REVIEW ARTICLE Agricultural Reviews, Volume 44 Issue 2: 164-172 (June 2023)

Heat Stress Responses in Small Ruminants under Arid and Semi-arid Regions of Western India: A Review

V. Bhateshwar[1], D.C. Rai[1], M. Datt[2]

10.18805/ag.R-2393

ABSTRACT

The main purpose of this review was to demonstrate the current state of the investigations on the responses of body weight, physiological and blood biochemical variables in the small ruminants (sheep and goats) reared in hot arid and semi-arid regions of western India. In recent years, scientific research has made it possible to measure how different breeds of sheep and goat respond to climatic influences and manage to be homoeothermic and adapt to various environmental conditions. The exposure of sheep and goats to heat stress leads to alterations in the physiological and biochemical profiles of blood and also affect the body weight, rectal temperature, respiratory rate, pulse rate, blood plasma properties, production, reproduction, milk quantity and its quality. There are some studies which prove that the central nervous system is susceptible to the deviations in body temperature and also that some cells are more agile in the cold than in heat. In summary, we mention that in different breeds, the rearing environment and its environmental variability can trigger the feed intake efficiency and utilization, body growth, physiological changes and biochemical changes in the blood which lead to heat increment in the body's thermal balance.

Key words: Blood biochemical, Goat, Heat stress, Physiological response, Sheep, Small ruminants.

Heat stress (HS) leads to impairment in body growth, physiology, morphology, blood biochemistry, reproduction, production, milk yield as well as natural immunity in small ruminants across the world (La Salles *et al.,* 2017). Increased temperature and higher relative humidity in summer can impair the thermal regulatory mechanisms of small ruminants and influence the loss of heat which leads to HS. Exposure of sheep and goats to raised temperature decreases the productive and reproductive performance, milk quantity and quality, body weight gain, daily average weight gain (AWG), growth rate and total body solids. It also reduces the animal's natural ability of physical immunity and makes them prone to highly-strung diseases (Marai *et al.,* 2000; Abdel-Hafez, 2002; La Salles *et al.,* 2017). This causes severe monetary loss for sheep and goat farmers. Heat stress affects ruminants through a combination of environmental factors like higher ambient temperature, lower relative air humidity, higher solar waves, lower wind velocity and rainfall (Al-Dawood, 2017). Aerial temperature and relative humidity have most direct effects on the production potential of ruminants (Seixas *et al.,* 2017). However, under extreme environmental conditions, sheep and goats show better heat stress compared to other ruminants (Bakheit *et al.,* 2017). They are the most adaptable and geographically wide-spread farm animal species, ranging from the high mountains of hypoxia to the extreme lowlands of thermally stressed environment (Brito *et al.,* 2015; Wei *et al.,* 2015). Sheep and goats adapt to extreme climatic conditions via behavioral, morphological, physiological and mostly genetic principles (Jose *et al.,* 2016). The main limitations of the arid and semi-arid subtropical climate are its lower biomass production, higher environmental variability and inadequacy in availability of ground water all year round.

[1]Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India.
[2]Department of Livestock Production Management, SKN Agriculture University, Jobner-303 329, Rajasthan, India.

Corresponding Author: V. Bhateshwar, Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India. Email: vinod.bhateshwar@bhu.ac.in

How to cite this article: Bhateshwar, V., Rai, D.C. and Datt, M. (2023). Heat Stress Responses in Small Ruminants under Arid and Semi-arid Regions of Western India: A Review. Agricultural Reviews. 44(2): 164-172. doi: 10.18805/ag.R-2393.

Submitted: 29-09-2021 **Accepted:** 31-12-2021 **Online:** 21-02-2022

Small ruminant population scenario

Small ruminants (sheep and goats) are an important part of livelihood in arid and semi-arid regions of western India. The rural population and landless farmers in the extremely heat stressed (arid and semi-arid) environmental conditions have sustainable and eco-friendly rearing systems. Approximately 50% of the sheep and goat population live in the arid regions of the world, which signifies their adaptability and possible tolerance to increasing temperatures (Gowane *et al.,* 2017). India's livestock sector is one of the largest, accounting for 11.6% (536.76 million) of the world's livestock population. This includes goat and sheep population of 26.40% (148.88 million; second position) and 12.17% (74.26 million; third position) respectively. In India's 20th livestock census, the state of Rajasthan ranked second as it shares 56.80 million of India's total livestock population (536.76 million). In case of small ruminants, Rajasthan is first among

other states with 20.84 million goat population and is fourth in sheep population (7.90 million) (DAHD, 2019). In Rajasthan, over than 51% of the livestock is reared in the western region, mostly in the arid and semi-arid parts of the state. Ranching of livestock (23% sheep, 41% goat, 21% cattle, 13% buffalo and 2% camel) has been the main source of income for local migrant/maldhari for centuries.

Heat stress measurement in small ruminants

The temperature humidity index (THI) is a good indicator of heat stress (HS) in livestock. It is a value that shows the discomfort, or is a combined assessment of the ambient temperature and relative humidity which has the objective to examine the contrast in climatic conditions (Wojtas *et al.,* 2014). Hence, THI enables us to better diction the impressions of a higher environmental temperature and humidity. The method described by NRC (1971) to calculate the temperature humidity index (THI) is as follows:

THI =
(1.8 × Tdb + 32) - [(0.55 - 0.0055 × RH) × (1.8 × Tdb - 26.8)]

Where
Tdb is the dry bulb temperature (°C) and RH is the relative humidity (%)/100, for sheep and goats.

