EC VETERINARY SCIENCE
Research Article

# Comparison of Heat Lamps and Heat Mats in the Farrowing House: Effect on Piglet Production, Energy Usage and Piglet and Sow Behavior through Digital Observation

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## Abstract

**Objective:** Pre-weaning mortality remains an industry concern. The study objectives were to 1) evaluate piglet performance and pre-weaning mortality when supplied with two heat source treatments at a constant temperature, 2) evaluate sow lying behavior and piglet location behavior in regard to heat source and proximity to the sow and 3) evaluate the energy usage of two different heat sources at a constant temperature.

**Materials and Methods:** Twenty-two multiparous crossbred sows housed in farrowing stalls were part of a completely randomized study and assigned to heat source treatment; Baby Pig Heat Mat - Single 48 (MAT; n = 12) or Poly Heat Lamp Fixture LAMP; n = 10). Piglets were weighed on D1 and weaning and any mortalities were recorded to evaluate piglet production measures. For seven days over the course of lactation (D1, D2, D3, D4, D5, W-7 and W-1) sows and their litters were recorded for 24-h. Still images were selected at 20-minute time increments and evaluated using a behavioral ethogram.

**Results and Discussion:** No piglet production differences were observed in, litter weaning weight ($P = .97$) and pre-weaning mortality ($P = .90$). There were piglet behavior differences within day by supplemental heat source treatment, however additional research is needed to further evaluate piglet behavior ($P < .0001$). Sows spent the majority of the time during observations lying laterally, further work is warranted to evaluate if heat source placement affects this behavior. Energy usage in kWh was different among treatments ($P < .0001$). Heat lamps (63.67 ± 0.79) utilized 3.8 times more electricity (kWh) than heats mats.

**Implications and Applications:** Significant energy and cost savings can be captured through the use of heat mats in the farrowing house as supplemental heat for the neonatal piglet from parturition to the end of lactation without negatively affecting pre-weaning mortality or piglet growth.

***Keywords:*** *Swine; Farrowing House; Heat Lamp; Heat Mat; Energy Use*

## Abbreviations

P1, P2, … P7+: Parity 1, Parity 2, … Parity 7 or Greater; NRC: National Research Council; MAT: Baby Pig Heat Mat Treatment Group; LAMP: Poly Heat Lamp Treatment Group; D1-D5: Day 1 Post-Farrowing to Day 5 Post-Farrowing; W-7: A Week Prior to Weaning; kWh: Kilowatt Hour; USDA: United States Department of Agriculture; W-1: A Day Prior to Wean

## Introduction

Within the farrowing environment, the sow and her piglets are at two very different life stages and have different social, physical environmental and thermal requirements. For example, ambient temperature requirements for lactating sows ranges from 15 to 26ºC, but individual newborn piglets prefer a higher temperature of 34ºC [1-3]. To reconcile these thermal differences, supplemental heat or warm bedding can be provided. This enhanced thermal microenvironment can minimize piglet pre-weaning mortality associated with cold stress. Implementing a 125-watt heat lamps for supplemental heat can account for over 36% of total electrical usage on a 3,000 head sow operation [4]. However, a 20% pre-weaning mortality level is estimated to cost the United States (U.S.) pork industry between $650 to $800 million annually, therefore economical compromises need to be considered [5].

Previous work by Stinn and Xin compared a heat mat to a heat lamp on piglet pre-weaning mortality, rate of gain, and electric power use [6]. The authors concluded that there was no difference in rate of gain or mortality, but mats used 36% less power compared to heat lamps. Further, MacDonald and colleagues reported that heat mats resulted in a 50% cost savings without detrimentally affecting piglet weaning weight or average daily weight gain [7]. Hrupka and colleagues reported that heat lamp location within a farrowing stall did not affect pre-weaning mortality, but fewer piglets were within 8 cm of the sow and more were located in the heat source area [8].

## Objectives of the Study

The objectives of this work were to 1) evaluate piglet performance and pre-weaning mortality when supplied with two heat source treatments at a constant temperature, 2) evaluate sow lying behavior and piglet location behavior in regard to heat source and proximity to the sow and 3) evaluate the energy usage of two different heat sources at a constant temperature.

