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Review Article

Heat Stress in Sheep: Physiological Responses, Management Strategies and Current Research Scenario

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Abstract

Heat stress is one of the most significant environmental constraints affecting the productivity and welfare of livestock worldwide (Silanikove, 2000; Marai et al., 2007). Sheep production systems are particularly vulnerable to increasing global temperatures and climate variability associated with climate change. Exposure to high ambient temperatures results in several physiological, metabolic and behavioural alterations that negatively influence feed intake, growth rate, reproduction and overall productivity of sheep. Heat stress responses in sheep involve increased respiration rate, elevated rectal temperature, altered endocrine activity and oxidative stress (Nardone et al., 2010; Sejian et al., 2018). Various mitigation strategies including improved housing systems, shearing practices, nutritional interventions and genetic selection have been investigated to reduce the adverse effects of thermal stress. Recent research has also focused on molecular mechanisms such as heat shock protein expression and antioxidant defense systems involved in stress adaptation. This review provides a comprehensive overview of heat stress in sheep, including global livestock statistics, physiological and biochemical responses, housing management strategies and recent advances in research aimed at improving thermal tolerance in sheep production systems. Sheep are generally considered relatively tolerant to harsh environmental conditions; however prolonged exposure to high environmental temperature significantly affects their physiological and metabolic functions (McManus et al., 2020).

Key words: Sheep Indigenous sheep, Heat stress, Sheep Production, Physiological response, Climate change, Housing Management, Oxidative stress

INTRODUCTION

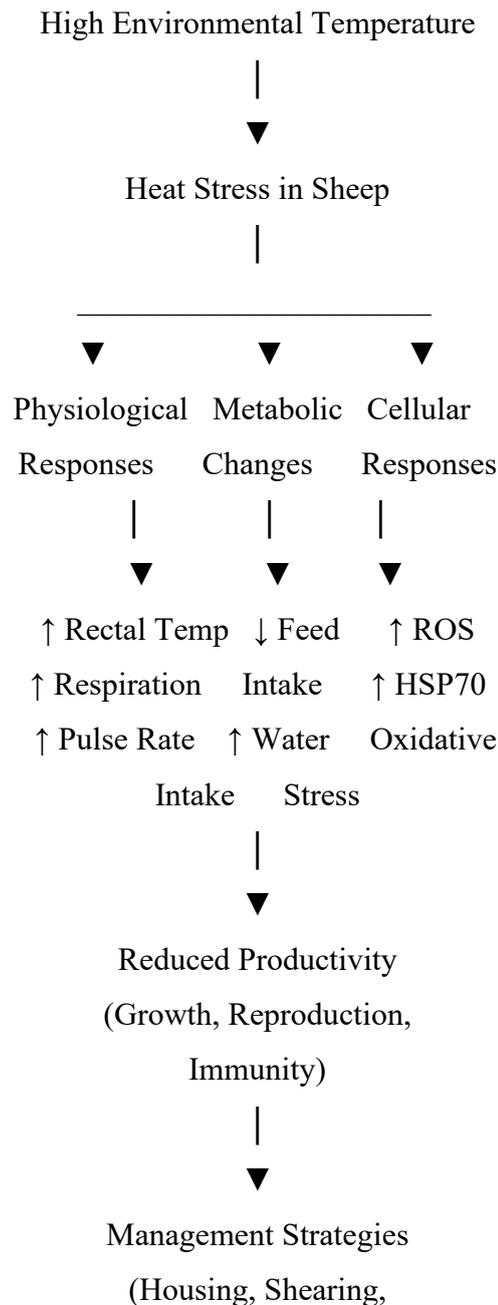
Livestock production plays a crucial role in global agriculture by contributing to food security, rural livelihoods and economic development. Among livestock species, sheep are widely distributed across different climatic regions due to their adaptability and relatively low input requirements. According to global livestock statistics, the worldwide sheep population exceeds **1.2 billion animals**, with the majority of flocks distributed across Asia and Africa.



Sheep are raised for multiple purposes including meat, wool, milk and skins, and they represent an important source of income for pastoral and smallholder farmers in many developing countries. However, livestock production systems are increasingly affected by environmental stressors, particularly heat stress caused by rising global temperatures.

