Global Scientific and Academic Research Journal of Multidisciplinary Studies
ISSN: 2583-4088 (Online)
Frequency: Monthly
Published By GSAR Publishers
Journal Homepage Link- https://gsarpublishers.com/journals-gsarjms-home/

EFFECT OF HEAT STRESS ON PHYSIOLOGICAL BEHAVIOUR IN DAIRY ANIMALS AND POULTRY

By

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Article History

Received: 05/10/2024
Accepted: 14/11/2024
Published: 16/11/2024

Vol – 3 Issue –11

PP: - 33-41

DOI:10.5281/zenodo.14169524

Abstract

Heat stress is a progressively primary concern in dairy and poultry farming, attributable to escalating global temperatures, which adversely impact animal health, productivity, and welfare. This review aims to synthesize contemporary studies to enhance understanding of the physiological, behavioral, and productive responses of dairy animals and poultry to heat stress. This review aims to investigate the molecular mechanisms such as the functions of heat shock proteins and oxidative stress, and the thermoregulatory and behavioral adaptations these animals utilize to manage increased temperatures. A thorough examination of recent research underscores the effects of heat stress on milk yield, egg-laying efficiency, and reproductive health. The study highlights significant areas for improvement in current research, notably the absence of long-term studies, inadequate emphasis on low-yielding and indigenous breeds, and the restricted investigation of the interactions between various environmental stressors and heat stress. This research assesses the efficacy of diverse mitigation techniques, including dietary therapies and technical solutions like cooling systems and wearable sensors, in alleviating the detrimental impacts of heat stress on livestock. The analysis offers pragmatic recommendations for future research, highlighting the necessity for interdisciplinary approaches that integrate physiology, nutrition, and technology to create sustainable solutions for cattle production. This evaluation enhances the resilience and welfare of dairy cattle and poultry in the context of climate change by addressing existing research gaps. Principal discoveries and consequences inform further research and direct practical applications in agricultural management methods.

Keywords: *heat stress, dairy animals, poultry, thermoregulation, productivity, mitigation strategies, livestock welfare.*

1. Introduction

Heat stress, or any unfavorable environmental temperature variation in general, and its effect on the physiological behavior of dairy animals and poultry are crucial for animal

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science and agricultural sustainability. It has considerable consequences for global food security and livestock welfare. Increasing heat stress due to climate change has significantly reduced livestock productivity, reproductive life, and health owing to increasing global temperatures (Ikram et al., 2022). Heat stress (HS) is an increasing concern for farmers and decision-makers because it impairs essential physiological functions such as thermoregulation, metabolism, and immune response (Mo et al., 2022). Although there is extensive data on heat stress in dairy and poultry animals, much information is needed regarding the molecular mechanism(s) and behavioral and management responses to reduce its detrimental effects effectively (Chen, Shu, Sun, Yao, & Gu, 2023). This review summarizes previous findings to clarify the extent and severity of heat stress on physiological behavior in species, emphasizing productivity, fertility, and potential mitigation strategies.

More recently, heat stress has been studied regionally concerning hot climates. For example, studies in tropical and subtropical areas have directly associated heat stress with reductions in both milk production (dairy cattle) and egg-laying performance (poultry), among many others. Although these studies offer important information, they still identify a need to consider the combined impacts of molecular and behavioral adaptation and farm management factors (Chen et al., 2023). Further, little research exists on how high-yielding animals differ from low-yielding ones in their resilience to heat stress and whether the effects (positive or negative) of heat stress are carryover effects that have consequences over multiple generations in livestock. Filling these gaps is vital for moving the discipline forward and securing livestock production under climate change.

This review aims to highlight such crucial research gaps and, through an extensive literature review, address the identified research void. Drawing attention to the shortcomings of existing studies – most notably, their focus on effects across short periods and a very narrow set of breeds – this review offers a new synthesis approach that brings together insights into physiology, nutrition, and technology. By analyzing heat stress management from multiple disciplines, this interdisciplinary analysis will improve past studies by discussing the benefits and constraints for the energetic gain of animals in productive systems and provide insights that can advance mitigation strategies for improving the productivity performance of livestock and animal welfare under extreme environmental conditions (Bonilla-Cedrez et al., 2023).

2. Physiological Mechanisms of Heat Stress in Dairy Animals and Poultry

2.1 Cellular and Molecular Responses to Heat Stress

Heat shock proteins (HSPs) are primary mediators of cellular responses to heat stress in dairy animals and poultry as shown in Figure 1. These molecular chaperones modulate protein folding, stability, and aggregation in response to thermal stress (Mayer et al., 2024). Higher temperatures up regulate HSP expression, thermo tolerance, and cell membrane integrity. The protective benefits of HSPs were delineated as far back as the 1990s in livestock challenged with heat stress. Over recent decades, however, advances in knowledge have broadened our perspectives regarding the roles played by heat shock proteins (HSP) during the immune response and overall health, making these molecules important players indirectly linked to the productivity and welfare of animals facing heat stress. This evolution highlights the significant role of HSPs in contemporary animal husbandry(Balakrishnan, Ramiah, & Zulkifli, 2023). Moreover, new research is being developed for the genetic selection of HSP with better expression, which can be used to develop strains that can endure progressively harsh environmental conditions (Zhang, 2023).

