

**Annotated Bibliography:** Entries are grouped into three categories. The first three articles look at behavioural responses to heat stress in sows, the next five investigate multiple methods of mitigating heat stress, and the final article is a review.

**Investigation of behavioural responses to heat stress in sows:**

**Muns, R., Malmkvist, J., Larsen, M. L. V., Sørensen, D., & Pedersen, L. J. (2016). High environmental temperature around farrowing induced heat stress in crated sows. *Journal of Animal Science*, 94(1), 377–384. <https://doi.org/10.2527/jas.2015-9623>**

**Summary:**

Previous studies have investigated the behavioural and physiological responses to high ambient temperature in crated and loose-housed sows during lactation and farrowing. This study altered the ambient temperature to exceed a sow's thermoneutral range (25°C), and investigated the behavioural response of sows to heat stress. Twenty sows were split into two treatment groups, with the control group housed in a farrowing room kept at 20°C, and the heat group housed in a room where the temperature was initially kept at 20°C, gradually raised to 25°C, and then lowered back to 20°C. The behaviour of sows was continuously monitored, and sow respiration rates, rectal temperatures, and udder surface temperatures were measured daily to indicate their response to increased ambient temperature. Piglets were weighed at intervals after farrowing. High ambient temperature around farrowing altered sow's postural behaviour. Heat sows spent a higher proportion of time lying in the lateral position than control sows in all observation periods, but both heat and control sows spent the same amount of time lying down. Heat sows had a higher respiration rate prior to farrowing and higher rectal and udder surface temperatures following farrowing than that of control sows.. Control sows had higher feed intake after farrowing and heavier litter weight at weaning than heat sows. The changes to respiration rate and body temperatures observed in the heat treatment indicate that these sows had more difficulty adjusting to the change in ambient temperature. Taken together with their behavioural responses, results show that increased ambient temperatures altered a sow's ability to thermoregulate and had a negative impact on piglet performance. Further research is required to determine effective regulatory strategies that can be employed to keep sows in a thermoneutral zone, and how increased or decreased bouts of ambient temperature change affect a sow's ability to thermoregulate.

**Contribution:**

This article was chosen as part of my literature review as it explores multiple responses of sows to heat stress, including changes in posturing as well as food intake and respiration. It also describes a relationship between heat stress in lactating sows and their corresponding piglet performance. The article supports previous findings based on studies conducted both in crated and loose-housed sows. It highlights the importance of finding a balance in temperature that is optimal for both sows and piglets.

**Quiniou, N., Renaudeau, D., Dubois, S., & Noblet, J. (2000). Influence of high ambient temperatures on food intake and feeding behaviour of multiparous lactating sows. *Animal Science*, 70(3), 471–479. <https://doi.org/10.1017/S1357729800051821>**

**Summary:**

Sow appetite is influenced by many factors, including sow body weight, parity, or diet composition. Previous studies have also examined the effects of ambient temperature on sow lactation performance, but little is known about the relationship between temperature and sow feeding behaviour. The objective of this study was to investigate the feeding behaviour of sows in response to five temperatures ranging from 18-29°C. Forty multiparous sows were split into five temperature treatments (18, 22, 25, 27, 29°C) and fed cereal and soya-bean based diets with one of two protein contents (140 or 170g/kg). Sows and piglets were weighed after farrowing and at weaning. The number of feeder visits, number of meals, food and water intake, total ingestion time, and total consumption and drinking time were measured daily, as well as the rate of food intake and ingestion time per meal. The backfat loss was lowest, and the piglet growth rate highest at 18°C. No relationship between diet composition and ambient temperature was found. The daily number of meals was affected by temperature, with sows housed at 29°C eating fewer meals than sows housed from 18-25°C. Meal size, rate of feed intake, water intake, and water ingestion time did not differ between treatment groups. Feed ingestion time and the number of meals eaten decreased with increased temperature, and the ratio between water and food intake was the highest at 29°C. Standing activity was not influenced by temperature. Results are consistent with previous literature, though most research into feeding behaviour has been focused on growing pigs. The study concludes that ambient temperature has an important impact on feed intake and the feeding behaviour of sows. Since these results were obtained under a system that maintained a constant temperature throughout the day, future research should be conducted under normal fluctuating daily temperatures.

