
Energy consumption of heat pads and heat lamps and aerial environment in a commercial swine farrowing facility

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Beshada, E., Q. Zhang and R. Boris. 2014. **Energy consumption of heat pads and heat lamps and aerial environment in a commercial swine farrowing facility.** Canadian Biosystems Engineering/Le génie des biosystèmes au Canada **56**: 5.1-5.6. An experimental study was conducted to compare two localized heating methods, namely heat pads and heat lamps, in a commercial swine farrowing facility. Two farrowing rooms each with 44 crates were instrumented for monitoring room environmental conditions (temperature and relative humidity) and energy consumption. One room was equipped with 175W (per crate) heat lamps and the other room with 65W (per crate) heat pads. The piglet mortality and weight gain were recorded. The air temperature in the two rooms was maintained at the same level using environmental controllers (set at the same setpoint). However, the relative humidity in the lamp room was found to be lower than that in the heat pad room probably due to more ventilation required to remove more sensible heat produced by the lamps. There were no significant differences in the mortality rate and weight gain between heat pads and heat lamps. The daily energy consumption by heat pads was 2.9 kWh less than that by heat lamps per crate. This represents a 73% saving of energy required for localized heating. **Keywords:** swine farrowing, localized heating, heat pad, heat lamp, energy consumption.

Une étude a été réalisée pour comparer deux méthodes de chauffage localisé dans des maternités commerciales, soit des lampes et des matelas chauffants. Deux salles de mise bas aménagées avec 44 cages ont été instrumentées pour faire le suivi des conditions ambiantes (température et humidité relative) et de la consommation énergétique. Dans une salle, chaque cage était munie d'une lampe chauffante de 175 W et, dans une autre salle, un matelas chauffant de 65 W par cage était installé. La mortalité ainsi que la prise de poids étaient mesurées. Les consignes de température étaient les mêmes dans les deux salles et la température était maintenue par des contrôles. L'humidité relative mesurée dans la salle munie de lampes chauffantes était plus faible que celle de la salle équipée avec les matelas chauffants. Ceci était dû aux niveaux de ventilation plus élevés, niveaux nécessaires pour évacuer la chaleur sensible additionnelle produite par les lampes. Les différences, entre le taux de mortalité et la prise de poids des salles munies de lampes chauffantes et celles équipées de matelas chauffants, n'étaient pas significatives. Pour chaque cage, la consommation énergétique quotidienne des matelas chauffants était inférieure de 2,9 kWh à celle des lampes chauffantes. Cette réduction représente une économie de 73% pour ce chauffage localisé. **Mots clés:** maternité, chauffage localisé, matelas chauffant, lampe chauffante, consommation énergétique.

INTRODUCTION

Swine farrowing barns are required to provide different thermal environments for sows and piglets because piglets require an environment temperature of 32.2 to 35°C, while sows prefer a temperature of 15.5 to 18.3°C (Stinn and Xin, 2014). Temperature in farrowing barns is typically maintained between 18 and 21°C for the comfort of sows (ASAE Standards, 2003), while localized heating is used to provide a warm temperature zone for piglets.

Heat lamps of 250 and 175 W are commonly used to attain localized heating in North America. Heat lamps have been identified as a major source of electricity consumption in farrowing rooms. By replacing heat lamps with electric heat pads with controllers, electricity use could be reduced by 66% (Chambers, 2011). There has been an increased interest and installation of heat pads in preference to heat lamps. Zhang and Xin (2001), Zhang and Xin (2000), and Xin and Zhang (1999) have extensively investigated the advantages of heat pads over heat lamps and studied the behavior of piglets under both heating systems. They have found that although the piglets spent more time under heat lamps during the first two days after birth, heat pads provided a more uniform heat over a larger area than did the heat lamps. Moreover, energy saving of up to 60% could be achieved by using heat pads (Xin and Zhang, 1999; Zhang and Xin, 2001). Stinn and Xin (2014) compared the performance of heat pads and heat lamps and found that there was no significant difference in the average weight gain (AWG) of piglets and mortality between the two systems. They reported a 36% reduction in power use by the heat pads in comparison with the lamps.

