HEATING UP THE HOUSE: EVALUATING THE EFFECT OF NOVEL MONITORING AND HEATING SYSTEMS ON THE PRODUCTIVITY, WELFARE AND ECONOMICS OF FARROWING HOUSES

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By

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Executive Summary

Investigation of novel ways to allow real time monitoring of pigs and innovative sustainable heating sources are required to ensure Australian pork production systems are future proof. The objective of the current project was to investigate the impact that a number of different heat lamps have on the thermal comfort of sows and piglets, comparing the overall performance of the conventional heat lamps that are widely used in Australian piggeries, and two new heating-source options (Aniheater® and Hog Hearth® Heat Mats). Due to the positive results reported in several countries, these two new heating methods were expected to provide better thermal conditions for piglets and sows, and to have a lower cost of maintenance than the conventional heat lamps.

In this project, n = 720 sows were allocated over 12 replicates to 1 of 3 treatments based on the heating source equipped in the pen: A) conventional heat lamp (Control); B) Hog Hearth® Heat Mats (Hog Hearth®, Canada) or C) Aniheater® (Aniheater®, Denmark). The project was also divided into three observation stages, summer, winter and annual. Several measures of gestation and lactation performance were taken from sows and piglets, including individual birth weights, overall mortality and piglets weaned per sow was recorded. All the costs linked to each of the heating sources (initial cost plus parts replacement and energy costs) were also collected to analyse their cost effectiveness and the return on investment of each of these.

It was found that the skin temperature of sows, especially the ear-base temperature is more sensitive to the heating source during the summer period. The type of heating source did not significantly influence the number of sows removed, the number of piglets born alive or number of stillborn piglets per sow. However, the mortality of piglets could be affected by the type of heating source, where litters in the heat mat treatment had significantly lower rates of mortality (especially from overlay) in summer, compared to those in the heat lamp and Aniheater treatments. It was observed that the conventional heat lamps had a higher maintenance cost when compared to the other heating sources. The heat mats had the lowest electricity usage of the three heat sources, and after a cost-benefit analysis it was determined that the payback period for the heat mat was 2.3 years, while it was 1.2 years for the Aniheater device (when compared to the traditional heat lamp).

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1. Introduction

The need to explore novel technologies, to be implemented as monitoring and surveillance methods on farms, has been recognised as a high priority for the pork industry (Jorquera-Chavez et al. 2021).

Optimal heating environment in farrowing houses is critical for the high standards of pig welfare and ensuring piglet survival. Heat lamps are widely used to provide additional heating support for the newborn piglets (Tamvakidis et al. 2015), assisting piglets to maintain an adequate body temperature. Several studies have shown the positive effect that this heating method has had in the survival rate of newborn piglets, while they still have poor body thermostability (Christison et al. 1997; Vila & Tummaruk 2016). However, some researchers have argued that the conventional heating-lamps are only able to heat a small area, being insufficient to keep all piglets warm and away from the sow. This could have a negative impact on the number of piglets becoming crushed by the sow, and the overall pre-weaning mortality.

Moreover, there is a significant gap in current scientific knowledge in relation to the impact that heat lamps have on the thermal comfort of sows. Sows and piglets have very different thermal requirements (Lane 2020), and that the welfare and productivity of sows are greatly affected by elevated temperatures (McConn et al. 2021; Liu et al., 2019; Liu et al., 2020). We recently conducted a pilot study (APRIL project 6A-104), using novel tools to assess sow welfare (thermal imagery), to investigate the impact of heat lamps on the skin and rectal temperature of sows. The study observed that sow's skin temperature of the area covered by this light was 1-4 °C higher than the skin temperature of the surrounding area, and that the rectal temperature of sows was higher ($p<0.05$) when an area of their body was covered by the heat lamp than when sows were not reached by the heat lamp (Jorquera-Chavez et al, 2021). Although this pilot study revealed some of the negative impacts that the conventional heat lamps could have on lactating sows, it also suggested that the pig industry is urgently needing more knowledge about how the heating methods used in farrowing houses are affecting the welfare and productivity of sows, specifically during hotter periods. Due to their inherent physical and energetic characteristics, conventional heat lamps not only lead to a high energy and maintenance cost, but also represent a potential work health and safety risk for the stock people when changing bulbs.

