Biological Functions of Lactating Farm Animals as Affected by Heat Stress

Arooj Fatima[1], Asad Ullah Kahloon[2], Khalil ur Rehman[2], Muhammad Asif Rafiq[2], Muhammad Huzaifa[2], Abdullah[2], Saadullah Sami[2], Muhammad Kamraan Subhani[2], Asghar Abbas[3] and Umair Younas[2,*]

[1]Department of Microbiology, Faculty of Veterinary Sciences, Cholistan University of Veterinary and Animal Sciences, Bahawalpur
[2]Department of Livestock Management, Faculty of Animal Production and Technology, Cholistan University of Veterinary and Animal Sciences, Bahawalpur
[3]Department of Pathobiology and Biomedical Sciences, Muhammad Nawaz Sharif University of Agriculture, Multan
*Corresponding author: umairyounas@cuvas.edu.pk

Abstract

To maintain homeostasis at elevated temperatures, biological processes such as metabolism, endocrine function, and immune response undergo specific adaptations. These include metabolic adjustments to manage energy demands, hormonal regulation to modulate stress responses, and immune modifications to counteract heat-induced oxidative stress. Based on these, this chapter will discuss the consequences of heat stress on lactating animals, especially physiological and molecular adaptations. Lactating animals are particularly susceptible to heat stress (HS) due to their simultaneous demands for thermoregulation and lactation, leading to decreased feed intake, metabolic changes, and reproductive impairment. Hormonal dysregulation, oxidative stress, and inflammatory responses are the key biological processes that can be influenced by HS, and these are highlighted in the chapter. This chapter will also discuss the role of the gut microbiota and how it can be modified as a strategy to mitigate HS. Recent advances in proteomics and genomes, which provide essential insights into the systems that mediate heat tolerance, are now enabling us to discover targeted therapies. This comprehensive review aims to bridge its findings from fundamental biology to practical activity, by delivering directions towards sustainable livestock management based on insights given for warming global temperature scenarios.

Keywords: Lactation, Farm animals, Heat stress, Production, Milk

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Introduction

Lactating farm animals are those animals that produce milk currently. That is the most important time in their lifecycle. Lactating farm animals like sheep, goats, and cows are essential for providing nutritious milk, manure, and offspring for meat and breeding. Proper management of these animals can improve productivity, health, and mitigate environmental impacts. Dairy animals contribute to global food security and agriculture sustainability. However, heat stress can negatively affect their welfare due to humidity, high external air temperature, and exposure to solar radiation. Dairy cattle regulate thermal energy balance during heat stress, maintaining body temperature normal through exercise, metabolism, growth, gestation, and lactation. Maintaining thermal balance is challenging when animals cannot dissipate enough metabolically absorbed or produced heat. Proper management can enhance agriculture sustainability and livelihood while promoting global food security (Becker et al., 2020).

In many farming regions worldwide, heat stress is a major problem. Both crops and cattle are impacted, which lowers output and leads to health hazards. One of the main issues impeding crop production worldwide is heat stress. It lowers the genetic potential of crops like wheat and results in biochemical disturbances and morphophysiological changes (Farhad et al., 2023).

Health Risks for Farm Workers: This chapter focuses on the effects of heat stress on lactation performance, fertility, reproductive processes, nutritional approaches, immune systems, and behavioral changes in nursing animals. It offers insights for farmers, veterinarians, and researchers to regulate and lessen heat stress's effects on farm animals.

