

# Comparison of heat lamps and heat mats in the farrowing house: effect on piglet production, energy use, and piglet and sow behavior through live observation

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## Summary

**Objectives:** To determine the effect of heat lamps versus heat mats on piglet performance measures, sow lying behavior, piglet behavior, and energy use.

**Materials and methods:** Seventeen multiparous crossbred sows housed in farrowing stalls were randomly assigned to one of two heat source treatments: Baby Pig Heat Mat - Single 48 (MAT; n = 8) or Poly Heat Lamp Fixture (LAMP; n = 9). Piglets were weighed on day 1 and at weaning and any mortalities were recorded to evaluate piglet production measures. For 7 days over the

course of lactation (day 1, 2, 3, 4, 5, week before weaning, and day before weaning), sows and their litters were observed for 2 hours twice daily to evaluate behavior. Electric meters were attached to individual heat source units to monitor energy use.

**Results:** Piglet production parameters were unaffected by treatment type; litter weaning weight ( $P = .85$ ), litter average daily gain ( $P = .79$ ), and preweaning mortality ( $P = .58$ ). Piglet behavior had variation in the number of piglets using a heat source within day across treatments ( $P < .001$ ). The number of piglets in contact with the

sow decreased during early lactation for both treatment types and increased during late lactation with more MAT pigs tending to be in contact with the sow ( $P < .001$ ).

**Implications:** Using heat mats as supplemental heat in the farrowing house may result in decreased energy use and increased savings without hindering piglet production parameters.

**Keywords:** swine, farrowing, preweaning mortality, heat sources, energy use

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## Resumen - Comparación entre lámparas de calor y tapetes térmicos en la maternidad: efecto sobre la producción del lechón, el uso de energía y el comportamiento de los lechones y cerdas a través de la observación en vivo

**Objetivos:** Determinar el efecto de las lámparas de calor versus los tapetes térmicos sobre las medidas de desarrollo del lechón, el comportamiento de las cerdas al estar acostadas, el comportamiento del lechón y el uso de energía.

**Materiales y métodos:** Diecisiete cerdas híbridas multíparas alojadas en jaulas de maternidad se asignaron aleatoriamente a

uno de dos tratamientos de fuente de calor: Baby Pig Heat Mat - Single 48 (MAT; n = 8) o Poly Heat Lamp Fixture (LAMP; n = 9). Los lechones se pesaron el día 1 y al destete y se registraron las muertes para evaluar las medidas de producción de los lechones. Durante 7 días en el curso de la lactancia (día 1, 2, 3, 4, 5, una semana antes del destete, y el día antes del destete), se observó a las cerdas y a sus camadas durante 2 horas dos veces al día para evaluar el comportamiento. Para registrar el uso de energía se conectaron medidores eléctricos a las unidades de fuente de calor individuales.

**Resultados:** Los parámetros de producción de los lechones no se vieron afectados por el

tipo de tratamiento; peso al destete de la camada ( $P = .85$ ), ganancia diaria promedio de la camada ( $P = .79$ ), y mortalidad antes del destete ( $P = .58$ ). El comportamiento de los lechones entre días tuvo una variación en el número de lechones que usaron una fuente de calor por tratamiento ( $P < .001$ ). En ambos tratamientos el número de lechones en contacto con la cerda disminuyó durante la lactancia temprana y aumentó durante la lactancia tardía con un mayor número de cerdas MAT tendiendo a estar en contacto con la cerda ( $P < .001$ ).

**Implicaciones:** El uso de tapetes térmicos como fuente de calor suplementario en la maternidad puede dar como resultado un

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menor uso de energía y un mayor ahorro sin afectar los parámetros productivos de los lechones.

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## Résumé - Comparaison entre lampes chauffantes et tapis chauffants dans la maternité: effets sur les performances de production des porcelets, l'utilisation d'énergie et le comportement des porcelets et des truies par observation visuelle

**Objectifs:** Déterminer les effets de lampes chauffantes versus des tapis chauffants sur les données de performance des porcelets, le comportement de décubitus des truies, le comportement des porcelets et la consommation d'énergie.

**Matériels et méthodes:** Dix-sept truies croisées multipares logées dans des cages de

maternité furent assignées de manière aléatoire à une des deux sources de chaleur : matelas chauffant (Baby Pig Heat Mat – Single 48 (MAT; n = 8) ou lampe chauffante (Poly Heat Lamp Fixture (LAMP; n = 9). Les porcelets furent pesés au jour 1 et au sevrage, et les mortalités furent notées pour évaluer les données de production des porcelets. Pendant 7 jours durant la lactation (jour 1, 2, 3, 4, 5, semaine avant le sevrage, et jour précédent le sevrage), les truies et leurs portées furent observées pendant 2 h deux fois par jour afin d'évaluer les comportements. Des compteurs électriques étaient reliés à chaque unité de source de chaleur pour vérifier la consommation d'énergie.

