

Organization

My work is split into three sections, 1) how heat stress affects cattle and feeding behaviour overall, 2) how shifting dietary parameters affect feeding behaviour in heat stressed cows and 3) how different levels of heat stress affect feeding behaviour. Within each category papers are organized chronologically All to answer the question how does heat stress affect cattle feeding behaviour.

1) Ominski, K. H., Kennedy, A. D., Wittenberg, K. M., & Moshtaghi Nia, S. A. (2002). Physiological and production responses to feeding schedule in lactating dairy cows exposed to short-term, moderate heat stress. *Journal of Dairy Science*, 85(4), 730–737.

[https://doi.org/10.3168/jds.S0022-0302\(02\)74130-1](https://doi.org/10.3168/jds.S0022-0302(02)74130-1)

Summary

This article attempted to characterize the effect of short term, moderate heat stress on cows and how changes in feeding behaviour, specifically time of feeding can either increase or decrease this. Ominski et al. (2002) defined heat stress with measurements of vaginal temp (°C), respiration rate (breaths/min) and temperature heat index. Feeding behaviour was kept as constant as possible with the only variable changing being the time at which the cattle fed switched from morning to night. Other variables used to measure feeding behaviour were dry matter intake (kg/d) and milk yield (kg/d). Previous studies have identified a negative correlation between heat stress and feeding behaviour but this study measures the effects of short term moderate heat stress and the effects feeding schedule may have on this. This study uniquely focussed on temperate climates as opposed to previous studies which focussed more on subtropical climates. This serves to answer the question, how does heat stress affect cattle dry matter intake and milk yield in temperate climates? The experiment was conducted assigning 8 mature holstein cows to one of two feeding regimens in which one group was fed in the morning hours and the other at night. The nutrient profile for both groups was kept constant and other parameters such as the temperature humidity index, respiratory rate, and vaginal temperature were constantly measured. The study found that short term, moderate heat stress adversely affects feeding and production but shifting feeding times from morning to night offered no improvement in terms of reducing stress. This study is significant because it suggests that cows in temperate climates are at risk of the adverse effects of heat stress even if only experienced in the short term. In future studies, researchers could explore other nutritional strategies to try and solve the problem.

Contribution

This article provides new insight into how short term, moderate heat stress can affect the feeding and production of cows in temperate climates. This article supports previous research in that it has experimentally found a negative correlation between moderate heat stress and feeding and

production but offered new information on temperate climates. This article is included in my literature review because it shows the effects of heat stress on feeding behaviour.

West, J. W. (2003). Effects of Heat-Stress on Production in Dairy Cattle. *Journal of Dairy Science*, 86(6), 2131–2144. [https://doi.org/10.3168/jds.S0022-0302\(03\)73803-X](https://doi.org/10.3168/jds.S0022-0302(03)73803-X)

Summary

This article reviews research that discusses the environmental conditions dairy cattle are exposed to, the effect these conditions have on heat stress and management options available to producers. The article focuses on the physiological responses of heat stress such as changes in blood hormones, acid-base chemistry, digestive systems and body temperature and the subsequent effects on feed intake and milk production of Holstein, Jersey and Brown cattle in humid subtropical environments of the southern United States in summer months (June to September). The review was conducted systematically. Previous studies have found negative correlations between temperature humidity index and dry matter intake for cattle as well as a positive correlation between body temperature production and metabolic processes and feed intake. These findings indicate that it is critical to maintain an optimal temperature (-0.5°C to 20°C) for cattle to increase feed intake and milk productivity. The article suggests ways to maintain this temperature such as shading which can reduce total heat load 30%-50% and increase milk yield by 9%, evaporative cooling systems for dairy and dry cows which reduces body temperature by up to 1°C and increased milk yield by up to 19%, nutritional selection which shows how different diets can alter heat production as well as genetic selection where black cows were up to 58% better at reflecting heat. All four of these methods have proven effective in reducing heat stress and increasing feed intake and milk production. Shading has proven the most economically effective method of cooling and a combination of these methods may provide the greatest results (highest increase in feed intake and milk production), but at the highest economical costs. Future studies may entail studying the effectiveness of new cooling technologies such as tunneling ventilation and further studying daily cation-anion difference, specifically K and Na supplementation.

Contribution

This article serves to compile existing information about environmental conditions cattle are exposed to and the effects they have on heat stress and suggests methods for producers to deal with this heat stress in an effective and economical manner. This article builds off of previous findings to find the best ways to mitigate heat strain on cattle. I included this article in my review because it explains the effects of heat stress on cattle and quantitatively describes how it reduces feed intake. Furthermore, my literature review is meant for producers and providing effective ways to reduce heat stress is beneficial.