It is clear that new and more effective and innovative monitoring techniques and heating sources for farrowing houses are required, and these should be evaluated in commercial systems to help improving pigs' monitoring and decreasing heat-stress in lactating sows. This would consequently help increase the productivity of sows and piglets and assist in ensuring sustainability of Australasian producers. For these reasons, this project aimed to:

i. Implement and evaluate innovative methods of thermal imagery (thermal cameras) as a non-invasive method to monitor thermal status of sows and piglets in farrowing houses;

ii. Compare the impact of conventional heat lamps and new heating-source options (Aniheater® and Hog Hearth® Heat Mats) on the thermal comfort of lactating sows during summer;
iii. Compare the impact of conventional heat lamps and new heating-source options (Aniheater® and Hog Hearth® Heat Mats) on the thermal comfort, survival, and productivity of piglets during winter;
iv. Compare the performance of different heating-sources in a farrowing house, and quantifying their impact on piglets' growth, rate of crushing, and pre-weaning mortality rates across all seasons (across one year); and,
v. Perform a cost effectiveness analysis of the current heating-source used in farrowing houses (conventional heat lamps), and new heating-source options (Aniheater® and Hog Hearth® Heat Mats).

This project included the implementation of thermal imagery as a non-invasive tool to assess sow welfare, more specifically to monitor sows and evaluate their thermal status during hot periods. Thermal imagery was also used to monitor piglets and evaluate their thermal status when an appropriate thermal support is crucial for their survival.

2. Methodology

2.1 Animal welfare statement

This experiment was conducted at a commercial farm (Huntly VIC, Australia) between December 2022 and February 2024. All procedures described were undertaken with prior approval from the Rivalea Animal Ethics Committee (protocol number 22-021).

2.2 Animals, experimental design, housing

A farrowing house was equipped with 20 pens containing each heat source, randomly allocated across the shed:

- Treatment A: Conventional heat lamps (Control). The conventional heat lamps used transfer heat through radiation using the filament inside the bulb to generate light and heat. Twenty heat lamps were used to equip 20 farrowing pens and placed over the creep area.

Figure 1: The conventional heat lamp placed over the creep area in the conventional farrowing crate.

- Treatment B: Heat mats. Ten double Hog Hearth® Heat Mats (Hog Hearth®, Canada) were used to equip 20 farrowing pens (1 mat sat beneath the mid-board between pens to service 2 pens each). The heat mats consisted of a heating element within the mat, covered by a non-slip surface. Heat is transferred to piglets through conduction when they are lying on the mat.

Figure 2: Piglets lying on the Hog Hearth® Heat Mats placed in the creep area in the conventional farrowing crate.

- Treatment C: Aniheater. Twenty Aniheater® devices (Aniheater®, Denmark) were used to equip 20 farrowing pens. Aniheater is a type of heating lamp with no filaments, spreading the heat more evenly than traditional heating lamps and a lower heat loss on the rear side of the device. Due to the special design, Aniheater has a lower surface temperature, thus making it safe for animals and giving space for more piglets. Heat is transferred to piglets through radiation.

Figure 3: The Aniheater® device placed over the creep area in the conventional farrowing crate.

Over a 14-month period (Dec 2022 to Feb 2024), these pens accommodated sows and their litters from farrowing to weaning (12 batches of sows/litters). The experiment was divided into two stages seasonal stage for analysis, summer and winter.

2.2.1 Annual performance (entire experimental period)

During the whole experimental period (Dec 2022 to Feb 2024; termed a one-year period), 12 batches of sows/litters were accommodated in the pens equipped with the different heating sources. Each batch had 60 sows/litters that were evaluated as part of the experiment (20 per treatment), having a total of 720 sows/litters (240 sows/litters per treatment).

