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Exploring Thermoregulatory Responses and Hormonal Changes in Heat Stressed Assam Hill Goats

S. Deori[1], S.N. Abedin[1], H. Chakravarty[1], R. Katiyar[1], B.U. Choudhury[1], E. Syiem[1], S. Doley[1] 10.18805/IJAR.B-5185

ABSTRACT

Background: Livestock productivity and health are adversely affected by heat stress (HS). The aim of this study was to determine the effects of HS on the thermoregulation and hormonal profile in Assam Hill Goats reared in the subtropical hilly regions of Meghalaya so as to arrive at a conclusion on its heat adaptation abilities.

Methods: An experiment was conducted during the year 2022 for 120 days with twelve (12) Assam Hill Goats, aged between 3-5 months, randomly divided into 2 groups (n=6 per group). The goats in group I were exposed to HS through natural exposure to sunlight during the extreme summer months (May to August) for 07 hours (8 AM to 3 PM) during grazing. The control animals (CON, group II) were maintained under shade with no exposure to sunlight. Thermoregulatory responses *viz*., rectal temperature, respiratory rate and pulse rate and body weight data were recorded every 15 days interval of the sampling period. The hormonal profile *viz*., serum T3 (nmol/L), T4 (nmol/L) and Cortisol (ng/mL) were also determined.

Result: Results revealed a significant ($p<0.05$) increase in rectal temperature, pulse rate (day 45 onwards to day 120) and respiratory rate in HS group in comparison to CON. A significantly ($p<0.05$) lower average daily gain was recorded in HS group. Serum T3 and T4 concentrations were significantly ($p<0.05$) reduced and cortisol concentration was significantly ($p<0.05$) elevated in HS group in comparison to CON. In conclusion, Assam Hill Goats exposed to environmental HS shows elevated thermoregulatory responses, decreased thyroid hormone activity and increased cortisol activity to reduce production to support life sustaining activities in the hilly regions.

Key words: Assam hill goats, Heat stress, Hormonal profile, Thermoregulatory response.

INTRODUCTION

In the tropics, goats hold great importance as valuable small ruminant resources, especially for impoverished families residing in rural areas. They possess a compact body structure that enables them to dissipate heat effectively by exposing a large surface area in proportion to their weight. The tropics' diverse climatic conditions have led to the development of distinct adaptive mechanisms in goats, enabling them to cope with a wide range of stressful environmental conditions. Environmental stress triggers noteworthy effects on thermoregulation, live body weight and physiological parameters in goats, as observed during both dry and wet seasons.

The adverse impact of heat stress (HS) on livestock productivity and health is well-established and it can severely disrupt the physiological equilibrium of goats. Consequently, it is essential to investigate goats' heat adaptation abilities in harsh environments from a scientific perspective multiple authors have suggested that the most effective thermo-physiological indicators for objectively assessing animal welfare in challenging conditions are rectal temperature, respiratory rate and blood indices (Helal *et al*., 2010; Sanusi *et al*., 2010). HS is more prevalent during the dry season, especially when there is high environmental temperature, high relative humidity and prolonged exposure to direct sunlight. Specific responses and reciprocal regulatory influences involving their nervous, endocrine and immune systems have been implicated in this process (Castanheira *et al*., 2010).

[1]Division of Animal and Fisheries Sciences, ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India.

Corresponding Author: S. Deori, Division of Animal and Fisheries Sciences, ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India. Email: sourabhd1@rediffmail.com

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Animals employ various adaptations to deal with HS, such as an increased sweating rate, elevated respiration rate, vasodilation resulting in enhanced blood flow to the skin surface, reduced metabolic rate, decreased dry matter intake (DMI) and changes in water metabolism, among other mechanisms (Baumgard and Rhoads, 2013; Sejian *et al*., 2018). The levels of circulating T3 and T4 experience a reduction of approximately 25% as well, mirroring the decrease in metabolic rate, dry matter intake (DMI) and overall production during HS conditions (Silanikove, 1992).

The objective of the current study was to measure the physiological, growth and hormonal responses to extreme HS conditions in Assam Hill Goats exposed to prolonged sunlight since no priori information is available on the effects of HS on this native breed, which is widely distributed in Assam and adjoining areas of Meghalaya.

MATERIALS AND METHODS

Animal care

The present study was reviewed and approved by the Institutional Animal Ethics Committee (IAEC) of ICAR RC for NEH, Umiam, India.