**Résultats:** Les paramètres de production des porcelets n'étaient pas affectés par le type de traitement; poids de la portée au sevrage

( $P = .85$ ), gain quotidien moyen de la portée ( $P = .79$ ), et mortalité pré-sevrage ( $P = .58$ ). Le comportement des porcelets présentait des variations dans le nombre de porcelets utilisant une source de chaleur à l'intérieur d'une journée entre les traitements ( $P < .001$ ). Le nombre de porcelets en contact avec la truie diminua durant le début de la lactation pour les deux types de traitement et augmenta durant la phase avancée de la lactation avec plus de porcelets du groupe MAT ayant tendance à être en contact avec la truie ( $P < .001$ ).

**Implications:** L'utilisation de tapis chauffants comme source de chaleur supplémentaire dans la maternité pourrait résulter en une utilisation moindre d'énergie et augmente les épargnes sans affecter les paramètres de production des porcelets.

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Preweaning mortality continues to be a cause for concern in the US swine industry. Current preweaning mortality estimates<sup>1</sup> from US commercial swine operations have been relatively stable at 17.5% between 2015 to 2017. At a 20% preweaning mortality level, it has been estimated to cost the US pork industry \$650 to \$800 million annually.<sup>2</sup> The majority of these losses occur during the perinatal period (during farrowing and the first 3 days after birth) and can account for up to 50% of total preweaning mortality.<sup>3</sup> Preweaning mortality has been described as multifactorial and include low birth weight, lack of sufficient energy stores, poor body temperature regulation, or strong competition between littermates for colostrum and milk.<sup>4,5</sup>

Within the farrowing environment, the sow and her piglets are at two very different life stages and have different requirements regarding their thermal, social, and physical production system environments. For example, ambient temperature requirements for the lactating sow range from 15°C to 26°C, but a higher temperature of 34°C is preferred by individual newborn piglets.<sup>6,7</sup> At birth, piglets are poorly equipped to deal with the environment they experience outside of the sow. They are especially susceptible to cold stress at birth because they lack a coat of hair, have a large surface area to body weight ratio, lack suitable energy reserves, and have poor body thermostability.<sup>8,9</sup> When the environmental temperature falls below 34°C the newborn piglet is subjected to cold stress and will begin to mobilize its glycogen reserves from the liver

and skeletal muscles. The newborn piglet increases heat production by consuming nutrient dense colostrum produced by the sow during the first few hours of lactation.<sup>10</sup> Under cold stress, the piglet undergoes reduced locomotive vigor resulting from weakness through starvation leading to decreased capabilities to avoid movements exhibited by the sow.<sup>11,12</sup> During lactation, littermates huddle to increase their thermal insulation and conduction.<sup>13,14</sup> In conventional indoor confinement systems, caretakers can provide piglets with supplemental heat sources (eg, lamps and mats) in an attempt to keep the piglets warm and away from their mother to reduce preweaning mortality.

Previous work by Stinn and Xin<sup>15</sup> compared a heat mat to a heat lamp on piglet mortality, rate of gain, and electric power use. The authors concluded that there was no difference in rate of gain or mortality, but mats used 36% less power compared to heat lamps. In agreement with this study, MacDonald and colleagues<sup>16</sup> found that heat mats can have a 50% cost savings without detrimentally affecting piglet weaning weight or average daily weight gain. Finally, Hrupka and colleagues<sup>17</sup> reported that heat lamp location within a farrowing stall did not affect preweaning mortality but did conclude that fewer piglets were within 8 cm of the sow and more were located in the area of the heat source. However, technology advancements in heat mats and heat lamps have occurred since these previous studies were published. Additionally, there are no publications to the authors' knowledge in the scientific literature that examines the

combination of heat source, piglet behavior, and the economics of various sources used to provide supplemental heat to piglets during lactation. Therefore, the objectives of this work were to 1) evaluate piglet performance and preweaning mortality when piglets are supplied with two different heat source treatments, 2) evaluate sow lying behavior and piglet location behavior in regard to heat source and proximity to the sow, and 3) evaluate the energy efficiency of two different heat sources.

## Materials and methods

The research protocol was approved by the Iowa State University Institutional Animal Care and Use Committee (IACUC-18-256). Sows were allotted a minimum of a 72-hour acclimation period prior to farrowing.

## Animals, location, and housing

A total of 17 sow and litter units housed at the Iowa State University Allen E. Christian Swine Teaching Farm in farrowing stalls during 2 farrowing groups (October to November 2018 and November to December 2018) were used in this study. The farrowing stalls used in this study had interlocking plastic flooring and a creep area on both sides of the sow. The total stall area measured 2.0 × 1.7 m<sup>2</sup>. The center sow area measured 2.0 × 0.6 m<sup>2</sup> with two creep areas measuring 2.0 × 0.55 m<sup>2</sup> on either side. Solid flooring, 1.2 × 0.4 m<sup>2</sup>, on one side of the piglet creep area was where the heat source was provided. The stalls



were distributed across 2 farrowing rooms (7 stalls per room) located in a negative-pressure, mechanically ventilated barn set at 21.1°C. Each stall contained a sow and her litter with no cross fostering, and the stall was the experimental unit. Multiparous crossbred sows (parity 1 = 5; 2 = 3; 3 = 4; 4 = 1; and ≥ 7 = 4) were randomly assigned to a treatment prior to entering the farrowing room. Sows were provided ad libitum access to water via one nipple and were hand fed once daily prior to farrowing. Post farrowing, sows were hand fed to appetite 3 times daily in 0.9 kg increments. All diets were prepared by a commercial feed mill (Key Cooperative) composed of primarily corn, soybean meal, dried distillers grains, and nutrients formulated according to NRC (2012) guidelines to meet or exceed gestating and lactating sow nutrient requirements. The diet contained 19.6% crude protein, 32 Mcal metabolizable energy/kg, and 1.17% total lysine.