During this stage, production data was collected from the farm management system. As part of this, the number of piglets' deaths by crushing, the overall mortality, and the number of piglets weaned-per-sow were recorded. Moreover, during the one-year period, all the costs linked to each heat source (initial cost + parts replacement + energy costs) were collected to assess their cost effectiveness.

2.2.2 Summer performance

During summer (Dec 2022 to Feb 2023; Dec 2023 to Feb 2024), 3 batches of sows and their litters (n=180) were randomly allocated in the pens that were equipped with the heating-sources to be investigated. Sow body weight was recorded on entry to the farrowing house and at weaning, where possible.

- Sow welfare/thermal status:
  - All sows were monitored two times per week, temperature was monitored by recording rectal temperature and using a thermal camera (FLIR E8-XT; FLIR Systems, USA) to measure eye and ear-base temperature (Jorquera-Chavez et al., 2021).
- Sow and piglet performance:

    - Individual live weight of sows was recorded when entering the farrowing house and at weaning.
    - Piglet litter weight was measured at 2 days of age (after fostering) and at weaning (26 ± 1.5 days of age; mean ± s.d.).
    - All sow/piglet mortality and morbidities during lactation were recorded.

2.2.3 Winter performance

During winter (May to Aug 2023), 3 batches of sows and their litters (n=180) were randomly allocated in the pens that were equipped with the heat sources to be investigated (heat sources remained in the same pens from the summer period). Sow body weight was recorded on entry to the farrowing house and at weaning, where possible.

- Piglet welfare/thermal status:
    - All sows were monitored two times per week, temperature was monitored by recording rectal temperature and using a thermal camera (FLIR E8-XT; FLIR Systems, USA) to measure eye and ear-base temperature (Jorquera-Chavez et al., 2021)
    - Thermal infrared images from piglets were obtained with a thermal camera (FLIR E8-XT) to evaluate the thermal status of piglets. To do this, thermal images of the ear-base area were obtained from the focal piglet once per week (one piglet per pen/time-point), when the piglets were resting in the closest proximity to the back fence of the pen. This was done to minimise the noise that physical activity could have in the analysis of piglets' thermal status.
    - The number of piglets sleeping next to the sow and the occurrence of piling of piglets (i.e., one or more piglets lying with part or all of their body on top of another pig; Hayne et al. 2000) were recorded just before obtaining the thermal images from sows, twice per week.
- Sow and piglet performance:
    - Individual live weight of sows was recorded when entering the farrowing house and at weaning.
    - Piglet litter weight was measured at 2 days of age (after fostering) and at weaning (26 ± 1.6 days of age).
    - Sow/piglet mortality and morbidity were recorded.

2.3 Statistical analysis

The statistical analysis was performed using Minitab® Statistical Software. Repeated-measures ANOVA was performed to test the heating treatment by time interaction in addition to the main effects of heating treatment to compare skin and rectal temperature between groups. No other fixed or random effects were fitted in the model. Chi-square analysis was used to compare piling occurrence during winter between treatments.

3. Outcomes

3.1 Performance over entire experimental period

Descriptive data for sow performance statistics are shown in Table 1.

Table 1: Descriptive statistics for sow performance characteristics from data collected during the entire experimental period.

Measure	n	Min	Max	Mean	sd
Sow parity at farrowing	720	1	12	3.1	2.27
Sow BWT at entry to FH (kg)	335	176	370	266	36.2
Sow BWT at weaning (kg)	337	163	340	243	33.5
BA	720	2	20	13.1	2.94
TB	720	3	23	14.4	3.15
Number weaned	707	6	16	11.3	1.72

BA = number of piglets born alive; BWT = bodyweight; FH = farrowing house; SB = number of piglets stillborn; TB = total born.