## Materials and Methods

The research protocol was approved by the Iowa State University Institutional Animal Care and Use Committee (8-17-8583-S). Sows were provided a minimum of a 72-h acclimation period to the farrowing stall with heat source treatment prior to farrowing.

### Animals, location and housing

A total of 22 sow and litter units housed in farrowing stalls were used in this study. Stalls had interlocking plastic flooring and a creep area on both sides of sow. The total stall area measured 2.0m x 1.7m. The center sow area measured 2.0m x 0.6m with two creep areas measuring 2.0m x 0.55m on either side. Solid flooring was provided, 1.2m x 0.4m, on one side of the piglet creep area where the heat source was provided. The stalls were distributed across two farrowing rooms (7 stalls per room) in a negative pressure, mechanically ventilated barn where the temperature was set at 21.1ºC. Six stalls per room were included in the study, with the first crate being excluded for off-test animals. Data was collected from September to December at the Iowa State University Allen E. Christian Swine Teaching Farm in Ames, IA. Multiparous crossbred sows (P1 = 5, P2 = 3, P3 = 5, P4 = 1, P5 = 3 and P7+ = 4) and their litters were enrolled. Sows were provided *ad libitum* access to water via one 1.9 cm nipple and were hand fed once daily prior to farrowing. Post-farrowing, sows were hand fed to appetite three times daily in 0.90 kg increments. Feeding to appetite to ensure constant access to fresh feed started with a 2.72 kg feeding when feed was fully consumed and at the next scheduled feeding an additional increment was added until more than 0.90 kg of feed remained in the feeder. Once the sow had reached full appetite this amount of feed was fed to her for the remainder of lactation. All diets were prepared by a commercial feed mill (Key Cooperative, Gilbert, IA) composed of primarily corn, soybean meal and dried distillers grains and nutrients formulated according to NRC (2012) guidelines to meet or exceed gestating/lactating sow nutrient requirements. The diet contained 19.6% crude protein, 32 Mcal ME/kg and 1.17% total lysine.

### Treatments

Two treatments were compared, treatment one; Baby Pig Heat Mat - Single 48 (MAT; 85 W, 34.29 cm x 121.92 cm, polyethylene; Kane Manufacturing, Pleasant Hill, IA; n = 12, Figure 1) and treatment two; Poly Heat Lamp Fixture (LAMP; 125 W, 25.4 cm x 30.48 cm, polypropylene; HogSlat, Newton Grove, NC; n = 10, Figure 2) with a 125 W Infrared Heat Bulb (QC Supply, Ames, IA). Both heat source treatment setpoint (defined as desired temperature at which the thermostat is set) was 32.2°C. The LAMP was controlled via a single step mechanical thermostat for a maximum temperature. LAMP height was set to match the temperature of MAT, which was controlled via Thermostat Programmable 1 Zone (Kane Manufacturing, Pleasant Hill, IA). The temperature settings for both treatments was confirmed using a handheld infrared temperature gun (Tool House Digital Infrared Thermometer: model 770343S, Alltrade Tools, LLC, Long Beach, CA; ± 2°C). Sows and their piglets were assigned to one of the heat source treatments, blocked by parity, throughout lactation and pigs were weaned at an average of 21-d of age.