### Treatments

Two treatments were compared: Baby Pig Heat Mat - Single 48 (MAT; Kane Manufacturing; 85 W; 34.29 × 121.92 cm<sup>2</sup>; polyethylene; n = 8; Figure 1) and Poly Heat Lamp Fixture (LAMP; Hog Slat; n = 9; 125 W; 25.4 × 30.48 cm<sup>2</sup>; polypropylene; Figure 2). The heat lamp thermal zone used for piglet observation was an area covering 40 × 121 cm<sup>2</sup>.

Both heat sources were set at 32.2°C. The LAMP was controlled via a single step mechanical thermostat for a maximum temperature and height was adjusted to match the temperature regimen of MAT, which was controlled via Thermostat Programmable 1 Zone (Kane Manufacturing). Heat source temperatures were confirmed with an infrared temperature gun (Tool House Digital Infrared Thermometer; model 770343S; Alltrade Tools, LLC; accuracy: 2°C). Sows and their piglets were blocked by parity and assigned to one of the heat source treatments throughout lactation. Mean piglet weaning age was 21 days.

### Production measures

Piglets were counted and weighed at processing and weaning. Piglets were administered 1 mL of Iron Hydrogenated Dextran (VetOne) and 0.5 mL of Excede (Zoetis) following manufacturer and veterinary guidelines used when developing farm standard operating procedures. Number born

alive was recorded for each litter. Preweaning mortality was defined as a loss incurred post farrowing and prior to weaning, calculated as percent mortality = (the number of pigs weaned/number of pigs born alive) × 100. Piglets were weighed individually on day 1 and at weaning using a digital scale (Mettler PM30-K; Mettler Toledo; accuracy: 0.5 g). All piglet deaths were recorded and included day, sex, and weight.

### Behavioral evaluation

Sows and their litters were observed by a single trained observer at 2 time segments over a 24-hour period on days 1, 2, 3, 4, 5, week before weaning (DW), and day before weaning (DD) using a live observation methodology. Each time segment consisted of 2 consecutive hours (09:00 to 11:00 and 21:00 to 23:00) and observations were collected every 15 minutes. Observer training took place prior to the first farrowing until the undergraduate student observer had > 95% agreement with the graduate student who developed the ethogram according to the study objectives and trained the observer. An ethogram was created that included 5 mutually exclusive sow postures, 2 piglet locations, and piglet contact with the sow (Table 1).

### Electrical use

Kill-A-Watt EZ Meter P4460 (P3 International Corporation; accuracy: 0.02%) were connected to the allotted heat source for the entire lactation duration to measure energy use by each experimental unit. Electric meter readings were monitored and recorded twice weekly by farm staff. Final energy use readings were recorded at weaning.

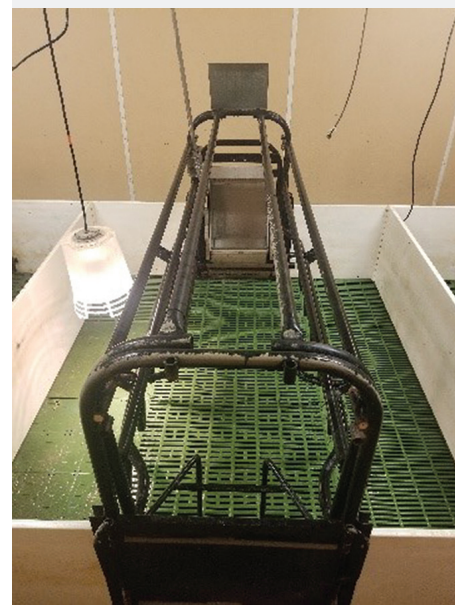
### Statistical analysis

All data were evaluated using mixed model methodology (Proc Mixed; SAS version 9.4; SAS Institute Inc). Sources of model variation were considered significant at  $P < .05$ . When fixed effect model variation was significant, least squares means for each level within the fixed effect source were separated using the pdiff option within the Proc Mixed procedure. Fixed effects in the model included group, parity, location of heat source, and treatment. Production data were analyzed using a generalized mixed model (Proc Glimmix; SAS version 9.3; SAS Institute Inc). A random effect for the interaction between room and stall was included in the model. Behavioral data were analyzed using a

**Figure 1:** Farrowing stall with heat mat. The Baby Pig Heat Mat – Single 48 (Kane Manufacturing) dimensions were 34.29 × 121.92 cm<sup>2</sup>.



