Alpha Zeta Fraternity. I have been on the Dean's List every semester since coming here. I graduated in May 2004, walking Magna Cum Laude and receiving a B.S. degree in agricultural education, communication, and technology. After graduation I plan to take some time off to spend with my daughter before pursuing my ultimate goal of teaching agriculture to high school students.

I was encouraged to do this project by my minor advisor, Dr. Don Johnson. The project was very fascinating, relating not only to poultry house uses but to non-commercial uses as well. This effort has taught me a lot about the research process and I would like to express my thanks to Dr. Johnson for his support and guidance throughout this research project.

INTRODUCTION

The 1997 Census of Agriculture reported that Arkansas had 3,106 broiler farms and produced slightly more than one billion broilers annually (14.9% of the U.S. total). Nationally Arkansas ranked second, only slightly behind Georgia, in the number of broilers produced (USDA, 1999).

According to Boucher and Gillespie (2002), electricity is the single largest direct expense for Georgia contract broiler growers, representing 26% of total direct expenses. The researchers estimated that operating a single 16,000-ft^2 (1,486 m^2) broiler house would require 20,556 kW/h of electrical energy per year, at a total cost of $1850 (at $0.09 / kW/h). While a majority of the electrical energy in a broiler house is used to power ventilation equipment, Czarick and Lacy (1997) indicated that producers can significantly reduce electrical costs by making relatively simple and inexpensive changes to their lighting systems.

One recommended change was the use of florescent lamps for broiler house lighting (Czarick and Lacy, 1997). Florescent lamps are more efficient than incandescent lamps in converting electricity into visible light. According to Darre (2000), florescent lamps produce 50 – 59 lumens per watt (lm/W), while incandescent lamps produce 8 – 24 lm/W. Since compact florescent lamps draw less current and have the same Edison-base as do incandescent lamps, no modifications to wiring or fixtures are required in order for growers to use compact florescent lamps in broiler houses. In addition, dimmable compact florescent lamps, which would be required for certain lighting schedules, are now available (Washington State University, 2003). Thus, the use of compact florescent lamps has the potential to decrease electrical use and expenses in broiler production.

Incandescent lamps produce visible light (380 to 780 nm) by passing electric current through a tungsten filament, heating it to incandescence at approximately 2620°C. Incandescent lamps are widely available and inexpensive to purchase; however, incandescent lamps are the least efficient of all lamps and have the shortest expected service life (Bern and Olsen, 2002). Compact florescent lamps produce visible light when electricity excites mercury-vapor contained in a glass tube. The excited mercury-vapor emits ultraviolet radiation which, in turn, strikes phosphor crystals on the inside of the glass tube, producing visible light. Compared to incandescent lamps, compact florescent lamps have a longer service live and are more efficient; however they are more expensive to purchase (Bern and Olsen, 2002).

Lewis and Morris (1998) reviewed the scientific literature to assess the effects of various artificial light sources on poultry. They found that there were no differences in growth, food utilization, mortality, or live bird quality between broilers grown using incandescent, florescent, or high-pressure sodium lamps.

Despite this potential savings and the lack of documented adverse effects, Dr. Susan Watkins, University of Arkansas Extension Poultry Specialist, estimated that fewer than 25% of Arkansas growers use compact florescent lamps in their broiler houses (personal communication, 14 May 2004). The purpose of this study was to conduct a laboratory-scale evaluation of incandescent and compact florescent lamps and compare them on measures of service life, illuminance, power use, efficiency, and cost of operation.

MATERIALS AND METHODS

Twelve molded plastic lamp holders (120V AC) were wired in parallel on a 121.9-cm x 243.8-cm x 1.9-cm thick sheet of exterior grade plywood using Type NM 12-2 WG cable. Four of each of three types of 60-W rated lamps were installed in the lamp holders: (a) 1000-h incandescent, (b) 2000-h incandescent, and (c) 6000-h compact fluorescent. All of the lamps were produced by the same manufacturer and were purchased at the same retail outlet. An Intermatic T101 (Intermatic Inc., Spring Grove, IL) mechanical clock-timer was installed in series with the electrical source and was set to energize the lamps for 23-h each day, with a 1-h off period. An SC100A split-core AC current sensor (Pace Scientific, Mooresville, NC) and an XR440 data logger (Pace Scientific, Mooresville, NC) were connected to a computer running Pocket Logger (v3.15A) software (Pace Scientific, Mooresville, NC) to monitor and verify on-off conditions and total "on time." Circuit current was logged every 0.25 h. For safety, the circuit was protected by a portable ground-fault circuit interrupter.

After each 250-h period of operation, the circuit was de-energized and the electrical consumption (W) and light output (lx) of each lamp were measured and recorded (Fig. 1). Each lamp was placed in a 30.5-cm x 30.5-cm x 48.3-cm long light-tight box constructed from 1.9-cm thick plywood. The interior of the box was painted with flat, black latex paint. A LS-100 light sensor (Pace Scientific, Mooresville, NC) was installed in the center of the fixed end of the box and was connected to the XR440 data logger and computer. The removable end of the box was fitted with a 120V AC molded plastic lamp holder connected to a 61-cm long power cord wired through a Lutron DW-6060 digital watt meter (Lutron Electronic, Taipei, Taiwan). The distance between the light sensor and the bottom of the lamp base was 36.2 cm.