Although there are some clear advantages of using heat pads, there is limited amount of information on the performance of heat pads in commercial swine production facilities. This study was conducted with the objectives of investigating the effect of pad heating on the thermal environment (temperature and relative humidity), the performance of the piglets (mortality and weight gain), and the energy saving in comparison with heat lamps in a commercial farrowing facility.

MATERIALS AND METHODS

The experiment was carried out in a commercial (756 sows) hog operation located near Arborg, Manitoba (latitude: 50.9°, longitude: -97.1°). Two farrowing rooms of 44 crates were selected for comparative testing and each room measured 7 by 42 m (23 × 138 ft). Both rooms were located in the middle of a 35-m wide by 126-m long building oriented in the north-south direction, and the rooms had only one exterior wall where the exhaust fans were mounted. The two rooms were identical in physical layout and operation, except different localized heating systems to be tested. One of the rooms was equipped with 22 double-size heat pads (2 × 4 ft, or 600 by 1200 mm), each of which served two crates and rated at 130 W (or 65 W per crate) (Hog Hearth, Innovative Heating Technologies Inc. (formerly Alternative Heating Systems), Oak Bluff, MB), while the other room was equipped with 44 infrared lamps, each rated at 175 W (per crate). Although Zhang and Xin (2000) recommend pad sizes larger than 1 × 4 ft for each litter to accommodate the space needed for the resting litter, the use of a double pad for two crates (1 × 4 ft per crate) is a common commercial practice. Larger pads, e.g., 1 × 5 ft per crate, are getting acceptance because of increased litter sizes in recent years (Stinn and Xin, 2014).

Three heat pads were randomly chosen to test if there were any differences in the temperature profile between and within the pads. Pads 1 and 2 had built-in temperature sensors for controlling pad surface temperature (master pad), while pad 3 was a slave pad whose temperature was controlled by the sensor in its master pad. In a typical commercial installation, heat pads are controlled in groups and each group has one master pad and up to 10 slave pads. The surface temperature of each pad was measured at the centre and the periphery of the pad with T-Type (Copper-Constantan) thermocouples positioned at 63 and 660 mm (2.5 and 26 in) diagonally from one corner of the heat pad and the other end connected to a data logger (Smart Reader Plus 6, ACR Systems INC. Surrey, BC). These thermocouples were firmly taped to the pad surface using duct tapes. The readings of the surface temperatures were recorded every 15 minutes throughout the entire experiment.

The temperature and the relative humidity of the rooms were measured using Onset HOBO sensor and data logger (H08-03-02 with T accuracy of -20 to +70 °C and RH accuracy of 0 to 95%; Onset, Bourne, MA) placed at the center of each room and about 3 m above the floor. The instruments were sensing and storing data every 10 minutes.

A pulse meter (Schlumberger Type Sentinel, Itron Canada Inc., Mississauga, ON) was installed in each room to record the peak power demand by all pads or lamps in the room. In addition the meter recorded the energy consumption in kWh every 15 minutes, from which daily and monthly electrical energy consumption were determined. Data from the two meters were downloaded

every three weeks and processed by using Microsoft Excel™. It should be mentioned that energy consumption by other equipment in the room, such as ventilation fans, was not measured because changes to the existing electrical wiring in the building were not permitted.

The experiment was conducted from October 15 to March 4, covering six consecutive farrowing-weaning cycles (about 21 days per cycle). Each cycle was considered to be a test trial and they were labeled as October, November, December, January, February and March trials. Each cycle started on the same date in both rooms. The barn operators recorded piglet performance data - the mortality and weight. The live born pre-weaning mortality was calculated from the total number of live born piglets and the number of piglets died after birth, which was counted from the date of farrowing to weaning. The weight gain was measured by weighing 10 litters (as a group) selected randomly per room at birth and a day before weaning. The same litters weighed at birth were weighed at weaning. The average daily gain (ADG) was determined from the difference between the two weighings.