The stress range for ruminants (sheep and goats) on the basis of temperature humidity index (THI): comfortable ≤72; under mild stress 73-78; under severe stress ≥ 80 (Fig 1). THI values of over 80 are considered to be moderate heat stress (MHS) in sheep and goats (Silanikove and Koluman, 2015). The degree of thermal stress in all places of Thar Desert (Western India) is that 100% of the places have an average THI of >80 and >35% of the places have a THI of >85 in May and June.

Heat stress responses in small ruminants

Body weight response

Body growth (BG) is defined as the increase in living biomass or cell proliferation. Heat stress (HS) has harmful effects on growth efficiency, *i.e.* the body growth rate, daily weight gain and live weight of animals (Gad, 2013). Among the differing changeable growth attributes, body weight is the most significant factor affected by heat stress in small ruminants (sheep and goats). The body weight performance of sheep and goats is influenced by genetics, surroundings, environment, balanced nutrient diet, hormones and enzyme activities in the body (Marai *et al.,* 2007). Body weight and average daily gain (ADG) are important selection standard for the meat breed animals (sheep and goat) and it is considered as a decisive trait in determining the meat production (Pragna *et al.,* 2018). The main factors for retardation of animal body growth can be the declined activity anabolism, decreased voluntary water intake and decreased feed consumption. Essential supplement nutrients are needed for metabolizable energy which gives proper nourishment, body weight gain and improved tissue catabolism (Gupta and Mondal, 2021).

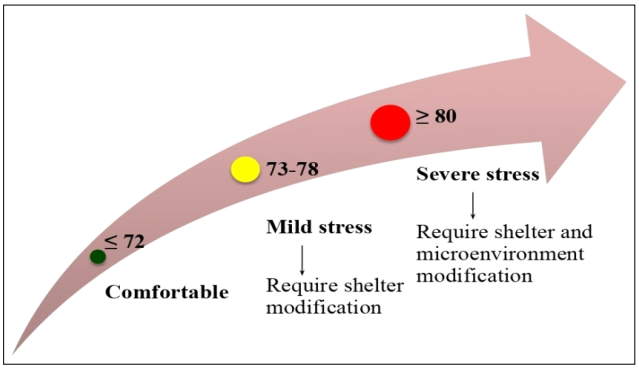

Fig 1: Temperature humidity index (THI) and small ruminants (sheep and goat) discomfort.

Among the multifarious environmental stresses, heat stress is a major stress, affecting the performance of body weight in small ruminants, especially sheep's and goats in the arid and semi-arid hot desert areas. Decreased body growth performance connected with summer heat stress is an ordinary phenomenon in tropical and subtropical regions of the world (Pragna *et al.,* 2018). In general, sheep and goats begin to experience heat after being exposed to 38°C and above with a THI greater than 75 (Sejian *et al.,* 2018). While the THI values affected the body weight gain due to heat stress, it significantly decreased the feed consumption in Indigenous goat breeds Osmanabadi, Malabari and Salem Black. Heat stress has negative effects on average daily gain (ADG) in all heat stress groups and the weight reduction rates were 3.4, 2.69 and 2.65 kg for Osmanabadi, Malabari and Salem Black goats respectively. The THI value 72 and less are considered comfortable; THI values between 75 and 78 are considered stressful and THI values above 78 are considered extreme distress (Pragna *et al.,* 2018). In another study carried out on goats exposed to summer heat stress (32.9°C), it was reported that the mean average daily gain (ADG) was reduced due to low feed consumption in the animals (Popoola *et al.,* 2014). The effects of heat stress on body weight gain, feed consumption and response to water intake in Malpura ewes in semi-arid tropical environment was studied at different temperatures several times a day and it was found that body weight and feed intake were reduced, while water intake increased significantly (Indu *et al.,* 2014). Thermal stress significantly changed the body weight and feed consumption in ewes under semi-arid hot environmental conditions (Sejian *et al.,* 2010a). According to Ismail *et al.* (1995) the live body weight gain, growth efficiency, body's total solids and daily solids gain (g) was affected after exposure to higher environmental thermal stress. A similar trend was observed that the body weight decreases under heat stress conditions in the different types of sheep and goats breeds, as mentioned in (Table 1).

Physiological response

High hot ambient temperatures in the arid and semi-arid region are connected to higher ambient temperature and

Table 1: Body weight responses of different breeds of sheep and goats under neutral stress and heat stress conditions.

Breeds	Environmental region	Body weight (kg)				References
		Neutral stress		Heat stress		
		Initial	Final	Initial	Final	
Sheep						
Malpura	Semi-arid	37.50	40.80	37.00	38.00	Indu *et al.* (2014)
Malpura	Semi-arid	34.80	39.50	34.70	35.00	Sejian *et al.* (2010a)
Malpura	Semi-arid tropical	33.75	39.67	33.52	35.19	Sejian *et al.* (2011a)
Malpura	Semi-arid tropical	30.87	32.63	31.52	29.54	Sejian *et al.* (2013b)
Malpura	Semi-arid	31.80	34.50	31.90	34.00	Sejian *et al.* (2014b)
Jaisalmeri	Hot-arid	26.00	34.00	27.50	31.00	Mathur *et al.* (2019)
Jaisalmeri	Hot-arid	27.50	32.60	27.50	30.00	Mathur *et al.* (2019)
Malpura	Hot semi-arid tropical	50.00	49.00	50.00	46.00	Maurya *et al.* (2019)
Malpura	Semi-arid	31.60	32.40	31.10	29.80	Kumar *et al.* (2019)
Malpura (lambs)	Semi-arid	19.44	26.19	19.52	25.29	De *et al.* (2017)
Magra (lambs)	Arid	5.66	15.93	5.34	15.92	Bothra *et al.* (2020)
Goat						
Osmanabadi	Hot-humid	16.78	18.80	17.07	15.40	Pragna *et al.* (2018)
Malabari	Hot-humid	13.43	15.08	13.46	12.40	Pragna *et al.* (2018)
Salem-Black	Hot-humid	16.85	18.30	16.53	15.65	Pragna *et al.* (2018)
Murciano-Granadina	Semi-arid	43.60	45.40	44.10	42.60	Hamzaoui *et al.* (2013)
Murciano-Granadina (kids)	Semi-arid	2.34	7.88	2.18	7.64	Garcia *et al.* (2020)

