



Original Research Paper

Impact of Agro-Horticultural Vegetation Buffers on Microclimate Regulation and Welfare in Livestock Environments

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Key Words

Abstract

Dairy cattle, Temperature–humidity index (THI), Physiological responses, Behavioral time budget, Nature-based solutions, Climate-resilient livestock housing.

Agro-horticultural vegetation buffers have been discovered to be a promising nature-based intervention in moderating thermal stress, and livestock production systems to improve livestock welfare. This paper has discussed the microclimatic and welfare advantages of planned multi-species tree-shrub buffers with fruits created strategically around open sided dairy cattle sheds in a sub-tropical environment. The critical environmental parameters were monitored during a 12-month monitoring period in sheds with vegetation buffers (VB) and with control sheds without them (CT) measuring the air temperature, relative humidity, black globe temperature, wind, and temperature humidity index (THI). At the same time physiological indicators (rectal temperature, respiration rate, skin temperature) was considered, behavioural time budgets (lying, feeding, ruminating, shade-seeking, agonistic interactions) as well as simple performance characteristics were assessed in 60 crossbred dairy cows. The findings indicated that VB sheds offered superior and steady microclimate atmosphere with a lower afternoon air temperature of 1.52.8 C and THI of 36 without a sharp difference in radiation burden and a controlled wind speed in comparison to CT. In hot climates, cows in VB were much less affected by heat stress as shown by a reduction in respiration rate and skin temperature, increased lying and ruminating time, and lesser discomfort behaviour. There was also the presence of slight gains in milk production and feed consumption in hot months of summer. In general, the results show that agro-horticultural vegetation buffer is indeed efficient to control near-animal microclimate, alleviate heat stress, and enhance superior behavioural welfare as well as provide ecological co-benefits, such as fruit and biomass production. Such results oppose the reason why vegetation buffers are an effective, inexpensive, and climatically sustainable approach to enhancing livestock housing conditions in subtropical areas.

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Introduction

Subtropical regions are exposed to a higher risk of thermal stresses in their livestock production systems as the global temperatures keep on increasing and the heat waves are becoming frequent under climate change (Calvin et al., 2023; Cheng et al., 2022; Saranya et al., 2020). The resultant increase in heat load at the shed level usually surpasses thermoregulation, intake of feed, and general wellbeing physiological comfort leading to health inhibition in dairy cattle (Dovolou et al., 2023; Frigeri et al., 2023; Senthil et al., 2021). Long-term heat stress has been shown to cause a decline in the milk production level, poor reproductive performance, and greater metabolic burden of dairy systems all over the globe (Dovolou et al., 2023; Fabbri et al., 2020; Frigeri et al., 2023; Janaki Sathya & Geetha, 2011). These predicaments highlight the fact that animals need immediate climate-adaptive livestock housing solutions that will be put in lessening the adverse consequences of environmental heat load on livestock welfare and performance.

Ecological solutions have become popular as effective solutions to better microclimate conditions in the area of livestock facilities. Agro-horticultural vegetation buffers, also known as a set of trees, shrubs, and fruit bearing species, provides several cooling abilities, such as, shading, evapotranspirative cooling, and cutback on solar radiation and turbulence of winds (Rasool et al., 2021; Singh et al., 2017). Research in silvopastoral systems and

agroforestry systems indicates that the vegetation structures have the ability to substantially stabilise near-animal thermal conditions and enhance behavioural comfort, however, no systematic studies have been conducted on this topic within the controlled or semi-controlled dairy housing systems (Brouillet & Sultan, 2023; Del Prado et al., 2023). Although vegetative shading system has benefits on ecology, the studies that evaluate the annual thermal value and welfare implications of vegetative systems in the real-life farm environment are limited.

In order to address this research gap, the current study analyses how the trend of multi-species agro-horticultural vegetation buffers located around the open-sided dairy cattle sheds affect the following key variables of microclimate variables, including air temperature, relative humidity, black globe temperature, wind speed, and temperature humidity index (THI). Besides parameters of the environments, the research focuses on physiological aspects of heat stress such as rectal temperature, respiration rate, and skin temperature, as well as behaviour time stocks, and fundamental productive performance. This study offers a thorough evaluation of the mitigation of thermal effects when vegetation and control sheds were studied at 12 months in the subtropical climatic conditions.