This is mainly due to the increased production of reactive oxygen species (ROS) leading to oxidative stress, which occurs following heat stress in dairy cattle and poultry when the antioxidants cannot be replete. Therefore, higher temperatures cause metabolic changes that lead to free radical production, damaging cellular components (lipids, proteins, and DNA). This oxidative damage disturbs their functions, impairs the immune response, causes thermal injuries, and thus reduces productivity and health (Kantakhoo & Imahori, 2021). Antioxidants like vitamins E and C, selenium, and phytochemicals have lately been demonstrated (in research studies) to counteract the damaging effects of oxidative stresses. Research has shown that including these antioxidants in diets increases the antioxidant ability of animals to cope with heat stress, fortifying their body against oxidative stress and reducing damage, leading to improved health and performance. In addition, new strategies such as probiotics and prebiotics to enhance antioxidant defenses in livestock may provide potential options for mitigating heat stress in agricultural systems (Zhang, 2023).

The impact of heat stress on dairy animals and poultry results in hormonal responses, two significant effects of cortisol and adrenaline, the principal hormones in endocrine system adaptation. The adrenal glands release cortisol, a steroid hormone that mobilizes energy stores and controls inflammation, a signal that originates from the hypothalamus when temperatures are abnormally high (Chu, Marwaha, Sanvictores, Awosika, & Ayers, 2024). Simultaneously, adrenaline (epinephrine) is secreted, which promotes cardiac output with an elevated metabolic rate to aid in thermoregulation. Together, these hormones establish homeostasis in the face of thermal stress. However, when heat stress persists over time, cortisol and adrenaline levels remain chronically elevated, which causes a hormonal imbalance that may impair animal health and productivity. For example, the physiological effects of these imbalances include decreased milk yield of dairy cows, decreased growth rates in poultry species, and weak immune function, causing increased disease susceptibility. Gaining more insight into these hormonal dynamics is crucial for establishing effective management strategies to alleviate heat stress conditions and restrain their pernicious effects on livestock welfare and productivity (Khan et al., 2023).

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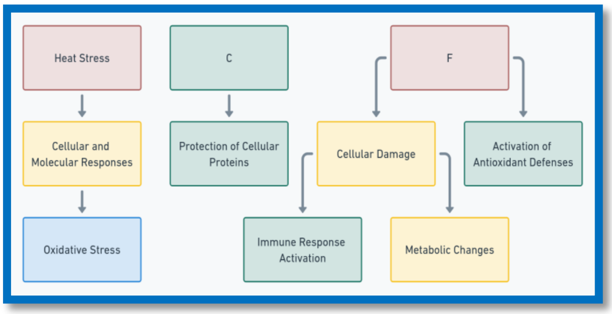

Figure 1: The Physiological Mechanisms of Heat Stress are delineated in this flowchart, with an emphasis on the molecular and cellular responses. C: The production of Heat Shock Proteins (HSPs) is a result of the activation of cellular pathways by heat stress, which serves to stabilize and protect cellular proteins. Concurrently, heat stress induces D: Oxidative Stress through F: Accumulation of Reactive Oxygen Species (ROS), which, if left unchecked, can result in cellular injury. Antioxidant defenses are activated during the oxidative stress response to maintain a balance of reactive oxygen species (ROS). As the body adjusts to stress conditions, these molecular changes further stimulate the immune response and modify metabolic processes in order to prevent cellular injury and preserve function.

2.2 Thermoregulation and Behavioral Adaptations

Heat stress profoundly impacts the behavior of dairy animals and poultry, and consequently, their feeding, drinking, and movement changes are pronounced as shown in Figure 2. In the case of high temperatures, dairy cows have been known to eat less and consume lesser quality forage as their needs for thermoregulation take priority over nutrition requirements (Chen et al., 2023). Animals spend more time seeking to cool down, so water consumption rises in a larger space as they aggregate at water sources. Poultry may become lethargic, often standing in shaded patches to protect themselves from heat stress. Such behavioral adaptations represent essential thermal strategies, reducing endogenous heat generation and stabilizing an organism's body temperature (Augenstein, Harrison, Klopatek, & Oltjen, 2020). Despite their usefulness, they have a limited effect and, therefore, require other management strategies to mitigate the physiological effects of heat stress (Nakshatrala, 2022).

Dairy animals and poultry use different thermoregulatory mechanisms to mitigate heat stress, such as increasing panting or sweating responses and ambient-dependent postures. For species such as cattle, sweat glands are limited; thus, rapid respiration is vital for increased body temperature and evaporative cooling (panting) (Nakshatrala, 2022). Sweating is common in some breeds and works by the evaporation of moisture to reduce body heat. They may also change their posture by spreading their legs or lying down to minimize direct contact with hot surfaces and improve ventilation (Collier, Baumgard, Zimbelman, & Xiao, 2019). The effectiveness of these thermoregulatory mechanisms varies among species and is influenced by environmental conditions. Panting is the predominant cooling mechanism in poultry due to its limited sweating capacity, unlike dairy cattle, which exhibit both sweating and panting responses (Bruchim, Horowitz, & Aroch, 2017).