Figure 1

Conceptual Mechanism of Heat Stress Response in Ruminants



Nutrition, Genetics) Climate change is predicted to increase the frequency and intensity of heat waves in many regions of the world, which may significantly influence livestock productivity and animal welfare. Heat stress occurs when animals are unable to



maintain a balance between metabolic heat production and environmental heat load. Under such conditions, animals experience physiological strain and reduced productivity.

Sheep are generally considered more tolerant to heat stress than other livestock species, but prolonged exposure to high ambient temperature can still impair their biological functions. Exposure to elevated environmental temperature has been reported to reduce feed intake, growth rate, reproductive performance and milk production in sheep.

Therefore, understanding the physiological responses of sheep to heat stress and developing effective management strategies are essential for maintaining productivity and animal welfare under changing climatic conditions.

GLOBAL SCENARIO OF SHEEP PRODUCTION AND CLIMATE CHANGE

Sheep production contributes significantly to global meat and fiber production. Global sheep numbers have reached approximately **1.26 billion animals**, indicating the importance of small ruminants in the agricultural economy.

Major sheep-producing countries include China, India, Australia, Iran and Sudan. India alone has around **75 million sheep**, making it one of the leading countries in sheep population worldwide.

Sheep production is particularly important in arid and semi-arid regions where crop production is limited. The ability of sheep to utilize low-quality forage and survive under harsh environmental conditions makes them valuable livestock species for marginal farming systems.

However, climate change is expected to influence livestock production through several pathways including increased temperature, altered rainfall patterns and changes in forage availability. Thermal stress can directly affect animal physiology and indirectly affect productivity by reducing feed intake and increasing water requirements.

Recent projections suggest that global sheep meat production may increase by around **15% by 2034**, driven by growing demand for animal protein and improvements in breeding and management practices.

Despite this projected growth, climate-related stress factors such as heat stress remain major challenges for sustainable sheep production.

PHYSIOLOGICAL RESPONSES OF SHEEP TO HEAT STRESS

Heat stress triggers a series of physiological and metabolic responses aimed at maintaining thermal balance in animals. These responses involve several mechanisms including behavioral adjustments, increased respiration rate and changes in blood circulation. Exposure to heat stress results in increased respiration rate, rectal temperature and pulse rate in sheep as part of



their thermoregulatory mechanisms (Ashutosh et al., 2000; Sejian et al., 2012). Heat stress also alters endocrine responses, particularly thyroid hormones and cortisol levels, which are associated with metabolic regulation and stress adaptation (Todini, 2007).

Rectal Temperature

Rectal temperature is widely used as an indicator of thermal stress in livestock. When environmental temperature exceeds the thermoneutral zone, body temperature begins to increase due to the accumulation of metabolic heat.

Studies have demonstrated that sheep exposed to high environmental temperatures exhibit elevated rectal temperature as a result of impaired heat dissipation mechanisms.

Table 1: Physiological Indicators of Heat Stress in Sheep

Parameter	Normal Range	Response Under Heat Stress	Physiological Significance	Key References
Rectal temperature	38.5–40.0 °C	Increases above normal range	Indicates body heat accumulation	Marai et al., 2007
Respiration rate	12–20 breaths/min	Increases significantly (panting)	Enhances evaporative heat loss	Sejian et al., 2012
Pulse rate	70–80 beats/min	Increases moderately	Improves blood circulation for heat dissipation	Ashutosh et al., 2000
Skin temperature	32–35 °C	Elevated due to peripheral vasodilation	Facilitates heat transfer from body surface	Piccione et al., 2002
Feed intake	Normal voluntary intake	Decreases during heat stress	Reduces metabolic heat production	West, 2003
Water intake	Moderate	Increases significantly	Maintains hydration and thermoregulation	McGregor, 1986
Cortisol level	Basal level	Increased under stress conditions	Indicator of physiological stress	Todini, 2007
Antioxidant enzymes (SOD, GPx)	Normal activity	Altered under heat stress	Reflect oxidative stress status	Slimen et al., 2016
Heat shock protein (HSP70)	Low expression	Increased expression	Cellular protection against thermal stress	Gade et al., 2010



Respiration Rate

Respiration rate increases significantly in heat-stressed animals. Panting enhances evaporative heat loss through the respiratory tract and is one of the primary mechanisms used by sheep to dissipate excess body heat.