RESULTS and DISCUSSION

Potential effect of room differences

The focus of this study was to compare the energy consumption and barn environment for two different localized heating systems. The comparisons were based on the differences in such measured variables as electricity usage, temperature, and relative humidity. However, because the experiment was conducted in a commercial swine facility, it was not possible to have a completely random experimental design to remove the effect of possible differences between the two test rooms, although the two rooms were physically identical in layout and managed in the same way. To assess the possible differences between the two rooms that were not related to the localized heating systems, room temperature and relative humidity were compared between the two rooms when the heat pads and lamps were not used. For a three-day period, both temperature and relative humidity in the two rooms were very close to each other (Figs. 1 and 2), with an average difference of 0.1°C in temperature and 2.6% in relative humidity. The largest difference (2.7°C) in temperature was observed at the beginning of test when the room was stabilizing. Similarly, the maximum difference in relative humidity was 6.5% during the stabilization period. The result from a paired t-test showed that the conditions (temperature and relative humidity) in the two test rooms were not statistically different ($P > 0.05$) when heat pads and heat lamps were not used. In other words, the measured differences in room conditions in the subsequent tests were attributed to the use of different localized heat systems.

Thermal Environment

A typical profile of recorded room temperature is shown in Fig. 3 for the heat pad room. The room temperature started at about 22°C at farrowing and lowered to about 20°C at weaning. Similar patterns of temperature variation were observed for other cycles and for the heat lamp room. The

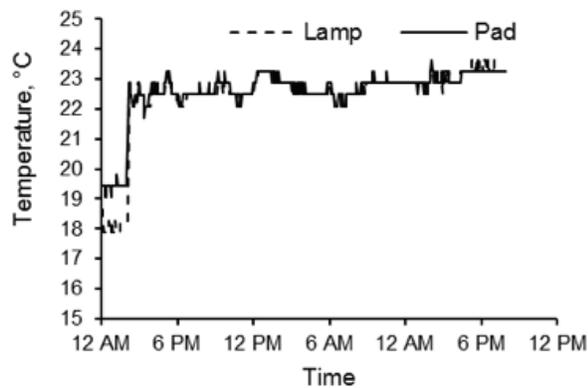


Fig. 1. Comparison of temperatures between the pad and lamp rooms when heat pads and heat lamps were not used during a 3-day period.

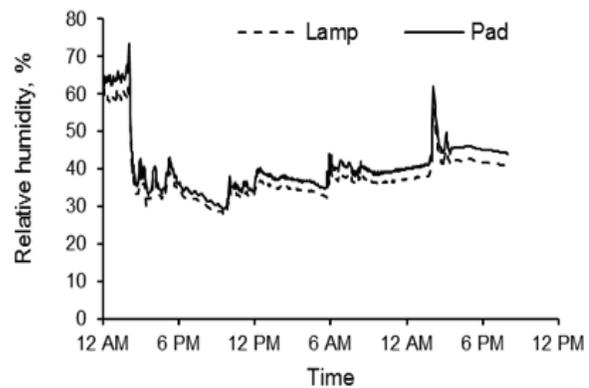


Fig. 2. Comparison of relative humidity levels between the pad and lamp rooms when heat pads and heat lamps were not used during a 3-day period.

daily average temperatures in the two rooms followed each other closely (Fig. 4). A paired t-test showed that was no statistically significant difference ($P > 0.05$) in room temperature between the heat pad and lamp rooms. The overall average temperatures recorded during the entire experiment period were 20.8°C for the heat pad room and 20.6°C for the heat lamp room.

