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Adaptive Mechanisms of Goat to Heat Stress

Bhabesh Mili and Tukheswar Chutia

Abstract

Goat is popularly known as ‘poor man’s cow’, rears mostly by the rural people due to better adaptive capability to harsh environment. Heat stress either hot or cold; negatively influence the goat productive and reproductive performance. Both survivability and reproductive performance of goat most often depend on its ability to cope with heat stressor. Goats can rear in a wide range of environment and geography may it be hilly terrain or undulating topography due to cope with the heat stress via combination of behavioral, morphological, physiological, biochemical, metabolic, hormonal and molecular changes at the gene level. All these adaptive mechanisms and genes are important for the assessment of heat stress, adaptability and strategies for management, production of heat-tolerant transgenic goat using advance biotechnological tools for sustainable goat production in challenged environment due to climate change.

Keywords: adaptation, climate, environment, goat, heat stress

1. Introduction

Heat stress is one of the challenging stress factors for goat farming under changing climatic scenario across the world due to global warming [1]. It is well established that environment stressor either hot or cold negatively affect the productive and reproductive performance of goat via reducing growth [2], milk yield [3], reproductive performance [4] and meat production [5], as well as immunity, making the goats more susceptible to various diseases and extreme cases even death [6, 7]. Therefore, the focus should be on adaptive capacity of goats for selection of breed which are best suited and reproduce, perform better under extreme environment [8, 9]. Hence, there is a growing demand for selection of goats that are best suited to a wide range of geographical and harsh environment. Like every animal, goats possess several unique morphological and physiological adaptive mechanisms [6]. It is important to understand the adaptive mechanisms of goat to heat stressor, to evolve fast-growing new breed of goat, identification of bio-markers at the gene level to produce heat-tolerant transgenic goat having high growth rate and adaptability. This chapter is therefore, an attempt to provide the underlying various adaptive mechanisms of goat to heat stressor.

2. Adaptation

Adaptation is the capacity and the process of adjustment of an animal to itself, to other living material and to external physical environment. In term of biology,

adaptation (biology) is defined as the morphological, anatomical, physiological, biochemical and behavioural characteristics of the animals, which promotes welfare and favour the survival in a specific environment. According to genetic, adaptation (genetic) is defined as the heritable animal characteristics which favour survival of a population in a particular environment. Further, in term of physiology, adaptation (Physiology) is defined the capacity and process of adjustment of the animals to itself to other living materials and its external physical environment. These adaptive changes either genetic or phenotypic (physiological) occur in animals in response to internal and external stimuli [10], which allows normal activity of the animals in an altered but tolerable climatologically range. There are series of behavioral, physiological, biochemical, hormonal, and molecular changes at the gene level to cope with heat stressor which may or may not lead to permanent genetic changes. Therefore, the adoptive capacity of animals to a stressful condition is a function of both its genetic and the intensity & duration of the stressor.

3. Materials and methods

Adaptive mechanisms of goat to heat stress either hot or cold were evaluated on the basis of behavioral, morphological, physiological, biochemical, hormonal and molecular changes at the gene level. This adaptive response to heat stress experiments were conducted either in climatic chamber under control climatic conditions or under natural environmental conditions especially seasonal variations such as extreme hot (summer) and cold season (winter). Many experiments were conducted in terms of comparative assessment between indigenous native goat breeds in their own home tract with that of exotic, crossbred as well as goat breed originated in different environmental condition under similar managemental condition, sufficient feed and clean adlibitum water.

A temperature humidity index (THI) was the most preferred method to detect goat under heat stress and co-relation to access adaptive capacity of goats to different environments/heat stressor. It was calculated from dry and wet bulb temperature using following formula.

$$THI = 0.72 (Dbt + Wbt) + 40.6,$$

where Dbt = dry bulb temperature in °C and Wbt = wet bulb temperature in °C.