**Figure 2:** Farrowing stall with Poly Heat Lamp Fixture (Hogslat) and 125 W heat bulb.



generalized mixed model with i-link distribution (Proc Glimmix). Fixed effects in the model included day, treatment, and time. Random effects were room and stall.

## Results

### Production

No litter weaning weight ( $P = .85$ ) or litter average daily gain ( $P = .79$ ) differences were observed when comparing piglets provided heat lamps and piglets provided heat mats in the study (Table 2). No treatment differences were observed in preweaning mortality ( $P = .58$ ). Sixty percent of mortalities occurred within the first 24 hours post farrowing.

### Behavior

The number of piglets using either a heat lamp or heat mat differed within a treatment day, with lamp being used by more piglets on day 1, 3, 4, DW, and DD (Figure 3;  $P < .001$ ). The number of piglets using the heat lamp treatment across days of lactation decreased after day 4 (Figure 4;  $P < .001$ ). Similarly, the number of piglets using the heat mat treatment over days of lactation decreased at DW until the end of lactation (Figure 5;  $P < .001$ ).

The number of piglets in physical contact with their dam by treatment within lactation day differed, with MAT piglets having greater physical contact with their dam on day 3 and 4 (Figure 6;  $P < .001$ ). The number of piglets in physical contact with their dam, within treatment, across days of lactation resulted in greater variation within LAMP treatment (Figure 7;  $P < .001$ ). The number of piglets in physical contact with their dam, within treatment, over days of lactation demonstrated that the piglets' physical contact with their dam remained relatively constant when provided supplemental heat using the MAT treatment (Figure 8;  $P < .001$ ).

Sow lying behavior was not affected by heat source type or location ( $\chi^2 = 2.14$ ,  $P = .14$ ). As a result of sows spending most of the time lying laterally, analysis was focused on these traits. Sow lying preference demonstrated that 7 sows preferred to lay laterally right and 8 sows preferred to lay laterally left. Five sows favored lying with their udder toward the heat source and 10 favored lying with their udder away from the heat source. There were 2 sows that showed no preference for lying position and therefore udder direction to the heat source.

### Energy

The mean (SD) energy consumption for the heat mat treatment (19.4 [2.99] kWh) was less than the energy use for the heat lamp treatment (68.5 [1.97] kWh) with a difference of 49.1 kWh/litter ( $P < .001$ ). Initial heat lamp and heat mat costs vary, with heat lamps requiring less initial investment, but has a greater cost associated with energy use (Table 3). Using an average cost of \$0.12/kWh in the Midwest,<sup>2</sup> the average 49.05 kWh energy savings can be translated into an average energy cost savings of \$5.89/litter (49.1 kWh  $\times$  \$0.12/kWh = \$5.89).

## Discussion

Challenges continue to exist in the farrowing house for the caretaker to supply a suitable environment for the sow and her piglets immediately after parturition and through the lactation period.<sup>8</sup> Consistent results across studies indicate that preweaning mortality will remain relatively constant regardless of supplemental heat source (ie, heat lamps or heat mats) used.<sup>15,17</sup> The current study supports the production parameter findings from previous studies, with no supplemental heat source effects on weaning weight, daily gain, or preweaning mortality further indicating that heat source type should be a management decision regarding what works best within a particular system. In agreement

**Table 1:** Sow and piglet behaviors measured during lactation to compare heat lamps and heat mats as supplemental heat sources for piglets

Measure*	Definition
<b>Definition</b>	
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
<b>Piglet contact with dam</b>	
Touch	Any part of the piglet is touching the sow
Not	No part of the piglet is touching the sow
<b>Sow posture</b>	
Lateral lie left	Pig lying on left side
Lateral lie right	Pig lying on right side
Sternal lie	Pig lying on sternum
Standing	All four feet on flooring
Sitting	Hindquarter on floor, front feet on flooring

\* Measures were observed through live observation by a single observer using a 15-minute scan sample between 09:00 and 11:00 and 21:00 and 23:00 on days 1 through 5, week before weaning, and day before weaning.

**Table 2:** Least squares means (SE) of production traits when comparing heat lamps and heat mats as supplemental heat sources for piglets during lactation\*

Treatment	Litter wean weight <sup>†</sup> , kg	Litter average daily gain <sup>‡</sup> , kg/day	Mortality <sup>§</sup> , %
Lamp	44.5 (8.50)	1.5 (0.29)	15.3 (2.52)
Mat	47.0 (8.86)	1.6 (0.30)	12.3 (3.32)