Excessive heat directly perturbs the circadian rhythms of dairy animals and poultry, resulting in adverse physiological and behavioral effects. High temperatures can disrupt the regular cycles of hormone release, feeding, and activity, leading to less feed consumption and poor digestion (Chen et al., 2023). The disturbances can also lead to reduced milk production in dairy cows and egg yield in poultry, resulting in a loss of productivity. The stress also inhibits immune function, making the animals more prone to diseases. Chronic heat stress may disrupt circadian rhythms. Chronic disruption of these natural patterns can cause chronic stress, impair reproductive performance, and reduce welfare (Mo et al., 2022).

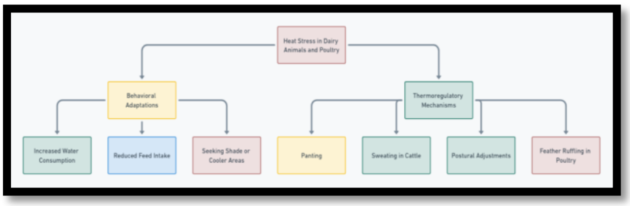

Figure 2: This diagram shows the adaptive strategies that dairy animals and poultry use under heat stress, including Behavioral Adaptations such as increased water consumption, reduced feed intake, and seeking shade, as well as Thermoregulatory Mechanisms like panting, sweating (in cattle), postural adjustments, and feather ruffling (in poultry).

2.3 Impact on Metabolism and Immune Function

Dairy cattle and poultry are directly affected by heat stress since it modifies their metabolic rate, nutrient absorption digestibility, and energy expenditure. High temperatures may raise metabolic rates, requiring animals to use more energy for thermoregulation, diverting energy away from growth and milk yield (Mo et al., 2022). In recent studies, heat-stressed dairy cattle may eat less and digest poorly, leading to a lower quantity and quality of milk. The same happens to poultry with reduced feed efficiency and egg production (Habeeb, 2020). Shehata, Saadeldin, Tukur, and Habashy (2020) reveal these metabolic adaptations, such as enhanced expression of heat shock proteins, which help buffer stress impact. However, overall productivity and health are further compromised by chronic thermal stress.

Immune system suppression due to heat stress in dairy animals and poultry increases disease susceptibility. At the physiological level, high temperature causes hormonal imbalance, especially cortisols that inhibit lymphocyte proliferation and production of cytokines from macrophages — both critical for immunity responses (Zeng et al., 2023). Studies show that heat stress may contribute to decreased levels of circulating immune cells like the T-lymphocytes and B-B-lymphocytes, which affect the adaptive immune system (Siddiqui, Kang, Park, Khan, & Shim, 2020). The effects of high humidity with heat stress are severe in dairy cattle, while age and breed-dependent responses to thermal and humid conditions could be observed in poultry. Several recent

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studies highlight the importance of effective management practices that can help reduce the severity of these effects and buffer against pathogens (Gupta, Sharma, Joy, Dunshea, & Chauhan, 2022).

Dairy cattle and poultry have shown a variety of physiological adaptive capacities to heat stress, differing in their metabolic and immune adaptations. Despite similarities in increased respiration rates and changes in feed intake in both animals, dairy cattle respond more behaviorally by seeking shade and drinking more water (Chen et al., 2023). At the same time, poultry exhibit reduced feed efficiency and often higher body temperatures. Compared with beef cattle, dairy cattle exhibit a more severe inflammatory response because of the immunological complexities between the two species, leading to an overstimulation of the stress response (Davis, 2022). Research focuses on breed-specific resilience as a response to heat stress, with specific dairy breeds surviving more efficiently under heat-stress conditions via improved thermoregulation and immune functions. At the same time, some broiler breeders preserve their production at greater efficiency levels than others. Such differences need to be identified for better management of heat-affected livestock (Wasti, Sah, & Mishra, 2020).

3. Impact of Heat Stress on Productivity and Reproductive Health

3.1 Heat Stress and Dairy Production: Milk Yield and Composition

Dairy cattle experience a significant drop in milk production due to increasing ambient temperatures via heat stress, disrupting the physiological processes crucial for lactation. High temperatures can increase respiration rates, cause reductions in feed intake, and exercise changes to hormone levels, negatively impacting (Chen et al., 2023). Dairy cattle experience a significant drop in milk production due to increasing ambient temperatures via heat stress, disrupting the physiological processes crucial for lactation. High temperatures can increase respiration rates, cause reductions in feed intake, and exercise changes to hormone levels, negatively impacting milk yield. For example, research has shown that Holstein cows experience a reduction of milk production by up to 20% during severe heat events. It is similar in Jersey cows, which are often considered more heat-tolerant; however, they also have decreased milk production under high temperatures, indicating that even these breeds are not entirely free of drought-climate vulnerabilities. Sound management strategies are necessary to lessen these impacts and maintain dairy production (Habimana et al., 2023).