Salem, M., & Bouraoui, R. (2010). Heat Stress in Tunisia: Effects on dairy cows and potential means. *South African Journal of Animal Science*, 39. <https://doi.org/10.4314/sajas.v39i1.61164>

Summary

This article attempted to characterize heat stress conditions that cows are exposed to in Tunisia (tropical, arid and subtropical climate zones) and their effects on the performance of lactating cows. Salem & Bouraoui (2010) defined heat stress with measurements of temperature humidity index gathered from 24 major weather stations over that past 10 years across Tunisia. Feeding behaviour in this case can be defined by the milk production (kg/d) of these cows as milk production is indicative of the quality of feeding behaviour. Quality in this case refers to cows receiving the correct amount of dry matter intake, dietary fiber and nutrition. Previous studies have found a positive correlation between temperature humidity index and heat stress but this study identifies the negative correlation between heat stress and milk production and thus feeding behaviour. This helps to answer the question, what is the effect of heat stress on feeding behaviour in cattle. This study was conducted by gathering average, minimum, and maximum temperature humidity index from 24 major weather stations in Tunisia over the past 10 years and comparing it to 6813 available records on milk production from 157 dairy farms from different climate zones. The study found a negative correlation between milk production and heat stress in cows across Tunisia. This suggests that cows in arid, subtropical and tropical environments all experience heat stress in a similar manner and that it has an adverse effect on feeding behaviour. The study goes on to suggest methods to reduce heat stress such as dietary fiber adjustments and protected fat supplementation. This study is significant because it solidified the fact that heat stress is the same across different climates, building a foundation for future studies. In future studies, researchers could explore methods of supplementation and feeding strategies to reduce the negative effects of heat stress.

Contribution

This article provides insight on the relationship between heat stress and milk production and how this can affect feeding behaviour. This article uniquely uses a very large sample size to support its conclusions. This article supports previous research that has found a correlation between heat stress and milk production but expands the research over a wider climate range. This article is included in my literature review because it shows the effects of heat stress on milk production and thus feeding behaviour.

Najar T., Rejeb M., Rad M.B.M. (2011) Modelling of the effects of heat stress on some feeding behaviour and physiological parameters in cows. In: Sauvant D., Van Milgen J., Faverdin P., Friggens N. (Eds.), *Modelling nutrient digestion and utilisation in farm animals* (pp. 130-136). Wageningen Academic Publishers, Wageningen. https://doi.org/10.3920/978-90-8686-712-7_14

Summary

This article reviews research that discusses the effects of heat stress on some feeding behaviour and other physiological parameters in cows. The article focuses on determining the correlation between indicators of heat stress such as respiratory rate (breaths/min), temperature humidity index, relative humidity (%), temperature (°C) and rectal temperature (°C), and feeding behaviour indicators such as dry matter intake (kg/d) and milk yield (kg/d). The review is a meta analysis conducted using the results from 96 papers with 370 treatments. Previous studies have found a positive correlation between respiratory rate and ambient temperature of 2.4 point per °C, this suggests that the cows are under higher levels of heat stress at higher ambient temperatures. Previous articles have also found a negative correlation between heat stress conditions and dry matter intake, suggesting that cows under higher heat stress will have greatly decreased dry matter intake. This article determined the correlation between the residual of respiratory rate - temperature humidity index and milk yield to be more sensitive at higher temperature. Through the combination of these results we can conclude that dairy cows would display a decreased milk yield in high heat stress environments, specifically in environments with a temperature humidity index that exceeds 90 units. A decreased milk yield is indicative of the negative effects of heat stress on feed intake, metabolism and physiology of the dairy cattle. Thus, this article concludes that high heat stress environments have a negative effect on feeding behaviour by causing milk yield, and dry matter intake to decrease. In future studies, researchers could measure the effects of heat stress on other feeding behaviours such as feed sorting.

Contribution

This article serves to compile existing information about heat stress conditions cattle are exposed to and the effects they feeding behaviour and other physiological parameters. This article builds off of previous findings to come to find correlations between high heat stress and feed intake, metabolism and physiology of the dairy cattle. I included this article in my review because it explains the effects of heat stress on cattle feeding behaviour and quantitatively describes how it reduces feed intake.