Lamps that failed were replaced at each 250-h interval and the electrical consumption and light output of the replacement lamp were measured and recorded along with the measurements for the lamps still functioning. One compact florescent lamp was accidentally broken after 3000 h of operation and was not replaced. The experiment continued, with a full set of readings being taken every 250 h, until a total of 6000 h of operation was reached. Due to time constraints, the experiment was terminated after 6000 h of total operation; however, the three intact florescent lamps were still functioning after 10,000 h of operation.

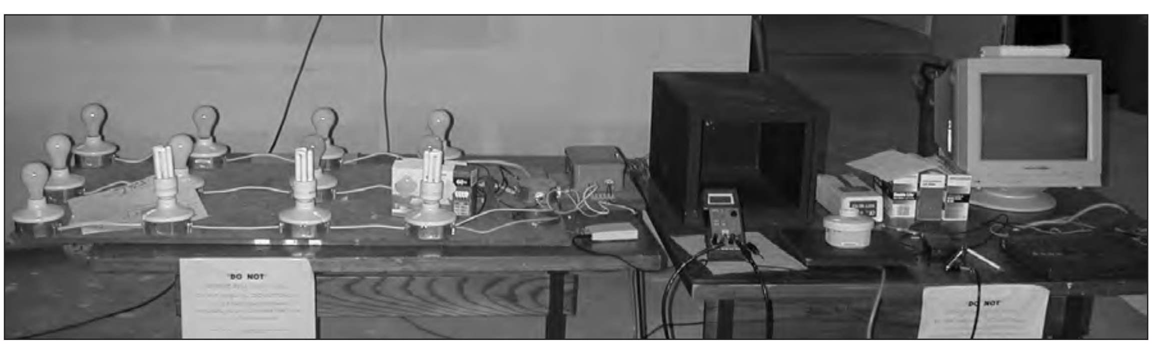

Fig. 1. Experimental set-up for lighting study

RESULTS AND DISCUSSION

Over the 6000 h of operation, the four original 1000-h incandescent lamps were replaced 22 times for a total (original plus replacements) cost of $6.96. The four original 2000-h incandescent lamps were replaced 14 times for a total cost of $8.86. None of the 6000-h rated compact florescent lamps were replaced during the 6000 h of operation. The total purchase cost for the four compact florescent lamps was $27.92.

Analysis of variance (ANOVA) indicated there was a significant difference in the mean illuminance (lx) for the tree types of lamps, $F(2, 72) = 29.43$, $p \leq .0001$, $R^2 = 0.45$. The Tukey HSD test revealed that the mean illuminance for both types of incandescent lamps was significantly higher than for the compact florescent lamps (Table 1). The compact florescent lamp had a mean illuminance 4.9% less than the 1000-h incandescent lamp.

Fig. 2 shows the mean illuminance for the two types of incandescent lamps and the compact florescent lamps at the start of the experiment and at each 250-h measurement interval. For the florescent lamps, the mean illuminance at 6000 h (1445 lx) was 2.7% less than the initial illuminance (1485 lx). The correlation between hours of operation and mean illuminance ($r = -.90$) explained 81% of the variance in illuminance for the florescent lamps.

There was a significant difference in electrical power use (W) for the three types of lamps, $F(2, 72) = 2631.58$, $p \leq .0001$, $R^2 = 0.99$. Both types of incandescent lamps used significantly more electrical power than did the compact florescent lamp (Table 1).

There was a significant difference between the efficiency (lx/W) of the three types of lamps, $F(2, 72) = 698.17$, $p \leq .0001$, $R^2 = 0.95$. The compact florescent lamp was more efficient than either type of incandescent lamp (Table 1).

Finally, the average total cost (purchase + replacement + electrical) to operate one unit of each type of lamp for 6000 h was estimated. According to Ozarks Electric Cooperative Corporation, the price of electrical energy for broiler houses ranges from approximately $0.04 to $0.09 per kW/h, depending on the customer's total demand and load-use pattern (J. Fitzgerald, personal communication, 12 May 2004). The lowest electrical rate of $0.04 per kW/h was used in all calculations to produce the most conservative estimate of cost differences between the three types of lamps.

As shown in Table 2, 6.5 of the 1000-h incandescent lamps, 4.5 of the 2000-h incandescent lamps, or one compact florescent lamp would be required in order to operate one lamp holder for 6000 h. However, purchasing the required number of either type of incandescent lamp would be less expensive than purchasing a single compact florescent lamp. The compact florescent lamps were more energy efficient, resulting in an estimated electrical cost savings of almost $11 per 6000 h of operation, when compared to the incandescent lamps. The total cost to purchase and operate a compact florescent lamp for 6000 h was approximately 36% less than of the total cost of purchasing and operating either type of incandescent lamp.