lower humidity. Additional reasonable factors such as discomfort due to increased level of heat stress, which in turn led to a reduction in the physiological activities of these small ruminants. The results of the various experiments show (Table 2) that heat stress or multiple stresses significantly influences the physiological response in sheep and goat breeds. Heat stress has significantly altered some of the physiological responses of small ruminants commonly assessed are rectal temperature, heart rate and respiratory rate, resulting in an incredible financial loss in sheep and goat farming. In addition, the environmental variables change drastically in a day; consequently, physiological reactions are also strongly influenced by the time of day. In addition, physiological responses generally increase from morning (07:00 a.m.- 10:00 a.m.) to noon (11:00 a.m.- 02:00 p.m.). However, from evening to night these responses begin to decrease (11:00 p.m.- 06:00 a.m.) and the values of the physiological variables remain constant throughout this time (Da Silva *et al.,* 2017). The influence of physiological reactions under heat stress state in small ruminants is clearly described in imagery (Fig 2). The variations in physiological responses have been always recorded not only between species but also between breeds and even between individuals within a breed (Table 2).

Rectal temperature

The body temperature ideally is a very good measurable indicator for the heat load in the body of animals and represents the consequence of all heat gain and heat loss transformation of the body. Rectal temperature is regarded as an important measure of the physiological state of animal (Koga *et al.,* 2004). Rectal temperature (RT) is a crucial index of body temperature that can be used to determine the adaptability of heat stress. The RT is measured with a diagnostic thermometer by interpolating the thermometer by 6-7 cm into the rectum at an angle to the rectum wall. In addition, increasing RT represents the failure of the thermoregulatory mechanism in the animal body. An increase in rectal temperature of 1°C or less is sufficient to decrease the performance of the animals (Rashamol *et al.,* 2018). The average daily variant in rectal temperature ranges from 0.3°C to 1.9°C (Piccione and Refinetti, 2003). The rectal temperature (RT) in sheep and goats fluctuates between 38.0°C to 40.0°C and is often used as an indicator of the body temperature, although there is a variance in body temperature in different parts of the body around the day. The rectal temperatures rates of goats increased from 0800 to 1700 h in heat stress (HS) groups compared to thermal neutral (TN) goats (Hamzaoui *et al.,* 2013). In contrast, some studies observed that there was no significant difference in rectal temperature in thermal stressed goats (Alam *et al.,* 2011; Panda *et al.,* 2016). In Malpura ewes the highest rectal temperature (RT) in semi-arid tropical environmental conditions was measured in morning for the normal stress group (101.38°F), while in the multiple stress group, the highest value (102.55°F) was measured in afternoon (Sejian *et al.,* 2013). Increased rectal temperature with an increase in temperature humidity index in summer season is an excellent indicator of heat stress in animals (Srikandakumar *et al.,* 2003).

Respiration rate

Breathing is the uptake of oxygen (O_2) and excretion of carbon dioxide (CO_2) under thermo-neutral conditions which

Table 2: Physiological responses of different breeds of sheep and goats under neutral stress and heat stress conditions.

Breeds			Physiological responses				References
			Ambient temperature (°C)	RT (°F)	RR (breaths/min)	PR (beats/min)	
Sheep							
Malpura	NS	Morning	23.4-31.0	38.4°C	24.4	57.5	Sejian *et al.* (2010a)
		Afternoon		38.9°C	40.1	74.6	
	HS	Morning		38.5°C	30.2	62.7	
		Afternoon		39.6°C	130.8	80.1	
Malpura	NS	Morning	35.0-41.0	101.38	22.93	62.42	Sejian *et al.* (2013b)
		Afternoon		102.14	52.86	72.42	
	HS	Morning		100.66	21.97	52.81	
		Afternoon		102.55	68.74	59.58	
Malpura	NS	Morning	16.43-35.27	100.12	26.07	58.50	Sejian *et al.* (2014b)
		Afternoon		101.79	41.93	71.89	
	HS	Morning		100.08	26.29	62.21	
		Afternoon		102.63	108.89	76.00	
Malpura	NS	Morning	16.9-36.9	101.5	30.0	60.0	Indu *et al.* (2014)
		Afternoon		102.0	50.0	70.0	
	HS	Morning		101.0	20.0	65.0	
		Afternoon		102.5	120.0	75.0	
Chokla	NS	Morning	68-101°F	101.8	26.75	73.43	Singh *et al.* (2016)
		Afternoon		102.24	36.31	84.51	
	HS	Morning		101.75	39.5	71.66	
		Afternoon		103.61	59.58	96.96	
Magra	NS	Morning	68-101°F	100.94	30.04	71.24	Singh *et al.* (2016)
		Afternoon		103.3	49.81	95.71	
	HS	Morning		101.6	34.2	78.56	
		Afternoon		103.55	58.11	99.9	
Marwari	NS	Morning	68-101°F	100.61	31.75	72.91	Singh *et al.* (2016)
		Afternoon		102.11	45.13	91.46	
	HS	Morning		101.31	35.48	78.48	
		Afternoon		103.33	57.93	99.9	
Jaisalmeri	NS	Morning	47.3-50.02	101.20	14.0	74.0	Mathur *et al.* (2019)
		Evening		102.0	16.0	76.0	
	HS	Morning		101.20	14.0	74.0	
		Evening		102.90	18.0	76.50	
Small-tail Han	NS	Ram	25.0-35.0	39.31°C	35.71	107.42	Li *et al.* (2018)
		Ewe		39.32°C	37.38	-	
	HS	Ram		39.47°C	87.71	-	
		Ewe		39.63°C	63.77	-	
Naimey	NS	-	23.6-38.5	39.3°C	61.0	-	AL-Haidary, (2004)
	HS	-		39.7°C	80.0	-	
Chokla	HS	-	78.95 THI	38.31°C	79.09	77.94	Ashutosh *et al.* (2000)
Avivastra	HS	-	78.95 THI	38.26°C	57.14	79.15	Ashutosh *et al.* (2000)
Goat							
Indigenous goats	NS	-	0 h	100.1	32.7	74.3	Alam *et al.* (2011)
	HS	-	4 h	102.9	111.0	82.3	
	HS	-	8 h	104.3	119.3	87.3	
Osmanabadi	NS	-	0 h	101.20	45.0	85.73	Panda *et al.* (2016)
	HS	-	2 h	102.45	124.3	93.73	
	HS	-	4 h	104.72	132.0	98.73	