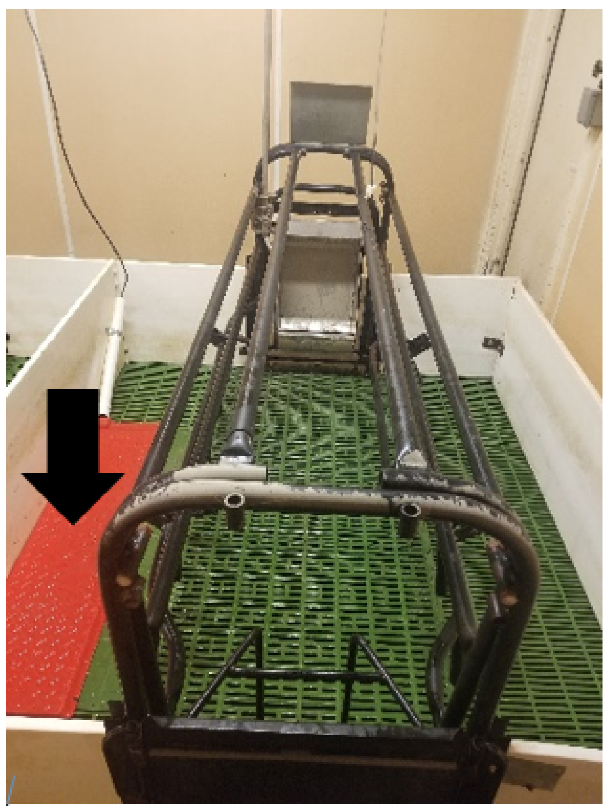

***Figure 1:*** *Image of farrowing stall with treatment Baby Pig Heat Mat used in study comparing heat mats and heat lamp to provide supplemental heat for piglets during lactation[1].*

[1]Baby Pig Heat Mat - Single 48 (34.29 cm x 121.92 cm) (Kane Manufacturing, Pleasant Hill, IA).

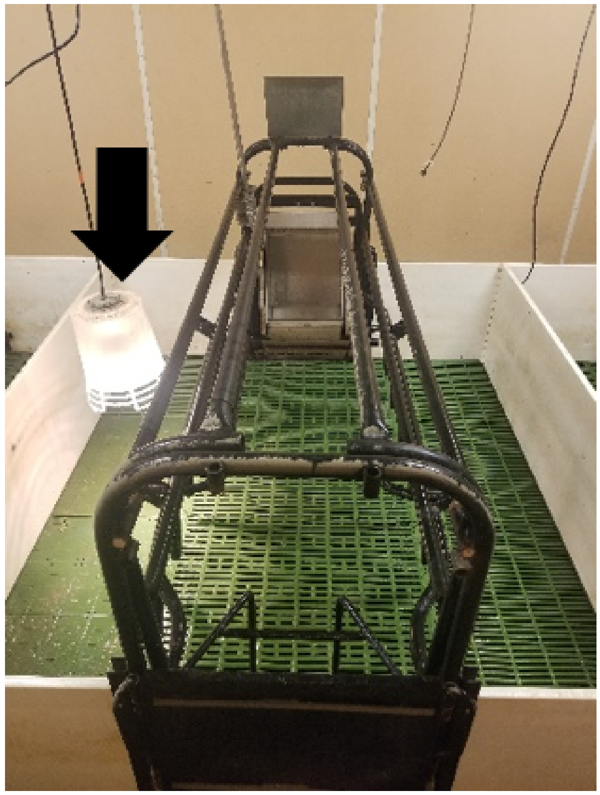

***Figure 2:*** *Image of farrowing stall with treatment Poly Heat Lamp Fixture used in a study comparing heat mats and heat lamps to provide supplemental heat for piglets during lactation[1].*

## Production measures

Number born alive and number weaned was recorded for each litter. Pre-weaning mortality was defined as a piglet death post-farrowing and prior to weaning, calculated as a percentage ([pigs weaned/pigs born alive] * 100). Piglets were weighed individually at processing (assignment of an individual ear notch, tail docking, 1cc IM iron supplement injection and 0.25cc IM antibiotic injection) and at weaning using a digital scale (Mettler PM30-K, Mettler Toledo. Columbus, OH; ± 0.5g). All piglet mortalities were recorded and included day, sex, weight.

## Behavioral evaluation

Video recordings of sows and their litters while in their stalls occurred continually over a 24-h period from D1 through D5, a week before weaning (W-7) and a day before weaning (W-1). Video was recorded using One 12 V color Close Circuit Television (CCTV) camera

[1]Poly Heat Lamp Fixture with 125W heat bulb (Hogslat, Newton Grove, NC).