While compact florescent lamps cost more to purchase than incandescent lamps, the overall cost (purchase + replacement + electrical) of operating a compact florescent lamp for 6000 h was 36% less than the overall cost of operating either type of incandescent lamp. This was due to the lower electrical energy use and the higher efficiency of the compact florescent lamp. Considering that cost estimates were made based on a conservative electrical energy cost of $0.04/kW/h and that the florescent lamps were still operating after 10,000 h, the present study likely underestimates the potential economic advantage of compact florescent lamps.

The compact florescent lamps produced slightly less (4.9%) mean illuminance than did the incandescent lamps. However, this finding may be somewhat misleading considering the experimental procedures used. Failed incandescent lamps were replaced at 250-h measurement intervals and the replacement lamps were measured and included in the mean illuminance. Thus, under conditions of actual use and replacement, the compact florescent lamps may well produce a higher mean illuminance than the incandescent lamps.

This laboratory-scale study indicates that compact florescent lamps provide a clear cost reduction when compared to incandescent lamps. The findings are consistent with those of Czarick and Lacy (1997). Producers should seriously consider replacing broiler house incandescent lamps with compact florescent lamps.

ACKNOWLEDGMENTS

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Table 1. Illuminance, power use, and efficiency for three types of 60-W rated lamps

Lamp	Illuminance (lx) M [z y]	Illuminance (lx) SD	Power (W) M [z y]	Power (W) SD	Efficiency (lx/W) M [z y]	Efficiency (lx/W) SD
1000-h incandescent	1546A	41.47	58.71A	2.84	26.39A	1.09
2000-h incandescent	1531A	45.38	58.12A	3.00	26.43A	0.98
6000-h florescent	1470B	15.91	13.17B	1.55	113.56B	16.43

[z] Mean of the 250-h interval means
[y] Means in the same column with different letters are significantly different ($P \leq .05$) by the Tukey HSD test

Table 2. Estimated total cost to purchase and operate one of each type of lamp for 6000 h

Lamp	Lamp: Number used[z]	Lamp: Cost ($)	Electricity: kW/h used	Electricity: Cost ($)[y]	Total cost ($)
1000-h incandescent	6.5	1.74	352.26	14.09	15.83
2000-h incandescent	4.5	2.22	348.72	13.95	16.17
6000-h compact florescent	1.0	6.98	79.02	3.16	10.14

[z] Total lamps (original + replacement) used / 4 lamp holders
[y] Based on an electrical cost of $0.04 per kW/h

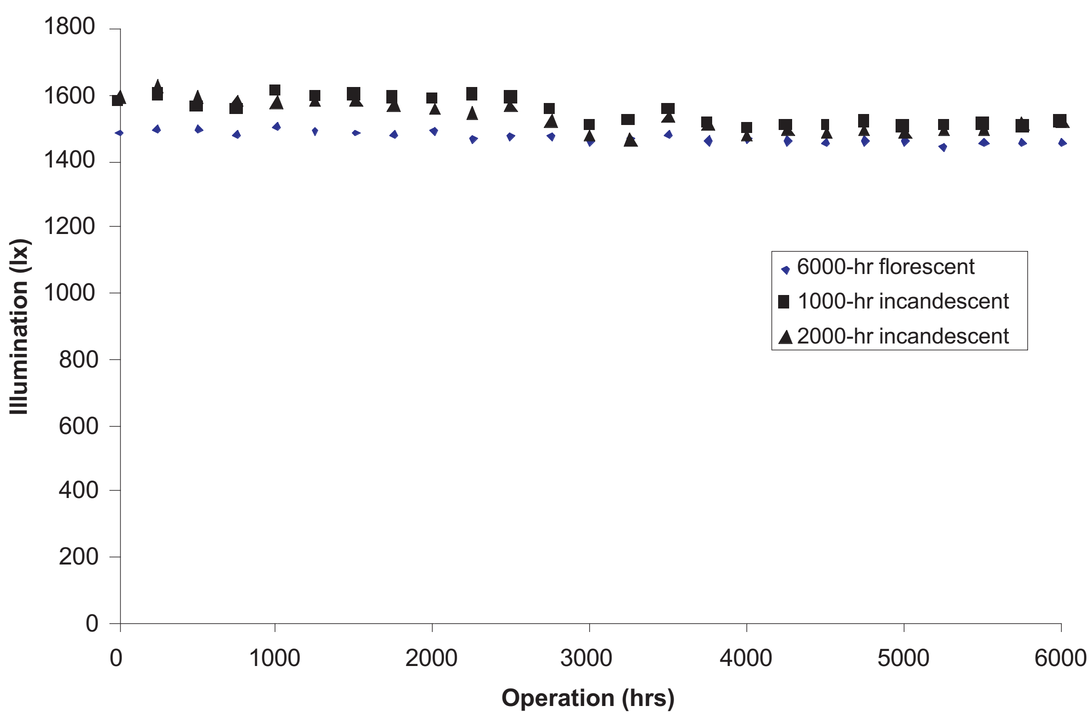

Fig. 2. Mean illuminance (lx) for the three types of lamps at 250-h measurement intervals