1. Heat Stress: Definition and Physiological Implications

During hot weather, cows undergo various physiological changes, including reduced feed intake, decreased activity, increased respiratory rate, and increased peripheral blood flow and sweating (West, 2003). These responses have a detrimental effect on both production and the physiological status of the cow. In thermal environments, milk yields were comparable for both restricted intake and thermal stress treatments. Mammary blood flow was generally lower in thermal comfort-fed cows than in ad libitum-fed cows, indicating that blood flow was responsive to the level of DMI. Heart stress causes hormonal changes, but it may be challenging to distinguish between the direct effects of heat stress and the consequences of lower feed DMI. Triiodothyronine concentration decreased with heat and with restricted intake, while plasma somatotropin tended to decrease with heat stress but did not change because of restricted DMI (Aggarwal et al., 2013). Milk temperatures of cows classified as low, medium, and high producers increased as their production increased, and when THI surpassed 70, milk somatotropin concentrations sharply decreased. The best way to maintain thermoneutral plasma thyroxine concentration was to start night cooling when the rectal temperature was at its highest, suggesting that strategically cooling the heat-stressed cow could improve her metabolic potential. Heat-stressed cows typically show a changed blood acid-base chemistry due to the change in cooling from conductive, convective, and radiation to evaporative cooling. A respiratory alkalosis results from panting's dramatic increase in CO_2 loss by pulmonary ventilation, which lowers blood carbonic acid levels and upsets the vital carbonic acid to bicarbonate balance required to regulate blood pH (Morey, 2004). The blood pH and blood bicarbonate levels of cows under heat stress in environmental chambers varied throughout the day, closely according to the cow's respiratory rate and rectal temperature. Over the course of 24 hours, cows' acid-base chemistry showed significant fluctuations from alkalosis to compensated acidosis, which could be crucial in the summer when producers usually feed high grain rations (West, 2003).

Thermal regulation is a brain mechanism that links internal and external thermal environments to create a stable internal environment (Kiyatkin, 2010). This process directly regulates endocrine system function and cellular metabolism. Peripheral circulation, regulated by the hypothalamus, helps cattle under environmental stress dissipate heat through perspiration and vasodilation, widening arteries and lowering blood pressure and blood flow velocity. The central neural system, peripheral nervous system, and endocrine components respond to these physiological reactions (Hopkins, 2007). Dairy cows' reactions to stress are acute and chronic. The "Sympathetic-Adrenal-Medullary (SAM)" and "Hypothalamus-Pituitary-Adrenal (HPA)" axis regulate acute and chronic stress, respectively (Chen et al., 2015). Acute stress reactions are transient, and cattle can adjust by increasing water intake, breathing more deeply, and perspiration. Thermal sensors in the skin and hypothalamuses react to changes in the environment, while the thalamus, hypothalamus, and central nervous system respond differently to the surroundings. The autonomic nervous system mediates acute reaction by releasing more catecholamines and glucocorticoids, which change metabolism. The adrenal medulla releases chemicals called noradrenaline or adrenaline, which activate physiological reactions to provide bodily balance and the required response to stress. Long-term environmental stress causes short-term adaptation pathways to malfunction, leading to elevated heart rate, perspiration, and standing symptoms. HPA is used to restore homeostatic and physical balance, while chronic stress can lead to metabolic disorders, digestive system diseases, immune system slowing, and suppression of growth and reproduction (Okuyucu et al., 2023).

2. Effects of Heat Stress on Lactating Efficiency

Heat stress affects lactating cows, leading to a decrease in total protein and fat yield. Milk volume decreases during the summer season, with milk fat being 9.7% less than normal. The mechanisms behind this reduction remain unknown. A study found that heat stress reduces milk protein by 4.1% and overall milk yield by 17%. During the heat stress, a decrease in the concentration of fatty acids and plasma glucose levels was observed and the use of the systemic amino acid increased. Alterations of the somatotropic axis, which controls metabolism, may also play a role in decreasing milk protein yield. The presence of heat stress can also reduce nutrient partitioning and the availability of protein precursors, affecting protein synthesis (Becker et al., 2020).

