

I organized my articles starting with both of my reviews at the beginning because they both provide a broad overview for what is to come with the following articles. I then added the articles that had a heavy focus on hormones next into the list as they influence behaviour and the last studies, I included at the end were those that focused heavily on observations. This is similar to how I wrote my summary.

Sammad, A., Umer, S., Shi, R., Zhu, H., Zhao, X., & Wang, Y. (2020). Dairy cow reproduction under the influence of heat stress. *Journal of Animal Physiology and Animal Nutrition*, 104(4), 978-986. <https://doi.org/10.1111/jpn.13257>.

### Summary

The goal of this review was to look at the effect of heat stress on the reproductive success and estrous behaviour of dairy cows to help farmers make informed choices. Estrous behaviour is a general term used to describe behaviours seen in female animals when they are sexually receptive and is often described as waiting to be mounted, standing while mounted and the time spent while being mounted. The method used to choose articles for this review was systematic and it contains sources from 1985 to 2019. Before this review, it was known that heat stress is a growing issue in the livestock industry. The temperature threshold for heat stress was also known, and it has also been well documented that heat stress causes a reduction in reproductive success. In this review it was discovered that the oocytes developing in a fetus can be affected by maternal heat stress, suggesting the threat starts before a female cow is sexually mature. Sammad et al. (2020) also discovered that heat stress can lead to changes in the oocyte, corpus luteum, and follicle, causing variations in hormone levels and ultimately a lack of estrous behaviour. It was also discovered that general effects of heat stress that include a compromised physical state, reduced feeding, and a negative energy balance can also affect the expression of estrous and reproductive success. This paper recommended several mitigation strategies including embryo transfer, hormone treatments, Artificial Timed Insemination, and cooling methods. The paper also mentions that repeated genetic selection for increased milk production has potentially caused a decrease in cows' resistance to heat and it instead suggests that farmers should be selecting for characteristics that will increase a cow's resistance to heat such as coat colour and density.

### Contribution

This article discusses, in-depth, the hormonal, physiological, and behavioural effects of heat stress as well as the effects on reproductive success. The sources in this review all appear to support one another. The review also provided several mitigation strategies that can be used by farmers to avoid the issues mentioned in this article which I can use in both my review as well as my project with the Alberta Farm Animal Care Association. This article provided important background information and I was also able to find important primary articles cited in this article to use in my review.

Penev, T., Dimov, D., Vasilev N., Mitev J., Miteva Tch., Marinov I., & Stojnov M. (2021). Influence of heat stress on reproductive performance in dairy cows and opportunities to reduce its effects – a review. *Agricultural Science and technology*, 13, 3-11.  
<https://doi.org/10.15547/ast.2021.01.001>.

### Summary

The goal of this review was to look at the current literature related to the effect of heat stress on reproductive success in dairy cows and was to reduce the effects. One thing that is often related to reproductive success in dairy cows is the expression of estrous behaviour which is seen in female animals when they are sexually receptive and is often described as female cows standing to be mounted, mounting other cows, sniffing, licking, or chin resting on the backs of other cows. The method used to select papers for this review was systematic. Before this review was done it was known that heat stress has large implications for reproductive success. It was also well observed that these effects were seen in hotter regions, but as global warming continues these consequences are being seen in “cooler” climates. This review begins by discussing the effect of heat stress on hormone levels. Heat stress has been observed to have a significant effect on the hormones that regulate the estrous cycle. Some hormones that decrease under heat stress include inhibin, estradiol, and progesterone. Heat stress can also affect the quality of follicles inside the ovary. Heat stress has been observed to decrease the dominance of the dominant follicle resulting in the lesser follicles being released during ovulation. This can cause issues in the developing fetus as the lesser follicles are of lower quality. Estrous expression is also observed to be decreased in heat stress cows. Conception rate and days open interval are two important sets of data for farmers and both are influenced by heat stress. Days open interval is much longer during warmer seasons and conception rates are also lower. Embryo loss is also observed in heat-stressed cows. Moving forward the authors suggest finding more methods to reduce the effects of heat stress.

### Contribution

This review is an important contribution to this field of research because it summarizes the information regarding heat stress, reproductive success in dairy cows and it offers several mitigation strategies that can be used. The findings presented in this review cover a range of studies that do or do not agree with each other. This review does support the findings presented in the other review that I discuss. This review is included in my paper because it provides a great overview of the literature, and it provides many mitigation strategies that I can include in my project with my community partner.