Heat stress substantially impacts dairy cattle milk quality in terms of decreased fat, protein, and lactose content. The physiological changes from high temperatures affect the metabolic systems, negatively affecting the synthesis of milk components due to reduced feed intake. Even when cows do eat, it is known that there is poor nutrient absorption efficiency in hot environments (Habeeb, 2020). New research shows that heat stress can reduce the activity of milk-protein synthesis enzymes and, as a result, fat and protein concentrations are reduced in dairy cows under heat load. The adverse effect can be overcome by environmental interventions along with nutritional strategies. These strategies may improve milk quality and maintain production under heat-stress conditions (Sesay, 2023).

The genetic differences observed between high and low-yielding dairy breeds influence that breed's physiological response to thermal stress, resulting in significantly different levels of heat stress resilience between these two groups of cows (Habimana et al., 2023). However, more heat-sensitive, high-yielding breeds, like Holsteins, significantly reduce milk production and health. In contrast, low-yielding breeds (such as Jerseys) have improved thermoregulatory capabilities, which might allow them to be productive under heat stress (Cartwright, Schmied, Karrow, & Mallard, 2023). Comparison of high and low-yielding breeds of dairy cattle during days of thermal stress indicate more severe decreases in milk yield and reproductive function for the high-yielding breed. However, such differences suggest that there are also significant genetic components, which explains some variability (Cartwright et al., 2023).

3.2 Effects of Heat Stress on Poultry Productivity: Egg Production and Quality

Poultry egg-laying performance and egg quality are impaired by heat stress, which causes a reduction in shell strength and yolk color. High temperatures stimulate physiological responses, such as increased respiration and changes in blood flow that negatively impact reproductive performance. It collapsed eggshell strength due to heat stress and pale yolk, which makes it not competitive in the market(palest and most pale) (Harlap, Matrosova, Chulichkova, Gumenyuk, & Butakova, 2021). Some recent studies have investigated mitigation strategies to mitigate the hot weather environment affecting egg production, including dietary manipulations, shading, and housing adjustments. These measures are essential to preserve the functionality of poultry in an increasing temperature world (Kim et al., 2020).

Heat stress adversely affects poultry egg production, and nutritional and environmental interventions are crucial to reducing these impacts. Recent research points to the role of dietary supplementation, including electrolytes and vitamins that improve thermoregulation in birds. For instance, introducing omega-3 fatty acids has enhanced egg quality and production (de Brito et al., 2023). Moreover, cooling methods such as evaporative cooling systems and shaded housing have effectively lowered environmental temperatures. These interventions have been shown to increase egg production and egg quality considerably. Therefore, they can serve as potential implements for a commercial poultry farm to sustain their yield per hen during warmer conditions (Gad, El-Shazly, Wasfy, & Awny, 2020).

Broilers and layers respond differently to heat stress both physiologically and behaviorally in poultry production. In broilers, high body mass and fat deposition result in faster growth rates, which, when exposed to thermal stress, exhibit increased respiratory rates and higher mortality than slow-

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growing birds (Wasti et al., 2020). Conversely, layers (which are selected for egg production) would suffer reduced feed intake and egg production due to heat but otherwise maintain better thermoregulation. Broilers have been shown to suffer a significant decrease in both weight gain and feed efficiency at high temperatures, while layers can acclimatize by shifting the laying style. Genetic improvement has been proven to improve heat tolerance and, in some classes of layer breed, improve resilience and production in high-temperature environmental conditions (Kim et al., 2020).

3.3 Reproductive Performance and Fertility under Heat Stress

Dairy cows suffer enormous fertility impacts during heat stress, with reduced conception and changes to estrus behavior. Hormonal imbalance is caused by high temperatures, reducing both progesterone and the most frequent levels of cortisol, leading to either failure of ovulation or embryo viability (Khan et al., 2023). The consequences of heat stress can lead to decreased feed consumption and nutrient utilization, impairing reproductive performance metabolically. Several strategies have been investigated in recent years to address the issues resulting from above-normal temperatures, such as shading, cooling systems, and nutrition manipulation, which can improve reproductive performance (Chaudhary et al., 2020). Transiently elevated progesterone concentration in heat-stressed dairy herds is also expected using genetic selection for heat tolerance and synchronization protocols to improve estrus detection and conception rates, leading to improved reproductive performance (Dovolou, Giannoulis, Nanas, & Amiridis, 2023).

Heat stress is well known to impair poultry reproductive performance, specifically hatching rates or embryo survival. Increased ambient temperature can disrupt reproductive physiology by changing hormone levels and decreasing ovulation and sperm quality (Bohler, Chowdhury, Cline, & Gilbert, 2021). More recent studies have shown that heat stress may elevate embryonic mortality, reducing overall hatchability. To alleviate these fertility problems, measures like environmental change, dietary control, and cooling systems have been investigated. Studies have demonstrated that reproductive performance can improve hatchery success and embryo health by providing shaded bird areas and more efficient use of feed formulations. Thus, heat stress prioritization is needed to maintain poultry production performance (Wasti et al., 2020).

Adequate nutrition and hormonal treatments are needed to alleviate the severe adverse effects of heat stress on dairy animal and poultry reproductive performance. Antioxidants, such as vitamin E and selenium, have recently been fed to improve fertility in heat stress. For example, one trial showed a higher conception rate in dairy cattle given these supplements than in animals that did not receive supplementation (Olgun, Abdulqader, & Karabacak, 2021). Furthermore, hormonal therapies such as gonadotropin-releasing hormone (GnRH) have been reported to alleviate heat stress through estrus synchronization and increased ovulation rates. All of these suggest that utilization directly affects reproductive outcomes and is a vital method for improving fertility under thermal stress conditions (López-Gatius & Hunter, 2020).