3.1 Measurement of different morphological variables

Body length, body height, body heart girth, horn length, ear length, tail length, coat colour, pigmentation and body weight are the mostly studied morphological variables to determine the adaptive capacity of goat to heat stressor. Body weight of the goats were weighed in fasting condition at early morning on settled platform after the setting of weighing balance at zero [9].

3.2 Measurement of behavioral variables

Behavioral responses like standing time, lying time, drinking frequency, defecation frequency, and urination frequency were recorded during the study period [11].

3.3 Measurement of physiological variables

Physiological variable such as respiration rate (RR) was recorded by counting flank movements per minute, from a distance of 4–5 meters without disturbing the experimental goats. The unit of measurement of RR was in breaths per minute. Rectal temperature (RT) was recorded using a clinical thermometer by gently restraining the goats. The unit of measurement of RT was in degrees centigrade. Skin temperature (ST) of goats varies based on the quantum of sun rays to which the different body parts were exposed. Generally, in male goats, the skin temperature was recorded on the head, scrotum, and flank region. Skin temperatures were recorded using an infrared thermometer (B.S.K. Technologies, Hyderabad, India) by maintaining a distance of 5 to 15 cm [11].

Heart rate (HR) was measured by auscultation method with the aid of a flexible stethoscope by counting the number of heart sounds and beats for 20 s; the results were multiplied by 3 to express the values on a minute-time scale.

Sweat glands number was analyzed by the histological method [12]. Approximately 1–2 cm of skin sampled from the neck, flank and hindquarters were collected. These samples were processed by paraffin embedding and prepared skin smear and stained with hematoxylin and eosin. The stained skin smear was conducted on a photomicroscope under 20 × magnifications. A total of 20 fields were examined for each skin smear and images were captured to count the number of sweat glands appeared by the ImageJ® software program. The numbers of sweat glands in these images were counted on the basis of the number of hair follicles that were observed.

3.4 Blood sampling and measurement of hematological, biochemical and hormonal variables

Blood samples were collected from experimental goats from jugular vein in vacutainer tubes with anticoagulant under aseptic conditions at fortnightly intervals for estimation of hematological, biochemical and hormonal variables. Plasma was immediately separated after centrifugation at 3500 g for 8 min and aliquated the plasma samples were stored at –80 °C until analysis.

Haematological variables were measured in fresh blood samples. These variables were measured using an automated blood analyzer. It was also measured as per conventional methods. Total erythrocyte and total leucocytes was measured by haemocytometer method. Packed cell volume was determined using capillary tubes in microhaematocrit centrifuge based on the technique described by Wintrobe method. Haemoglobin concentration was estimated by cyanmethemoglobin method. Fresh blood was used for preparing smears for differential leukocytes count (DLC). The blood film was dried by waving the slide in the air and stained with field stain, and counting was done under microscope. The biochemical variables such as AST, ALT, glucose, total protein, albumin, globulin, total cholesterol, triglycerides, and blood urea nitrogen (BUN) were analysed using a biochemical analysis apparatus (Thermo Scientific Genesys 10S Vis, Centreville, VA, USA) as well as few experiments quantified by using commercial diagnostic kits as per manufactures protocols. Non-Ester fatty acids (NEFA), β -hydroxybutyrate (β -HBA), cortisol, aldosterone, triiodothyronine (T3) and thyroxine (T4) were quantified by using commercial diagnostic kits as per manufactures protocols.

3.5 Measurement of molecular markers

Blood samples were collected from experimental goats from the jugular vein in a heparinized vials and centrifugation was done at 3500 rpm for 25 min at 4 °C for

collection of peripheral blood mononuclear cells (PBMC) pellet. Total RNA was extracted from the PMBC pellet using RNA extraction kit as per manufacturer's protocol. The total RNA was reverse transcribed into complementary DNA (c-DNA) using cDNA synthesis kit for real-time quantitative polymerase chain reaction as per manufacturer's protocol. Relative expression of mRNA transcripts of Heat Shock Protein (HSP) and other stress associated genes by quantitative real-time PCR using SYBR Green as per manufacturer's protocol. Each sample was run in triplicate and in all cases, samples of total RNA were used as negative control.