**Contribution:**

This study was included in my literature review as it investigates one specific behavioural response of sows to increased ambient temperatures. Sows will adjust to heat stress conditions in multiple ways, and one of these ways is by changing their feeding behaviour. This article stresses the importance of finding a sow's ideal thermoneutral temperature and finding ways to help them stay within it during farrowing and lactation. By doing so, farmers can ensure that they are raising livestock that is healthy as well as profitable.

**Liu, L., Tai, M., Yao, W., Zhao, R., & Shen, M. (2021). Effects of heat stress on posture transitions and reproductive performance of primiparous sows during late gestation. *Journal of Thermal Biology*, 96, 102828. <https://doi.org/10.1016/j.jtherbio.2020.102828>**

**Summary:**

Previous studies investigating the behavioural responses to heat stress in sows have focused mainly on factors such as changes in feed intake, farrowing rate, and lactation time, as well as the performance of piglets. However, the effects of heat stress on posture changes of sows during gestation are not well researched. This study investigated the effects of posture changes in response to heat stress in sows and evaluated corresponding piglet performance. In this study, ten sows were randomly assigned to two treatment groups. Ambient temperature was kept at 18-22°C for the thermoneutral group and 28-32°C for the heat stress group. Posture transitions were recorded from 72 hours prepartum until 24 hours after the birth of the first piglet (BFP). Litter size, birth site, and litter weight at birth, day ten, and weaning were also recorded for each treatment group. Results show the frequency of posture change increased for both thermoneutral and heat stress groups during 24 h prepartum, but the average frequency of posture change for heat-stressed sows was significantly lower than the thermoneutral group. During the entire observation, dynamic posturing such as sitting and standing was lower in the heat stress group. Heat stress sows showed an increase in farrowing duration, as well as delivery time for individual piglets, and had lower litter weights at d10 and weaning. Large variations in posture changes between the two groups were difficult to identify, though it can be said that thermoneutral sows were more active than heat stress sows overall. In terms of piglet performance, the high ambient temperature had a negative impact on sow lactating behaviour, which led to lower litter weight. Further research should be conducted on the posture changes of sows in relation to their maternal ability, and studies should include larger sample sizes for more distinct results.

**Contribution:**

This article was chosen as part of my literature review, as it investigates one specific behavioural response of sows to heat stress. It also provides additional information about the effects of heat stress on piglet performance and supports the findings of other articles included in my literature review. This article is the first to investigate the impact of heat stress on postural change as a primary objective and provides a starting point for future research into this topic. The results of this study also align with similar literature investigating piglet performance in response to heat stress.

### **Methods of regulating heat stress in sows:**

**Cabezón, F. A., Schinckel, A. P., Marchant-Forde, J. N., Johnson, J. S., & Stwalley, R. M. (2017). Effect of floor cooling on late lactation sows under acute heat stress. *Livestock Science*, 206, 113–120. <https://doi.org/10.1016/j.livsci.2017.10.017>**

#### **Summary:**

Previous studies have examined the effects of water drip and snout cooling systems, as well as increased ventilation rates as regulators of heat stress of lactating sows. The objective of this study was to investigate the impact of three different water flow rates through a floor cooling pad on a sow's physiological response to summer heat stress. Ten multiparous sows were housed in individual farrowing crates equipped with cooling pads. Sows were randomly selected to receive a constant water flow based on four different treatments: control (0L/min), low (0.25L/min), medium (0.55L/min), or high (0.85L/min) for 100 minutes. Physiological parameters such as respiration rate, skin temperature, rectal temperature, and vaginal temperature were used as indicators of a sows response to heat stress. These parameters were measured prior to the addition of cooling pads, and throughout the duration of the trial. Water flow rates and temperatures were recorded to quantify heat removal. In general, respiration rates and skin, rectal, and vaginal temperatures were the lowest for sows in the high flow rate treatment and the highest in the control treatment. Overall calculated heat removal was the greatest for the high flow rate treatment. The results of this experiment show that cooling pads with low, medium, and high flow rates were able to effectively reduce sow respiration rate, as well as rectal, vaginal, and skin temperature overall, with the high flow rate treatments showing the greatest reduction in all of these parameters. The cooling pads removed excess heat from sows while maintaining relatively low water usage. Further areas of research could include studies that evaluate the optimum water flow rate for these cooling pads or the possible outcomes of a similar experiment conducted in winter months.