In addition, mixed-effects models are utilised in order to measure seasonal and diurnal variation but considering repetitive measures with individual differences among cows (Cheng et al., 2022; Veerappan & Arvinth, 2023; Tan &

Knight, 2018). The strength of this approach of analysis is that it facilitates the strength of inference on the impacts of treatments and improves understanding on the mechanism of vegetation buffers of livestock settings to act as cooling systems like ecological cooling systems. The ideal conceptual plan of vegetation–

microclimate–welfare relationships in the research is shown in Figure 1. Comprehensively, it is hoped that the results will help in the design of livestock houses resistant to climatic changes that can better the welfare of milking cows, consistent production, and the ease of farm aesthetic appearance.

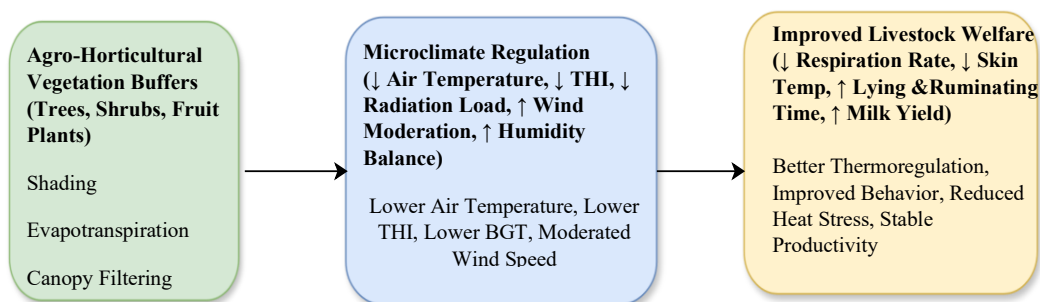


Figure 1: Conceptual Framework of Vegetation Buffer Effects on Microclimate and Livestock Welfare

Literature Review

Agro-horticultural and agro forestry systems have long been known to be able to control microclimate based on shading, canopy buffering, evapotranspiration, and changes in wind flow patterns. Studies of both silvopastoral and tree-integrated livestock systems indicate that vegetation cover could greatly decrease the ambient temperature, radiant heat load and solar exposure around animal habitats, thus increasing comfort and alleviating heat stress (Brouillet & Sultan, 2023; Cheng et al., 2022; Dovolou et al., 2023). Behavioural advantages of natural shading have also been recorded including more lying time, less panting and less shade seeking during hot seasons. These results demonstrate the possibilities of vegetation based cooling systems to increase the welfare of livestock, but the majority of the current literature has been performed at grazing or open-field conditions

but the microclimate conditions are more different in structured housing conditions. An overview of similar previous researches has been presented in (Table 1).

Vegetation buffers in strategic locations surrounding livestock sheds enhance the concept of microclimate modification using the biological cooling method and incorporated built infrastructure. These buffers perform the functions of natural shields that minimise the incoming solar radiation, cooler the black globe, enhance the airflow caused by the canopy, and provide cooling effects locally near the animal shelters. It has also been proved that in some climatic conditions, vegetative shading is more useful in minimising thermal load as compared to artificial structures (Cheng et al., 2022; Fabbri et al., 2020; Mazzoni et al., 2022; Yan et al., 2022). Moreover, vegetation buffers can have supplementary ecosystem makes such as

retaining soil water, accumulating carbon, and increasing biodiversity. Nevertheless, their systematic appraisals of their annual performance in dairy housing systems are wanting despite their perceived ecological and welfare benefits.

Recent studies of heat stress mitigation have focused on the role of analysing physiological responses involving changes in respiration rate, rectal temperature, and skin temperature and behavioural changes such as feeding, lying, ruminating, agonistic act (Dovolou et al., 2023; Frigeri et al., 2023; Rasool et al., 2021; Ramya et al., 2018). These are thermoregulatory sensitive indicators that can be used to show a quantifiable effect of the level of thermal comfort or stress in cattle. Although it has been studied on the synergistic action of shade, ventilation and cooling systems, there is a paucity of research investigating the isolated action of agro-horticultural vegetation buffers on specific welfare parameters. This highlights the necessity of finer analysis, basing on

international data to measure the extent to which vegetation-mediated microclimate changes can be converted into better welfare outcomes.