Dairy cows with proper blood flow in the udder produce better volumes of milk, but heat stress can limit this flow and decrease feed intake. However, the exact mechanisms involved in this are yet to be resolved, although the heat stress lowers the trans-mammary glucose disappearance rate as well. Dairy cow udder temperature correlates with deep body temperature, and, in summer season, milk and surrounding temperatures showcase the mammary gland cell exposure to increased temperatures. In vitro, heat stress responses (which include heat shock responses-HSRs, apoptosis, and morphological modifications) and in vivo (gene expression in heat-stressed mammary biopsies) have shown that increased gene expression due to heat stress may lead to increased apoptosis. Heat stress also strongly influences mammary metabolism and may interact with mammary development and immune activation (Tao et al., 2020).

Reduced milk production is the most prominent effect of heat stress. It was also fatal to fertility because the estrus cycle, ova, and embryo quality are also affected. Research shows that the chances of mastitis increased in summer. The immune system is also affected because of reduced immune cell function, and the chances of diseases also increase. Lameness also increased in summers due to an increase in the standing behavior of animals due to heat stress. When body temperature rises, feed intake is also reduced and affects rumination activity (Bhamare et al., 2022).

3. Impact on Reproductive and Metabolic Functions

3.1. Heat Stress and Fertility Challenges in Lactating Animals

Lactating cattle are highly susceptible to heat stress (HS), which significantly lowers reproduction rates and contributes to a global 20–30% reduction in conception rates during summer. HS impairs fertility through hormonal imbalances, including suppressed LH pulse amplitude and frequency, which hinder follicle maturation, estradiol secretion, ovulation, and corpus luteum function, leading to low progesterone levels. At the same time, HS increases FSH secretion by reducing plasma inhibin, promoting the growth of more ovarian follicles and potentially resulting in twin calving (Khan et al., 2023). Additionally, HS elevates glucocorticoid levels through ACTH secretion, inhibiting oocyte maturation.

HS also affects reproductive and metabolic functions by raising core body temperature, reducing estrus duration and intensity, and decreasing pregnancy rates after artificial insemination. This disruption is especially marked in the summer, where up to 80% of estrus goes undetected, further reducing fertility. Enhanced endometrial PGF-2α secretion in HS endangers pregnancy sustainability and changes follicular dynamics, creating low fertility in summer and autumn months. Conception rates decrease from approximately 40%–60% in cooler months to 10%–20% or less when the cow is extremely thermally stressed (Wakayo et al., 2015).

3.2. Alterations in Energy Balance and Metabolic Pathways

Dairy cows under heat stress (HS) experience an energy imbalance and disruption of metabolic pathways in several aspects. It decreases voluntary feed intake, consequently reducing available energy, while also changing glucose metabolism, increasing glucose disposal and insulin activity to the detriment of health, production and reproduction. HS can also disrupt mammary gland metabolism, as it interferes with glycolysis, lactose synthesis, and amino acid metabolism, and it elevates the body temperature, which later can affect fat synthesis in the mammary gland (Abbas et al., 2020). Moreover, HS produces respiratory alkalosis from increased respiration rate and sweating, which produces decreased blood carbonic acid concentration. This leads to a negative energy balance in the body, which makes glucose the energy source of choice. Impacts of HS in general can be classified into decreased milk production, changed milk composition, lower reproductive performance, and increased mortality. In this research, the decrease in milk production under heat stress in dairy cows is demonstrated to occur associated with reduced feed consumption and metabolic disorder, specifically influenced by altered glucose and lipid homeostasis. The use of recombinant bovine somatotropin partially alleviates some of these effects, emphasizing the multiple pathways by which heat stress can impact milk production (Das et al., 2016).

3.3. Hormonal Changes and their effects

Luteinizing hormone (LH) and follicle-stimulating hormone (FSH) are essential for follicular growth, ovulation, and corpus luteum (CL) development. Heat stress disrupts ovarian function by altering gonadotropin secretion, reducing LH receptor expression in ovarian follicles, and decreasing LH and steroid concentrations, which collectively impair ovulation, oocyte maturation, and CL formation. At the same time, heat stress increases FSH secretion due to reduced inhibin levels, promoting the development of more follicles and contributing to a higher incidence of double ovulations and twin births during summer (Wu et al., 2007).