#### **Contribution:**

This article was included as part of my literature review as it investigates one way in which pork operations can reduce heat stress in sows. Though it doesn't look into sow feeding, drinking, or posturing behaviour in response to heat stress, it is still an important addition to my review, as it addresses some key ways in which we can monitor heat stress in sows that are more quantifiable than observing behaviour. It is one of many articles to evaluate floor cooling, and the results are consistent with other articles that I reviewed upon completing my topic and article selection.

**Jeon, J. H., Yeon, S. C., Choi, Y. H., Min, W., Kim, S., Kim, P. J., & Chang, H. H. (2006). Effects of chilled drinking water on the performance of lactating sows and their litters during high ambient temperatures under farm conditions. *Livestock Science*, 105(1–3), 86–93. <https://doi.org/10.1016/j.livsci.2006.04.035>**

**Summary:**

Previous studies have investigated the effects of cooling systems such as drip cooling, snout cooling, and cooled floors to mitigate heat stress in lactating sows. Each of these methods have their benefits and downfalls. The aim of this study was to evaluate the impact of chilled drinking water on the performance of lactating sows and their litters under heat stress. Thirty sows were divided into three treatment groups and given 10°, 15°, or 22° degree drinking water, with the first two treatment groups receiving chilled water (CW) and the third group serving as a control. Daily feed intake and water consumption were recorded, and litter weight and size were evaluated after cross-fostering and at weaning. Respiration rate and rectal temperature were measured three times daily throughout the study. Average weekly temperature in the farrowing rooms remained above 20°, and relative humidity was about 70% which means sows were exposed to heat-stressed conditions for the duration of the experiment. Sows in the CW groups ate and drank more when compared with the control group. No difference in litter size was observed among treatment groups, but estimated milk production and average weaning weight of piglets from CW groups were higher than the control treatment. Sows in the CW groups were also able to maintain lower respiration rates and rectal temperatures throughout the study. Results indicate that chilled drinking water increases feed intake, water consumption, milk production, and weaning weight and decreases rectal temperature and respiration rate. From these results, we can conclude that supplying sows with chilled drinking water may improve both piglet and sow performance during periods of heat stress. Further studies should be conducted to determine the optimal temperature to provide chilled drinking water in order to minimize the impact of heat stress.

**Contribution:**

This article was included as part of my literature review because it examines another way in which pork operations can reduce heat stress in sows. Similar to the previous article, it uses methods such as measuring respiration rate and rectal temperature, but it also includes an investigation of sow feed intake and the effects that feeding has on milk production, and consequently, the performance of piglets. Based on the comparison of this study to the previous study, I would determine chilled drinking water to be a more effective method of mitigating heat stress, but more research is required.

**Zhu, Y., Johnston, L. J., Reese, M. H., Buchanan, E. S., Tallaksen, J. E., Hilbrands, A. H., & Li, Y. Z. (2021). Effects of cooled floor pads combined with chilled drinking water on behaviour and performance of lactating sows under heat stress. *Journal of Animal Science*, 99(3), skab066. <https://doi.org/10.1093/jas/skab066>**