Alba, J., & Asdell, S.A. (1945). Estrous behaviour and hormones in the cow. *Journal of Comparative Psychology*, 39(2), 119-123. <https://doi.org/10.1037/h0060346>

### Summary

The objective of this study was to find the average dose of estrogen that was needed in ovariectomized cows to bring them into heat or induce estrous behaviour. Estrous behaviour is a type of behaviour exhibited by female animals when they are sexually receptive and in this study, it was described as female cows attempting to mount other female cows or being mounted. Before this study was done it was known that the estrous cycle lasts approximately 21 days with 14 hours spent in estrous. It was also known that the external vaginal region of the cow does not swell like that of some nonhuman primates. The cows were ovariectomized and received varying doses of estrogen. The cows were both observed and then later slaughtered, and their uteri examined. This study also included a freemartin cow that was genetically female but also had simple testes making it infertile. The freemartin had interesting differences in its behaviour before she was treated with estrogen. Before estrogen, she was able to detect other female cows in heat, but she did not exhibit common behaviours such as lowering her head, pushing, or movements often made by males while mounting. After being treated with estrogen she then exhibited behaviour like the other female cows. It was discovered that a dosage of 250 R.U. was able to produce 'coming in heat' symptoms while a dose of about 600 R.U. was needed to induce estrous. It was also found that continuous large doses of estrogen can cause the uterus to be intensely active but the length of estrous remained unchanged. The results of this study suggested that estrous behaviour can be divided into three categories that were described as the 'coming in' phase, the 'receptive' phase, and a phase where they are actively pursuing mates.

### Contribution

This study presented new information on the amount of estrogen needed to induce estrous in dairy cows and it also included a freemartin cow which provided interesting insights. The findings in this paper support those of other studies done on different animals but since it was a new field of research there were not many other cow studies to compare to at the time. This article is included in my review because it provides a detailed description of estrous behaviour and includes the study of a freemartin cow which is very interesting.

Hein, K.G., & Allrich, R.D. (1992). Influence of exogenous adrenocorticotrophic hormone on estrous behaviour in cattle. *Journal of Animal Science*, 70(1), 243-247.  
<https://doi.org/10.2527/1992.701243x>.

### Summary

The goal of this study was to look at the effect of adrenocorticotrophic hormone (ACTH) injections on estrous behaviour in cows. Estrous behaviour is a general term used to describe behaviour seen in female animals when they are sexually receptive and in this study, it is defined as attempted mounts by other cows as well as successful mounts. Before this study was completed, it was not fully known what hormones controlled estrous in dairy cows, but several connections had already been made. The mechanisms behind the estrous cycle were known to include estradiol, the luteinizing hormone, ACTH, cortisol, and progesterone. 20 female cows with intact reproductive organs and 12 ovariectomized female cows were used in this study. Both trials were then split into control groups and experimental groups with the experimental groups receiving treatment with ACTH and the controls receiving gelatin. After the treatments, the cows were then observed continuously starting at the time of injection and continued for 54 hours. Blood samples were also taken regularly. In this study, it was discovered that ACTH delayed but did not inhibit the release of estradiol. This suggested that ACTH affects the function of the reproductive system in dairy cows. It was also observed that ACTH decreased the duration of estrus in the intact dairy cows and increased levels of progesterone and cortisol. However, it was noted that cortisol could have increased due to the repeated handling of the animals. In the ovariectomized cows, treatment with ACTH inhibited estrous behaviour completely but this may have also been influenced by the increase in cortisol and progesterone. This study suggested that acute stresses, which cause the release of ACTH, can delay estrous and it was hypothesized that extreme stressors may be able to inhibit estrous altogether.

### Contribution

As previously mentioned, the full mechanism behind estrous behaviour in dairy cows was not known and this study helped to fill in some of the missing information, specifically the role that ACTH plays. This article helped to synthesize the theory that stress or extreme stress can affect the estrous cycle in cows. This study supports previous findings that stress hormones can delay or inhibit the estrous cycle altogether. This article is included in my review because it focuses on the hormones and internal mechanisms related to stress which I can then extend to heat stress specifically.