(Model WV-CP484, Matsushita Co Ltd., Japan) positioned centrally over the stall (2.54m). Behavioral measures were captured digitally utilizing a Noldus portable lab (Noldus Information Technology, Wageningen, The Netherlands). Cameras were fed into a multiplexer, allowing images to be recorded using a PC with HandiAvi (v4.3, Anderson's, AZcendant Software, Tempe, AZ, USA) at 30 fps. A computer screen was used to view the output to ensure picture clarity and camera positioning prior to each behavioral recording session. Videos were converted to a still frame image every 20-mins using a JPG converter (Free video to JPG converter, Digital Wave Ltd., London, United Kingdom). A total of 11 (10 female and 1 male) observers were used. One trainer with 16 years of swine and behavioral experience was responsible for observer training prior to image analysis. An ethogram was create/adapted that included five mutually exclusive sow postures, two piglet locations and piglet contacting or not contacting the sow were recorded (Table 1). To test for inter-observer reliability, 14 images were viewed. One image per day per treatment were utilized in the training. All observers independently reviewed these images using the previously described ethogram. All observers reached a 90% or greater agreement with the trainer. Due to the nature of the images, observers were unable to be blinded to the treatment, therefore observers were assigned to images involving a heat source that they had no previous experience.

| **Measure**[1] | **Defined** |
|---|---|
| **Piglet Location**[2] | |
| Mat | 75% or more of the piglet is touching the heat mat |
| Lamp | 75% or more of the piglet is under the heat lamp |
| Other | Anywhere in the stall not associated with the heat source |
| **Piglet Contact**[3] | |
| Touch | Any part of the piglet is touching the sow |
| Not | No part of the piglet is touching the sow |
| **Sow Posture**[4] | |
| Lateral lie left | Lying on pig's left side |
| Lateral lie right | Lying on pig's right side |
| Sternal lie | Lying on pig's sternum |
| Standing | All four feet on flooring |
| Sitting | Hindquarter on floor, front feet on flooring |

***Table 1:*** *Behavioral measures recorded when evaluating sows and their litters using a 20-minute scan sample through digital images for D1 through D5 of the trial, a week before (W-7) and a day before weaning (W-1)*[5].

[1]This was used in a study comparing heat lamp and heat mats as supplemental heat sources for piglets during lactation.

[2]Piglet location within the stall.

[3]Piglet physical contact with the sow.

[4]Sow lying posture within the stall.

[5]Behavioral measures were obtained through digital observation.

### Electrical usage

Kill-A-Watt EZ Meter P4460 (P3 International Corporation, New York, NY; Accuracy: 0.02%) were connected to the allotted heat source for the entire lactation duration to measure kilowatt hour (kWh) energy usage by each experimental unit. Electric meter readings were recorded twice weekly by farm staff. Final kWh usage readings were recorded at weaning.

### Statistical analysis

All data was evaluated using mixed model methodology (Proc Mixed, SAS version 9.4, SAS Institute Inc., Cary, NC). Sources of model variation were considered significant at $P < 0.05$. When fixed effect model variation was significant, LS means for each level within the fixed effect source were separated using the pdiff option within the Proc Mixed procedure (SAS version 9.4, SAS Institute Inc., Cary, NC). Fixed effects in the model included group, parity, and treatment. Production data was analyzed using a generalized mixed model (Proc GLM, SAS version 9.3, SAS Institute Inc., Cary, NC). A random effect for the interaction between farrowing room and stall was included in the model. Behavioral data was analyzed using a generalized mixed model with an i-link distribution (Proc Glimmix, SAS version 9.3, SAS Institute Inc., Cary, NC). Fixed effects in the model included day, treatment and time. A random effect for room and stall within room were included in analysis models.

## Results and Discussion

When comparing supplemental heat source treatments (i.e. heat lamps and heat mats) there were no litter weaning weight ($P = .97$) or pre-weaning mortality ($P = .90$) differences observed.