The relative humidity in the pad room was generally higher than that in the lamp room and a typical profile is shown in Fig. 5 for the second trial (November) (other trials had the similar pattern). Relative humidity in both rooms fluctuated much more than did temperature. The occurrence frequencies (distribution) of different relative humidity levels are shown in Figs. 6a and 6b. In the pad room, the relative humidity stayed mostly between 70% and 80% (the combined occurrence frequency was about 90%), except in the October trial where the relative humidity was mostly in the 50% to 70% range (Fig. 6a). In terms of the environmental requirement for animals, the desirable relative humidity should be between 40% and 80% (ASAE Standards, 2003). The occurrence frequency of relative humidity higher than 80% ranged from 0% in the October trial to 15% in the December and March trails

(Fig. 6a). Relative humidity rarely went below 40% (the highest frequency was 2% for the November trial). In the lamp room, the relative humidity was found mostly between 50% and 70% (the combined occurrence frequency was greater than 90%) (Fig. 6b). Relative humidity rarely rose above 90% (occurrence frequency < 2%) or went below 40% (occurrence frequency < 3%) (Fig. 6b). The average relative humidity level was 58%, 62%, 72%, 70%, 72%, and 73% for the six trials, respectively, in the heat pad room. The corresponding values were 48%, 56%, 56%, 55%, 52%, and 53% for the six trials respectively in the lamp room. Statistical analysis showed that the relative humidity between the two rooms was significantly different ($P < 0.05$).

The lower relative humidity in the lamp room might be attributed to more sensible heat produced by the heat lamps in comparison with pads; more sensible heat caused a higher ventilation rate, and consequently a lower relative humidity level in the lamp room. The total sensible heat produced by heat lamps was 44 crates x 175 W per crate = 7700 W, whereas, the heat pads produced 2860 W (44 crates x 65 W per crate). Since thermostats in both rooms controlled ventilation and both rooms were maintained at

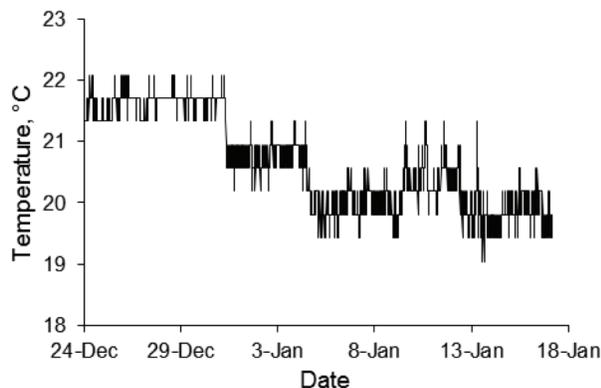


Fig. 3. Room temperature recorded in the heat pad room in December trial.

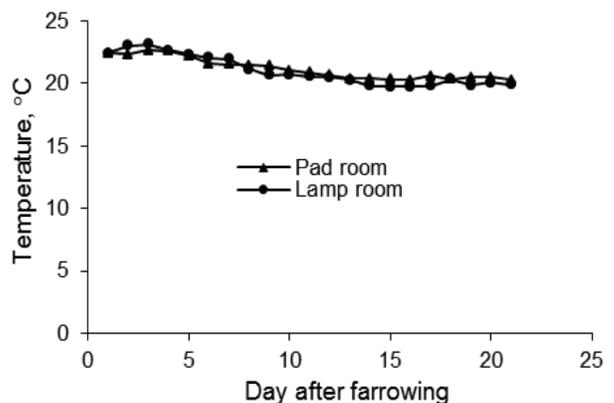


Fig. 4. Variation in daily average temperature from farrowing to weaning, average of six trials.

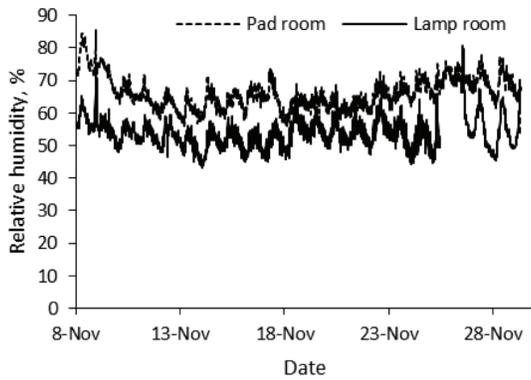


Fig. 5. Measured relative humidity in heat pad and heat lamp rooms in November trial.