As hypothesised, the total number of piglet deaths (Table 2) and the number of piglets overlain (Table 3) seemed to be affected by the type of heating source used in their crates. In the case of total deaths, the results showed that the lowest number of piglet deaths per sow during lactation was within the litters that were in the heat mat group (Table 2).

Table 2: Comparison of the total number of piglet deaths during lactation (per litter) between treatments (Aniheater, heat lamp, and heat mat) from the data collected during the entire experimental period, in winter, and in summer.

Heating Source	One-year period			Winter			Summer		
	Mean	StDev	95% CI	Mean	StDev	95% CI	Mean	StDev	95% CI
Aniheater	1.3^{AB}	1.7	(1.1, 1.5)	1.4^{A}	1.9	(1.0, 1.8)	1.5^{A}	2.1	(1.1, 1.9)
Heat lamp	1.5^{A}	1.6	(1.3, 1.7)	1.4^{A}	1.5	(1.0, 1.8)	1.6^{A}	1.6	(1.1, 2.0)
Heat mat	1.0^{B}	1.4	(0.9, 1.2)	1.3^{A}	1.3	(0.9, 1.7)	0.9^{B}	1.2	(0.5, 1.3)

^{A,B} Different superscripts indicate significant differences ($p<0.05$) between heat source treatments within time period.

Table 3: Comparison of the number of piglet deaths from being overlain (per litter) between treatments (Aniheater, heat lamp, and heat mat) from the data collected during the entire experimental period, in winter, and in summer.

Heating Source	One-year period			Winter			Summer		
	Mean	StDev	95% CI	Mean	StDev	95% CI	Mean	StDev	95% CI
Aniheater	1.0^{AB}	1.4	(0.8, 1.1)	1.0^{A}	1.2	(0.6, 1.3)	1.1^{AB}	1.9	(0.7, 1.5)
Heat lamp	1.2^{A}	1.4	(1.0, 1.3)	1.3^{A}	1.5	(1.0, 1.7)	1.3^{A}	1.5	(0.9, 1.7)
Heat mat	0.8^{B}	1.1	(0.6, 1.0)	1.1^{A}	1.2	(0.8, 1.4)	0.6^{B}	0.8	(0.2, 0.9)

^{A,B} Different superscripts indicate significant differences (p<0.05) between heat source treatments within time period.

It was observed that the number of sows removed during lactation did not differ between treatments (p>0.05) during the entire experimental period, the winter observations, or the summer observations. A similar trend was observed when analysing the number of piglets born alive and the number of stillborn per sow in each treatment, where no significant differences were found during the entire experimental period, the winter period, or the summer period (Table 4).

Table 4: Comparison of the number of stillborn piglets (per litter) between treatments (Aniheater, heat lamp, and heat mat) from the data collected during the entire experimental period, winter, and summer.

Heating Source	One-year period			Winter			Summer		
	Mean	StDev	95% CI	Mean	StDev	95% CI	Mean	StDev	95% CI
Aniheater	1.1	1.3	(0.9, 1.2)	1.0	1.1	(0.7, 1.3)	1.1	1.3	(0.8, 1.4)
Heat lamp	1.0	1.2	(0.8, 1.1)	1.1	1.2	(0.9, 1.4)	1.0	1.2	(0.7, 1.3)
Heat mat	0.9	1.1	(0.7, 1.0)	1.1	1.1	(0.8, 1.4)	0.9	1.1	(0.6, 1.2)

3.2 Summer performance

3.2.1 Sow welfare/thermal status

In the case of eye temperature, differences between treatment groups were not significant (p>0.05; Figure 4). When comparing ear-base temperature between heat source treatments, the differences were significant (p<0.05; Figure 5). Ear-base temperature was significantly higher (p<0.01) in sows housed in pens equipped with heat lamps compared to those in pens with the heat mats or the Aniheaters. As rectal temperature is considered the gold standard for measuring the body temperature of sows, this was also analysed to be compared with eye and ear-base temperatures. When comparing rectal temperature between groups, no significant differences were found between treatments (p>0.05).