Behavioral differences were observed with supplemental heat source type. The number of piglets utilizing heat source differed by supplemental heat source treatment within day with more piglets using the LAMP on D5, W-7 and W-1 compared to piglets in the MAT treatment ($P < .0001$; Figure 3). The number of piglets in physical contact with the dam was different among treatments within day of lactation ($P < .0001$; Figure 4). A greater number of piglets within the LAMP heat source treatment were in contact with their dam over D3 through D5 compared to piglets within the MAT treatment. On W-1, piglet contact with the dam was greater for MAT (Figure 4). Due to environmental and recording limitations in the current study, a category for 'location unknown' and 'touch unknown' were recorded, these categories accounted for 1.5 ± 2.3 pigs per litter per day. Due to the large variation in unknown and limitations in this study as a result of recording equipment and environmental factors, additional research work will be required to ascertain piglet heat source usage and contact with the sow utilizing a different observation method such as live observation or different camera location. Sow lying patterns observed in the present study demonstrated that sows spent nearly 80% of their time in a lateral lying position. A total of 7,751 sow observations over D1-D5, W-7 and W-1 were evaluated throughout the duration of the project, during which 2,744 incidences of lateral lie left (35.4%) and 3,256 incidences of lateral lie right (42.0%) were recorded. With sows spending the majority of time lying laterally (77.4%), further research work is required to evaluate if heat source position effects sow lying patterns across days within lactation and during the entire lactation phase of production.

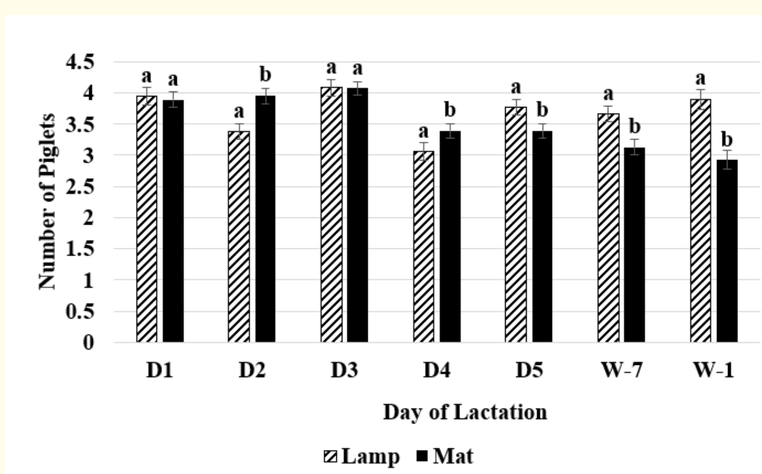


***Figure 3:*** *Piglet heat source usage within day of lactation by treatment (P < .0001)[1,2,3,4].*

[1]Differing superscripts within day of lactation represent differences by treatment.

[2]Error bars represent standard error.

[3]Number of piglets represents the piglets using the heat source within day of lactation, other piglets are in other stall location or location unknown.

[4]Energy usage was obtained using a Kill-A-Watt EZ Meter P4460 (P3 International Corporation, New York, NY; Accuracy: 0.02%).