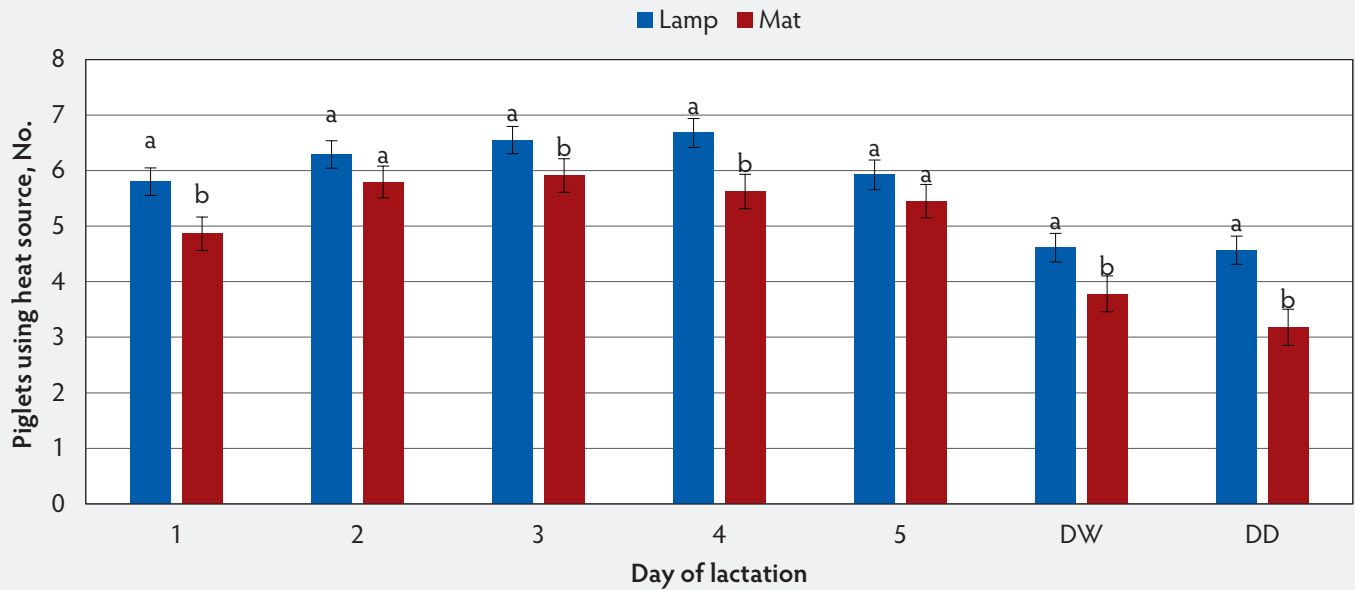
\* No differences in production traits observed ( $P \geq .58$ ).

<sup>†</sup> Piglets were weighed individually then summed together for litter weaning weight.

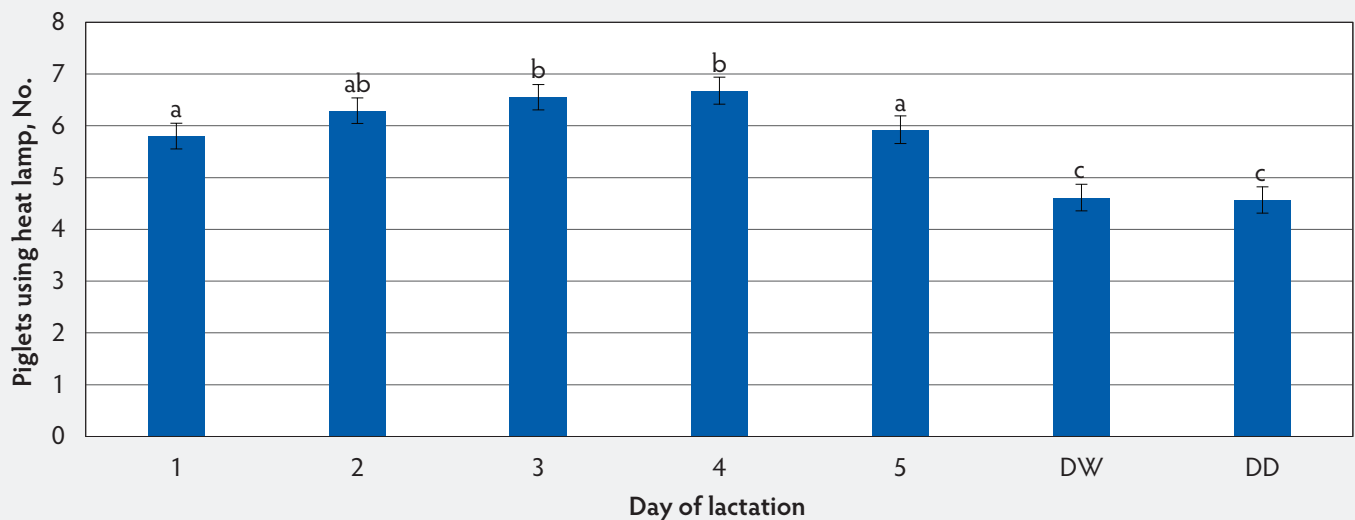
<sup>‡</sup> Litter average daily gain = (litter wean weight – litter birth weight) / days of lactation.

<sup>§</sup> Percent mortality = (total mortalities / total number born alive)  $\times$  100.