These results suggest that skin temperature, precisely ear-base temperature, is more sensitive to the heating sources' effect on sows during the hottest period of the year. These results also agree with previous observations performed at Rivalea (APRIL Project 6A-104), where heat lamps seemed to impact the skin temperature of sows, which could consequently negatively impact the thermal comfort of lactating sows during hot periods, impacting their well-being and productivity.

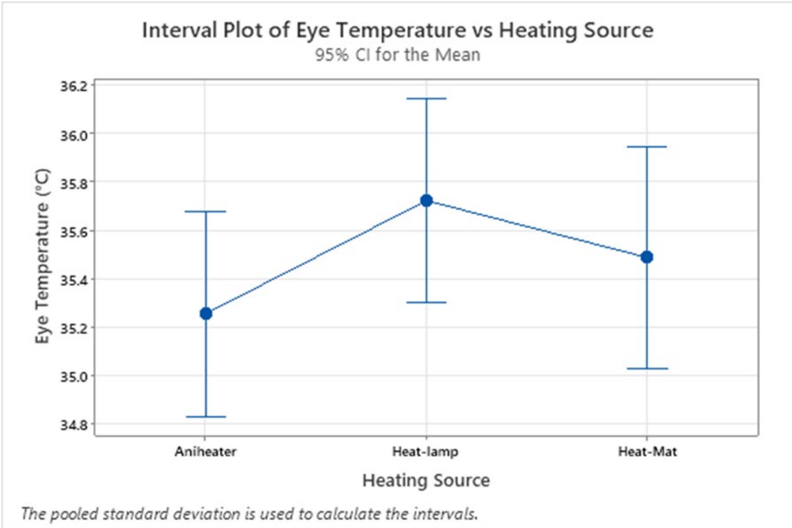

Figure 4: Interval plot comparing the eye temperature of sows between different heat source groups during summer.

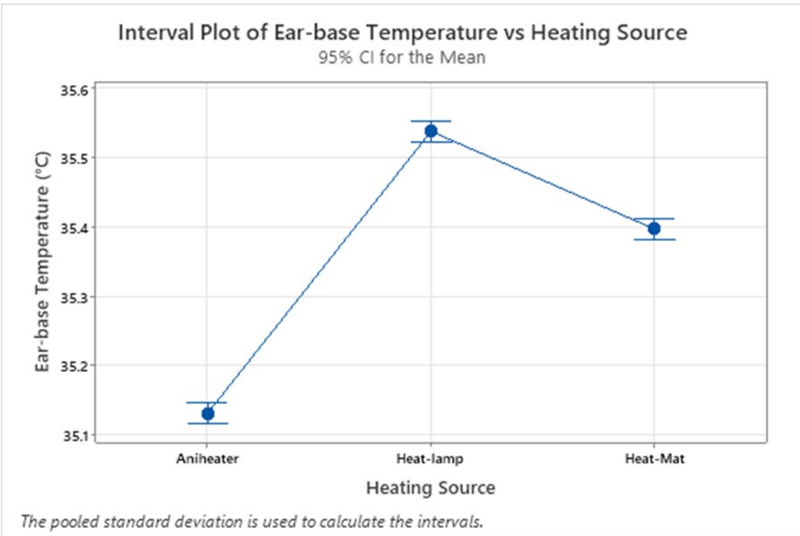

Figure 5: Interval plot comparing the ear-base temperature of sows between different heat sources groups during summer.

3.2.2 Sow and piglet performance

During hot periods the mortality of piglets was impacted by the heating source present in the crate, showing significant differences between groups ($p<0.05$). In summer, piglet mortality was higher when the crate was equipped with an Aniheater, when compared with the heat lamp and heat mat treatments (Table 2).