2)

Arieli, A., Rubinstein, A., Moallem, U., Aharoni, Y., & Halachmi, I. (2004). The effect of fiber characteristics on thermoregulatory responses and feeding behavior of heat stressed cows. *International Thermal Physiology Symposium: Physiology and Pharmacology of Temperature Regulation*, 29(7), 749–751. <https://doi.org/10.1016/j.jtherbio.2004.08.050>

Summary

This article investigated the effects of replacing forage fiber with non forage fiber, namely wheat hulls with soy hulls, on feeding parameters in heat stressed cows. Arieli et al. (2004) measured feeding behaviour parameters by measuring changes in eating rate (kg/min), feed intake (kg DM/meal), meals/ day, meal duration (min), eating phase (min/ day), day feeding time (%), and night feeding time (%). Heat stress was characterized by measurements of rectal temperature (°C), heart rate (beats/ min), oxygen consumption (VO₂) and heat production (kj/kg). Previously, researchers conducted studies about how what physiological changes heat stresses induces in cattle but this study measures the effect of different diets on feeding behaviour in heat stressed cows, serving to answer the question, how does a different diet change feeding behaviour? The experiment was conducted by dividing 40 cows into two equal groups and subjecting them to the same daily treatment including diets with the same nutrition concentration with the 2kg of wheat hulls in a control treatment being replaced with 2kg of soy hulls in the experimental group. The study found that daily feed intake (22.6kg of DM/day), mean heart rate, and mean heat production were similar in both the control and experimental groups. The study also found that eating rate was 10% faster and meal duration was 20% shorter in the experimental soy hull group of cows. This suggests that shifting a diet to non forage fiber such as soy hulls allows cows to consume their food faster which reduces feeding costs and can act as a thermoregulatory means. The study was significant as it found a link between implementing non forage diets and reducing heat stress in cattle. In future studies researchers could observe the effects of other non forage fibers such as oat hulls, or cottonseed hulls.

Contribution

This article provides new insight into how changing dietary parameters may affect feeding behaviour, specifically in heat stressed cows. This article supports previous research in that it has experimentally discovered a link between changing diets to non forage fibers and shifts in feeding behaviour which lead to reduced heat stress. The article was included in my literature review because it clearly shows the effects of diet on feeding behaviour and how this is different in heat stressed cows which helps to pinpoint the effects of heat stress on the feeding behaviour of cattle.

Shwartz, G., Rhoads, M. L., VanBaale, M. J., Rhoads, R. P., & Baumgard, L. H. (2009). Effects of a supplemental yeast culture on heat-stressed lactating Holstein cows. *Journal of Dairy Science*, 92(3), 935–942. <https://doi.org/10.3168/jds.2008-1496>

Summary

This article investigated the effects of supplementing yeast culture (*Saccharomyces cerevisiae*) on heat stressed lactating Holstein cows. Heat stress is known to cause acidosis and yeast has been hypothesized to reduce it. Shwartz et al. (2009) measured heat stress through measurements of respiration rate (breaths/min), surface temperature on the shoulder, rump and tail-head (°C), and body temperature obtained through rectal temperature (°C). Feeding parameters were measured from milk yield (kg/d) and feeding efficiency. Previous studies have determined the effects of differing diets on the feeding behaviour in heat stressed cows but this study expands on this topic by measuring the effects of yeast supplementation. This study measures the effect of a yeast supplemented diet on feeding behaviour in heat stressed cows, serving to answer the question, how does a yeast supplemented diet change feeding behaviour and reduce heat stress? The experiment was conducted by randomly dividing 23 Holstein cows into either a control group or a YC group that was given a yeast supplemented diet. Both groups were first subjected to mild conditions (18°C and 20% humidity) for 8 days and then simulated heat stress conditions (29.4-37.8°C and 20% humidity) for another 20 days. Grain and fat supplementation increases acidosis in cows and this study was significant because it found that yeast supplementation is not a better substitute as previously hypothesized. The study found that although cows fed the yeast diet had a decrease in rectal temperature, indicative of better heat stress tolerance, feeding the yeast culture did not have a significant impact on reducing the negative effects of heat stress. This suggests that yeast supplementation does not work to reduce heat stress. In future studies, researchers could increase the trial length or use different supplements.

Contribution

This article provides new insight into how changing dietary parameters may affect feeding behaviour, specifically to reduce heat stress in cows. This article supports previous research in that it has experimentally discovered a link between heat stress and dry matter intake and milk yield. The article was included in my literature review because it clearly shows the effects of a yeast supplemented diet on feeding behaviour and how this may or may not reduce heat stress. This helps to determine the effects of heat stress on the feeding behaviour of cattle.