4. Nutritional and Farm Management Strategies to Mitigate Heat Stress

4.1 Nutritional Interventions to Alleviate Heat Stress

Vitamins E and selenium are crucial in improving thermotolerance due to their actions against oxidative stress under heat stress conditions. These nutrients help maintain stable cellular membranes and modulate immune responses that improve livestock's overall health, leading to better productivity (Olgun et al., 2021). It was found in recent studies that the supplementation of vitamin E markedly decreased lipid peroxidation and enhanced antioxidant enzyme activity in heat-stressed birds, improving growth rate and egg production. Likewise, the role of selenium has also been connected with improved feed efficiency and lowered deaths due to heat stress in dairy cattle, possibly due to the protective effects of selenium against oxidative damage (de Brito et al., 2023).

Alongside environmental adjustments, dietary modifications in the form of careful feed additives and supplements are vital credible methods to mitigate heat stress in dairy cows and poultry. Adding electrolytes, vitamins, and minerals can help with hydration and metabolic function. For example, propylene glycol and niacin increase milk yield in high temperatures in dairy cattle (de Brito et al., 2023). Likewise, adding omega-3 fatty acids to poultry diets can improve feed efficiency and egg quality. In addition, its provision of high-fiber feeds can enhance rumination/saliva production and acid buffering so that animal welfare is maintained by boosting productivity over thermal stress scenarios (Archana, Sankaralingam, Anitha, Joseph, & Vasudevan, 2023).

Heat stress significantly affects livestock feed efficiency and nutrient uptake through physiological mechanisms such as increased gut permeability and reduced digestive enzyme activity. The challenge of heat stress in agricultural animals has mainly been characterized by reducing feed intake, which demands nutritional strategies. Adding some amino acids and antioxidants has been reported to improve gut health and nutrient absorption, thereby increasing feed conversion ratios (Augenstein et al., 2020). Moreover, management techniques such as probiotics and prebiotics may counteract the adverse effects of heat stress and promote digestive buffering capacity and thriving gut microbiome during high-temperature seasons to boost animal performance (Ali et al., 2020).

4.2 Farm Management Practices: Cooling Systems and Ventilation

Technological advancements in cooling systems, including evaporative cooling, misting, and fans, efficiently mitigate heat stress in dairy cows and poultry, tremendously impacting animal welfare and hardiness. For example, a dairy case study in California showed evaporative-cooled dairy farms with at least a 20% increase in milk production over peak summer months (Gaughan, Sharman, & McGowan, 2023). In Texas, a

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poultry farm that used misting systems saw its heatwave mortality rates lowered by 15 %. These systems reduce the ambient temperature and improve air circulation, decreasing stress levels of animals and leading to a better feed conversion ratio, thereby increasing farm profit (Augenstein et al., 2020).

Shade, shelter, and ventilation for livestock can alleviate heat stress and reduce the physiological burden on livestock during hot weather. Proper shading, in the form of trees or canopies, minimizes direct solar radiation exposure; properly designed covers increase air movement around animals and reduce ambient temperature. Studies show that natural or mechanical ventilation accelerates evaporative cooling to assist animals in thermoregulation. For example, farms in those researches experiencing such changes have reported a decreased respiratory rate and an increased feed intake, which will improve general health and productivity. This not only leads to improved welfare outcomes but is also beneficial in terms of sustainability and economic feasibility of the farm (Mueller et al., 2023).

Case studies from farms in various climates have proved the benefits of effective cooling and ventilation in intensive livestock systems. Research shows that these measures help reduce heat stress, improving the animals' welfare and increasing productivity and reproductive performance (Cao et al., 2020). One study done in dry climates showed the cost-effective benefits of evaporative cooling systems, with the milk yield for dairy cows increased by 20%. Additionally, sustainable measures such as natural ventilation in poultry farms have been proven to cut energy costs by as much as 30%, showcasing the economic feasibility and long-term advantages of such innovative measures (Strpić et al., 2020).

4.3 Use of Technology and Sensors in Heat Stress Management

However, developing wearable sensors for real-time monitoring of physiological responses in dairy cattle and poultry under heat stress (such as changes in body temperature and heartbeat) is a significant breakthrough toward high-tech modern farming systems (Reis, Nguyen, Sujani, & White, 2023). With these sensors, farmers can identify early signs of heat stress and intervene in time to ensure better animal welfare and productivity; such constant monitoring systems like SmartBow for cattle and Featherweight for poultry can alert farmers to significant variations in animal health. The benefits include better herding, lower mortality rates, and more milk and egg production. These technologies help create environmentally friendly, net-positive, and viable agricultural practices (Neethirajan, 2023).