**Summary:**

Previous studies have investigated the effect of heat stress on factors such as sow farrowing behaviour, feed intake, weight, and litter performance, as well as strategies such as snout cooling, drip cooling, and floor cooling as methods of regulating heat stress in sows. The objective of this study was to investigate the combined effects of floor cooling and chilled drinking water on sow thermoregulatory behaviour and litter performance. Thirty sows were placed into either the cool room (cooled floor mats and drinking water) or the control room (no cooled floor mats or drinking water) throughout their stay in the farrowing room. Drinking behaviour, as well as posture changes were observed for each treatment. Rectal temperature, respiration rate, sow weight, and feed intake were recorded for each sow throughout the study period. Litter performance was also measured for each group. Heat stress was partially compensated in sows given access to both a cooled floor pad and chilled drinking water. Sows with access to these cooling mechanisms altered their feeding behaviour, consuming more food and showing a reduce in weight loss when compared to control sows. The sows in the cool room also displayed altered physiological responses to heat stress, with lower rectal temperatures and respiration rates than sows in the control room. However, sows in the cool room were not able to effectively downregulate their temperature to within their thermoneutral range. The cooling treatment did not change farrowing, drinking, or posturing behaviour of sows in this study. Previous studies have shown positive impacts of individual systems that regulate heat stress in sows, but more research is needed to investigate the combined effects of more than one cooling system. Future research could also investigate the optimal area and location of cooled floor pads to maximize the alleviation of heat stress in sows.

**Contribution:**

This study differs from articles I have previously studied as it focuses on practical ways to alleviate that heat stress and combines the two techniques investigated in the previous articles. The results of this study are recent and inconclusive, and further research is required into this topic to better understand the effects of heat stress in sows and how employing methods such as the ones described in this study can benefit the well-being of our livestock.

**de Oliveira Júnior, G. M., Ferreira, A. S., Oliveira, R. F. M., Silva, B. A. N., de Figueiredo, E. M., & Santos, M. (2011). Behaviour and performance of lactating sows housed in different types of farrowing rooms during summer. *Livestock Science*, 141(2–3), 194–201. <https://doi.org/10.1016/j.livsci.2011.06.001>**

### **Summary:**

Numerous articles have investigated the impact of heat stress on sow behaviour and welfare, as well as piglet performance. This article provided insight into the influence of different sow housing systems on heat stress. Thirty sows were divided into three treatment groups, with T1 housing sows in a conventional farrowing crate, T2 using a conventional farrowing crate with floor cooling, and T3 making use of a semi-outdoor farrowing pen. Physiological parameters such as rectal temperature, respiratory rate, and surface temperature were compared between groups. Behavioural parameters such as feeding and drinking as well as posture changes were also recorded. Due to the study being performed in a tropical region, sows spent the majority of the experiment under heat-stressed conditions, with sows in the T3 group exposed to higher overall temperatures (20.7-26.5°C) and T1 and T2 groups exposed to slightly lower temperatures ranging from 21-25.7°C. Sows with access to floor cooling (T2) had lower respiratory rates and surface temperatures than T1 and T3. Sows in T3 consumed the most feed and spent the most time at the drinker of all the treatment groups. High respiratory rate in the T1 and T3 sows indicates their difficulty adapting to the high ambient temperature and is further supported by their high surface temperatures. T3 sows likely consumed more water due to their increased feed consumption and their exposure to slightly higher ambient temperatures than the sows housed indoors. Overall, T2 sows maintained their body weight while consuming less food and were still able to maximize piglet performance. The results of the experiment indicate that cooled floors, as well as semi-outdoor farrowing rooms, are effective regulatory methods of heat stress in sows. Further research is required to generalize results, as the study was performed in tropical conditions.

### **Contribution:**

This article was included as part of my literature review, as it explores three different housing systems and their relationship with heat stress in lactating sows. It investigated multiple physiological and behavioural responses to heat stress in sows and provided possible explanations for the responses observed in each treatment system. This study was performed in Brazil, so the results obtained are specific to the tropical environment, but it can be used as a point of comparison for past, present, and future research regarding sow housing systems and temperature regulation.