To manage such research gaps, the emerging trend in livestock environment research is the use of more sophisticated statistical models, especially mixed-effects models to support repeated measures of physiological and behavioural traits including the individual variation in animals, and time-dependent in climate variations. These are robust models that can be able to assess the role of vegetation buffers in diurnal temperatures and seasonal shift variation that can further understand the functionality of vegetation buffers as climate adaptive strategies of housing. The combination of vegetation buffers and these forms of analytical approach is an attractive research area on which sustainable livestock management systems can be developed to help improve welfare, stabilise productivity, and enhance resilience to increasing thermal stress.

Table 1: Summary of Key Studies on Heat Stress Mitigation and Vegetation-Based Microclimate Regulation in Livestock Systems

Study	Context / Species	Heat Stress Variable	Key Findings	Relevance to Present Study
Brouillet & Sultan, 2023	Livestock in West Africa	Climate-related stressors & heat exposure	Identified increasing cumulative heat load affecting livestock resilience	Highlights urgency of climate-adaptive housing solutions
Cheng et al., 2022	Global livestock systems	Effects of climate change on productivity	Demonstrated direct links between rising temperatures and reduced productivity	Supports need for microclimate interventions
Dovolou et al., 2023	Dairy cows	Physiological heat stress	Reported adverse effects of heat stress on reproductive physiology & welfare	Reinforces importance of physiological indicators used in this study
Fabbri et al., 2020	Dairy farms	THI & milk production	Found reductions in milk yield with increasing THI levels	Justifies evaluating THI reduction from vegetation buffers
Frigeri et al., 2023	Confined dairy cows	Heat stress in housing systems	Scientometric review showing behavioral & physiological impacts of indoor heat stress	Supports relevance of behavioral observations in this research

Methodology

The experiment was carried out as a twofold 12 months process in subtropical area with definite seasons of summer, monsoons, and winter and gave the opportunity to conduct a complete evaluation of seasonal and diurnal changes. Two open-sided dairy cattle sheds were chosen in as experimental units, applying multi-species agro-horticultural vegetation buffers (VB) to one shed and having only no vegetation buffers (CT) to the other. They were randomly and evenly allocated 60 crossbred dairy cows to these sheds to avoid selection bias. The spatial arrangement of the experimental, position of buffers and shed.

The vegetation buffer around the VB shed was purposely crafted under a layered architecture by tall shade trees, medium-height shrubs, and fruit-bearing species that are grouped to provide the greatest coverage as well as shading and wind buffering. This building was to allow a natural microclimate barrier to have the capacity to lessen thermal radiations, optimise evaporation cooling, and stabilise air movement around the shed. The CT shed on the other hand did not have any vegetative structures on the perimeter as cows were exposed to ambient conditions. The vegetation buffer species were chosen according to the canopy density, rapid growth and adaptation to the local climatic conditions, which guaranteed the same shading and cooling effects during the research process.

Data collection of the microclimate parameters were taken thrice a day; in the morning, afternoon, and evening so as to record

the daily variation and the total heat load. The environmental factors were the air temperature, relative humidity, wind speed, black globe temperature as well as temperature-humidity index (THI), which are commonly used in assessing cattle thermal comfort. They had instruments that had been calibrated frequently to ascertain accuracy and placed at near animal height so that they simulated real conditions that cows experienced. At the same time, elaborate welfare measurements were recorded. Direct indicators of heat stress were physiological responses namely, rectal temperature, skin temperature and respiration rate. Structured observational schedules were used to record the behavioural time budgets such lying, ruminating, feeding, shade-seeking and agonistic behaviours. Monitoring of productive performance indicators as the daily milk yield and summer feed intake were also used to evaluate the benefits of microclimate modification in downstream.

Linear Mixed-Effects Models (LMM) and Generalised Linear Mixed Models (GLMM) were used in estimating the statistical significance of vegetation buffer effects on microclimate and physiological responses, behaviour, and performance. Fixed effects included treatment (VB vs. CT), time of day, season and individual cow identity (Cow ID). A random effect was defined so as to deal with individual cow identity (Cow ID) to accommodate repeated measurements at a point in time. The outputs of the models consisted of estimated marginal means, 95% confidence interval and the size of the effects to assess the

strength of the treatment. Post-hoc Turkey adjustments were also applied in conducting pair-wise comparisons where the important differences were found. This analytical framework allowed the strict evaluation of the impact of the vegetation buffer variable on the temporal and individual variability, which makes the results of the study more reliable.