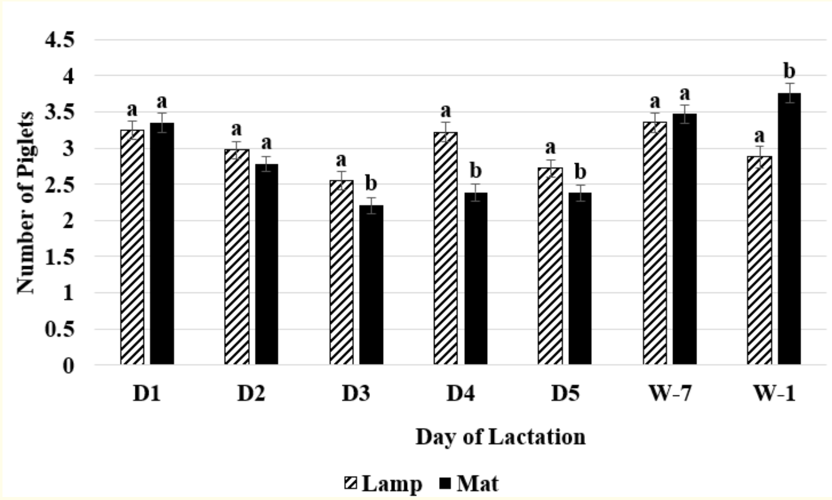


***Figure 4:*** *Piglet physical contact with the dam within day of lactation by treatment (P < .0001)[1,2,3,4].*

Energy usage (kWh) was different between the two supplemental heat sources evaluated in the present study (P < .0001). LAMP (63.6 ± 0.79 kWh) utilized 3.8 times more electricity (kWh) when compared to MAT (16.4 ± 0.73 kWh). The 47.3 kWh difference between the two supplemental heat systems utilized in this study can be translated into an energy cost savings by multiplying by the kWh difference by the cost per kWh. According to the Bureau of Labor Statistics, the average cost per kWh in the Midwest is $0.12 [9]. Therefore, an energy cost savings of $5.67 per litter can be achieved when heat mats with a programmable control are used to provide supplemental heat during lactation when compared to heat lamps operated in a manner to mimic the mats temperature regiment (energy difference in kWh x kWh cost). The 2017 Pork Industry Analysis reports litters/sow/year of 2.28, implementation of mats in this manner may result in a savings of $12.92 sow/year. Heats mats have a higher initial cost of implementation at $86.00 which includes the heat mat and portion of the controller capable of running 20 mat units. In contrast, heat lamps have a lower initial cost at $14.43 which includes one light bulb however, a minimum one additional light bulb would be required per year based off expected usage according to the manufacturer with the potential for larger numbers being required based on breakage rates on specific farms. Given this information, heat mats present a payback period of one year when implemented using a controller. This results on a 17.6% return on investment (ROI) is anticipated in year 1 and 100% ROI in following years that do not require supplemental heat source replacement (Table 2). Additionally, disease risk from mat use may be a cause for concern and would warrant further work, but proper cleaning and disinfecting should mitigate risk.

[1]Differing superscripts within day of lactation represent differences by treatment (P < .05).

[2]Error bars represent standard error.

[3]Number of piglets represents the piglets in physical contact with the dam within day of lactation, other piglets are not in contact with the sow or contact could not be determined.

| Item | Heat Mat[1] | Heat Lamp[2] |
|---|---|---|
| Farrowing House[3] | $68,800.00 | $11,544.00 |
| Farrowing Room[4] | $3,440.00 | $577.20 |
| Farrowing Stall[5] | $86.00 | $14.43 |
| Replacement[6] | $0.00[7] | $1.58[8] |
| Energy Usage per Year (kWh)[9] | 247 | 954 |
| Energy Cost per Year[10] | $29.52 | $114.48 |
| Total Cost Year 1 | $115.52 | $130.69 |
| Payback Period | 12 months | |
| ROI - Replacement | 17.6% | |
| ROI - Non-Replacement | 100% | |

***Table 2:*** *Initial cost comparison of heat mats run on a controller systems at a set temperature compared to heat lamps set at a specific height to maintain the same temperature for an example 20-room farrowing house with 4 rows per room and 10 stalls per row, totaling 40 stalls per room and 800 total farrowing stalls.*

## Conclusion

Implementing heat mats along with a programmable controller as the supplemental heat source for piglets in the farrowing house may result in a significant return on investment, despite higher initial investment of $86.00 for MAT compared to LAMP at $14.43. These savings are a result of decreased energy usage when compared to the more traditional heat lamp managed to follow the temperature regiment of the MAT controller. However, additional research work is needed to evaluate piglet and/or sow behavioral differences resulting from using different supplemental heat sources in the farrowing phase.

[1]Heat Mat set up includes controller mats and relays required to achieve energy savings; Baby Pig Heat Mat - Single 48 (Kane Manufacturing, Pleasant Hill, IA).

[2]Heat Lamp includes one 125W bulb per lamp for initial cost; Poly Heat Lamp Fixture (Hogslat, Newton Grove, NC).

[3]Cost to entire 20 room, 800 stall farrowing house.

[4]Cost to outfit on 40 stall room.

[5]Cost per single farrowing stall.

[6]Replacement of units or bulbs annually.

[7]Heat mat replacement rate is every 7 - 10 years.

[8]Bulbs have a 5,000-hour life or 208 days, therefore at least one replacement will be required per year.

[9]Assuming 15 turns per year (2 days pre-farrowing, 21-day lactation, and 1 day for cleaning).

[10]Assuming $0.12 per kWh

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## Conflict of Interest

The authors have no conflict of interest.

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