3.6 Statistical analysis

The data were analyzed by two way ANOVA using SPSS 16.0 statistical software. Results were expressed as the mean $\pm$ SEM. A difference with value $p < 0.05$ was considered statistically significant.

4. Behavioral adaptive response

Behaviour is the first and foremost one of the most effective adaptive mechanism, at least for the short term period. This mechanism allows goat to reduce the heat load by avoiding/reducing direct exposure to solar radiation. Behavioral changes include seeking shelter [11], changing posture (eg: standing or altering orientation to the shade or wind breaks [13, 14], reducing feed intake (When exposed to hot) or increasing feed intake (When exposed to cold) [15], standing time, lying time, drinking frequency, defecation frequency, urination frequency [11] etc. Goat tends to spend more time on standing in hot humid environment to avoid direct solar radiation as well as radiation heat from the ground. For example; Fawn goats have different eating behaviors in comparison with Saanen x hair goats, when they were exposed to heat stress and poor nutritional condition [16]. These behavioral responses are to prevent additional heat load from the ground as well as to facilitate effective heat dissemination from the body of the animals to the surrounding environment [17]. Hence, the understandings of normal behaviors goats are paramount for assessing the impact of heat stress and adaptive capabilities.

5. Morphological adaptive response

Goats can cope with a variety of geography that include deserts, alpine regions, high altitude mountain hilly area, wet and dry tropics, arctic and temperate zone. Morphological or phenotypic variations are part of adaptive changes to a wide range of geography and environment. These variations are depending upon their ecological niche where they are originated. The most common morphological changes are

- a. Size and shape.
- b. Coat colors and pigmentation.

5.1 Size and shape

Morphological adaptive changes due to heat stressor in animals are the most pronounced and efficient response to cope with the heat stressor. Bergmann [18] stated that the smaller sized breed of a given species are found in the warmer regions of ecological range and the larger sized breeds in the cooler localities. Further, the

extremities (eg. ear, tail, bills) are smaller in the species inhabiting the cooler part of ecological range than those in warmer parts [19]. All these morphological characteristics are very crucial from the adaption point of view as it directly influence the heat exchange mechanisms via convection, radiation and evaporation between goats and surrounding environment [13]. For example Sudanese and Egyptian desert goats have relatively medium to large body size, which help in evaporative heat loss and it is a part of morphological adaptive response [20]. Similarly, non-dwarfed breeds of goats in the desert and savannah areas of Africa are much smaller than typical European breed of goats [21].

5.2 Coat colors and pigmentation

Coat colors and skin pigmentation are directly attributed towards heat loss from the body via conduction and convection in goats. The sensible heat loss via conduction and convection from the body of the animal are affected by the surface area per unit body weight, coat color, the magnitude of the temperature gradient between the goats the skin to the surrounding air [22]. Light coats colour and sleek and shiny hair coats are reflected a greater proportion of incident solar radiation than hair coats that are dark in colour or more dense and woolly [23]. For example, West African dwarf goats have smooth, short, and straight hair, which helps them to adapt in hot and humid environment [22]. Similarly, Black coat colour goats are dominant in hot deserts area and they have advantages to cope with direct exposure of solar radiation over white goats. Although, the black coat absorbs much more incident of direct solar radiation, these goats can drink an amount of water that equal to about 35% of their body weight, thus help in efficiently adjust to hot and humid environment by evaporation mechanism [24]. In addition, pigmented skin protects the deep tissues from direct short wave UV radiation by blocking its penetration in hot tropical regions. Thus, it prevents extra heat gain by the goats through direct solar radiation.

6. Physiological adaptive response

The physiological adaptations are most often caused by acute stressors. These changes are manifested as respiration rate, sweating rate, body temperature, skin temperature, heart rate etc.