Heat stress impacts reproductive physiology by disrupting hormone balance and cellular functions in ovarian and germ cells, as well as embryos. It reduces dry matter intake, leading to decreased secretion of key reproductive hormones like GnRH and LH, which hinders follicle development, ovulation, and overall fertility. Additionally, heat stress alters the uterine environment, increasing embryo loss and infertility. The decline in GnRH and LH levels, combined with elevated FSH levels, exacerbates these reproductive challenges (Boni, 2019). Moreover, heat stress elevates prolactin, thyroxine (T4), and cortisol levels, while decreasing progesterone secretion, which limits endometrial functions critical for supporting embryo development. The increased secretion of endometrial prostaglandin F_2-alpha further threatens pregnancy maintenance and reduces fertility (Kelly, 1994).

4. Heat Stress-Induced Health Disorders

4.1. Immune Suppression and Susceptibility to Diseases

Based on this DNA, 3D cellular identities ensure sustainable livestock health. Heat stress is a major challenge to livestock sustainability causing negative effects on health and productivity due to impairment of the immune system and greater susceptibility to diseases (Choudary et al., 2024). The mechanisms underlying these immune dysfunctions are complex and incompletely understood, as heat stress leads to metabolic changes and disrupts the tightly inter-linked nervous, endocrine, and immune systems. Species, breed, productivity, age, physiological stage, metabolism, and thermoregulatory ability all play a role in these effects.

One major mechanism by which heat stress suppresses the immune system is through activation of the hypothalamic-pituitary-adrenal (HPA) axis, resulting in secretion of cortisol, a stress hormone. The abnormal rise of cortisol dampens cytokine production, which acts as a signaling protein for immune regulation. This results in the impaired activation and proliferation of T-lymphocytes and B-lymphocytes necessary for strong immunity. As a result, the body's defense against pathogens and infections is severely impaired (Afsal et al., 2018).

4.2. Oxidative Stress and Cellular Damage

Heat stress (HS) is an important risk factor for the lucrative sustainability of livestock, especially dairy cattle, with the main economic impacts arising from lowered milk yield and decreased milk protein content. Studies show HS (Heat Stress) causes OS (Oxidative Stress) in the tissue; increased ROS levels (Reactive Oxygen Species) and mitochondrial dysfunction were observed in dairy cows under high temperatures (Sammad et al., 2020). Oxidative stress is one of the important factors contributing to the decrease in the milk protein, which induces insulin resistance and apoptosis, thereby reducing the synthesis of milk protein. Mammary gland apoptosis promotes mammary epithelial cell death, and insulin resistance alters the mTOR signaling networks involved in protein synthesis. Moreover, heat-stressed cows have significantly observed decreased total antioxidant capacity (T-AOC) and superoxide dismutase (SOD) levels, and elevated levels of lipid peroxidation aggravate oxidative stress. Such oxidative damage impairs immune function, as evidenced by alterations in immunoglobulin G (IgG), endotoxins, and proinflammatory cytokines, including IL-10, IL-1β, and TNF-α (Cheng et al., 2018).

4.3. Adaptation Mechanisms in Lactating Animals

There are the following mechanisms to adapt the animals by dissipating the heat from their body:

1. Behavioral adaptation
2. Physiological adaptation
3. Genetic selection adaptation

4.3.1. Behavioral Adaptation

Along with the changes in the behavior of cows under heat force action are these that change ephemeral preferences and their demand. Adopting a mechanism that plans to reduce the daily production of heat, via the reduction of feed and water intake, is found for shading or minimizing movement (Council et al., 2011). The rumination process increases metabolic heat so reported that the rumination is decreased. The cattle manage the time of rumination depending on climate temperature. So, the animals can start ruminating in nighttime for the longest time to dissipate heat from the environment. Due to heat stress, the animals reduce grazing time between hot time, and they feed at the day end which can reduce the feed intake up to 30%. Cows alter the time and consume highly nutritive feed during cooler times to meet their requirements (Mader & Davis, 2004).