Table 2: Continue...

Table 2: Continue...

Murciano-Granadina	NS	-	0800 h	38.54°C	34.0	-	Salama *et al.* (2020)
			1200 h	38.57°C	39.0	-	
			1700 h	38.80°C	46.0	-	
	HS	-	0800 h	39.25°C	81.0	-	
			1200 h	40.02°C	171.0	-	
			1700 h	40.46°C	187.0	-	
Barbari	NS			37.94°C	24.40		Kumar *et al.* (2018)
	HS	-	45.53°C	38.61°C	26.60	-	
Sirohi	NS	-		37.71°C	24.20		Kumar *et al.* (2018)
	HS	-	44.53°C	37.80°C	28.80	-	
Jhakrna	NS	-		37.78°C	24.20		Kumar *et al.* (2018)
	HS	-	44.53°C	37.65°C	28.80	-	

NS = Neutral stress; HS = Heat stress; RT = Rectal temperature; RR = Respiration rate; PR = Pulse rate; - Absence of observation.

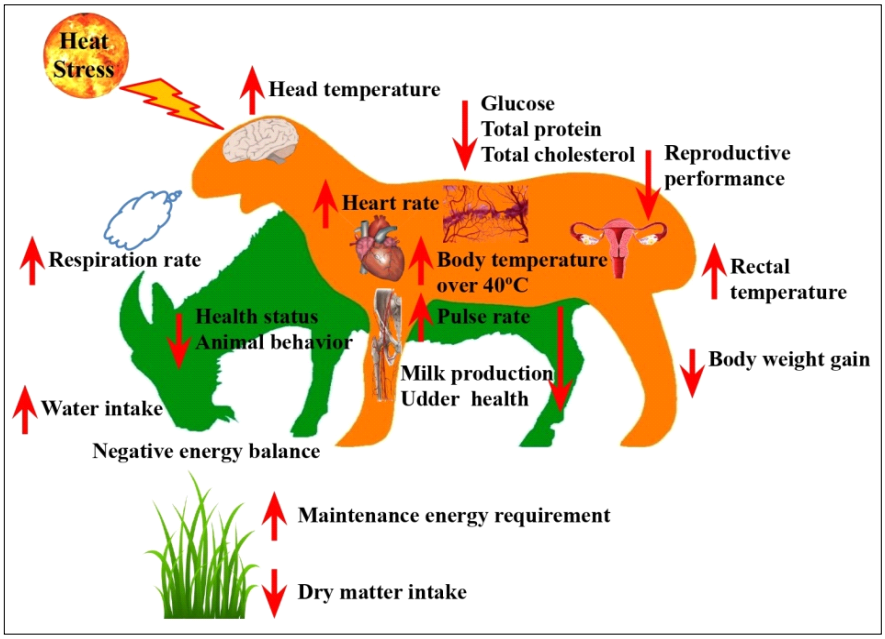

Fig 2: Negative effects of heat stress on sheep and goat under arid and semi-arid conditions.

leads to evaporation and removal of moisture from the respiratory tract to control thermo equilibrium. The respiration rate (RR) is a realistic and reliable indicator for thermal stress (Okoruwa, 2014). The RR is determined visually by counting the flank, either its up or down movements per minute using a stopwatch without disturbing the animal (Shaji *et al.,* 2016). Normally the physiological respiratory rate in sheep and goats is 15 to 30 breaths per minute. The severity of heat stress can be classified based on the respiring rate (breaths/min) (low: 40-60, medium: 60-80, high: 80-120 and severe: >200), as this is the most approachable and easiest way to evaluate the effects of heat stress (Silanikove, 2000). During the experimental study on Indigenous goats on average (temp. 28.74°C and RH 87.83%) with division into three experimental groups as: 0 hrs, 4 hrs and 8 hrs of heat exposure, the respiratory rate in goats was higher with the increasing heat stress from 0 to 8 hrs of heat exposure (Alam *et al.,* 2011). In another study, goats with heat stress (147 breaths/min) compared to neutral thermal goats (40 breaths/min)showed a positive increase in respiratory rate over the day in accordance with the increase in daily heat-stress rate (HS) from 0800 until 1700 h (Salama *et al.,* 2020).