Moreover, it is also found that in the summer period the mortality of piglets from being overlain was impacted by the heating source present in the crate ($p<0.05$). In the summer season, the number of piglets being overlain was higher when the farrowing crate was equipped with an Aniheater, when compared with piglets having a heat lamp or heat mat (Table 3). These results agree with our hypothesis that the heating source would have a greater impact on the incidence of overlaying during summer, and more specifically, that heat mats would provide a source of heat that would keep piglets away from the sow as much as possible, avoiding the sow overlaying them. This may also suggest that the thermal comfort of sows in pens with the alternate heat sources (heat mat or Aniheater) may be improved, and further studies to determine the impact of the heat source on sow posture changes and overall comfort would be of interest in the future.

3.3 Winter performance

3.3.1 Piglet welfare/thermal status

To evaluate the effect that heating sources have on piglets' behaviour and how this may minimise overlaying and improve piglets' survival during winter, the number of piglets resting next to the sow and the incidence of piling was monitored. The results obtained from these observations suggested that at the time of monitoring, there was no significant difference in the number of piglets resting in close proximity to the sow between types of heating source ($p>0.05$). In the case of the incidence of piling during winter, the results revealed that heating source is a factor that impacts the incidence of piling (Chi-square: 29.30; $p<0.01$). The use of heat mats encouraged less piling than the heat lamps or the Aniheater treatments. From the total timepoints where piling was monitored in the participating litters, the litters in the heat mat group were piling 7.6% of the time, while the litters in the heat lamps showed piling 23.6% of the time, and the litters in the Aniheater group were piling 29.6% of the time. These results could indicate that the heat mats provided a more adequate heating source to piglets and that the area that this heating source covers is appropriate to provide heat to a greater number of piglets.

3.3.2 Sow and piglet performance

The observations performed during winter did not show significant differences in piglet deaths between the Aniheater, heat lamp or heat mat treatments (Table 3), nor was there a significant difference in piglets overlain piglets per litter between heating treatments (Table 4). While we hypothesised that the heating source would have a greater impact on piglet deaths during winter, these results showed that the impact was bigger when considering the whole year and during summer.

3.4 Evaluation of heating sources on maintenance cost and electricity usage

A cost-benefit analysis was conducted using the results of the experiment (entire experimental period) and some assumptions based on current trends and market figures (Table 5). Overall, the payback period for heat mats (replacing conventional heat lamps) was 2.3 years and it was 1.2 years for the Aniheater device (Table 5). In terms of the maintenance of these devices and their electricity usage, it was observed that the maintenance of the heat lamps had higher labour and cost requirements (Table 5). This was due to the change of bulbs that was required during this study. During the duration of the study (December 2022 and February 2024), 20% of pens with a heat lamp required a bulb replacement. In contrast, the Aniheater and heat mats did not require any replacement of parts or maintenance during the one-year period of this study.

Moreover, when analysing the electricity usage of the three heating sources, significant differences were found between these sources ($p<0.01$). The results showed that the heat-mats had a significantly lower usage of electricity, with an average usage of 34.3 kWh (per crate/per lactation), followed by the heat- lamps and Aniheater (81.3 and 84.2 kWh per crate/per lactation, respectively). These results suggest heat lamps as a heating source for the farrowing house could be the least cost-effective system, as they required the greatest resources for maintenance, and they used a greater amount of electricity (albeit lower than the Aniheater device).

Furthermore, the heat mats required less labour to clean as they could be turned off from the energy source and left in place while the shed was being washed. However, conventional heat lamps had to be turned off from the energy source and placed up high as to avoid them being damaged during the washing process.

Table 5: Cost benefit analysis model assumptions (all amounts are in AUD, inc. GST).