Study area and design

The study was conducted in the Livestock Farm, Indian Council of Agricultural Research (ICAR) Complex for North-Eastern Hill Region (NEHR), Umiam, Meghalaya, India. In the present study, twelve (12) Assam hill goats, aged between 3-5 months were randomly divided into two groups, consisting six (6) animals each. The goats in group I (HS) were exposed to heat stress through natural exposure to sunlight during the extreme summer months (1st May to 31st August, 2022) for 07 hours (8 AM to 3 PM) during grazing. The control animals (CON, group II) were maintained under shade with no exposure to sunlight during the entire experimental period. Roughage and concentrate feed were supplied every day at adequate amount to all the animals in each group with free access to drinking water.

Collection of data

Climatic data

Ambient temperature (°C) and relative humidity (RH%) were measured two times daily (morning and evening) using a thermometer and barometer respectively, throughout the study period. Temperature-humidity index (THI) was calculated using the formula as reported by Helal *et al*. (2010). Further, the climatic variables were crosschecked with the data provided by the State Meteorological Department, Meghalaya.

Thermoregulatory and live bodyweight data

The rectal temperature (°F), respiratory rate (Per minute) and pulse rate (Beats per minute; bpm) of each goat were measured on three occasions (Morning, afternoon and evening) at 9:00, 13:00 and 16:00 hours every 15 days throughout the sampling period and the mean value of the three readings was calculated. To measure rectal temperature, a digital thermometer with a disinfected sensory tip was inserted into the rectum when the thermometer displayed the temperature reading in degrees celsius (°C) and then readings were converted to Fahrenheit (°F). Respiratory rate was determined by counting the number of abdominal movements per minute. Pulse rate was recorded by placing the fingertips on the femoral arteries of the hind limb for one minute as reported by Sanusi *et al*. (2010). The body weight (Kg) of goats in each treatment group was measured and the average daily gain (g) was calculated.

Hormonal profile

Monthly blood samples were collected from all animals to measure the serum levels of T3 (nmol/L), T4 (nmol/L) and Cortisol (ng/mL) in both groups. Aseptic techniques were employed to collect the blood samples from the jugular vein using a 5 mL syringe. The serum samples were then separated and analyzed for hormone estimation using a species-specific ELISA kit provided by ELK Biotechnology, Co. Ltd.

Statistical analysis

Statistical package for social sciences programme version 23 (IBM SPSS) was used for statistical analysis. Data obtained from thermoregulatory, bodyweight and hormonal indices were expressed as Mean±SE and analyzed using the Student's 't' test. $P<0.01$ and $P<0.05$ were considered highly significant and significant at 99% and 95% confidence interval respectively.

RESULTS AND DISCUSSION

Climatic data

Table 1 shows the THI during the experimental period. The experiment was carried from 1st May to 31st August, 2022. During the period the THI ranged from 71.27 to 74.39.

Thermoregulatory responses

Rectal temperature

Fig 1 depicts the trend of rectal temperature (°F) in both the experimental groups. The rectal temperature significantly ($p<0.05$) increased in HS goats in comparison to CON. Even under challenging weather conditions, goats exhibit a certain level of thermoregulatory control to uphold their body temperature within a narrow range. In a thermo-neutral

Table 1: Average monthly temperature, relative humidity and THI during the experimental period (1st May, 2022 to 31st August, 2022).

Months	Average monthly temp (°C)	Relative humidity (%)	THI
May	22.35	88.0	71.27
Jun	24.13	89.3	74.39
Jul	24.19	87.9	74.36
Aug	24.02	88.6	74.14

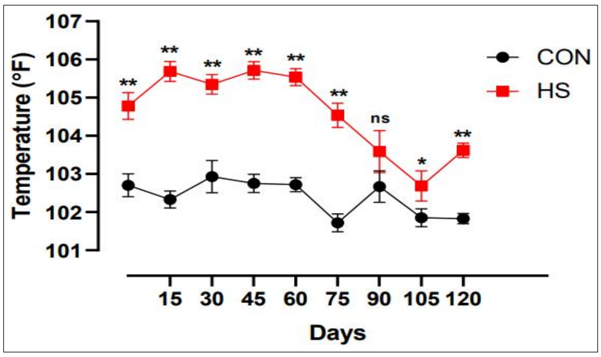

Fig 1: Variation in rectal temperature in control (CON) and heat stressed (HS) group.