However, the significant race differences between hot and cold-adapted goats were recorded for the respiration rates with the highest average values in cold-adapted goats (Gaddi and Chegu) compared to those of hot-adapted goats (Sirohi and Barbari). Another study found that Malpura ewes in a semi-arid tropical setting showed significant changes in respiration rates. The respiration rates for ewes in the heat stress group were lower in morning and significantly highest in the afternoon, compared to ewes in the normal stress group (Indu *et al.,* 2014). Similarly in another study, the respiratory rates in neutral thermals were significantly lower (52.85 breaths/min) and it was higher after multiple exposures of ewes recorded in the afternoon (68.74 breaths/min)

(Sejian *et al.,* 2013). The impression of heat stress on Naimey sheep in a semi-arid environment with one room was recorded as the normal room temperature (23.6°C) and the other room was used as the heat stress room (33-38.5°C). It was recorded that the increase in respiratory rate is an attempt to increase respiratory evaporation. This is caused by higher skin temperature which occurs due to heat stress in sheep (AL-Haidary, 2004). It is concluded that both respiratory rate and rectal temperature is a very good indicator of heat stress and it can be used to define the adverse effects of heat stressed environment.

Pulse rate

Pulse rate (PR) is the regularly beating rate of the arteries as blood is pumped through them to the heart. In addition to the general metabolic status, the pulse rate primarily reflects the homeostasis of the circulatory system (Sejian *et al.,* 2010). The heart rate can change quickly due to external factors such as time of year, time of day, higher ambient temperature, relative humidity and physical exercise (Marai *et al.,* 2007; Phulia *et al.,* 2010). The pulse rate is generally measured by palpating the hand's femoral artery in sheep and goats. Hand is placed on the inside of the animal's thigh: the saphenous artery runs along the inside of the hind leg. Normally, pulse rates for sheep and goats range from 90 to 95 frequencies/min. However, it rises with thermal stress to release more heat to the environment by increasing blood circulation to the body surfaces (Shilja *et al.,* 2016). In addition, Shaji *et al.* (2016) also observed a positively higher pulse rate in heat-stressed Osmanabadi goats, which indicates the role of pulse rate in appraising the amount of heat stress in these animals. In another study, Alam *et al.* (2011) observed that the pulse rate in domestic goats heightened with increasing heat stress from the zero-hour heat exposure group (74.30 frequency/min) to the eight-hour heat exposure group (87.30 frequency/min). The sheep in Thar region preferred shade especially of tree scales when THI is above 88. The cooling effect of the leaves due to moisture evaporation and free air flow in the pasture area compared to erected thatched shade along with supplementary concentrate and health management methods maintained a normal heart rate in Jaisalmeri breed of sheep (Mathur *et al.,* 2019).

Blood biochemical response

In general, the biochemical blood profile indicates the health status, metabolic activities and nutritional conditions of the animal (Calamari *et al.,* 2016). Heat stress changes the blood plasma content of various blood biochemical parameters such as total protein, total cholesterol, glucose, globulin and albumin (Gupta and Mondal, 2021). The general fluctuations in blood biochemical parameters of animals in

Table 3: Blood biochemical responses of different breeds of sheep and goats under neutral stress and heat stress conditions.

Breeds		Blood biochemical responses								References
		GLU (mg/dL)	TP (g/dL)	TC (mg/dL)	ALB (g/dL)	GLO (g/dL)	TG (mg/dL)	Ca (mg/dL)	P (mg/dL)	
Sheep										
Malpura	NS	52.08	8.88	52.31	-	-	-	-	-	Sejian *et al.* (2010a)
	HS	47.80	7.95	42.96	-	-	-	-	-	
Malpura	NS	65.55	7.25	66.77	-	-	-	-	-	Sejian *et al.* (2014b)
	HS	58.18	6.27	63.05	-	-	-	-	-	
Malpura	NS	45.40	7.27	-	-	-	-	8.84	5.57	Sejian *et al.* (2013b)
	HS	39.39	6.37	-	-	-	-	9.01	5.93	
Malpura	NS	55.0	10.0	49.0	3.4	6.5	-	-	-	Indu *et al.* (2014)
	HS	50.0	9.0	50.0	3.8	6.0	-	-	-	
Chokla	NS	63.56	6.13	102.40	2.33	-	48.06	8.73	5.19	Singh *et al.* (2016)
	HS	59.93	7.00	65.00	3.23	-	12.42	9.05	3.88	
Magra	NS	57.81	6.22	102.43	2.05	-	27.43	9.87	4.73	Singh *et al.* (2016)
	HS	55.65	6.86	59.54	3.20	-	11.94	9.38	4.01	
Marwari	NS	50.20	6.54	104.73	2.84	-	47.60	8.80	4.81	Singh *et al.* (2016)
	HS	55.64	6.74	54.50	3.22	-	11.77	8.31	4.25	
Goat										
Osmanabadi	NS	57.85	7.62	97.83	5.26	2.56	8.95	-	-	Aleena *et al.* (2020)
	HS	60.64	7.40	85.73	5.31	2.23	7.04	-	-	
Malabari	NS	52.13	6.65	72.25	3.57	3.21	9.1	-	-	Aleena *et al.* (2020)
	HS	58.52	7.09	89.97	3.74	3.50	10.09	-	-	
Salem Black	NS	53.03	6.84	83.29	4.37	2.23	8.58	-	-	Aleena *et al.* (2020)
	HS	47.98	6.17	78.48	4.20	2.17	7.15	-	-	

NS = Neutral stress; HS = Heat stress; GLU = Glucose; TP = Total protein; TC = Total cholesterol; ALB = Albumin; GLO = Globulin; TG = Triglycerides; Ca = Calcium; P = Phosphorous; - Absence of observation.