Roman-Ponce, H., Thatcher, W.W., & Wilcox, C.J. (1981). Hormonal interrelationships and physiological response of lactating dairy cows to a shade management system in a subtropical environment. *Theriogenology*, 16(2), 139-154. [https://doi.org/10.1016/0093-691X\(81\)90097-2](https://doi.org/10.1016/0093-691X(81)90097-2)

### Summary

The objective of this study was to analyze different physiological and plasma hormonal responses during the estrous cycle in female dairy cows exposed to shade management systems. During the estrous cycle, estrous behaviour is seen in female dairy cows which occurs when they are sexually receptive. Estrous behaviour is often described as mounting other cows, sniffing other cows, and chin resting on other cows. Before this study was done it was known that heat stress in dairy cows causes a decrease in both milk production and reproductive success. It is thought that heat stress can cause these symptoms because it decreases energy intake and affects metabolic and lactogenic hormones. 64 cows were used in this study, and they were randomly assigned to shade or no shade treatments. Temperatures were monitored daily during the study. Milk yield, body weight, respiration rate, rectal temperatures, frequency of mastitis, and conception rates were monitored regularly throughout the study. Subsamples of cows were also selected for monitoring hormone levels. Cows with no shade had higher respiration rates and rectal temperatures. Cows with no shade ate less food but drank much more water. Milk yields and reproductive success were higher in the cows with shade. Stress hormones, progesterone, and luteinizing hormone concentrations were higher in cows with no shade but the estradiol to progesterone ratios were lower. This evidence suggested regular estrous cycles occurring in heat-stressed cows but the decrease in food intake could have caused lower milk yields and reproductive success. The authors also suggested that changes in steroid concentrations could affect blood flow to the uterus. The authors suggested looking into the connection between catecholamines and reduced uterine blood flow as catecholamines have vasoconstrictive effects and increase concentration during stress.

### Contribution

This study is significant because it provides evidence that changes in steroid concentrations may affect uterine blood flow in dairy cows and therefore affect reproductive success. This study confirms findings seen in other studies but also helps to fill in the blanks that were unknown regarding the mechanism. Although this study does not investigate estrous behaviour specifically, it does focus on hormones that influence behaviour. I included this study in my review because it provides me with a deeper understanding of the proximate influences on behaviour so that I can describe what can't be seen through observations.

Schüller, L.K., Michaelis, I., & Heuwieser, W. (2017). Impact of heat stress on estrus expression and follicle size in estrus under field conditions in dairy cows. *Theriogenology*, *102*, 48-53. <https://doi.org/10.1016/j.theriogenology.2017.07.004>.

### Summary

The objective of this study was to investigate the effect of heat stress on the expression of estrous behaviour and the size of the follicle at the time of estrus. Estrous behaviour is seen in female animals when they are sexually receptive and in this study, it is described as female cows standing to be mounted, mounting other cows, sniffing, licking, or resting the chin on the backs of other cows. Before this study, it was known that heat stress affects estrous expression in dairy cows, but it was also known that heat stress can cause changes in endometrial function and the quality of the follicle. The barn used in this study was a commercial dairy barn that had a free-stall design with cement floors. 676 cows were used in this study. Images of the follicles were measured throughout the study and body condition and locomotion were scored using 5-point scales. Cows were observed for estrus with an automated system as well as by herd managers. Cows detected in estrus by the automated system were inseminated within 12 hours of detection and monitored for signs of pregnancy. Other data collected in this study includes mounting traces, estrous discharge, and colour of the discharge. Temperature at the study site was recorded hourly. As temperature increased, the conception rate was observed to have decreased. Heat stress was observed to have a significant effect on the frequency of mounting traces, estrous discharge, and colour of the discharge. Follicle size also decreased as the temperature at the study site increased. The authors suggested that more research is needed to better understand the mechanisms behind the varying levels of estradiol seen in cows experiencing heat stress as well as the effect of different temperature thresholds during the estrous cycle of hormone patterns.

### Contribution

This article advances knowledge in the field because it provides some of the first evidence that the intensity of estrous behaviour in dairy cows is related to the presence of a healthy follicle at the time of estrus. This article supports previous findings that follicle size and estrous behaviour decrease under heat stress. I am including this article in my review because it not only studies estrous behaviour under heat stress but also one of the mechanisms behind the reduction in heat stress under estrous behaviour. This study also used a large sample size suggesting the results are more accurate.