Alter eating the behavior of cows causes rumen acidosis. Normally cows consume 12-15 meals/day but reduce grazing frequency 3-5 meals/day between HS. The cows eat meals in large quantities in the day following heat patterns causing acidosis.

5.3.2. Physiological Responses to Maintain heat Dissipation

Environmental change is linked to heat stress which is inversely proportion to animal production. The animals adapt several mechanisms which are crucial for their lives in harsh climate conditions. But the overall performance of the animal is middle course. Among the different strategies, that aid in balancing the body system of animals for proper functioning. The physiological adaptation was recognizing the first response strategy, the heat-forced animals to survive during heat stress. This analysis is important to provide knowledge on the review, to understand the importance of physiological adaptation in animals and their actions in life on stressful climates (Renaudeau et al., 2012).

Heat-forced animals; physiological response is divided into two categories

1) Heat load via radiation, convection, metabolism, and heat exchange with the climate.
2) Heat dissipation via sweat evaporation.

Some physiological considerations of adaptations to heat force are respiration rate (RS), rectal temperature (RT), and pulse rate (PR). These considerations decrease the production ability of animals.

5.3.2.1. Respiration rate

Respiration is inhale of Oxygen (O_2) and exhale of carbon dioxide (CO_2) under ambient conditions which edge to evaporation and amusement of moisture by the respiratory pipe to maintain temperature balance. So, this action is too important in avoiding low body temperature. The RR is observed by calculating flank movements per minute using a stopwatch without disturbing the animal (Shilja et al., 2016). The RR plays a role in diagnosing the heat stress situation in animals at an early stage. But the rise in RR from a considerable level shows the animals are an effort to balance the temperature by below the heat force from their body. Higher RR is visualized in cattle in a result of increased relative humidity and ambient temperature. Increased the level of RR of an animal between heat stress is stimulated to upsurge the respiratory evaporative cooling mechanisms (RECM) by the discharge of body heat. In a comparison study, the RR was 15.738±0.795, 15.779±1.136 in winter, 18.158±0.795, 22.979±1.136 in spring, and 29.818±0.795, 47.299±1.136 in summer seasons in Sahiwal cattle and in Karan Fries cattle respectively (Sailo et al., 2017).

This exhibits the different breeds of animals rely on the (RR) to balance the thermo-neutral zone during the display to different climate temperatures. The higher body temperature aloft the ambient climate temperature is commonly by decreased feed intake can affect the performance and health status of animals.

5.3.2.2Rectal Temperature

Rectal temperature is diagnosed as the optimal indicator for heat force in an animal's body. It is examined as a chief measure of physiological adaptation. If other mechanisms of heat dissipation fail to balance body temperature provide an edge to increases in RT. The rectal temperature is recorded by the clinical thermometer put in the rectum 6-7cm inside of the rectum and touches the bulb of the clinical thermometer by the rectum wall for exact reading (Sawka et al., 2011).

5.3.2.2. Pulse Rate

The pulse rate first follows the homeostasis of vogue on with the basic metabolic mode. The cardio-respiratory function is controlled by day timing, season, exercise, humidity, and ambient temperature. The pulse rate is measured by palpating the femoral artery (present in the thigh near to skin) in the animal. An increase in the pulse rate indicates a high temperature. Metabolic activity and feed intake depend on the season so; the heart rate is assumed to depend seasonally. Heat is dissipated insensibly and sensibly (Datt et al., 2021).

5.3.2.3. Skin Temperature

In animals, skin is a very effective route for heat conversion among the surrounding environment and body. The skin temperature is measured in body parts forehead, back, and flank by using a thermo-couple probe. The skin temperature varies based on sun rays with direct contact. Higher skin temperature means that contact with heat stress can increase the blood flow on the surface of the skin (Buratti, 2020).