setting, rectal temperatures usually range from 38.3 to 39.9°C. Rectal temperature measurement is widely employed as a prominent indicator of body temperature, offering insight into the core temperature (Al-Tamimi, 2007). It is recognized as a crucial physiological parameter for assessing animal welfare in hot environments (Silanikove, 2000). The outcomes of the present investigation indicated a significant ($p<0.05$) elevation in rectal temperature on all days, except at 90 days, during periods of HS. Current results were in accordance with the reports of Kandasami *et al*. (2023) in Kanni Adu and Kodi Adu goats of Tamil Nadu, where HS caused marked increase in rectal temperature during summer. These heightened rectal temperatures observed in the context of hot summer conditions unequivocally demonstrate that the animals were subjected to HS (Alamer and Al-Hozab, 2004; Al-Haidary *et al*., 2012; Minka and Ayo, 2012). In the face of elevated temperatures, animals employ strategies to maintain thermal equilibrium and dissipate excess heat from their bodies. One notable response is an evident increase in the respiratory rate or panting. However, if the body is unable to effectively maintain this thermal equilibrium, it leads to an elevation in body temperature (Marai *et al*., 2007). The outcomes of the present study are in line with published research on Saudi Arabian goats (Al- Samawi *et al*., 2014), indicating concurrence with the previous findings. However, these results contradict the reports associated with Black Bengal goats where heat treatments did not increase skin and rectal temperatures (Alam *et al*., 2011).

Pulse rate

Fig 2 depicts the trend in pulse rate (bpm) in the different experimental groups. There was no significant ($p>0.05$) change in pulse rate on day 0, 15 and 30 days, but a significant ($p<0.05$) increase was recorded from day 45 onwards till 120 days in the HS group in comparison to CON group. The results of our study are consistent with the reports of Alam *et al*. (2011) in Black Bengal goats and Kandasami *et al*. (2023) in Kanni Adu and Kodi Adu goats. The pulse rate primarily indicates the stability of circulation and the overall metabolic condition. When exposed to high environmental temperatures, the pulse rate tends to increase (Aboul-Naga, 1987). In goats, it was found that the pulse rate during summer was considerably higher compared to winter (Ismail *et al*., 1995). This similar pattern was also observed in grazing goats (Khan and Ghosh, 1989). An increase in the pulse rate promotes enhanced blood flow from the core to the body's periphery, leading to increased heat loss through both sensitive means (conduction, convection and radiation) and insensitive means (Water loss through diffusion from the skin) (Marai *et al*., 2007).

Respiration

Fig 3 depicts the trend in respiration rate (per minute) in the experimental groups. Results revealed a significant ($p<0.05$) increase in respiratory rate in the HS group in comparison to the CON. The present results were in agreement with previous findings where it was reported that respiration rate can be elevated through HS in goats (Habeeb *et al*., 1992; Minka and Ayo, 2012; Kandasami *et al*., 2023). The respiratory rate was employed as a measure of HS and served to assess the detrimental impact of environmental temperature (Alamer and Al-Hozab, 2004). For goats, the respiration rate is higher during summer compared to winter (Fahmy, 1994). In essence, the increased respiration rate during summer signifies HS and can be considered one of the mechanisms employed by animals to dissipate excessive heat through evaporation.

Live body weight

Table 2 depicts the average body weight gain in the experimental goats in both the treatment groups. Results revealed a significantly ($p<0.05$) lower average daily gain in the HS group in comparison to CON. Current results are in agreement with the reports of Pragna *et al*. (2018) who

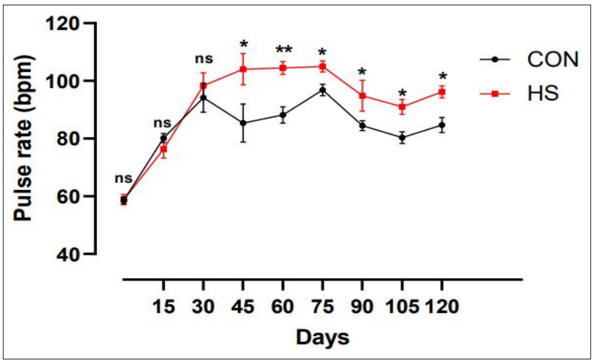

Fig 2: Variation in pulse rate in control (CON) and heat stressed (HS) group.