	Heating source		
Item	**(A) Heat lamp**	**(B) Heat mat**	**(C) Aniheater**
Costs			
Pens per shed	100	100	100
Lactations per year per pen	10	10	10
Capital cost per unit	$20	$470	$100
Pens serviced per unit	1	2	1
Period of use before replacement (years)	2	12	12
Electricity cost (/kW)	$0.16	$0.16	$0.16
Electricity usage (/lactation)	81.3	34.3	84.2
Replacement part cost (AUD)	$7.20	-	-
Replacement parts required per year (%)	20%	-	-
Benefits			
Piglet survival (pigs/litter)	0	0.5	0.2
Litter size (n)	13	13	13
Piglet survival (%)	-	3.8	1.5
Revenue (extra pigs weaned, per pen)	-	$20.40	$8.05

Table 6: Annual costs and benefits associated with each heating source (all amounts are in AUD, incl. GST).

Item	Annual cost per heating source (AUD) (A) Heat lamp	(B) Heat mat	(C) Aniheater
Costs			
Capital investment	$10.00	$19.58	$8.33
Electricity	$130.10	$54.90	$134.70
Replacement parts	$1.44	$0	$0
Total	$141.54	$74.48	$143.03
Comparative to (A)	-	-$67.06	+$1.49
Benefits*			
Piglet survival (net revenue)	-	$204.00	$80.50
Net benefit	-	$271.06	$79.01
Payback period	-	2.3 years	1.2 years

*Compared to traditional heat lamp (A), calculated using PigEV.

4. Application of Research

The findings from this project have significant implications for the Australian pork industry, particularly in optimising farrowing house environments. The use of thermal imagery technology has proven to be a valuable tool for monitoring pigs' welfare, offering real-time data that can be used to make informed management decisions. The commercial application of these technologies could lead to more precise monitoring of animal welfare, reducing heat stress in sows and improving piglet survival rates.

The comparison of conventional heat lamps with Aniheater® and Hog Hearth® Heat Mats highlights the potential for these novel heating solutions to replace traditional methods, offering improved thermal comfort for piglets and enhanced energy efficiency. More specifically, the implementation of these heating technologies could reduce operational costs and improve the sustainability of pig farming operations, making them highly attractive to commercial producers.

4.1 Opportunities uncovered by the research

This project uncovered several key opportunities for the pork industry:

1. **Adoption of Thermal Imagery**: Thermal imagery has shown promise as a non-invasive method to monitor the thermal status of sows and piglets. This technology could be integrated into existing monitoring systems to enhance welfare and productivity.
2. **Improvement in Heating Systems**: The findings suggest that heat mats offer superior thermal comfort and energy efficiency compared to conventional heat lamps. This presents an opportunity for producers to reduce energy consumption and improve piglet survival rates.

4.2 Commercialisation and adoption strategies

To facilitate the commercialisation and adoption of the research findings:

1. **Stakeholder Meetings and Demonstrations**: Conducting producer meetings across Australia will help demonstrate the benefits of the new technologies under different conditions, building confidence among producers.
2. **Training and Support**: Providing training programs for farm staff on how to use thermal imagery technologies effectively will be crucial. Additionally, offering technical support during the transition to new heating systems will ensure successful adoption.
3. **Collaboration with Industry Bodies**: Partnering with industry bodies to promote these innovations will enhance their reach and acceptance within the industry.

4.3 Potential benefits to cost of production

The adoption of the new technologies and heating systems studied in this project is expected to yield several cost-related benefits:

1. **Reduction in Energy Costs**: Hog Hearth® Heat Mats have shown to consume significantly less energy than conventional heat lamps, leading to lower utility bills for producers.
2. **Lower Maintenance Costs**: These new heating systems also require less maintenance, reducing labour costs and the need for frequent replacements, which are common with heat lamps.
3. **Increased Piglet Survival**: Improved thermal comfort for piglets is expected to lead to lower mortality rates, resulting in higher weaning rates and potentially increased profitability for producers.

4.4 Ease of adoption by producers

The thermal camera technology used in the current project is relatively easy to adopt, requiring minimal infrastructure changes. Producers can integrate thermal cameras into their existing monitoring systems with appropriate training. The transition from conventional heat lamps to Aniheater® or Hog Hearth® Heat Mats is straightforward, but initial costs may be a barrier for smaller producers. However, we have demonstrated that these devices will pay for themselves after 1.2 to 2.3 years, assuming a 12-year replacement period. Financial incentives or subsidies could help mitigate this.