cold and heat stress environments can be due to the inadequacy to adapt in diversified climatic and geographic circumstances which is necessary for their survivability (Banerjee *et al.,* 2015; Singh *et al.,* 2016). However, variations in the coordination of these entire manners to maintain the production capability under heat stressed conditions have been seen not only among species, but also among breeds and even among individuals within a breed. (Marai and Haeeb, 2010). The sheep and goat breeds differ in various responses of blood biochemical profile in a specific heat stress environmental condition which is included in (Table 3). The fluctuations in the biochemical blood parameters (plasma enzymes, hormones and blood sugar) was significantly noted within breeds and seasons for cold-adapted breeds (Gaddi and Chegu) and heat-adapted races (Sirohi and Barbari) (Banerjee *et al.,* 2015). Helal *et al.* (2010), however, conducted an experiment on Balady goat breed which was exposed to thermal stress and recorded a decrease in total plasma protein, globulin and albumin. Some studies showed that the goats in high environmental temperature conditions had lower blood glucose and cholesterol levels, which is an indicator of homeostasis failure (Sezen and Guney, 2010; Ribeiro *et al.,* 2016). However, in Malpura ewes during the semi-arid tropical climatic conditions, the blood plasma glucose and whole blood cholesterol were found to be lower. The blood plasma urea was higher in the group of heat-stressed ewes than in the neutral heat-stressed ewes. The total plasma protein, plasma albumin and plasma globulin recorded had non-significant differences in both normal and heat-stress ewe groups (Indu *et al.,* 2014). While in another study conducted on Chokla, Magra and Marwari sheep breeds, the mean values of the biochemical parameters for total protein and albumin increased whereas cholesterol and triglycerides content decreased during heat stress conditions. The glucose values for Marwari breed increased and for Chokla and Magra decreased. This signifies the higher stress state in Marwari sheep (Singh *et al.,* 2016). The plasma blood cortisol concentration heightened among the group of heat stress ewes (Sejian *et al.,* 2010a). The relationship between heat stress and raised secretion of cortisol, the most important glucocorticoid hormone in small ruminants is well indemnified (Ali and Hayder, 2008). Some of the authors observed that heat stress affects the biochemical blood parameters of sheep and goats (Alam *et al.,* 2011; Phulia *et al.,* 2010; Sharma and Kataria, 2011; Kumar *et al.,* 2010).

CONCLUSION

This review highlights that in arid and semi-arid regions, different breeds, breeding environments and their climatic conditions affect the body growth, physiological responses and biochemical changes in the blood which result in heat increment of body's thermal balance. Among these, higher ambient temperature, higher thermal humidity index, low relative air humidity and sunlight are the main climatic factors that are responsible for heat stress in small ruminants. Although sheep and goats are considered to be more resilient animals than other ruminants, little is known about their adaptation to heat-stressed environmental conditions by a combination of morphological and physiological responses, animal behavior, housing and nutritional management as well as genetic principles. Thus, detailed studies should be carried out on the responses of small ruminants in arid and semi-arid heat stress conditions.

Conflict of interest: None.

REFERENCES

Abdel-Hafez, M.A.M. (2002). Studies on the reproductive performance in sheep. 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: 37-45.

Al-Dawood, A. (2017). Towards heat stress management in small ruminants- A review. Annals of Animal Science. 17: 59-88.

Aleena, J., Sejian, V., Krishnan, G., Bagath, M., Pragna, P., Bhatta, R. (2020). Heat stress impact on blood biochemical response and plasma aldosterone level in three different indigenous goat breeds. Journal of Animal Behaviour and Biometeorology. 8: 266-275.

AL-Haidary, A.A. (2004). Physiological responses of Naimey sheep to heat stress challenge under semi-arid environments. International Journal of Agriculture and Biology. 6: 307-309.

Ali, A. and Hayder, M. (2008). Seasonal variation of reproductive performance, foetal development and progesterone concentrations of sheep in the subtropics. Reproduction in Domestic Animals. 43: 730-734.

Ashutosh, A., Dhanda, O., Kunou, R. (2000). Physiological responses of native and crossbred sheep to climatic stress under semi-arid conditions. Indian Journal of Animal Science. 8: 857-861.

Bakheit, S.A., Ibrahim, I.E., ElShafei, I.M., Musa, M.A. (2017). Effects of water deprivation and environmental temperature on physiological performance of Sudanese desert goats. Journal of Scientific and Engineering Research. 4: 243-250.

Banerjee, D., Upadhyay, R.C., Chaudhary, U.B., Kumar, R., Singh, S., Ashutosha, Das, T.K., De, S. (2015). Seasonal variations in physio-biochemical profiles of Indian goats in the paradigm of hot and cold climate. Biological Rhythm Research. 46: 221-236.

Bothra, T., Patel, A.K., Kumar, V., Jain, D., Saini, N., Prajapat, U.K. (2020). Effect of improved nutrition and improved shelter on growth performance of Magra lambs in two lambing seasons under arid zone. International Journal of Livestock Research. 10: 62-67.

Brito, L.F., Jafarikia, M., Grossi, D.A., Kijas, J.W., Porto-Neto, L.R., Ventura, R.V.,Salgorzaei, M., Schenkel, F.S. (2015). Characterization of linkage disequilibrium, consistency of gametic phase and admixture in Australian and Canadian goats. BMC Genetics. 16: 67.

Calamari, L., Ferrari, A., Minuti, A., Trevisi, E. (2016). Assessment of the main plasma parameters included in a metabolic profile of dairy cow based on fourier transform mid-infrared spectroscopy: preliminary results. BMC Veterinary Research. 12: 4.

Da Silva W.E., Leite, J.H.G.M., de Sousa, J.E.R., Costa, W.P., da Silva, W.S.T., Guilhermino, M.M., Façanha, D.A.E. (2017). Daily rhythmicity of the thermoregulatory responses of locally adapted Brazilian sheep in a semiarid environment. International Journal of Biometeorology. 61: 1221-1231.