Results and Discussion

The vegetation buffer (VB) sheds showed obvious benefits compared to the control (CT) sheds regarding micro climate in all seasons. Air temperatures and THI values of VB sheds were also lower by 1.5 to 2.8 °C and 3 to 6 units, respectively; the reductions clearly referred to high amounts of mitigation of heat load. Loss of temperature in the black globes was further affirmative that there was a loss in radiant heat exposure, and the reined wind speeds indicated a more stable and comfortable near-animal climate. Such findings are condensed in (Table 2) that shows the relative performance of VB and CT sheds in Micro climate. The results of the Linear Mixed-Effects Model (LMM) established that the treatment (VB vs. CT) was also a significant predictor ($p < 0.05$) of all the major microclimate variables, which reinforces the cooling property of the agro-horticultural vegetation buffers.

The physiological responses in the dairy cows were found to be strongly consistent with the improvement in micro climate seen in the vegetation-buffered sheds. Cows which were under VB conditions had low respiration rate, low temperatures on their skin surface and low rectal temperature during peak heat hours, than

the cows kept under CT sheds. These declines are within the range of thresholds of identifying relief against moderate to severe heat stress proving that the vegetative buffer system was more efficient in promoting thermoregulation. This is in consonance with the existing literature, which suggests heat-stressed cattle to be involved in increased respiration and peripheral vasodilation to cool down, which were quantitatively reduced in the VB environment with increased microclimate moderation.

The time-budget behavioural observations showed a significant enhancement in welfare of cattle kept in VB sheds. The more one lied and was able to ruminate, the more comfortable the rumination levels became, whereas the less shade-seeking behaviour one had, the less the need to use more heat-avoidance behaviour. There was also less frequent agonistic behaviours which were often inflamed by thermal discomfort in VB sheds implying a relaxed social atmosphere. Generalised Linear Mixed Models (GLMM) showed significant links between reduced THI and welfare behaviours, which highlights the use of vegetation induced cooling to enhance behavioural stabilisation. These results are in addition to previous studies that have shown that behavioural indicators are sensitive and early indicators of thermal stress of livestock.

The wider benefits of vegetation buffers were backed up by productive performance results. Despite the small differences, VB sheds cows had slight, but consistent feed intake and milk yield results in the peak summer months.

This is explained by the fact that it decreases the amount of heat stress and this usually inhibits appetite, rumination output, and metabolic equilibrium. The integration of these results indicates that agro-horticultural vegetation buffers are multifunctional systems, which leading to environmental comfort ability,

stabilising physiological functions, encouraging positive behavioural response, and protective productivity in response to thermal stress. Taken together, these findings make vegetation buffers effective, low-cost, and eco-friendly climate-adaptation strategies of dairy production systems.

Table 2: Comparison of Microclimate Variables between Vegetation Buffer (VB) and Control (CT) Sheds

Microclimate Variable	VB Shed (Mean ± SD)	CT Shed (Mean ± SD)	Difference / Effect	Remarks
Air Temperature (°C)	31.2 ± 1.8	33.8 ± 2.1	↓ 1.5–2.8°C	Cooler afternoon microclimate
Temperature– Humidity Index (THI)	74–78	79–84	↓ 3–6 units	Lower thermal load on cows
Black Globe Temperature (°C)	34.5 ± 2.0	38.2 ± 2.3	↓ 3.0–4.0°C	Reduced radiant heat exposure
Wind Speed (m/s)	0.8 ± 0.2	1.4 ± 0.3	Moderated airflow	Buffering effect reduces turbulence
Relative Humidity (%)	62 ± 5	58 ± 6	Slightly ↑ in VB	Vegetation increases localized moisture

Future Research

Further studies would be needed to cover a broader scope of climatic zones in the current study to determine the effectiveness of agro-horticultural vegetation buffers to different environmental stressors. The present paper that was done in the subtropical climate has shown that, they are effective in decreasing the heat load and enhancing the welfare of livestock; nevertheless, microclimate reactions might vary in the arid, semi-arid, temperate and coastal areas. Multi-location studies over a longer period would also be able to give a deeper insight into the adaptability, resilience, and seasonal variation of vegetation buffers thus allowing more generalised guidelines on climatic-resistant livestock housing designs.