6.1 Respiratory rate

Respiratory rate is the first foremost physiological response to heat stressors in goats [8, 25]. Respiration is the process of inhalation of oxygen (O_2), followed by elimination of carbon dioxide (CO_2), produced as a result of cellular metabolisms by the cells which lead to evaporative moisture loss from the respiratory tract to maintain thermal balance of the animals. This mechanism is very crucial for preventing the hypothermia which otherwise occur under thermal/heat stress [26]. As temperature increased above the thermal comfort zone of the goats, a marked increase in the respiratory rate from the normal level indicated that the goats are trying to maintain homeostasis by dissipating heat load from the body through evaporative cooling mechanism by vaporizing more moisture to the surrounding environment [27, 28]. Normally, respiration rate increased during summer due to increase in ambient temperature and decreased during winter due to decline in ambient temperature. Respiration rate increased during summer to increase heat loss through sweating and respiration. When this physiological adaptive response

is failed to alleviate the effect of heat load by evaporation cooling mechanism, the body temperature may increase to a point at which goat's well-being and productive performances are compromised mainly due to reduce feed intake and extra energy loss in the process heat loss from the body. Respiratory rate increased during the summer season which indicated that goats are under stressed [29]. So, rapid increase in the respiratory rate in response to heat stress indicates the greater susceptibility of goats to heat stress. This physiological response has been found to be different from breed to breed. This adaptive response may be attributed to breed difference and adaptation to different heat stress [1, 29, 30]. For example, a higher respiratory rate was recorded in cold-adapted goats (Gaddi and Chegu) compared to that of heat adapted goats (Sirohi and Barbari) during summer [30].

6.2 Rectal temperature

Rectal temperature represents the resultant of all heat gain (both metabolic and radiation heat) and heat loss of the body. It is used to measure the core body temperature of animals. Also, it acts as a natural passage way for dissipation of extra heat to maintain physiological homeostasis and body temperature [1]. Hence, it is an indicator of heat stress and may be used to assess the heat stress and adaptive capacity of goats. Normal rectal temperature of goats ranges between 38.3 to 40 °C. An elevation of the rectal temperature occurs only when the sweating and respiratory evaporation mechanisms failed to maintain homeothermy in goats [29–31]. This physiological response is varied from breed to breed and climatic conditions. For example, a higher rectal temperature was recorded in cold-adapted goats (Gaddi and Chegu) compared to that of heat adapted goats (Sirohi and Barbari) during summer and might be attributed to different heat stress [30].

6.3 Skin temperature

Skin is an important passageway for heat exchange between the animal's body and the surrounding environment. Skin temperature is a result of blood flow to the skin, which ends with regulation of heat exchange between body core and the skin [32]. Skin temperature increased under stressful condition for redistribution of blood flow to the skin surfaces so as to form a gradient between ambient temperature and skin surface temperature for heat dissipation from the body of the animals to the surrounding environment. So, when an ambient temperature is greater than skin temperature, the temperature gradient between the body surface and the environment decreases, impeding heat dissipation in this case by an evaporative mechanism [25]. But, it depends on heat stressor including nutritional stress. For example, highest skin temperature of the head, flank, and scrotum was recorded during the afternoon of a day in Osmanabadi goats subjected to combined (heat and nutritional) stressors [11]. This increased in skin temperature for vasodilatation of the skin capillary bed and consequently increases the blood flow to the skin surface to facilitate heat dissipation.

6.4 Heart rates

Heart rate reflects primarily the homeostasis of circulation along with the general metabolic status of animals. Heart rate of animals increased under stressful condition to increase blood flow from the core to the surface of the body to give a chance for more heat to be lost by sensible (conduction, convection and radiation) and insensible (diffusion water from the skin) means [33]. A marked acceleration of the heart rate occurs during the hottest part of the day to decrease heat production [34].