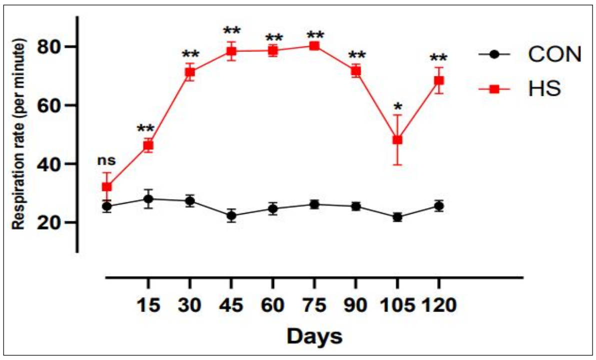

Fig 3: Variation in respiration rate in control (CON) and heat stressed (HS) group.

Table 2: Effect of heat stress on the body weight gain (Mean±SE) of Assam hill goats.

Groups	Initial body weight (kg)	Final body weight (kg)	Average daily gain (g)
HS	9.51±0.45	12.18±0.41	22.22^{b}±1.85
CON	9.41±0.27	13.36±0.28	32.91^{a}±3.59

Means with different superscript differ significantly ($p<0.05$).

Table 3: Effect of heat stress on hormonal profile (Mean±SE) of Assam hill goats.

Groups	T3 (nmol/L)	T4 (nmol/L)	Cortisol (ng/mL)
HS	3.14^{b}±0.35	102.83^{b}±12.78	65.16^{a}±7.36
CON	4.97^{a}±0.37	140.83^{a}±13.33	50.36^{b}±9.58

Means with different superscript differ significantly (p<0.05).

reported reduced average daily gain in Osmanabadi and Malabari heat stressed goats. Upon exposure to high temperatures, goats activate their physiological adaptability to maintain homeothermy (Aleena *et al*., 2018). These adaptive processes consume considerable energy, leading the animals to redirect their energy from productive pathways towards the adaptive pathway (Sejian *et al*., 2018; Aleena *et al*., 2018). This behavior, characterized by a reduction in production to prioritize life-sustaining activities, is typically observed in adapted goat breeds.

Hormonal profile

Table 3 depicts the serum concentration of hormones *viz*., T3 (nmol/L), T4 (nmol/L) and Cortisol (ng/mL) in the experimental groups. T3 and T4 were important hormones in regulating energy balance (Hefnawy *et al*., 2011). Environmental temperature was the main external regulator of the thyroid gland activity (Dickson, 1993). The present study revealed that T3 and T4 serum concentrations were significantly ($p<0.05$) reduced in HS animals in comparison to CON. These outcomes are in agreement with the findings reported previously, indicating a decrease in blood concentrations of T3 and T4 during thermal stress (Silanikove, 2000). Furthermore, an inverse relationship between temperature and the activity of thyroid gland hormone secretion (T3 and T4) has been observed in sheep (Starling *et al*., 2005) and goats (Todini *et al*., 1992). The thyroid and adrenal glands play vital roles in animal adaptation by regulating heat production within the organism. When animals are exposed to high temperatures, the reduction in thyroxine secretion occurs as a response to reduced thermogenesis requirements, representing a significant step in countering heat stress (Coelho *et al*., 2008). This decrease in thyroid hormone release is influenced by the impact of heat on the hypothalamic-pituitary-adrenal (HPA) axis, leading to a decrease in thyroid hormone release and subsequently reducing basal metabolism. Similarly, during cold stress, the increased levels of T3 and T4 stimulate oxygen consumption and heat production in cells, resulting in an elevation of basal metabolism (Bernabucci *et al*., 2010).