the same temperature, the difference in ventilating rate between the two rooms could be estimated as follows:

$$\Delta V = \frac{q_L - q_P}{\rho C_p \Delta t} \quad (1)$$

where:

ΔV = difference in ventilation rate between the two rooms, m^3/s ,

q_L = sensible heat produced by heat lamps, 7700 W,

q_P = sensible heat produced by heat pads, 2860 W,

ρ = air density, $1.2 \text{ kg}/m^3$,

C_p = specific heat of air, $1006 \text{ J kg}^{-1} \text{ }^\circ\text{C}^{-1}$,

Δt = temperature difference between incoming ventilation air and exhaust air, $^\circ\text{C}$.

The air entering the rooms was preheated to 4°C , therefore, the temperature difference Δt was determined to 16.7°C ($20.7^\circ\text{C} - 4^\circ\text{C}$). So the difference in ventilation rate between the lamp and pad rooms was estimated to be $0.25 \text{ m}^3/s$ based on the sensible heat balance (Eq. 1). The ASAE (2003) recommends a typical winter ventilation rate of $9.5 \times 10^{-3} \text{ m}^3/s$ per sow and litter, or $0.42 \text{ m}^3/s$ for each room ($44 \times 9.5 \times 10^{-3}$). In other words, the difference in ventilation rate between the pad and lamp rooms ($0.25 \text{ m}^3/s$) caused by the difference in sensible heat production could be 60% of the design winter ventilation rate ($0.42 \text{ m}^3/s$). This relatively large difference in ventilation rate could result in significant difference in relative humidity level between the two rooms.

Heat Pad Surface Temperature

The heat pad surface temperature is critical in providing a comfortable thermal environment to piglets. A typical pad temperature profile is shown in Fig. 7. It should be noted that the temperature recorded by the thermocouples was about $1 - 2^\circ\text{C}$ higher than the setpoint temperature because the duct tape used to fix the thermocouples on the pad surface acted as a thermal insulator, causing higher temperature at the point of measurement than the rest of pad surface. The pad stayed almost constant at the setpoint

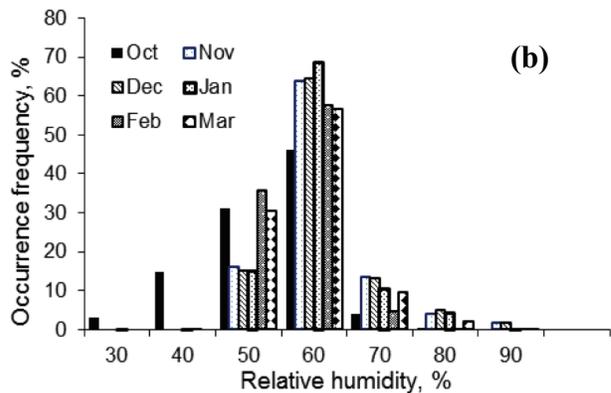
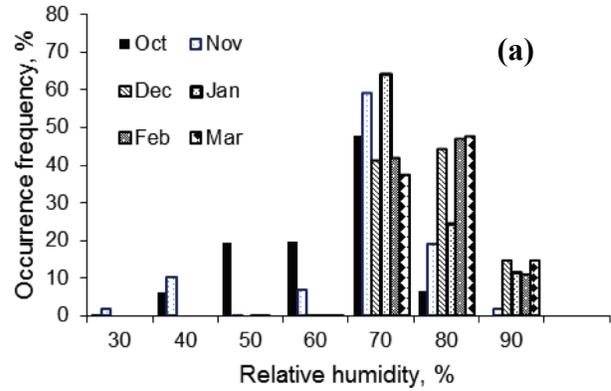


Fig. 6. Distribution of relative humidity level in each trial. (a) heat pad room; (b) heat lamp room.

before farrowing. As piglets started to rest on the pad after farrowing, the pad temperature fluctuated (Fig. 7). The temperature rose above the setpoint (36°) when the piglets were lying on the pad and dropped back to the setpoint when the piglets left the pad. A similar observation was made by Zhang and Xin (2000). This temperature fluctuation was attributed to the temperature control mechanism in the heat pad. When piglets were resting on the pad, heat loss from the pad surface to the ambient air was reduced, causing the pad temperature to rise above the setpoint. This rise in temperature would trigger the pad controller to reduce or cut off power to the heating elements in the pad to bring temperature back to the setpoint.