The intelligent farm system is essential for animal welfare due to the automated climate control features and data-driven decision-making of smart farms that monitor environmental conditions and adjust accordingly. Automated ventilation systems in dairy farms are an example, where the temperature and humidity can be controlled to decrease heat stress during summer at its peak (Kiktev et al., 2021). Like in poultry houses, where intelligent technologies such as misting systems and reflective roofing materials reduce heat and maintain optimal temperatures to achieve the required comfort level for birds, These innovations improve animal health. However, they help to maximize the efficiency and sustainability of farms even more (Junior, Siqueira, Nogueira, Souza, & Tokura, 2020).

Technological solutions such as using sensors and climate control systems are complex, especially in smallholder farms where high implementation costs and low technical knowledge inhibit adoption. The data complexity with large-scale farms would need help integrating new technologies using existing practices and be concerned about data privacy and management (Mushi, Serugendo, & Burgi, 2023). However, research shows that these barriers are worsened by unawareness and a lack of training, leaving farmers unable to take full advantage of such innovations. Countering these challenges would require specific educational programs, governmental incentives, and collaborative efforts among tech developers and farmers. These can help with transitions, ensuring that both small and large farms benefit from modernization in agricultural technology (Chowdhury, Sourav, & Sulaiman, 2023).

5. Conclusion

This review has highlighted the significant impact of heat stress on the physiological behavior, productivity, and welfare of dairy animals and poultry. Key findings emphasize the role of molecular and cellular mechanisms, such as heat shock proteins and oxidative stress, in thermotolerance, while also discussing behavioral adaptations like changes in feeding and thermoregulation. The review also revealed the detrimental effects of heat stress on milk yield, egg production, and reproductive performance, stressing the importance of nutritional strategies, technological interventions, and farm management practices to mitigate these effects. Despite these insights, several research gaps persist, including limited studies on low-yielding and indigenous breeds, the lack of long-term studies on heat stress across generations, and the need for comprehensive models that account for multiple environmental stressors. Moreover, while technological interventions hold promise, further research is required to assess their scalability and applicability, particularly in small-scale farming systems. Future research should broaden the focus to include a wider range of livestock breeds, conduct longitudinal studies on cumulative heat stress impacts, and evaluate the combined effects of various stressors. In addition, there is a need to explore the cost-effectiveness of technological solutions for mitigating heat stress. The review is limited by its focus on dairy and poultry animals and its exclusion of older studies, as well as potential publication bias. Nonetheless, this review provides crucial insights for future research and policy development, emphasizing the need to address heat stress in livestock farming, especially as global temperatures rise. The findings contribute to the ongoing efforts to improve livestock resilience, productivity, and sustainability in the face of climate change, offering a foundation for future work in this evolving field.