5.3.2.4. Sweating Rate

The loss of excessive heat by the body via skin following the mechanism of evaporation cooling is called sweating. Panting and sweating are an important consideration for heat change in the environment and animals. In animals' evaporation is very important to lose heat from the body. The experiment was performed on lactating cows and the sweating rate was found to be low in light color skin cows than in black cows (Robertshaw, 2006).

5.3.3. Genetic Selection Adaptation

Upper-level heat freedom animals possess the genetic ability to expel metabolic heat from their bodies. This can be minimized through management methods like feed additives, shade, fans, and sprinklers, as well as genetic selection through gene editing and genomic selection. Farmers can use the thermal circulation index trait to achieve heat freedom and abundance, as it drives genetic improvement with minimal impact on production traits. Heterosis is used to upgrade profitable traits in meat breeds and adapt this to milk breeds. Other genetic characteristics, such as cellular, morphological, and physiological functions, also contribute to heat regulation in milk breeds. Genetic development programs increase production traits that increase an animal's susceptibility to high climate temperatures. *Bos indicus* cows have thermotolerant genes, allowing them to have lower rectal temperature and respiration rates compared to *Bos taurus spp*. under the same high-stress conditions (Kumar et al., 2023).

6. Mitigation Strategies for Heat Stress

6.1. Environmental Modifications

Environmental changes are a large-scale technique used to reduce heat stress (HS) conditions in farm animals. However, these strategies may not be suitable for animals with disease control, breeding factors, or nutrition restrictions. To reduce heat, simple acts such as ventilation, opening facilities, and construction characteristics can be applied. Artificial or natural shade can be provided to animals for cooling and reducing HS. Different cooling systems, such as conditioning, evaporating water from cooling pads, and fogging systems, can also be used. Air circulation is an effective factor in reducing heat stress, and providing fresh air to animals can be the most effective way to increase HS production (Firfiris et al., 2024).

6.2. Feeding Strategies

Feeding plans are used to minimize the effect of HS using different feed additives. The main point is to maintain nutrients, electrolytes, and water balance during HS like minerals and vitamins. In animals, formulating diets with less heat addition can also aid better feed consumption and production during HS. In hot weather, the requirement of nutrients is changed during HS, which ensures the reformulation of feed. Fiber consumption is decreased for the proper functioning of the rumen, including fat additives mainly due to their high energy level and less heat production, and applied in animal feed to avoid metabolic disturbance. As stated, HS had ability to produce oxidative injuries, and an additive of vitamins are important impact on the production of HS animals. Animals drop a large quantity of minerals (especially Na and K) through sweating. According to Tebbe, Alexander Wade (2017) in HS milking cattle, Na and K adding in feed by NRC recommendations result in 3%-11% higher milk production. The addition of electrolytes in water or in feed decrease the HS effect on animals (Lamar, 2013).

6.3. Genetic Selection

The completely immutable genetic solution is considered to more suitable face with environmental changes, like the gene editing or genome selection of heat freedom. It is also worthwhile exploring many other genetic characteristics which allow milk-type breeds to greater control or throw away heat well-regulated under hot climates, like those connected to cellular (fluidity, stability and cell repair), morphology (hair thickness, coat color, and coat length) and physiological (respiratory and cardiovascular systems) functions. Genetic development programs increase production traits that enhance an animal's susceptive to high climate temperatures under the close relation linking generation of metabolic heat and producing level (Balistreri, 2023).

7. Case Studies or Research Evidence

Heat stress negatively impacts dairy cows' hormonal, physiological, metabolism, and immunity systems. Increased environmental temperature negatively affects the hypothalamus brain, affecting apatite and decreasing feed intake. This leads to a negative energy balance (NEB) stage, affecting the body condition score (BCS) and weight of the animal. Heat stress also affects milk production and composition, especially in genetically merited animals. Both male and female reproductive system cellular functions are affected by heat stress. In farm animals, silent heat and anestrus increase, while estrous intensity reduces. Bulls require high fertility for fertilization of oocytes, and the temperature of the testes must be 2°C-6°C for fertile sperm production (Krishnan et al., 2017). Heat stress can also cause nutritional deficiencies and affect survival and embryonic growth. Cows, particularly dairy cows, experience two types of sweating due to heat stress.