**Figure 3:** Number (SE) of piglets using the heat source within lactation day ( $P < .001$ ). Differing superscript letters within a lactation day indicate treatments were significantly different ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



**Figure 4:** Number (SE) of piglets using the heat lamp by lactation day within treatment ( $P < .001$ ). Differing superscript letters indicate a significant difference between lactation day within treatment ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



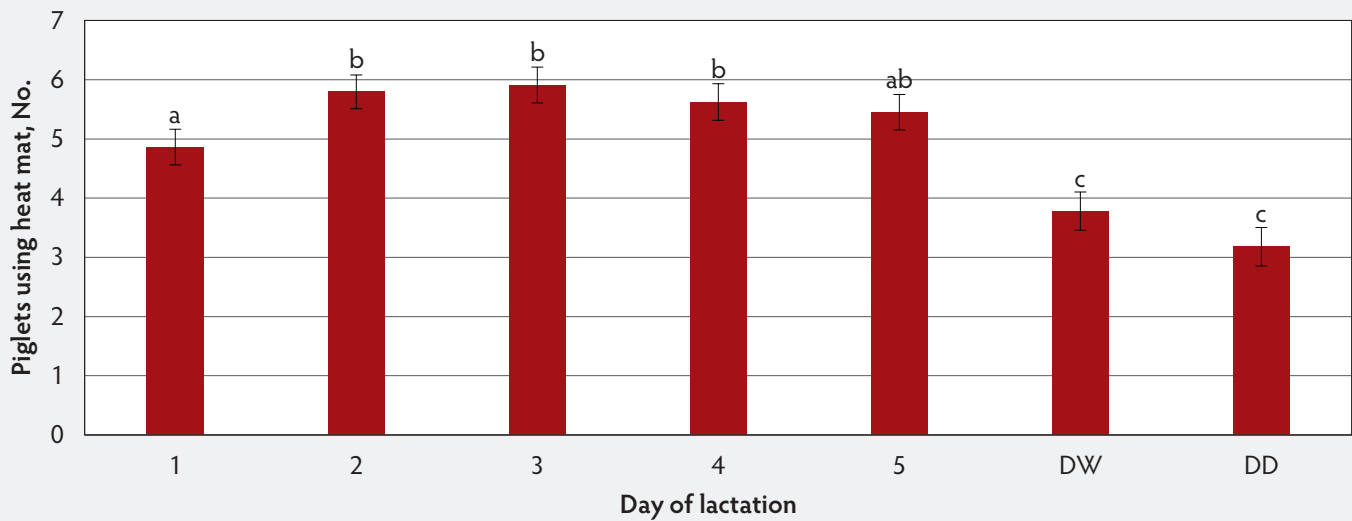
with previous studies, the majority of pre-weaning mortality occurred within the first 24 hours post farrowing.<sup>18</sup>

During the first 24 hours, when mortality rates were the greatest, behavior findings showed a greater number of piglets spending time in contact with their dam across treatments. Other studies have reported that the day-old piglets spend 60% to 75% of their time nursing or lying near their dam regardless of supplemental heat source position.<sup>19</sup>

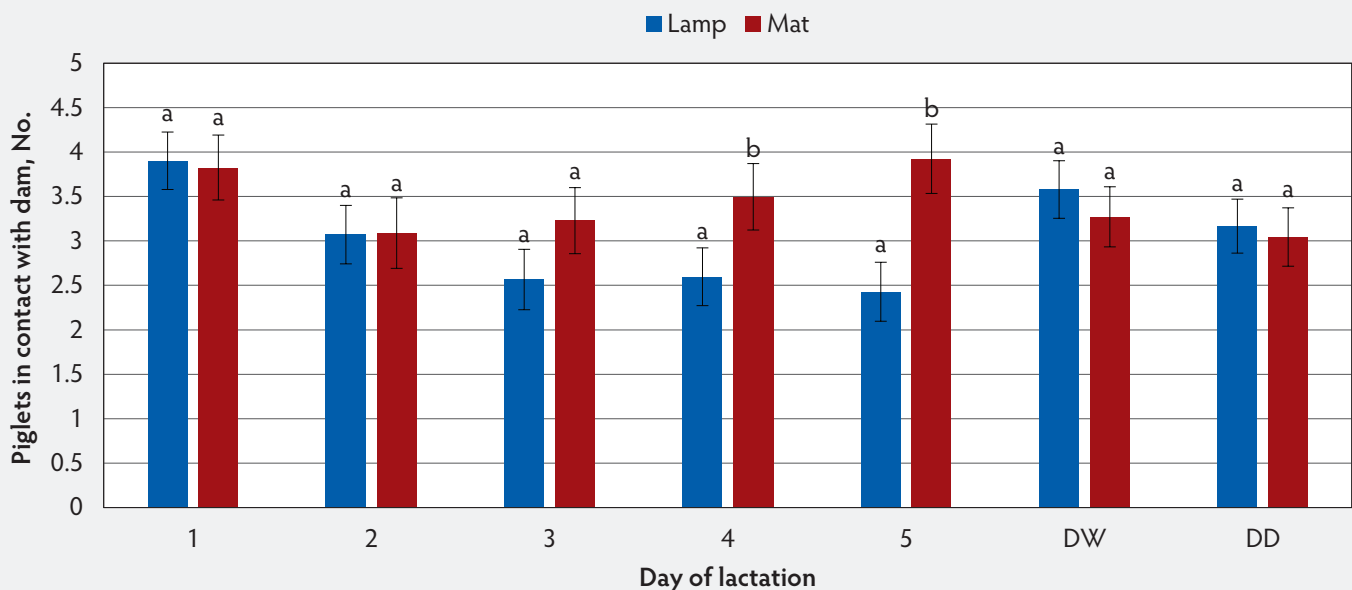
In the current study, heat source type did not affect this behavior. Several biological factors could provide an explanation for this piglet behavior difference. The sow provides nutrition for the piglet, which is critical for the piglet to produce heat so that it can maintain its thermodynamics. Additionally, milk let-down initially is constant, therefore piglet nursing bouts and teat fidelity have not been established until later in lactation. Other factors that may contribute to the piglets' preference to lie next to or near the