DAHD (2019). 20th Livestock Scenes all India Report. https://www.dahd.nic.in

De, K., Kumar, D., Singh, A.K., Kumar, K., Sahoo, A., Naqvi, S.M.K. (2017). Effect of protection against hot climate on growth performance, physiological response and endocrine profile of growing lambs under semi-arid tropical environment. Tropical Animal Health and Production. 49: 1317-1323.

Gad, A.E. (2013). Effect of olive pulpe levels in the diet of buffalo calves on physiological body functions and productive traits under heat stress conditions. Isotope and Radiation Research. 45: 61-77.

Garcia, W.C., Mehaba, N., Llonch, P., Caja, G., Such, X., Salama, A.A.K. (2020). Prenatal heat stress effects on gestation and postnatal behavior in kid goats. PLoS ONE. 15: e0220221.

Gowane, G.R. Gadekar, Y.P., Prakash, V., Kadam, V., Chopra, A., Prince, L.L.L. (2017). Climate change impact on sheep production: Growth, milk, wool and meat. V. Sejian *et al.* (Eds.), Sheep Production Adapting to Climate Change. Springer Nature: Singapore, pp. 31-69.

Gupta, M. and Mondal, T. (2021). Heat stress and thermoregulatory responses of goats: A review. Biological Rhythm Research. 52: 407-433.

Hamzaoui, S., Salama, A.A.K., Albanell, E., Such, X., Caja, G. (2013). Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions. Journal of Dairy Science. 96: 6355-6365.

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

Indu, S., Sejian, V., Naqvi, S.M.K. (2014). Impact of simulated heat stress on growth, physiological adaptability, blood metabolites and endocrine responses in Malpura ewes under semi arid tropical environment. Animal Production Science. 55: 766-776.

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 Review of Animal Production. 30: 95-105.

Jose, C., Manuel, A., Pereira, F., De Mira, A., Morita, L., Antonio, E., Titto, L. (2016). Thermoregulatory response in hair sheep and shorn wool sheep CristianeGonc. Small Ruminant Research. 144: 341-345.

Joy, A., Dunshea, F.R., Leury, B.J., Clarke, I.J., DiGiacomo, K., Chauhan, S.S. (2020). Resilience of small ruminants to climate change and increased environmental temperature: A review. Animals. 10: 867.

Koga, A., Kuhara, T., Kanai, Y. (2004). Comparison of body water retention during water deprivation between swamp buffaloes and Friesian cattle. Journal of Agricultural Science. 138: 435-440.

Kumar, D., De, K., Shekhawat, I., Bahadur, S., Balaganur, K., Naqvi, S.M.K. (2019). Combined effect of heat and nutritional stress on superovulation of Malpura ewes in a semi-arid region. Journal of Thermal Biology. 80: 158-163.

Kumar, D., Yadav, B., Choudhury, S., Kumari, P., Madan, A.K., Singh, S.P., Rout, P.K., Ramchandran, N., Yadav, S. (2018). Evaluation of adaptability to different seasons in goat breeds of semi-arid region in India through differential expression pattern of heat shock protein genes. Biological Rhythm Research. 49: 466-478.

Kumar, M., Jindal, R., Nayyar, S., Singla, M. (2010). Physiological and biochemical responses in Beetal goats during summer season. The Indian Journal of Small Ruminants. 16: 255-257.

La Salles, A.Y.F., Batista, L.F., Souza, B.B., Silva, A.F., Correia, E.L.B. (2017). Growth and reproduction hormones of ruminants subjected to heat stress. Journal of Animal Behaviour and Biometeorology. 5: 7-12.

Li, F.K., Yang, Y., Jenna, K., Xia, C.H., Lv, S.J., Wei, W.H. (2018). Effect of heat stress on the behavioral and physiological patterns of small-tail Han sheep housed indoors. Tropical Animal Health and Production. 50: 1893-1901.

Marai, I.F.M., Bahgat, L.B., Shalaby, T.H., Abdel-Hafez, M.A.M. (2000). Fattening performance, some behavioural traits and physiological reactions of male lambs fed concentrates mixture alone with or without natural clay, under hot summer of Egypt. Annals of Arid Zone. 39: 449-460.

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. 7: 1-12.

Marai, I.F.M., Haeeb, A.A.M. (2010). Buffalo's biological functions as affected by heat stress- A review. Livestock Science. 127: 89-109.

Mathur, B.K., Kumar, A., Tanwar, S.P.S., Barewa, M., Singh, J.P., Bhatt, R.K. (2019). Climate change adaptation: Croping strategies for minimizing constraints of extreme climatic conditions of Thar Desert on sheep production. Annals of Arid Zone. 58: 107-115.

Maurya, V.K., Sejian, V., Kumar, D., Naqvi, S.M.K. (2019). Impact of heat stress, nutritional stress and their combinations on the adaptive capability of Malpura sheep under hot semi-arid tropical environment. Journal of Animal Behaviour and Biometeorology. 7: 31-38.

NRC (1971). National Research Council. A Guide to Environmental Research on Animals. National Academy of Sciences, Washington, DC, USA.

Okoruwa, M.I. (2014). Effect of heat stress on thermoregulatory live bodyweight and physiological responses of dwarf goats in southern Nigeria. European Scientific Journal. 10: 255-264.

Panda, R., Ghorpade, P.P., Chopade, S.S., Kodape, A.H., Palampalle, H.Y., Dagli, N.R. (2016). Effect of heat stress on behaviour and physiological parameters of Osmanabadi goats under katcha housing system in Mumbai. Journal Livestock Sciences. 7: 196-199.