8. Comparative Analysis of Mitigation Techniques

To minimize the loss of production and to enhance the comfort of the cows during the summer season under adverse thermal conditions the management of the environment is necessary in different parts of the world. The strategies that are used for cooling cows have four common thermodynamic principles that are important for heat transfer (conduction, radiation, convection and evaporative cooling). Providing benefits that are combined with thermal cooling facilities, genetic improvements, nutrition, and artificial insemination at a fixed time are important. The roofs and shedding on dairy farms also play an important role in protecting animals from heat stress. At dairy farms, we also use bedding. It will provide cooling to the animal when the cow lies down. By keeping good air quality, we will keep the environment less stressful inside the shed. Two designs of dairy barns that are commonly used are naturally ventilated buildings and the other is tunnel ventilated buildings (Bewley et al., 2017).

9. Challenges and Future Directions

Barriers to implementing effective heat stress management. When climate changes it will affect dairy production including lower production rates and reduced animal weight gain also lower feed conversion rates in areas of high temperature. Production and reproduction are two interesting aspects in livestock that will affect the profitability of livestock. Incomplete endometrium preparation of the uterus altered estrous conception and events the size of corpus luteum are reduced by heat stress in many ways and the ability of animal to reproduce is affected. The production of animals will be affected by climate in four ways: the changes in livestock price and feed grains availability have great impacts, livestock forage crop production and pasture quality have great impacts, changes in pests and livestock diseases, the direct effects of extreme events and whether on animal growth, health and reproduction (Rust & Rust, 2013).

9.1. Emerging Technologies and Innovations in Combating Heat Stress

To ensure sustainable production and the well-being of animal health, it is necessary to minimize heat stress. To mitigate the effects that are harmful to livestock by heat stress it is necessary to provide shade for the animals. The shades change the micro-climate inside the shed and provide the physiological needs of the animals by reducing the temperature, heat discomfort and protecting the animal from diverted Sunlight. In this way, the farmer also reduced the harmful effects and promoted growth, productivity and reproduction. The administration of diuretics, diaphoretics, and goitrogens helps to mitigate the effects of heat stress on animals through pharmacological and nutraceutical treatments (Krishnan et al., 2023).

9.2. Climate Change and its Implications

The production of livestock animals is badly affected by climate change. Milk production is more sensitive as compared to growth to heat stress and the yield of milk decreased to 35%-40% is common. The obvious sign in heat stress is a dramatic reduction in the intake of feed up to 50% and it is responsible for the lower performance of the animal. In the animal production system, the financially devastating are physiological effects on animals' productivity by heat stress. Reproductive performance decreases by the change flow of blood and various hormone production. It is not easy to mitigate the oocyte quality that is affected by the detrimental effects of heat stress. Heat stress directly damage the preovulatory oocyte and prolonged estrous cycle indirectly. The major threat in survival of different ecosystems and species is climate change. Livestock disease outbreaks are affected by several factors that are influenced by climate change (Bett et al., 2017).

Conclusion

Heat stress significantly impacts the health, productivity, and well-being of farm animals, particularly in areas with harsh weather conditions. Understanding the physiological and molecular processes underlying heat tolerance is crucial for developing effective therapies. Strategies for improving resilience include genetic selection for heat-tolerant features, dietary supplementation, and gut microbiome modification. Adaptive management techniques like better cooling systems and house designs are also essential. Future advancements can be made using advanced technology like predictive modeling and precision livestock husbandry. This comprehensive approach ensures the productivity and well-being of nursing animals and helps livestock systems remain sustainable in the face of climate change. This chapter provides a roadmap for addressing heat stress in cattle husbandry, bridging the gap between research discoveries and real-world application.

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