Increased respiration rate is often considered one of the earliest physiological indicators of heat stress.

Pulse Rate

Heat stress also affects cardiovascular activity. Increased pulse rate facilitates greater blood flow to peripheral tissues, allowing animals to dissipate heat through the skin surface.

Skin Temperature

Skin temperature reflects changes in peripheral blood circulation during thermal stress. Increased skin temperature indicates enhanced heat transfer between the body surface and the environment.

METABOLIC AND ENDOCRINE RESPONSES

Heat stress significantly influences metabolic and hormonal functions in sheep. Hormones such as triiodothyronine (T3), thyroxine (T4) and cortisol play important roles in regulating metabolism and stress responses. Alterations in thyroid hormone levels have been reported in animals exposed to high environmental temperatures

Cortisol is considered a major stress hormone and its concentration often increases during periods of physiological stress.

Recent studies have also emphasized the role of oxidative stress in heat-stressed animals. Heat stress stimulates the production of reactive oxygen species (ROS), leading to oxidative damage in cells.

Antioxidant enzymes such as superoxide dismutase, catalase and glutathione peroxidase help protect cells from oxidative damage by neutralizing free radicals.

EFFECT OF HEAT STRESS ON FEED INTAKE AND WATER CONSUMPTION

Heat stress significantly influences feeding behaviour in sheep. Exposure to high environmental temperature reduces voluntary feed intake as animals attempt to minimize metabolic heat production. Feed intake is significantly reduced during heat stress because animals attempt to decrease metabolic heat production (West, 2003; Bernabucci et al., 2010). Reduced feed intake ultimately affects growth performance and productivity in sheep (Bhatta et al., 2005). Water intake, on the other hand, increases significantly during periods of high environmental temperature in order to maintain thermoregulation (McGregor, 1986; Silanikove, 1992).



Reduced feed intake leads to decreased nutrient availability, which ultimately affects growth performance and productivity.

In addition to reduced feed intake, heat stress increases water consumption in sheep. Increased water intake is essential for maintaining thermoregulation and preventing dehydration.

Studies have shown that animals exposed to heat stress require greater amounts of water to maintain body temperature and metabolic balance.

HOUSING MANAGEMENT AND SHELTER DESIGN

Housing management is one of the most effective strategies for mitigating heat stress in livestock production systems. Providing adequate shelter protects animals from direct solar radiation and reduces environmental heat load. Roofing materials play a crucial role in determining the microclimate within animal shelters.

Housing management is considered an effective strategy to mitigate heat stress in livestock production systems (Collier et al., 2006). Provision of shade or improved shelter design reduces exposure of animals to solar radiation and improves animal welfare (Nardone et al., 2010). Several studies have investigated the effect of roofing materials on thermal comfort and productivity in sheep.

For example, Khant et al. (2021) reported that sheep housed under agro-net roofing consumed more feed and exhibited improved physiological responses compared to animals housed under asbestos roofing.

Similarly, Khant et al. (2021) also observed that roofing materials influence hemato-biochemical, hormonal and antioxidant profiles of sheep, indicating their role in stress adaptation.

Several studies have investigated the influence of roofing materials on sheep performance. Khant et al. (2021a) reported that indigenous sheep maintained under agro-net roofing consumed more feed and exhibited improved growth performance compared to those maintained under asbestos roofing systems. Similarly, Khant et al. (2021b) demonstrated that roofing materials significantly influence hemato-biochemical, hormonal and antioxidant parameters in sheep.

Improved housing design with adequate ventilation and shading can significantly reduce heat stress in sheep production systems.

ROLE OF SHEARING IN THERMOREGULATION

Shearing is a common management practice in sheep production systems that influences heat exchange between the animal and the environment. Shearing is another



important management practice affecting thermoregulation in sheep. Removal of fleece improves heat dissipation and reduces thermal load during hot weather conditions (Klemm, 1962; Aleksiev, 2008). Sheared sheep often exhibit lower rectal temperature and respiration rate compared to non-sheared animals during summer months (Piccione et al., 2002).