sow include odors and sounds the sow makes that might be comforting to piglets. However, further research is needed to identify factors truly associated with the piglets' desire to lie next to or very near their dam. Regardless of motivation, the area around the sow remains dangerous to piglets with crushing being an imminent threat as the number one reason for piglet mortality continues to be crushing or laid on by the sow.<sup>12</sup> After the initial 24 hours post farrowing, supplemental heat source use by piglets increased across

**Figure 5:** Number (SE) of piglets using the heat mat by lactation day within treatment ( $P < .001$ ). Differing superscript letters indicate a significant difference between lactation day within treatment ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



**Figure 6:** Number (SE) of piglets in physical contact with the dam across treatments by lactation day ( $P < .001$ ). Differing superscript letters within a lactation day indicate treatments were significantly different ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



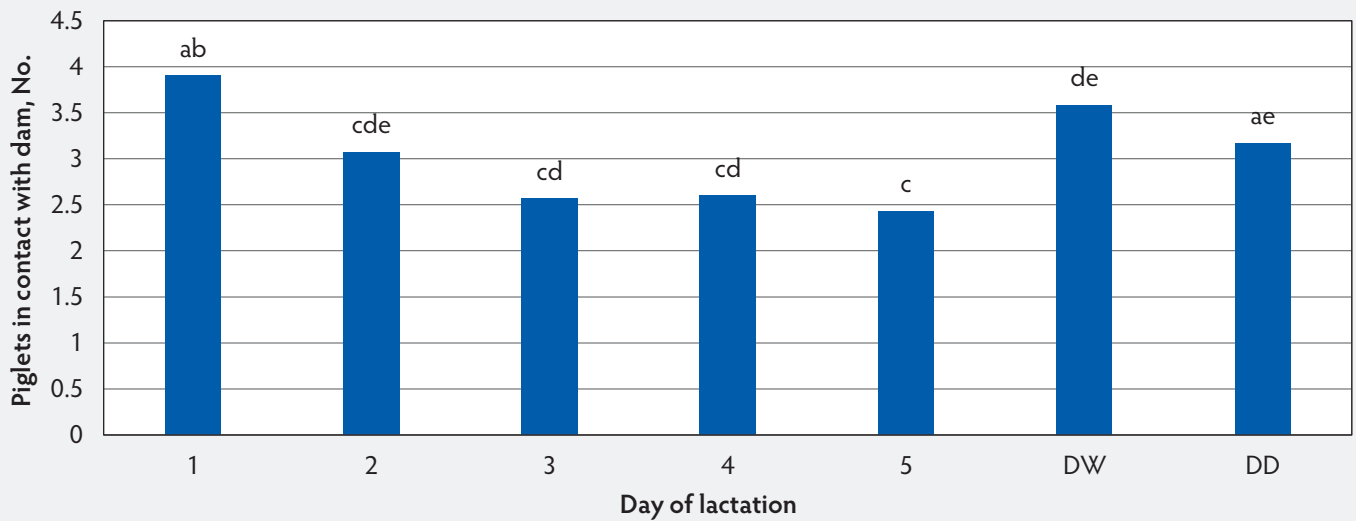
treatments, likely as a result of better thermodynamics and nursing bouts being initiated. Sow posture was unaffected by supplemental heat source location, decreasing heat stress concern from the supplemental heat provided for piglets. Additional research work is needed to examine other supplemental heat source options and piglet preference or motivation for each heat source.