*Corresponding Author: **Amisha Naz**

6. References

1. Ali, Hassan S Mohamed, Abdoun, Khalid A, Samara, Emad M, Al Badwi, Mohamed A, Okab, Aly B, & Al Haidary, Ahmed A. (2020). Direct heat stress-induced effects on rumen fermentation characteristics and nutrients degradability in sheep pair-fed alfalfa hay. *Spanish journal of agricultural research, 18*(3), 5.
2. Archana, S, Sankaralingam, S, Anitha, P, Joseph, Beena C, & Vasudevan, VN. (2023). Dietary inclusion of flaxseed oil, fish oil and their combinations on production performance and egg quality traits in White Leghorn hens. *J. Vet. Anim. Sci, 54*(2), 360-367.
3. Augenstein, Sheyenne M, Harrison, Meredith A, Klopatek, Sarah C, & Oltjen, James W. (2020). Heat stress alleviation and dynamic temperature measurement for growing beef cattle. *Translational Animal Science, 4*(Supplement_1), S178-S181.
4. Balakrishnan, Krishnan Nair, Ramiah, Suriya Kumari, & Zulkifli, Idrus. (2023). Heat shock protein response to stress in poultry: A review. *Animals, 13*(2), 317.
5. Bohler, Mark W, Chowdhury, Vishwajit S, Cline, Mark A, & Gilbert, Elizabeth R. (2021). Heat stress responses in birds: A review of the neural components. *Biology, 10*(11), 1095.
6. Bonilla-Cedrez, Camila, Steward, Peter, Rosenstock, Todd S, Thornton, Philip, Arango, Jacobo, Kropff, Martin, & Ramirez-Villegas, Julian. (2023). Priority areas for investment in more sustainable and climate-resilient livestock systems. *Nature Sustainability, 6*(10), 1279-1286.
7. Bruchim, Yaron, Horowitz, Michal, & Aroch, Itamar. (2017). Pathophysiology of heatstroke in dogs–revisited. *Temperature, 4*(4), 356-370.
8. Cao, Mengbing, Zong, Chao, Wang, Xiaoshuai, Teng, Guanghui, Zhuang, Yanrong, & Lei, Kaidong. (2020). Numerical simulations of airflow and convective heat transfer of a sow. *Biosystems Engineering, 200*, 23-39.
9. Cartwright, Shannon L, Schmied, Julie, Karrow, Niel, & Mallard, Bonnie A. (2023). Impact of heat stress on dairy cattle and selection strategies for thermotolerance: A review. *Frontiers in veterinary science, 10*, 1198697.
10. Chaudhary, Shikha, Devi, Poonam, Bhardwaj, Anjali, Jha, Uday Chand, Sharma, Kamal Dev, Prasad, PV Vara, . . . Nayyar, Harsh. (2020). Identification and characterization of contrasting genotypes/cultivars for developing heat tolerance in agricultural crops: current status and prospects. *Frontiers in Plant Science, 11*, 587264.
11. Chen, Xiaoyang, Shu, Hang, Sun, Fuyu, Yao, Junhu, & Gu, Xianhong. (2023). Impact of Heat Stress on Blood, Production, and Physiological Indicators in Heat-Tolerant and Heat-Sensitive Dairy Cows. *Animals, 13*(16), 2562.
12. Chowdhury, Mohammad Raziuddin, Sourav, Md Sakib Ullah, & Sulaiman, Rejwan Bin. (2023). The Role of Digital Agriculture in Transforming Rural Areas Into Smart Villages. In *Technology and Talent Strategies for Sustainable Smart Cities: Digital Futures* (pp. 57-78): Emerald Publishing Limited.
13. Chu, Brianna, Marwaha, Komal, Sanvictores, Terrence, Awosika, Ayoola O, & Ayers, Derek. (2024). Physiology, stress reaction. In *StatPearls [Internet]*: StatPearls Publishing.
14. Collier, Robert J, Baumgard, Lance H, Zimbelman, Rosemarie B, & Xiao, Yao. (2019). Heat stress: physiology of acclimation and adaptation. *Animal Frontiers, 9*(1), 12-19.
15. Davis, Ellen. (2022). Immunometabolism and inflammation: a perspective on animal productivity. *Animal Frontiers, 12*(5), 5-7.
16. de Brito, Anna Neusa Eduarda Ferreira, Kaneko, Isabelle Naemi, Cavalcante, Danilo Teixeira, Cardoso, Anilma Sampaio, Fagundes, Naiara Simarro, Fontinhas-Netto, Garros, . . . Costa, Fernando Guilherme Perazzo. (2023). Hydroxy-selenomethionine enhances the productivity and egg quality of 50-to 70-week-old semi-heavy laying hens under heat stress. *Poultry Science, 102*(2), 102320.
17. Dovolou, Eleni, Giannoulis, Themistoklis, Nanas, Ioannis, & Amiridis, Georgios S. (2023). Heat stress: A serious disruptor of the reproductive physiology of dairy cows. *Animals, 13*(11), 1846.
18. Gad, S, El-Shazly, MA, Wasfy, Kamal I, & Awny, A. (2020). Utilization of solar energy and climate control systems for enhancing poultry houses productivity. *Renewable Energy, 154*, 278-289.
19. Gaughan, JB, Sharman, K, & McGowan, MR. (2023). The effect of day-only versus day-plus-night cooling of dairy cows. *Journal of Dairy Science, 106*(7), 5002-5017.
20. Gupta, Shruti, Sharma, Arvind, Joy, Aleena, Dunshea, Frank Rowland, & Chauhan, Surinder Singh. (2022). The impact of heat stress on immune status of dairy cattle and strategies to ameliorate the negative effects. *Animals, 13*(1), 107.
21. Habeeb, Alsaied Alnaimy Mostafa. (2020). Deterioration effects of heat stress on farm animals performance in tropical and subtropical regions. *World Journal of Biology Pharmacy and Health Sciences, 4*(2), 007-0025.
22. Habimana, Vincent, Ekine-Dzivenu, Chinyere Charlotte, Nguluma, Athumani Shabani, Nziku, Zabron Cuthibert, Morota, Gota, Chenyambuga, Sebastian Wilson, & Mrode, Raphael. (2023). Genes and models for estimating genetic parameters for heat tolerance in dairy cattle. *Frontiers in Genetics, 14*, 1127175.
23. Harlap, S Yu, Matrosova, Yu V, Chulichkova, SA, Gumenyuk, OA, & Butakova, NI. (2021).

*Corresponding Author: **Amisha Naz**

Physicochemical parameters and morphological qualities of edible eggs depending on the period of the reproductive period of chickens. Paper presented at the IOP Conference Series: Earth and Environmental Science.