Her, H., Wolfenson, D., Flamenbaum, I., Folman, Y., Kaim, M., & Berman, A. (1988). Thermal productive and reproductive responses of high-yielding cows exposed to short-term cooling in summer. *Journal of Dairy Science*, 71(4), 1085-1092. [https://doi.org/10.3168/jds.S0022-0302\(88\)79656-3](https://doi.org/10.3168/jds.S0022-0302(88)79656-3).

### Summary

The goal of this study was to analyze the effect of short-term cooling on thermal responses, reproductive performance, and milk production in dairy cows. This study also observed estrous behaviour which is defined as behaviour seen in female animals when they are sexually receptive. Before this study, it was generally known that heat stress can affect the productivity of dairy cows. It was also known that heat stress can cause the failure of fertilization and early embryonic mortality, but it has been observed that cooling dairy cows for a while after insemination can improve fertility. There were 66 dairy cows studied in this experiment and they were randomly assigned to be in the cooled or non-cooled group. The cows were kept in an open barn with a concrete floor, and they also had access to an unshaded yard with shaded areas. The cows in the cooled group were cooled nine times a day, for ten days, and each cooling session lasted 30 minutes. Ambient temperature and relative humidity were measured continuously in the barn and rectal temperatures were also taken. Dairy production data was collected, and estrous behaviour was observed four times a day, but it was not described. The rise in body temperature seen in the noncooled cows was eliminated in the cooled cows. It was observed that there was a decline in milk production in the noncooled cows, but the overall pattern matched that of the cooled cows. More cooled cows were observed to be in standing estrous and noncooled cows had a higher prevalence of anestrus. These findings suggested that cooling can successfully decrease the body temperature of dairy cows, increase milk production, and improve the expression of estrous.

### Contribution

This article does not present many new findings in this topic of research, but it does provide further evidence for previous observations and theories. This article provided evidence that the use of cooling systems can reduce the effects of heat stress which often manifest as decreased milk production and expression of estrous behaviour. This article supports previous findings and any variations seen in the results between this study and others are contributed to the use of different methods. This article is included in my review because it supports previous findings in the literature and those included in my paper.

Akbar, J., Yusuf, M., Toleng, A.L., Masturi, & Sahiruddin (2021). Estrus expression of dairy cows after calving with and without using cooling system. *IOP Conference Series: Earth and Environmental Science*, 788, 012147. <https://doi.org/10.1088/1755-1315/788/1/012147>

### Summary

The overall goal of this study was to compare the expression of estrous in dairy cows treated with or without a cooling system to better understand estrous expression in postpartum cows. Estrous behaviour is described as behaviour seen when a female animal is sexually receptive and for cows, it is characterized by the action of mounting or being mounted by other cows. Before this study was done it was known that heat stress can both disrupt the estrous cycle and shorten it. It was also known that reduced expression of estrous can lead to fewer cows being inseminated and poorly timed artificial insemination. The number of animals used in this study was nine dairy cows with three of them being exposed to a cooling system and six of them not being exposed to a cooling system. The cooling system sprayed the cows ten times during the day and ten times during the night. The study had two parameters that included secondary signs of estrous such as state of the vulva, mating behaviour, and mucus secretions, and the second parameter was the duration of estrous. Expression of estrous was analyzed based on the frequency of the behaviours and duration of estrous was analyzed using a t-test. In this study, it was found that estrous behaviour was much clearer and more pronounced in cows that were cooled compared to those that were not and mucus secretion was also more intense in cows that were cooled. Cows with the cooling system also had a much longer duration of estrous. The results in this study suggest that the use of a cooling system can greatly improve the expression of secondary estrous. It also suggests that the use of cooling systems by farmers would improve the reproductive success of their cows.

### Contribution

This article presented information that highlighted the importance of husbandry methods for the management of heat stress and increasing reproductive success. This article supports the knowledge that heat stress can shorten the length of estrous as well as reduce the expression of estrous in dairy cows. This article also supported the observations that reduced estrous behaviour is likely due to increased lethargy under heat stress. This article is included in my review because it looked at the external signs of estrous that included both mounting behaviours as well as mucus excretions.