However, consideration should be placed on the energy savings when utilizing heat mats. Under the circumstances in the current study, energy savings can be achieved by controlling heat mats with a controller as compared to varying heat lamp height. Heat mats can result in a savings of \$18.30/farrowing stall or a total of \$5856 return on investment (ROI) in

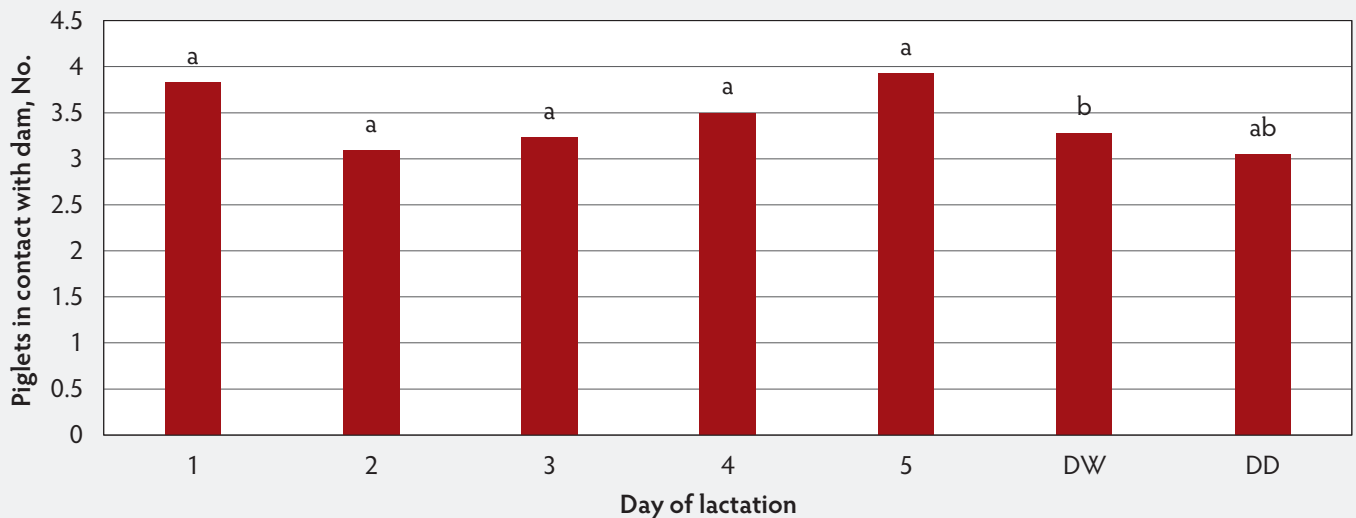
year 1, a 21.2% ROI (initial year savings = [initial cost of heat lamp + heat mat energy costs] - [initial cost of lamp + bulb replacement + heat lamps energy costs]). In subsequent years that do not require heat source replacement, a savings of \$89.87/stall or \$28,758.40 total ROI, or 104.5%, can be acquired (total savings with mat = energy cost of mat - energy cost of lamp). Given the energy savings of the heat mat, a payback period of 11.7 months can be achieved. As



**Figure 7:** Number (SE) of piglets in physical contact with the dam within the heat lamp treatment by lactation day ( $P < .001$ ). Differing superscript letters indicate a significant difference between lactation day within treatment ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



**Figure 8:** Number (SE) of piglets in physical contact with the dam within the heat mat treatment by lactation day ( $P < .001$ ). Differing letters indicate a significant difference between lactation day within treatment ( $P < .05$ ). DW = week before weaning; DD = day before weaning.



stewards of the land and the environment, according to the Pork Quality Assurance Plus Good Production Practices, additional value can be found in minimizing the carbon footprint of swine production.<sup>20</sup>

## Implications

Under the conditions of this study:

- Choice of mats or lamps can be based on factors other than pig performance.
- Energy savings can be achieved by using heat mats with a controller.

## Acknowledgments

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## Conflict of interest

None reported.

## Disclaimer

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**Table 3:** Initial cost comparison of heat mats managed with a controller on a decreasing temperature regimen compared to heat lamps raised to decrease temperature\*

	Heat Mat <sup>†</sup>	Heat Lamp <sup>‡</sup>
Total farrowing house cost, \$	27,520.00	4617.60
Cost/farrowing room, \$	3440.00	577.20
Cost/farrowing stall	86.00	14.43
Annual replacement cost, \$	0.00 <sup>§</sup>	1.58 <sup>¶</sup>
Energy use/turn, kWh	19.4	68.5
Energy use/y, kWh**	291.3	1027.05
Energy cost/Year <sup>††</sup> , \$	34.96	123.25
Total cost Year 1 <sup>††</sup> , \$	120.96	139.26
Payback period, mo	11.7	

\* The example farm used in this analysis was an 8-room farrowing house that contains 4 rows/room and 10 stalls/row, with a total of 40 stalls/room and 320 total farrowing stalls in the farrowing house.

<sup>†</sup> Heat mat set up included Baby Pig Heat Mat – Single 48 (Kane Manufacturing) with controller and relays required to achieve energy savings. Costs for this setup provided by Kane Manufacturing.

<sup>‡</sup> Heat lamp set up included one 125 W bulb per Poly Heat Lamp Fixture (Hogslat). Costs for this setup available at [www.hogslat.com](http://www.hogslat.com).

<sup>§</sup> Heat mat replacement rate is every 7 to 10 years.

<sup>¶</sup> Bulbs have a 5000-hour life or 208 days, therefore at least one replacement will be required per year.

\*\* Assuming 15 turns/year (2 days prefarrowing, 21-day lactation, and 1 day for cleaning).

<sup>††</sup> Assuming \$0.12/kWh.

the rules and regulations governing research or the practice of veterinary medicine in their country or region.

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