The second direction that is central is; optimization of vegetation buffer composition and structural architecture. The purpose of this having a selective impact between species, canopy height, leaf density and spatial arrangement which affects shading, evapotranspiration and wind moderation. Comparative trials on various combinations of plants, buffers, and designs could conclude on the most efficient system to employ to achieve maximum cooling as well as minimising thermal stress. The studies on the growth rate, maintenance demands, and ecological compatibility would also increase the scalability and sustainability of such buffers implementation on commercial farms.

Combination of vegetation buffers with renewable cooling and technological cooling is

another opportunity of advancing innovations. Microclimate regulation could also be enhanced by incorporating natural shading combined with low-energy solutions, namely misting systems, solar-powered ventilation, or reflective surfaces, in particular when the events of extreme heat take place. It could also be used to consider hybrid systems on the basis of energy efficiency, cost-effectiveness and environmental impact, developing an overall system of sustainable livestock thermal management. Moreover, remote sensing and Internet of Things (IoT)-based monitoring digital tools would potentially allow assessing the performance of buffers continuously.

A potential future innovation that can be used to forecast heat stress responses and welfare challenges is advanced computational modelling. Microclimate, physiological, and behavioural data can be trained using machine learning algorithms like LightGBM, random forest, and neural networks to produce predictive models that can motivate the management of early warning of heat stresses. Such models may facilitate systems in decision making that assist farmers in adapting proactively to environment and housing arrangements or management practises. It could serve to expand the capacities and application of vegetation-based livestock microclimate policies and, ultimately, further alternative livestock species including sheep, goats, buffalo and poultry, would also help in creating a more multi-layered and multi-species approach to climatic adaptive livestock production.

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The authors do not underestimate the importance of the work of field technicians and data recording teams who facilitated the process of collecting physiological and behavioural indicator, such as the rectal temperature, respiration rate, skin temperature, time-budget observations, etc. They were very meticulous in their work, a fact that prevented uncertainty in the dataset. The research coordinators, farm management authorities, and administrative units played a very key role in supporting the logistics, availability of resources and ethics during the study. Lastly, the authors acknowledge the benefactors of funding bodies and academic collaborators who enabled this study to take place by providing financial and technical assistance through support.

Conclusion

The paper has established that agro-horticultural vegetation buffers are an efficient and nature-based method of increasing microclimate control and dairy cattle welfare in subtropical houshous set-ups. The vegetation buffers helped greatly to reduce heat stress and allowed the plants to achieve greater physical stability as indicated by decreased respiration rates and skin temperatures by lowering air temperature, reducing THI, and minimising radiant heat load. Enhanced animal comfort was also confirmed by additional behavioural indicators, such as more lying and decreased ruminating time, and reduced actions related to discomfort. Mixed-effects modelling supported the consistency of these gains (seasonal and daily) and minor water gains in the peak summer showed the practical value of their gains in milk and feed intake. All in all, vegetation buffers are low-cost, multimodal, and sustainable solutions to enhancing climate resilience in livestock housing systems.

References

- [1] Brouillet, Audrey, and Benjamin Sultan. "Livestock exposure to future cumulated climate-related stressors in West Africa." *Scientific Reports* 13, no. 1 (2023): 2698.
- [2] Calvin, Katherine, Dipak Dasgupta, Gerhard Krinner, Aditi Mukherji, Peter W. Thorne, Christopher Trisos, José Romero et al. "IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland." (2023).
<https://doi.org/10.59327/IPCC/AR6-9789291691647>
- [3] Cheng, Muxi, Bruce McCarl, and Chengcheng Fei. "Climate change and livestock production: a literature review." *Atmosphere* 13, no. 1 (2022): 140.
<https://doi.org/10.3390/atmos13010140>
- [4] Del Prado, Agustin, Brian Lindsay, and Juan Tricarico. "Retrospective and projected warming-equivalent emissions from global livestock and cattle calculated with an alternative climate metric denoted GWP." *Plos one* 18, no. 10 (2023): e0288341.
<https://doi.org/10.1371/journal.pone.0288341>
- [5] Dovolou, Eleni, Themistoklis Giannoulis, Ioannis Nanas, and Georgios S. Amiridis. "Heat stress: A serious disruptor of the reproductive physiology of dairy cows." *Animals* 13, no. 11 (2023): 1846.
<https://doi.org/10.3390/ani13111846>
- [6] Fabbri, Maria Chiara, Andrea Confessore, Carolina Pugliese, and Francesco Sirtori. "Effects of THI changes on milk production and composition of three dairy cattle farms in Mugello from 2010 to 2018: a preliminary study." *Acta Fytotechnica et Zootechnica* (2020): 167-173.
<https://doi.org/10.15414/afz.2020.23.mi-fpap.167-173>