In response to stressful conditions, the activation of the hypothalamic-pituitary-adrenal (HPA) axis leads to an increase in plasma cortisol concentration (Silanikove, 2000; Mormède *et al*., 2011). Our study revealed that the exposure of Assam Hill Goats to heat stress resulted in an elevation of serum cortisol concentration. These results are consistent with the findings of Zhengkang *et al*. (1994), who observed a significant ($p<0.01$) increase in blood cortisol concentrations in relation to higher environmental temperatures. Additionally, Mormède *et al*. (2011) reported an increase in plasma cortisol concentration when animals were exposed to direct sunlight during hot summer conditions. Higher plasma cortisol concentrations in animals subjected to heat stress were also reported (Wise *et al*., 1988). The elevation in cortisol levels can be attributed to the direct impact of heat stress, particularly from solar radiation, as stress conditions activate the hypothalamic-pituitary-adrenal (HPA) axis (Mormède *et al*., 2011). The hypothalamus responds by releasing corticotrophin-releasing factor (CRF), which acts on the anterior pituitary, leading to the release of adrenocorticotropic hormone or corticotrophin (ACTH). This, in turn, stimulates the adrenal cortex to produce corticosteroid (Cortisol) hormones (Mormède *et al*., 2011). Cortisol, the primary glucocorticoid, plays a crucial role in various physiological processes, including the regulation of metabolism, body water distribution, electrolyte balance and blood pressure. Its secretion triggers physiological changes that enable animals to cope with the stress caused by a hot environment. In the initial stages of acute heat stress, the animal's response is primarily emotional rather than thermoregulatory. However, during severe acute heat stress, cortisol likely contributes to the induction of hyperglycemia, facilitating the anticipated increase in glucose utilization (Bernabucci *et al*., 2010).

CONCLUSION

In conclusion, Assam Hill Goats exposed to environmental HS shows elevated thermoregulatory responses, decreased thyroid hormone activity and increased cortisol activity to reduce production to support life sustaining activities in the hilly regions. Such behavioural changes are aimed to increase the animal's basal metabolism and is a typical characteristic of goat breeds towards climatic adaptation.

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Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

REFERENCES

Aboul-Naga, A.I. (1987). The role of aldosterone in improving productivity of heat-stressed farm animals with different techniques. Ph. D. Thesis. Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

Alam, M.M., Hashem, M.A., Rahman, M.M., Hossain, M.M., Haque, M.R., Sobhan, Z., Islam, M.S. (2011). Effect of heat stress on behavior, physiological and blood parameters of goat. Progressive Agriculture. 22(1-2): 37-45.

Alamer, M., Al-Hozab, A. (2004). Effect of water deprivation and season on feed intake, body weight and thermoregulation in Awassi and Najdi sheep breeds in Saudi Arabia. Journal of Arid Environments. 59: 71-84.

Aleena, J., Sejian, V., Bagath, M., Krishnan, G., Beena, V., Bhatta, R. (2018) Resilience of three indigenous goat breeds to heat stress based on phenotypic traits and PBMC HSP70 expression. International Journal of Biometeorology. 62: 1995-2005.

Al-Haidary, A., Aljumaah, R.S., Alshaikh, M.A., Abdoun, K.A., Samara, E.M., Okab, A.B., Alfuraiji, M.M. (2012). Thermoregulatory and physiological responses of najdi sheep exposed to environmental heat load prevailing in Saudi Arabia. Pakistan Veterinary Journal. 32: 515-519.

Al-Samawi, K.A., Al-Hassan, M.J., Swelum, A.A. (2014). Thermoregulation of female Aardi goats exposed to environmental heat stress in Saudi Arabia. Indian Journal of Animal Research. 48(4): 344-349. doi: 10.5958/0976-0555.

Al-Tamimi, H.J. (2007). Thermoregulatory response of goat kids subjected to heat stress. Small Ruminant Research. 71: 280-285.

Baumgard, L.H., Rhoads, R.P. (2013). Effects of heat stress on postabsorptive metabolism and energetics. Annuual Review of Animal Biosciences. 1: 311-337.

Bernabucci, U., Lacetera, N., Baumgard, L.H., Rhoads, R.P., Ronchi, B., Nardone, A. (2010). Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal. 4: 1167-1183.

Castanheira, M., Parva, S.R., Louvandini, H., Landim, A., Fiorvanti, M.C.S., Dallago, B.S., Correa, P.S., McManus, C. (2010). Use of heat tolerance traits in discriminating between groups of sheep in central Brazil. Tropical Animal Health and Production. 42: 1821-1828.

Coelho, L.A., Sasa, A., Bicudo, S.D., Balieiro, J.C.C. (2008). Plasma concentrations of testosterone, triiodothyronine (T3) and thyroxine (T4) in bucks submitted to heat stress. Arquivo Brasileiro de Medicina Veterinária e Zootecnia. 60: 1338-1345.

Dickson, W.M. (1993). Endocrine Glands. In: Duke's Physiology of Domestic Animals, 11th edition [(ed.) Swenson, M.J. and Reece W.O.)], Comstock Publishers Association, Ithaca and London pp. 629-664.