6.5 Sweating

Heat stress leads to activation sweating to maintain physiological homeostasis and body temperature. Specially, when respiratory mechanism is failed to maintain physiological homeostasis, it activate the evaporative heat loss mechanisms by involving an increase in sweating rate and respiratory minute volume about 70–85% [35]. The goats have greater sweating rate and lower body weight: surface ratio, which allows efficient way to heat dissipation from the body to the surrounding environment [36]. For example Black Bedouin goats can able to store large volumes of body water, and have considerable sweating capacity which allows them to cope in hot environment [37].

7. Hematological adaptive response

The hematology profile is an attributing adaptive response to cope with heat stress either hot or cold in animals. Heat stress effects on hematological parameters such as packed cell volume (PCV), hemoglobin (Hb), total erythrocytes count (TEC), total leukocytes count (TLC), lymphocytes, neutrophils, eosinophils, monocytes, granulocytes, and pH [38]. Hb, PCV, TEC and TLC levels increased during winter season in cold climate climatic condition whereas these variables levels decreased during summer in goats [30, 39]. Similarly, Upadhyay and Rao [40] and Abdelatif et al. [41] observed decreased levels of mean TLC, TEC, Hb and PCV during summer months and increased during winter months in goat. Increased in PCV and Hb levels could be availability of adequate nutrients for synthesis of Hb as the goat consumes more feed during winter season [42]. Further, hematological response to the heat stressor is varied from breed to breed [30]. They reported a decreased in mean Hb, PCV, TEC and TLC levels during summer in Sirohi and Barbari goats as they were well adapted to hot climate and less susceptible to heat stress. But the decline in Hb, PCV, TEC and TLC was more in Gaddi and Chegu goats as they were less adapted to hot climate more susceptible to heat stress during summer.

8. Biochemical adaptive response

Biochemical composition is directly proportional to the metabolic status of animals and can be used as an index for assessing the adaptation capacity to heat stressors. Heat stress causes alteration in blood biochemical parameters such as glucose, NEFA and β -HBA, total protein, albumin, globulin, to maintain physiological homeostasis especially energy balance through basal metabolic heat production. These responses may be due to a direct effect of high temperature on metabolic function or may be a result of heat impacting gene expression.

A decreased level of blood glucose, cholesterol and free fatty acid levels were recorded in goats in response to heat stress [38]. This low level of blood glucose level could be related to reduce feed intake due to heat stress especially during summer [30, 43]. Further, increased blood glucose level in cold-adapted goat breeds such as Gaddi and Chegu was higher during summer in compared to Sirohi and Barbari goats as they are well adapted to hot climate [29]. The high blood glucose level during summer may be due to increased glucocorticoids especially cortisol due to increase level of stress related to ambient temperature. Further, NEFA and β -HBA are used for energy status of the animals [28]. Heat-stressed goat showed

a decreased level of NEFA and β -HBA [36]. This may be related to the adaptive capability of the goats to maintain constant energy requirements.

Heat stress affects the protein metabolism of goats [44]. Metabolism is a part of adaptive response to the heat stress. Helal et al., [45] reported decreased in total plasma protein, albumin and globulin levels in goats subject to heat stress [45]. This might be due to an increase in plasma volume as a result of heat stress. In contrast, heat stress increased total protein and albumin levels due to increase respiration rate in goats for enhancing evaporating cooling [46]. This variation is might be due to adaptive capacity of goods. Indigenous breeds of goats are relatively better adapted to heat stress in their own native place.