Rodtian, P., King, G., Subrod, S., & Pongpiachan, P. (1996). Oestrous behaviour of Holstein cows during cooler and hotter tropical seasons. *Animal Reproduction Science*, 45, 47-58. [https://doi.org/10.1016/S0378-4320\(96\)01576-X](https://doi.org/10.1016/S0378-4320(96)01576-X).

### Summary (Primary Article)

Before this study was conducted it was thought that cows would usually exhibit estrous behaviour for approximately 18 hours and it was also known that the type of housing, routine husbandry activities, transport, and temperature can place stress on cows which in turn can affect their behaviour. Estrous behaviour is a set of behaviours seen when a female is sexually receptive. The goal of this study was to provide information on the effect of heat stress so that better decisions can be made regarding genotype selection and the design of husbandry systems. The animals studied were Holstein cows with the sample number ranging from 30-40 in each group. The cows were watched continuously for 24 hours a day for 8 weeks during the cooler and hotter months in year one, and six weeks for each season in year two. Cows were also housed in different environments with the ground either being strictly cement or cement and dirt. Their milk progesterone levels were also analyzed to determine estrous cycles. Their behaviour was split into categories including sexually associated interactions (licking, sniffing, and chin pressing), times standing when mounted, and time spent standing while mounted. The temperature-humidity index and precipitation were also recorded during the experiment. In this study, it was observed that estrous behaviours decreased in frequency during the summer even when estrous was detected through the testing of milk. Estrous behaviour was also observed to be reduced in cows that lived strictly on cement. It was noted in this study that estrous behaviour duration was significantly shorter than the previously noted 18 hours. These findings support results seen in other experiments and provide additional proof against the idea that estrous behaviour lasts on average about 18 hours. They also suggested looking further into the AM: PM rule for Artificial Timed Inseminations.

### Contribution

This article does an excellent job of supporting previous literature on this topic regarding how heat stress and various husbandry methods can affect estrous behaviour in dairy cows. Although it does not present any discoveries it further supports evidence that can be used to improve dairy farming. It also supports getting rid of the idea that estrous lasts approximately 18 hours and instead suggests it is much shorter. This article is included in my review because it directly examines various aspects of estrous behaviour under heat stress but also investigates how different husbandry methods may affect estrous behaviour.

Pennington, J.A., Albright, J.L., Diekman, M.A., & Callahan, C.J. (1985). Sexual activity of Holstein cows: Seasonal effects. *Journal of Dairy Science*, 68(11), 3023-3030.  
[https://doi.org/10.3168/jds.S0022-0302\(85\)81197-8](https://doi.org/10.3168/jds.S0022-0302(85)81197-8).

### Summary

The goal of this study was to compare the effect of varying temperatures on the timing, patterns, and expression of estrous behaviour in female dairy cows. Estrous behaviour is seen in female animals when they are sexually receptive and in this study, it was described as mounting other cows, chin resting, sniffing, licking, and rubbing. Before this study was done it was known that almost 50% of estrous periods are missed by dairy farmers which leads to longer interbirth intervals and a decrease in profits. It was also known that hot weather can affect estrous behaviour, but some studies also showed that cows kept in close quarters were more likely to express estrous behaviour during the night. The temperature was recorded daily at the study site and the experiment took place during the hottest and coldest times of the year. 73 cows were used in this study, and they were housed in free-stall housing with a concrete drylot. Milk samples were collected every day and assayed for progesterone. Cows were injected with progesterone to balance all their reproductive cycles and observations began 12 hours after injection and continued until six hours after no cow was seen mounting. The results of this study suggested that cows in hot weather expressed more simple estrous behaviour such as chin resting or licking rather than mounting. It was also observed that cows in hot weather expressed more estrous behaviour at night rather than during the hottest parts of the day. Cows were also seen to exhibit mounting behaviours in areas that provided the best footing. The authors suggested that more research needs to be done to better understand why heat-stressed cows express more simple estrous behaviours rather than mounting as there may have been a mechanism not studied in this paper.

### Contribution

This article advances knowledge in this field of research because it shows evidence that heat stress can affect the circadian profile of mounting behaviour which can help explain why some farmers miss estrous periods. This article contradicts previous findings that heat stress cows exhibit reduced estrous behaviour and instead they exhibit smaller behaviours rather than mounting behaviours. This article is included in my review because of the discovery of increased activity during the night rather than the day in heat-stressed cows in new information I had not yet come across in other studies.