Kanjanapruthipong, J., Junlapho, W., & Karnjanasirm, K. (2015). Feeding and lying behavior of heat-stressed early lactation cows fed low fiber diets containing roughage and nonforage fiber sources. *Journal of Dairy Science*, 98(2), 1110–1118. <https://doi.org/10.3168/jds.2014-8154>

Summary

This article investigated the effects of low fiber diets containing non forage fibers, namely rice straw and soy hulls/ cassava residues, on feeding and lying parameters in heat stressed cows. Kanjanapruthipong et al. (2015) characterized feeding behaviour by meal frequency (frequency/d), meal length (min/meal), meal time (min/d), meal size (dry matter/meal), lying frequency (frequency/d) and lying duration (h/d). The level of heat stress was measured by rectal temperature (°C), body weight change (kg/d), dry matter intake (kg/d), and temperature humidity index. Previously, researchers conducted studies about the effects of different diets on feeding behaviour in heat stressed cows but this study expands this topic by measuring the effects of more diets and compares the results at differing levels of heat stress. This answers the question, how does a different diet change feeding behaviour in heat stressed cows? The experiment was conducted by dividing 30 crossbred cows into 10 groups of 3 where each cow in each group was subjected to a different treatment. The only variable that changed in the treatments was fiber source. The study found that cows fed non forage fibers (soy hulls and cassava residues) had an increased dry matter intake during the day by increasing meal size and length and lying duration ($P < 0.01$). The study also found that as temperature heat index increased the duration of feeding decreased. This suggests that cows fed non forage fibers may display more optimal feeding and lying behaviour when exposed to severely heat stressed conditions. The study was significant because it expanded existing research on diet manipulation by testing the effects of multiple non forage diets and the effects of differing levels of heat stress on feeding behaviour. In future studies, researchers could make different changes to dietary parameters.

Contribution

This article provides new insight into how changing dietary parameters may affect feeding behaviour in heat stressed cows and how different levels of heat stress affect feeding behaviour. This article supports previous research in that it has experimentally discovered a link between changing diets to non forage fibers and shifts in feeding behaviour which lead to reduced heat stress. The article was included in my literature review because it clearly shows the effects of diet on feeding behaviour and how differing levels of heat stress affect feeding behaviour in cows.

3)

Miller-Cushon, E. K., Dayton, A. M., Horvath, K. C., Monteiro, A. P. A., Weng, X., & Tao, S. (2019). Effects of acute and chronic heat stress on feed sorting behaviour of lactating dairy cows. *Animal*, 13(9), 2044–2051. <https://doi.org/10.1017/S1751731118003762>

Summary

This article investigated the effects of acute and chronic heat stress on feed sorting behaviour. Miller-Cushon et al. (2019) defines heat stress with measurements of barn air temperature (°C), relative humidity (g/kg), temperature humidity index, respiration rate (breaths/min) and vaginal temperature (°C). Acute heat stress was defined as cows in heat stress conditions for more than 10 days and chronic heat stress was defined as cows in heat stress conditions for more than 62 days. The feed sorting behaviour was characterized by measuring individual feed intake. This is the amount of particles offered and refused taking into account 4 particle sizes, large (>19mm), medium (19mm>x>8mm), small (8mm>x>1.18) and fine (<1.18). Previously, researchers measured feeding behaviour with dry matter intake but this study explores a different measure of feeding behaviour, feed sorting. This answers the question, how does heat stress affect feeding sorting behaviour? The experiment was conducted by randomly dividing 32 cows into two groups, a control cooled group and a heat stressed group, and measuring their heat stress parameters as well as feed sorting parameters. The only variable that differed between the two treatments was the exposure to heat stress. The study found that during both acute and chronic heat stress, cows preferentially sorted for the long particle fraction more than the control group cows. This suggests that cows may change their feeding behaviour during heat stress to maintain nutrient intake that would otherwise be lowered during heat stress. The study was significant because it found a change in feeding behaviour that points to a correlation between heat stress and feed sorting for longer, more nutrient dense food particles. In future studies, we could expand this research to learn how feed sorting may change when cows are given differing diets.

Contribution

The article provides new insight on how heat stress may affect a less studied aspect of cattle feeding behaviour, feed sorting. This article supports and builds off of previous research that has found a correlation between heat stress and changes in feeding behaviour in cattle. The article was included in my literature review because it clearly shows the effects of heat stress on feeding behaviour, specifically feed sorting, and how differing levels of heat stress affect this feeding behaviour in cows. This helps to answer the question, how does heat stress affect cattle feeding behaviour?