9. Neuro-endocrine adaptive response

Neuro-endocrine responses to heat stress play an integral role in the adaptive mechanisms in animals. It is a crucial stress axis to accomplish physiological homeostasis by releasing several hormones for regulation of energy mobilization, cardiovascular and respiratory functions [47]. The hypothalamus serves as the main integrative control unit for neuro-endocrine responses. It receives information from peripheral as well as central nervous system and triggers an appropriate hormonal signal to maintain the internal milieu of the animals. The activation of the hypothalamo-pituitary-adrenal axis leads to enhance synthesis and release of cortisol and aldosterone levels into circulation under stressful conditions in goats [48]. These hormones are regulated the metabolism, also behavioral response to heat stressor in goats by favoring glycogenolysis, lipolysis, and proteolysis to supply required energy to restore homeostasis. However, the cortisol level was varied considerable between heat- and cold-adapted goats. For example, the cortisol level was higher in heat-adapted goats such as Sirohi and Barbari than in the cold-adapted breeds such as Gaddi and Chegu [30]. The differences in the cortisol levels may be due to adaptation of heat- and cold-adapted goats to different environment conditions, which might helps in physiological adjustment to the environment and enables goats to tolerate stressful conditions. In case of heat-tolerant breeds such as Sirohi and Barbari goats, the cortisol level increased during winter. This increase in cortisol level during winter due to cold stress so as to increase basal metabolism to maintains of the normal body temperature. However, in case of cold-tolerant goats, the cortisol level was lower during winter, thus it is reflected as adaptive response and comfortably to cold climatic condition.

Thyroid hormones (T3 and T4) stimulate oxygen consumption and heat production by the cells [49], and regulate the basal metabolic heat production in animals. Thus, the level of thyroid hormones may reflect an adaptation response to the heat stressor in order to reduce the basal metabolic heat production. Decrease levels of T3 and T4 during heat stress is an adaptive response [50], which enables reduces the basal metabolic rate and thus metabolic heat production goats [51–53] and heat production by the cells [54]. The secretion and release of thyroid hormones are affected by environmental stressor and adaptive capacity of the goats breed. For example, a high blood thyroid hormone levels was recorded in cold-adapted breeds (Gaddi and Chegu) than for heat adapted breeds (Sirohi and Barbari) goats [30]. This may be attributed to breed differences and their adaptation to different climatic conditions, which is associated with energy metabolism. The increased level of thyroid hormones may be due to low ambient temperature during winter to increase metabolic rate and increased body heat production to maintain core body temperature.

10. Molecular adaptive response

With the advancing modern biotechnological tools, it could able to identify and characterize gene expression patterns associated with cellular adaptation mechanisms of goats at the molecular level [29, 42]. A complex network of gene associated with adaptation to heat stressor in goat [55]. Out of these, many genes determine an individual's capability to adapt to the heat stress. Heat shock proteins (HSPs) are perhaps the best-studied examples of genes whose expression are associated with adaptive capacity of to heat stress. These HSP genes such as HSP60, HSP70, and HSP90 are highly conserved proteins belong to the chaperones family proteins across evolutionary lines that are expressed under various kinds of stressor and play pivotal role in regulating the proper folding of proteins [56], intracellular transport, maintenance of proteins in an inactive form, the prevention of protein degradation [57], and to adapt progressively to the changing environment to ameliorate the deleterious effects of heat stress [58]. The genes expression profile is depended on kind of goat breeds and type of environmental stressor such as heat or cold [29, 59]. For example, the expression of HSP70 was unregulated in heat stressed goats remained elevated only for 4 hours and returned back to basal level after 8 hours of heat stress withdrawal [60, 61]. Further, it was reported that cold stress was not enough to produce an alteration in HSPs gene expression except in Jhakrana goats [29]. They reported that an increase in HSP90 expression during winter season in Jhakrana goats indicated that cold stress could induce stress in Jhakrana goats, while Barbari and Siorhi goats exhibited adaptation to the same. Madhusoodan et al. [58] reported that the native indigenous goats breed was comparatively better adopted to own ecological niche or environment. They recorded a low level of expression of all heat shock response genes such as HSP70, HSP90, super oxide dismutase (SOD), nitrous oxide synthase 1 (NOS1) in Salem Black goats. The lower level of expression may be due to a sub-threshold level of the heat stress attained in the study to induce cellular stress response in Salem Black goats.