24. Ikram, Muhammad, Chen, Jingfang, Xia, Yanshi, Li, Ronghua, Siddique, Kadambot HM, & Guo, Peiguo. (2022). Comprehensive transcriptome analysis reveals heat-responsive genes in flowering Chinese cabbage (Brassica campestris L. ssp. chinensis) using RNA sequencing. *Frontiers in Plant Science, 13*, 1077920.
25. Junior, Moacir José Dalmina, Siqueira, Jair Antonio Cruz, Nogueira, Carlos Eduardo Camargo, Souza, Samuel Nelson Melegari de, & Tokura, Luciene Kazue. (2020). Optimization of Energy Efficiency and Environmental Comfort in Broiler House. *Journal of Agricultural Science, 12*(10), 162.
26. Kantakhoo, Jirarat, & Imahori, Yoshihiro. (2021). Antioxidative responses to pre-storage hot water treatment of red sweet pepper (Capsicum annuum L.) fruit during cold storage. *Foods, 10*(12), 3031.
27. Khan, Imran, Mesalam, Ayman, Heo, Yun Seok, Lee, Seo-Hyun, Nabi, Ghulam, & Kong, Il-Keun. (2023). Heat stress as a barrier to successful reproduction and potential alleviation strategies in cattle. *Animals, 13*(14), 2359.
28. Kiktev, Nikolay, Lendiel, Taras, Vasilenkov, Viktor, Kapralyuk, Oksana, Hutsol, Taras, Glowacki, Szymon, . . . Kowalczyk, Zbigniew. (2021). Automated Microclimate Regulation in Agricultural Facilities Using the Air Curtain System. *Sensors, 21*(24), 8182.
29. Kim, Da-Hye, Lee, Yoo-Kyung, Lee, Sung-Dae, Kim, Sang-Ho, Lee, Sang-Rak, Lee, Hong-Gu, & Lee, Kyung-Woo. (2020). Changes in production parameters, egg qualities, fecal volatile fatty acids, nutrient digestibility, and plasma parameters in laying hens exposed to ambient temperature. *Frontiers in veterinary science, 7*, 412.
30. López-Gatius, Fernando, & Hunter, Ronald Henry Fraser. (2020). Local cooling of the ovary and its implications for heat stress effects on reproduction. *Theriogenology, 149*, 98-103.
31. Mayer, Matthias P, Blair, Laura, Blatch, Gregory L, Borges, Thiago J, Chadli, Ahmed, Chiosis, Gabriela, . . . Edkins, Adrienne L. (2024). Stress biology: Complexity and multifariousness in health and disease. *Cell Stress and Chaperones, 29*(1), 143-157.
32. Mo, Fan, Zhou, Xu, Yang, Mengting, Chen, Leyi, Tang, Zhining, Wang, Chong, & Cui, Yanjun. (2022). Trehalose attenuates oxidative stress and endoplasmic reticulum stress-mediated apoptosis in IPEC-J2 cells subjected to heat stress. *Animals, 12*(16), 2093.
33. Mueller, Joaquin, Haile, Aynalem, Getachew, Tesfaye, Santos, Bruno, Rekik, Mourad, Belay, Berhanu, . . . Rischkowsky, Barbara. (2023). Going to scale—From community-based to population-wide genetic improvement and commercialized sheep meat supply in Ethiopia. *Frontiers in Genetics, 14*, 1114381.
34. Mushi, Gilbert Exaud, Serugendo, Giovanna Di Marzo, & Burgi, Pierre-Yves. (2023). Data management system for sustainable agriculture among smallholder farmers in Tanzania: research-in-progress. *Information Technology for Development, 29*(4), 558-581.
35. Nakshatrala, Kalyana B. (2022). Modeling thermal regulation in thin vascular systems: a mathematical analysis. *arXiv preprint arXiv:2208.07397*.
36. Neethirajan, Suresh. (2023). Artificial intelligence and sensor technologies in dairy livestock export: charting a digital transformation. *Sensors, 23*(16), 7045.
37. Olgun, O, Abdulqader, AF, & Karabacak, A. (2021). The importance of nutrition in preventing heat stress at poultry. *World's Poultry Science Journal, 77*(3), 661-678.
38. Reis, Barbara Roqueto dos, Nguyen, Tien, Sujani, Sathya, & White, Robin R. (2023). Open-source wearable sensors for behavioral analysis of sheep undergoing heat stress. *Applied Sciences, 13*(16), 9281.
39. Sesay, Abdul Rahman. (2023). Effect of heat stress on dairy cow production, reproduction, health, and potential mitigation strategies. *J. Appl. Adv. Res, 8*, 13-25.
40. Shehata, Abdelrazeq M, Saadeldin, Islam M, Tukur, Hammed A, & Habashy, Walid S. (2020). Modulation of heat-shock proteins mediates chicken cell survival against thermal stress. *Animals, 10*(12), 2407.
41. Siddiqui, Sharif Hasan, Kang, Darae, Park, Jinryong, Khan, Mousumee, & Shim, Kwanseob. (2020). Chronic heat stress regulates the relation between heat shock protein and immunity in broiler small intestine. *Scientific Reports, 10*(1), 18872.
42. Strpić, Kristina, Barbaresi, Alberto, Tinti, Francesco, Bovo, Marco, Benni, Stefano, Torreggiani, Daniele, . . . Tassinari, Patrizia. (2020). Application of ground heat exchangers in cow barns to enhance milk cooling and water heating and storage. *Energy and Buildings, 224*, 110213.
43. Wasti, Sanjeev, Sah, Nirvay, & Mishra, Birendra. (2020). Impact of heat stress on poultry health and performances, and potential mitigation strategies. *Animals, 10*(8), 1266.
44. Zeng, Hanfang, Xia, Haibin, Wang, Xinling, Wang, Yue, Fang, Jian, Li, Shujie, . . . Han, Zhaoyu. (2023). Comprehensive profiling of ceRNA (circRNA-miRNA-mRNA) networks in hypothalamic-pituitary-mammary gland axis of dairy cows under heat stress. *International Journal of Molecular Sciences, 24*(1), 888.

*Corresponding Author: **Amisha Naz**

45. Zhang, Shihai. (2023). From Challenge to Opportunity: Addressing Oxidative Stress in Animal Husbandry. *Antioxidants, 12*(8), 1543.

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