Phulia, S.K., Upadhyay, R.C., Jindal, S.K., Misra, R.P. (2010). Alteration in surface body temperature and physiological responses in Sirohi goats during day time in summer season. Indian Journal of Animal Science. 80: 340-342.

Piccione, G. and Refinetti, R. (2003). Thermal chronobiology of domestic animals. Frontiers in Bioscience. 8: s258-264.

Popoola, M.A., Bolarinwa, M.O., Yahaya, M.O., Adebisi, G.L., Saka, A.A. (2014). Thermal comfort effects on physiological adaptations and growth performance of West African dwarf goats raised in Nigeria. European Scientific Journal. 3: 275-281.

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

Rashamol, V.P., Sejian, V., Bagath, M., Krishnan, G., Archana, P.R., Bhatta, R. (2018). Physiological adaptability of livestock to heat stress: An updated review. Journal of Animal Behaviour and Biometeorology. 6: 62-71.

Ribeiro, N.L., Costa, R.G., PimentaFilho, E.C., Ribeiro, M.N., Crovetti, A., Saraiva, E.P., Bozzi, R. (2016). Adaptive profile of Garfagnina goat breed assessed through physiological, haematological, biochemical and hormonal parameters. Small Ruminant Research. 144: 236-241.

Salama, A.K., Jodar, A.C., Love, S., Mehaba, N., Such, X., Caja, G. (2020). Milk yield, milk composition and milk metabolomics of dairy goats intramammary-challenged with lipopolysaccharide under heat stress conditions. Scientific Reports. 10: 5055.

Seixas, L., De Melo, C.B.,Tanure, C.B., Peripolli, V. (2017). Heat tolerance in Brazilian hair sheep. Asian-Australasian Journal of Animal Sciences. 30: 593-601.

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

Sejian, V., Maurya, V.P., Kumar, K., Naqvi, S.M.K. (2013b). Effect of multiple stresses on growth and adaptive capability of Malpura ewes under semi-arid tropical environment. Tropical Animal Health and Production. 45: 107-116.

Sejian, V., Maurya, V.P., Naqvi, S.M.K. (2010). Adaptive capability as indicated by endocrine and biochemical responses of Malpura ewes subjected to combined stresses (thermal and nutritional) in a semi-arid tropical environment. International Journal of Biometeorology. 54: 653-661.

Sejian, V., Maurya, V.P., Naqvi, S.M.K. (2010a). Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. Tropical Animal Health and Production. 42: 1763-1770.

Sejian, V., Maurya, V.P., Naqvi, S.M.K. (2011a). Effect of thermal stress, restricted feeding and combined stresses (thermal stress and restricted feeding) on growth and plasma reproductive hormone levels of Malpura ewes under semi-arid tropical environment. Journal of Animal Physiology and Nutrition. 95: 252-258.

Sejian, V., Singh, A.K., Sahoo, A., Naqvi, S.M.K. (2014b). Effect of mineral mixture and antioxidant supplementation on growth, reproductive performance and adaptive capability of Malpura ewes subjected to heat stress. Journal of Animal Physiology and Nutrition. 98: 72-83.

Sezen, O.C.A.K. and Guney, O. (2010). Physiological responses and some blood parameters of bucks under Mediterranean climate conditions. Anadolu Tarım Bilimleri Dergisi. 25: 113-119.

Shaji, S., Sejian, V., Bagath, M., Mech, A., David, I.C.G., Kurien, E.K., Varma, G., Bhatta, R. (2016). Adaptive capability as indicated by behavioral and physiological responses, plasma HSP70 level and PBMC HSP70 mRNA expression in Osmanabadi goats subjected to combined (heat and nutritional) stressors. International Journal of Biometeorology. 60: 1311-1323.

Sharma, A.K. and Kataria, N. (2011). Effects of extreme hot climate on liver and serum enzymes in Marwari goat. Indian Journal of Animal Science. 81: 293-295.

Shilja, S., Sejian, V., Bagath, M., Mech, A., David, C.G., Kurien, E.K., Varma G., Bhatta, R. (2016). Adaptive capability as indicated by behavioral and physiological responses plasma HSP70 level and PBMC HSP70 mRNA expression in Osmanabadi goats subjected to combined (heat and nutritional) stressors. International Journal of Biometeorology. 60: 1311-1323.

Silanikove, N. (2000). The physiological basis of adaptation in goats to harsh environments. Small Ruminant Research. 35: 181-193.

Silanikove, N. and Koluman-Darcan, N. (2015). Impact of climate change on the dairy industry intemperate zones: Predications on the overall negative impact and on the positive role of dairy goats in adaptation to earth warming. Small Ruminant Research. 123: 27-34.

Singh, K.M., Singh, S., Ganguly, I., Ganguly, A., Nachiappan, R.K., Chopra, A., Narula, H.K. (2016). Evaluation of Indian sheep breeds of arid zone under heat stress condition. Small Ruminant Research. 141: 113-117.

Srikandakumar, A., Johnson, E.H., Mahgoub, O. (2003). Effect of heat stress on respiratory rate, rectal temperature and blood chemistry in Omani and Australian Merino sheep. Small Ruminant Research. 49: 193-198.

Wei, C., Wang, H., Liu, G., Wu, M., Cao, J., Liu, Z., Liu, R., Zhao, F. (2015). Genome-wide analysis reveals population structure and selection in Chinese indigenous sheep breeds. BMC Genomics. 16: 194.

Wojtas, K., Cwynar, P., Kolacz, R. (2014). Effect of thermal stress on physiological and blood parameters in merino sheep. Bulletin of the Veterinary Institute in Pulawy. 58: 8.