4.5 Impact of the research

The impact of this research on the pork industry could be profound, leading to:

1. **Enhanced Animal Welfare**: By improving thermal conditions and monitoring, the research directly contributes to better welfare outcomes for both sows and piglets.
2. **Operational Efficiency**: The technologies investigated can lead to more efficient farm operations, with lower energy consumption, reduced maintenance needs, and better animal management.
3. **Sustainability**: The reduction in energy use and improvement in piglet survival rates align with the industry's goals of increasing sustainability and reducing the environmental footprint of pork production.

5. Conclusion

This project has demonstrated the significant potential of novel monitoring technologies and heating systems to improve the welfare, productivity, and economic sustainability of farrowing houses within the Australasian pork industry.

The comparative assessment of conventional heat lamps with Aniheater® and Hog Hearth® Heat Mats revealed that the latter two options provided superior thermal comfort for piglets, reducing mortality rates and improving productivity. The heat mats, in particular, demonstrated lower energy consumption and maintenance requirements, making them a cost-effective alternative to traditional heating methods.

These findings suggest that adopting these innovative technologies can lead to significant improvements in piglet welfare and operational efficiency in farrowing houses. Furthermore, the results from this study showed that improvements in piglet survival seen with the use of the heat mats are mostly evident in summer. It may be speculated from this data that the thermal comfort of the sow is impacted and may influence postural changes and hence piglets are less likely to be overlain, which deserves to be further studied. Whilst the eye and ear temperatures of sows measured in the current study did not exceed upper critical temperature limits, udder temperatures were not measured, and this may be where the thermal comfort of the sow is impacted, in close proximity to the placement of the conventional heat lamps. Results from our previous project (APRIL 6A-104) certainly suggest this.

Continued research and refinement of these technologies will be crucial to fully realise their potential benefits and sustain the growth and competitiveness of the Australasian pork industry.

6. Limitations/Risks

- Several brands and types of heat mats exist in the market, generally developed outside Australia, similar to the Aniheater. Although the heat mats and Aniheater showed good performance in an Australian system, it is important to evaluate what product is more suitable for each farm (e.g., the size of the mat and the position of the power cord).
- The investment required to move from heat lamps to heat mats or the Aniheater could be a limitation for small producers. Supporting small producers with appropriate information may be needed to promote this change.
- In the case of heat mats and Aniheaters, these heating sources do not produce light, so if these are used it may be required to improve the light systems in the farrowing houses to provide adequate lighting in farrowing houses where the heat lamps are removed.

7. Recommendations

As a result of the outcomes in this study the following recommendations have been made:

1. **Adoption of Thermal Imagery as a Monitoring Tool**:
    - **Objective**: Utilize thermal cameras as a non-invasive, efficient method for monitoring the thermal status of sows and piglets.
    - **Action**: Encourage producers to integrate thermal imagery into their existing monitoring frameworks. Training programs should be established to ensure farm staff can effectively use this technology. This tool should be particularly emphasized for use during hot weather to prevent heat stress in sows.
2. **Transition to Hog Hearth® Heat Mats for Farrowing Houses**:
    - **Objective**: Enhance piglet survival and welfare through the use of more effective heating systems.
    - **Action**: Promote the adoption of Hog Hearth® Heat Mats as a preferred heating solution, given their superior performance in reducing piglet mortality and energy consumption.
3. **Improvement of Lighting Systems in Farrowing Houses**:
    - **Objective**: Compensate for the lack of light provided by the new heating systems.
    - **Action**: Evaluate and upgrade lighting systems in farrowing houses where heat lamps are replaced by non-light-emitting heat sources like Hog Hearth® Heat Mats and Aniheater®. Ensuring adequate lighting will maintain animal welfare and worker safety.

8. References

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