Corazzin, M., Romanzin, A., Foletto, V., Fabro, C., da Borso, F., Baldini, M., Bovolenta, S., & Piasentier, E. (2021). Heat stress and feeding behaviour of dairy cows in late lactation. *Italian Journal of Animal Science*, 20, 600–610. <https://doi.org/10.1080/1828051X.2021.1903818>

Summary

This article investigated the effects of mild heat stress on feeding behaviour of Holstein dairy cows in late lactation. Corazzin et al. (2021) defined heat stress through measurements of rectal temperature (°C), and THI. A mild heat stress was maintained by keeping the temperature humidity index between 72 and 78 and monitoring rectal temperature. Feeding behaviour was defined through measurements of rumination time (min/d), eating time (min/d), rumination chews (no./d), eating chews (no./d), boluses (no./d) and rumination intensity (no. chews/bolus). Previous studies have come to the conclusion that heat stress is negatively associated with milk production and temperature humidity index. This study expands on this by focussing on other feeding behaviors serving to answer the question, how does heat stress affect feeding behaviour? This experiment was conducted by placing 8 cows in a barn with controlled temperature and humidity that was measured every second. The cows were first exposed to a control environment for 7 days, then under heat stress by increasing the temperature humidity index for 7 days and then in a cooling environment by decreasing the temperature humidity index for 7 days. The study found that mild heat stress (72 < temperature humidity index < 78) affected the feeding behaviour of Holstein dairy cows by reducing the time and number of chews of rumination and the number of boluses. This study is significant because most studies were done with high heat stress but this suggests that even mild heat stress can have adverse effects on feeding behaviour. This study was unique as it measured time and number of chews as well as number of boluses to characterize feeding behaviour. In future studies, researchers may want to use a greater sample size and or longer experimental results to see if it affects the results.

Contribution

This article provides new insight into how heat stress may affect unique parameters of feeding behaviour. This article supports previous research in that it has experimentally discovered a link between temperature heat index and heat stress, dry matter intake and milk yield. The article was included in my literature review because it clearly shows the effects of heat stress on feeding behaviour. This helps answer my research question by determining the effects of heat stress on the feeding behaviour of cattle.

Skonieski, F. R., Souza, E. R., Gregolin, L. C. B., Fluck, A. C., Costa, O. A. D., Destri, J., & Neto, A. P. (2021). Physiological response to heat stress and ingestive behavior of lactating Jersey cows in silvopasture and conventional pasture grazing systems in a Brazilian subtropical climate zone. *Tropical Animal Health and Production*, 53(2).
<https://doi.org/10.1007/s11250-021-02648-9>

Summary

This article investigated the physiological response to heat stress of lactating Jersey cows in silvopasture and conventional pasture grazing systems. Skonieski et al. (2021) aimed to characterize heat stress through measurements such as respiratory rate (breaths/min), heart rate (beats/min) and rectal temperature (°C) and determine how heat stress would affect the grazing systems of lactating Jersey cows. These systems include resting time (min), rumination time (min), water intake (L/100kg), and water intake frequency (visits). Previously, researchers conducted studies about the effect of different diets on the response to heat stress but this study measures the effects of changing the level of heat stress on feeding behavior, serving to answer the question, how does heat stress change feeding behaviour? The experiment was conducted by dividing an experimental area into 12 sections, 6 sections for silvopasture grazing and 6 for conventional grazing and rotating the cows through each section and measuring heat stress and grazing parameters. The studies found that the silvopasture reduces heat stress which is shown by lower respiratory rates and lower rectal temperatures in cows that grazed in those areas. The studies also found that silvopasture cows presented higher grazing times, lower water intake and less standing behaviour for rumination and resting. These findings may suggest that the greater thermal stress accumulation in conventional pasture cows decreased their digestive activity and forced them to spend more time in unfavourable positions which may lower their milk productivity. The study was significant as it discovered a negative correlation between heat stress and grazing behaviour in lactating Jersey cows. In future studies, researchers could observe how different types of trees in the silvo pastures affect heat stress. It may be useful to design a similar experiment with a greater sample size for more conclusive results.

Contribution

This article provides new insight into how heat stress may affect ingestive behaviours of cows specifically in a subtropical climate zone with an elevated temperature humidity index. This article supports previous research in that it has experimentally discovered a negative correlation between heat stress and feeding behaviours in dairy cows. This article was included in my literature review because it clearly and effectively helps to determine the effects of heat stress on the feeding behaviour of dairy cows.