Removal of fleece enhances heat dissipation by allowing greater air circulation around the skin surface. Sheared sheep generally exhibit lower body temperature and respiration rate compared to non-sheared animals during hot weather conditions.

Several studies have demonstrated that shearing improves feed intake, growth performance and thermal comfort in sheep.

However, the timing of shearing is important because animals may become susceptible to cold stress if shearing is performed during cooler seasons.

Table 2: Management Strategies to Mitigate Heat Stress in Sheep

Strategy	Description	Impact on Sheep	Key References
Improved housing design	Use of ventilated sheds, shade structures	Reduces solar radiation and environmental temperature	Nardone et al., 2010
Roofing materials	Agro-net or reflective roofing	Improves ventilation and reduces heat load	Khant et al., 2021
Shearing management	Removal of fleece during hot season	Improves heat dissipation	Aleksiev, 2008
Nutritional supplementation	Vitamins, minerals and antioxidants	Enhances stress tolerance	Sejian et al., 2018
Adequate water supply	Continuous access to clean drinking water	Prevents dehydration and improves thermoregulation	Silanikove, 1992
Genetic selection	Breeding heat tolerant sheep breeds	Improves long-term adaptation	McManus et al., 2020
Shade provision in grazing	Trees or artificial shade in pasture	Reduces direct solar radiation exposure	Collier et al., 2006
Precision livestock monitoring	Sensors to monitor physiological responses	Early detection of heat stress	Bernabucci et al., 2010



OXIDATIVE STRESS AND MOLECULAR RESPONSES

Heat stress induces oxidative stress in animals by increasing the production of reactive oxygen species. Heat stress also induces oxidative stress in animals due to increased production of reactive oxygen species (ROS) (Slimen et al., 2016). Antioxidant enzymes such as superoxide dismutase and glutathione peroxidase play crucial roles in protecting cells against oxidative damage (Maan et al., 2013). Heat shock proteins, particularly HSP70, are also involved in cellular protection against thermal stress (Gade et al., 2010).

Oxidative stress leads to cellular damage and may impair immune function, growth and reproduction.

Heat shock proteins (HSPs), particularly HSP70, play an important role in protecting cells from thermal damage. Increased expression of HSP70 has been observed in animals exposed to high environmental temperatures.

Heat shock proteins act as molecular chaperones that stabilize cellular proteins and prevent damage caused by heat stress.

GENETIC AND BREEDING APPROACHES FOR HEAT TOLERANCE

Recent advances in animal genetics have opened new possibilities for improving heat tolerance in livestock.

Genetic selection for thermotolerance traits can help develop sheep breeds that are better adapted to hot climates.

Molecular studies have identified several genes associated with heat tolerance, including genes involved in heat shock protein expression and oxidative stress regulation.

Selection of heat-tolerant animals can improve productivity and resilience of sheep production systems under climate change.

FUTURE RESEARCH DIRECTIONS

Future research should focus on developing integrated strategies to mitigate heat stress in sheep production systems.

Key research areas include:

- Development of climate-resilient housing systems
- Nutritional interventions to improve thermotolerance
- Genetic selection for heat-tolerant breeds
- Molecular studies on stress adaptation
- Development of precision livestock technologies for monitoring thermal stress

Such research will help improve productivity and sustainability of sheep production systems under changing climatic conditions.



CONCLUSION

Heat stress represents one of the major challenges for sustainable sheep production worldwide. Rising global temperatures and climate variability are expected to increase the frequency and severity of thermal stress in livestock production systems.

Physiological responses such as increased respiration rate, elevated rectal temperature and altered hormonal activity are common indicators of heat stress in sheep.

Management strategies including improved housing systems, appropriate shearing practices and nutritional interventions can significantly reduce the adverse effects of heat stress.

Future research focusing on genetic improvement and molecular mechanisms of stress tolerance will be essential for developing climate-resilient sheep production systems.

Conflict of Interest: None

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