**Devillers, N., & Farmer, C. (2008). Effects of a new housing system and temperature on sow behaviour during lactation. *Acta Agriculturae Scandinavica, Section A - Animal Science*, 58(1), 55–60. <https://doi.org/10.1080/09064700802127422>**

**Summary:**

Previous studies have investigated sow welfare in regards to housing systems. Results of these studies suggest that sows provided with access to a modified pen with a free area maintain their weight throughout lactation and produce healthier piglets. The objective of this study was to examine the effects of ambient temperature on sows in different housing systems. Seventy sows were placed into two treatment groups, with the thermoneutral group being exposed to an ambient temperature of 21°C, and the heat stress group exposed to 29°C. Half of the sows from each group were then assigned to a conventional farrowing crate and the other half to a modified farrowing pen system with a free back area. Posture, nursing interval, duration of nursing, productive and non-productive nursing, and the use of the back area were recorded for each temperature treatment. Sows housed in modified pens spent most of their time and performed most of their nursing in the free back area regardless of ambient temperature. Water use was higher in the group exposed to 29°C, and these sows spent the most time in the sitting posture and the least amount of time in the standing posture. Though a drop in feed intake and an increased weight loss were observed in the heat-stressed sows, these effects were reduced by the modified pen system. The nursing duration was shorter for heat-stressed sows, but they also showed a greater frequency of productive nursings. Results show that sows seemed to prefer the modified pen system regardless of temperature. This may be due to several factors such as feeder location, comfort, or access to water for drinking and floor cooling. Future research must be conducted to determine which of these factors make the free back area appealing to sows.

**Contribution:**

This article was included as part of my literature review as it includes a comparison of nursing and posturing behaviour in thermoneutral versus heat-stressed sows. Since this article also tested a sow's preference for two types of housing systems, distinctions between the two temperature groups were harder to determine. Nevertheless, this article is still a valuable component of my literature review as it supports findings described in previous articles regarding posturing, feeding, and drinking behaviours of sows.



## **Review articles:**

**Bjerg, B., Brandt, P., Pedersen, P., & Zhang, G. (2020). Sows' responses to increased heat load – A review. *Journal of Thermal Biology*, 94, 102758. <https://doi.org/10.1016/j.jtherbio.2020.102758>**

### **Summary:**

Many studies have investigated how increased air temperature affects the productivity, health, behaviour, reproduction, and physiology of sows. However, there is a gap in research regarding the effects of air humidity and velocity on the indicators of sow and piglet performance listed above. This review summarized 39 studies that have investigated some of the most common responses to heat stress in sows, and the current methods of regulating heat stress that are in place. This review discussed heat stress response in sows in terms of air temperature, velocity, and humidity, as well as the temperature of surrounding surfaces, and the opportunity for sows to moisten their skin. The review summarized knowledge of how air temperature affects a sow's physiology, such as respiration rate, rectal, vaginal, gastrointestinal, and skin temperatures. It also investigated sow performance in response to heat stress including changes in feed intake, milk yield, sow body weight loss during lactation, mortality, litter weight, and sow behaviour. The reviewed studies indicated that, on average, rectal and skin temperatures and sow respiration rate increased with increased air temperature. Statistically significant results were not produced for the relationship between air temperature and feed intake, milk yield, or sow body weight loss. A relationship between air temperature and sow mortality is not evident. Multiple studies investigating snout cooling as a method of controlling air velocity were included in the review, but produced results were not consistent enough to draw a conclusion. The effects of floor and drip cooling were also examined, but results showed substantial variation. A gap in the knowledge base remains for the relationship between air velocity and air temperature for mitigating heat stress in sows. Authors suggest further research into this relationship, as well as the investigation of air humidity as a contributing parameter.

### **Contribution:**

This review article summarized an understanding of a sow's response to increased ambient temperature, including physiology, production, and behaviour changes. It is relevant to my literature review as it explores multiple responses of sows to heat stress and the ways in which they have been studied. It highlighted the topics that have been well studied, as well as gaps in the knowledge base that require further research. This review is a valued resource, as it allowed me to find additional primary articles related to my topic.