Fahmy, S. (1994). Effect of crossing Romanov with Rahmani sheep on some physiological and productive performance. M. Sc. Thesis, Faculty of Agriculture, Al-Azhar University, Cairo, Egypt.

Habeeb, A.A., Marai, I.F.M., Kamal, T. H (1992). Heat Stress. In: Farm Animals and the Environment. [Philips, C., Piggens, D. (Eds.)], C.A.B. International, pp. 27-47.

Hefnawy, E.A., Shousha, S., Youssef, S. (2011). Hematobiochemical profile of pregnant and experimentally pregnancy toxemic goats. Journal of Basic and Applied Chemistry. 1: 65-69.

Helal, A., Hashem, A.L.S., Abdel-Fattah, M.S., El-Shaer, H.M. (2010). Effects of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. American-Eurasian Journal of Agriculture and Environmental Science. 7(1): 60-69.

Ismail, E., Abdel-Latif, H., Hassan, G.A., Salem, M.H. (1995). Water metabolism and requirements of sheep as affected by breed and season. World Rev. Animal Production. 30(1-2): 95-105.

Kandasami, R., Sangameswaran, R., Rajesh, G., Loganathasamy, K. (2023). Effect of summer heat stress on physiological and haemato-biochemical characters in Kanni ADU and Kodi ADU Goat breeds of Tamil Nadu. Indian Journal of Small Ruminants (The). 29(1): 50-54.

Khan, M.S., Ghosh, P.K. (1989). Physiological responses of desert sheep and goats to grazing during summer and winter. Indian Journal of Animal Sciences. 59(5): 600-603.

Marai, I.F.M., El-Darawany, A.A., Fadiel, A., Abdel-Hafez, M.A.M. (2007). Physiological traits as affected by heat stress in sheep-A review. Small Ruminant Research. 71: 1-12.

Minka, N.S., Ayo, J.O. (2012). Assessment of thermal load on transported goats administered with ascorbic acid during the hot-dry conditions. International Journal of Biometeorology. 56: 333-341.

Mormède, P., Foury, A., Terenina, E., Knap, P.W. (2011). Breeding for robustness: The role of cortisol. Animal. 5: 651-657.

Pragna, P., Sejian, V., Bagath, M., Krishnan, G., Archana, P.R., Soren, N.M., Bhatta, R. (2018). Comparative assessment of growth performance of three different indigenous goat breeds exposed to summer heat stress. Journal of Animal Physiology and Animal Nutrition. 102(4): 825-836.

Sanusi, A.O., Peter, S.O., Sonibare, A.O., Ozojie, M.O. (2010). Effects of coat colour on heat stress among West African dwarf sheep. Nigerian Journal of Animal Production. 38(1): 28-36.

Sejian V., Bhatta, R., Gaughan, J.B., Dunshea, F.R., Lacetera, N. (2018). Adaptation of animals to heat stress. Animal. 12: s431-s444.

Silanikove, N. (1992). Effect of water scarcity and hot environment on appetite and digestion in ruminants: A review. Livestock Production Science. 30: 175-194.

Silanikove, N. (2000). Effects of heat stress on the welfare of extensively managed domestic ruminants: A review. Livestock Production Science. 67: 1-18.

Starling, J.M.C., da Silva, R.G., Negrao, J.A., Maia, A.S.C., Bueno, A.R. (2005). Seasonal variation of thyroid hormones and cortisol of sheep in tropical environment. Revista Brasileira de Zootecnia. 34: 2064-2073.

Todini, L., Lucaroni, A., Malfatti, A., Debenedetti, A., Costarelli, S., (1992). Male-female differences in the annual profiles of the thyroid hormones blood level by the goat. Atti della Societa Italiana delle Scienze Veterinarie. 46: 169-173.

Wise, M.E., Armstrong, D.V., Huber, J.T., Hunter, R., Wiersma, F. (1988). Hormonal alterations in the lactating dairy cow in response to thermal stress. Journal of Dairy Science. 71(9): 2480-2485.

Zhengkang, H., Zhenzhong, C., Shaohua, Z., Vale, W.G., Barnabe, V.H., Mattos, J.C.A. (1994). Rumen metabolism, blood cortisol and T3, T4 levels and other physiological parameters of swamp buffalo subjected to solar radiation. Proas World Buffalo Congress., Sao Paulo, Brazil. 2: 39-40.