The centre of the pad was about 3 to 5°C warmer than the periphery of the pad. This was expected as the heating element at the periphery was surrounded by colder outer edges. However, the edge area represented only small fraction of the pad surface; therefore, it would have little impact on the overall pad performance.

Energy Consumption

The daily electrical power consumption by all heat pads in the room stayed fairly constant at 48 kWh, and by the lamps at 176 kWh (Fig. 8). The occasional drops in power consumption by the lamps were due to turning off the lamps to replace burned-out lamps. It is interesting to note

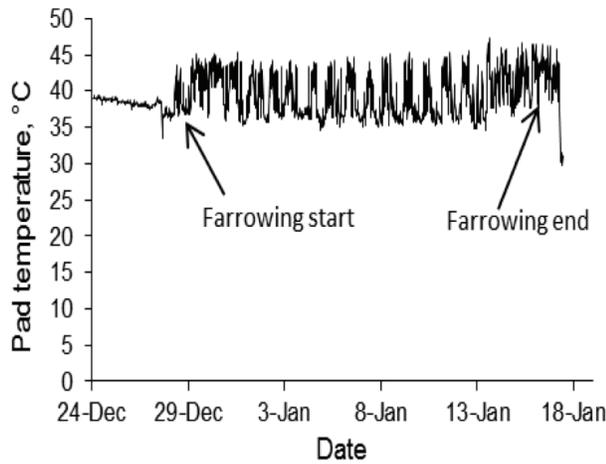


Fig. 7. Pad surface temperature recorded for a period in December trial.

that the recorded electricity consumption in the pad room (48 kWh) was only 70% of the nominal (rated) capacity of heat pads (0.065 kW/crate x 44 crates x 24 h = 69 kWh). This was attributed to the temperature control in the heat pad. As discussed in the previous section, the pad was powered down when its temperature rose above the setpoint, as piglets were lying on the pad (Fig. 7). This means that the heating elements in the heat pad did not consume energy all the time, and therefore the actual energy consumption was lower than that calculated from the rated wattage. In contrast the recorded daily electricity consumption (176 kWh) by the heat lamps was close to the nominal (rated) capacity of hat lamps (0.175 kW/crate x 44 crates x 24 h = 184.8 kWh). Based on the nominal (rated) capacity, the energy consumption by the heat pads were 37% of that by heat lamps (65÷175). However, the recorded daily electricity consumption by the pads 27% of that by the lamps (48 vs. 176 kWh), or a 73% saving in electricity.

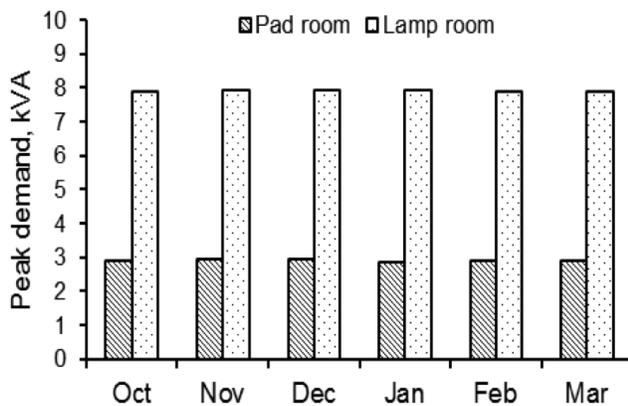


Fig. 9. Recorded monthly peak demand in electricity use in heat pad and lamp rooms.