- [7] Frigeri, Karen Dal'Magro, Kariane Donatti Kachinski, Nédia de Castilhos Ghisi, Matheus Deniz, Flávio Alves Damasceno, Matteo Barbari, Piotr Herbut, and Frederico Márcio Corrêa Vieira. "Effects of heat stress in dairy cows raised in the confined system: A scientometric review." *Animals* 13, no. 3 (2023):350. <https://doi.org/10.3390/ani13030350>
- [8] Janaki Sathya, D., and K. Geetha. "Comparative study of different edge enhancement filters in spatial domain for magnetic resonance images." *Amse Signal Process Pattern Recogn J* 54 (2011): 30-43.
- [9] Mazzoni, M., M. Zampiga, P. Clavenzani, G. Lattanzio, C. Tagliavia, and F. Sirri. "Effect of chronic heat stress on gastrointestinal histology and expression of feed intake-regulatory hormones in broiler chickens." *animal* 16, no. 8 (2022):100600. <https://doi.org/10.1016/j.animal.2022.100600>
- [10] Ramya, K. C., K. Vinoth Kumar, K. Geetha, and C. S. Boopathi. "Design of D shaped plasmon–photonic crystal fiber for bio sensing application." *Results in Physics* 10(2018):993-994. <https://doi.org/10.1016/j.rinp.2018.08.020>
- [11] Rasool, Sanober, S. A. Hamdani, Niha Ayman, Aaliya Fayaz, Sheikh Shubeena, Namera Thahaby, Burhan Nabi, Abdul Hai, and A. H. Akand. "The impact of natural disasters on livestock sector: A review." *Journal ISSN 2766* (2021): 2276. <https://doi.org/10.37871/jbres1295>
- [12] Saranya, N., K. Geetha, and C. Rajan. "Data replication in mobile edge computing systems to reduce latency in internet of things." *Wireless Personal Communications* 112, no. 4 (2020): 2643-2662.
- [13] Senthil, T., C. Rajan, and J. Deepika. "An efficient CNN model with squirrel optimizer for handwritten digit recognition." *International Journal of Advanced Technology and Engineering Exploration* 8, no. 78 (2021): 545. <https://doi.org/10.19101/IJATEE.2021.874073>
- [14] Singh, Vir, Akanksha Rastogi, Nanda Nautiyal, and Vrinda Negi. "Livestock and climate change: the key actors and the sufferers of global warming." *The Indian Journal of Animal Sciences* 87, no. 1 (2017): 11-20. <https://doi.org/10.56093/ijans.v87i1.66795>
- [15] Tan, Chan Lek, and Zachary A. Knight. "Regulation of body temperature by the nervous system." *Neuron* 98, no. 1 (2018): 31-48. <https://doi.org/10.1016/j.neuron.2018.02.022>
- [16] Veerappan, Saravanakumar, and N. Arvinth. "Machine Learning–Based Plant Disease Detection Using Leaf Image Classification in Smart Horticulture Systems." *National Journal of Plant Sciences and Smart Horticulture* 1 no. 1, (2023): 48-53.

- [17] Yan, Leyan, Mengdie Hu, Lihong Gu, Mingming Lei, Zhe Chen, Huanxi Zhu, and Rong Chen. "Effect of heat stress on egg production, steroid hormone synthesis, and related gene expression in chicken preovulatory follicular granulosa cells." *Animals* 12, no. 11 (2022): 1467. <https://doi.org/10.3390/ani12111467>