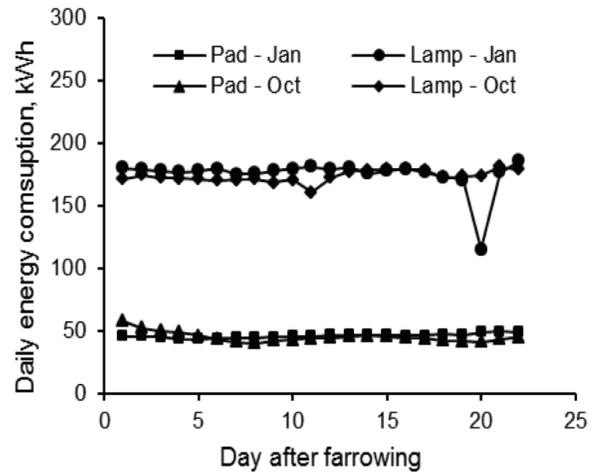


Fig. 8. Daily electrical energy consumption for October and January trials.

The electricity cost for commercial and industrial customers often consists of three components: basic charge, energy (consumption) charge (by kWh), and peak demand charge (kW) (the rate at which energy is used). The monthly demand charge for billing is often based on the 15 minutes during a billing period with the "highest average" kW use. The recorded peak demand in the heat lamp room was about 5 kW higher than that in the heat pad room (Fig. 9), or 113 W per crate. The difference between the two rooms was consistent through out the test period.

Mortality and Average Daily Gain

The mortality data were recorded for only five cycles and the average daily gain for four cycles because of the lack of labor availability in managing the facility. The pre-weaning mortality ranged from 8.8% to 13.8% in the pad room in comparison with 7.6% to 12.8% in the lamp room (Table 1), and the averages of the two rooms were almost identical (pad room: 10.6%, lamp room 10.8%). These averages are within the range of typical mortality in commercial farrowing operations. For example, O'Reilly et al. (2006) summarized the mortality data reported by farmers for 67 British swine herds and concluded a median mortality to be 10.7%, with an interquartile range of 8.5% to 14%. Kilbride et al. (2012) reported an average of pre-weaning mortality of 12% for 112 commercial swine farms in England. Statistical analysis (t-test) showed that the mortality was not significantly different ($P>0.05$) between the two heating systems.

The ADG of the piglets in the pad room appeared slightly higher than that in the lamp room. Specifically, piglets had higher ADG in the pad room than the lamp room in three of the four cycles (Table 1). However, the statistical analysis showed that the difference was not significant ($P>0.05$). The variation in ADG was greater in the pad room (from 221 to 268 g/d) than that in the lamp room (from 223 to 236 g/d).

Table 1. Mortality and average daily gain (ADG) of piglets recorded in the pad and lamp rooms (n = 10 litters in each room for determining ADG).

Cycle (Trial)	Mortality, %		Daily Average Gain, g/day	
	Pad Room	Lamp Room	Pad Room	Lamp Room
1	10.1	10.7	268	236
2	13.8	7.6	239	223
3	8.8	10.3	256	231
4	8.8	12.8	221	229
5	11.4	12.4	--	--
Average	10.6	10.8	250	230
St. Dev.	2.1	2.1	20	5

Note: the daily average gain was not measured by the operator in trials 5.

CONCLUSION

1. The piglet performance (mortality and average daily gain) in a room equipped with 65W (per crate) heat pads for localized heating was not statistically different ($P>0.05$) from that in a farrowing room equipped with 175W (per crate) heat lamps.
2. The use of 65W heat pads (per crate) reduced energy consumption by 73% in comparison with 175W heat pads (per crate). This energy saving was greater than that calculated from the rated wattages for heat pads and lamps (pads rated at 65W and lamps at 175W, or a calculated saving of 63%).
3. The heat pad room tended to have higher levels of relative humidity than the heat lamp room in the winter months. While the relative humidity stayed mostly within the 40% to 80% range in the heat lamp room, the occurrence frequency for relative humidity above 80% was up to 15% in the pad room in the winter months.

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