Apart from HSP genes, several other genes such as SOD, NOS, thyroid hormone receptor (THR) and prolactin receptor (PRLR) genes are associated with heat tolerant in animals [62]. Higher expression of NOS was reported in heat stressed goats, which help in vasodilatations of the skin to favor cutaneous evaporative cooling mechanisms to dissipate excess heat from the skin surface [31, 58]. Variations in the gene expression were due to gene–environment interaction and which favor the

Breeds	Genes	Function	Reference
Mexico goat	<i>HSP-70</i>	Thermo-tolerant	[67]
Chines goat	<i>ASIP, KITLG, HTT, GNA11, and OSTM1</i>	Coloration	[68]
Chines goat	<i>TBX15, DGCR8, CDC25A, and RDH16</i>	Body size	[68]
Baraki goat	<i>FGF2, GNAI3, PLCB1</i>	Thermo-tolerance (melanogenesis)	[66]
Baraki goat	<i>BMP2, BMP4, GJA3, GJB2</i>	Body size and development	[66]
Baraki goat	<i>MYH, TRHDE, ALDH1A3</i>	Energy and digestive metabolism	[66]
Baraki goat	<i>GRIA1, IL2, IL7, IL21, IL1R1</i>	Nervous and autoimmune response	[65]
Ugandan goat	<i>IL10RB and IL23A</i>	Immune response	[69]

Table 1.
Enlisted a few genes associated with heat tolerance in goats.

survival of a population in a particular environment [63–65]. Therefore; heat-tolerant genes play a significant role for regulation of physiological homeostasis and body temperature [66], and could be useful for production of heat stress tolerant goat breed by conventional approach through artificial selection as well as advance biotechnology tools using transgenic technology. Affymetrix Gene Chip Bovine Genome designed to monitor expression of approximately 23,000 transcripts, it has identified 39 and 74 genes whose expression was up- and down-regulated, and respectively by heat stressor in the blood cells of goats [3] and the genes are as follows (Table 1).

11. Conclusions

Heat stress has negatively affected the productive and reproductive performances of goat. Under the changing climate scenario due to global warming, the immediate need is to understand the adaptive mechanisms and identification of heat tolerant genes. Adaptive mechanism will provide basis strategies for management and to evolve fast-growing new goat breed as well as the production of heat tolerant transgenic goat for sustainable and profitable goat farming under challenged environment.

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References

- [1] El-Tarabany M S, El-Tarabany A A, Atta M A. Physiological and lactation responses of Egyptian dairy Baladi goats to natural thermal stress under subtropical environmental conditions. *International Journal of Biometeorology*. 2017; 61: 61-68. DOI: 10.1007/s00484-016-1191-2.
- [2] Baumgard L H, Rhoads R P, Rhoads M L, Gabler N K, Ross J W, Keating A F, Boddicker R L, Lenka S, Sejian V. Impact of climate change on livestock production. In *Environmental stress and amelioration in livestock production* (ed. V Sejian, SMK Naqvi, T Ezeji, J Lakritz and R Lal), Springer-2012; 413-468. Verlag GmbH Publisher, Heidelberg, Germany.
- [3] Salama A A K, Hamzaoui S, Badaoui B, Zidi A, Caja G. Transcriptome analysis of blood in heat-stressed dairy goats. *Journal of Dairy Science*. 2012; 95(2): 188.
- [4] Fonseca W J L, Azevêdo D M M R, Campelo J E G, Fonseca W L, Luz C S M, Oliveira M R A, Evangelista A F, Borges L S, Sousa Júnior S C. Effect of heat stress on milk production of goats from Alpine and Saanen breeds in Brazil. *Archivos de Zootecnia*. 2016; 65(252): 615-621.
- [5] Archana P R, Sejian V, Ruban W, Bagath M, Krishnan G, Aleena J, Manjunathareddy G B, Beena V, Bhatta R. Comparative assessment of heat stress induced changes in carcass traits, plasma leptin profile and skeletal muscle myostatin and HSP70 gene expression patterns between indigenous Osmanabadi and Salem Black goat breeds. *Meat Science*. 2018; 141: 66-80. DOI: 10.1016/j.meatsci.2018.03.015
- [6] Yasha A, De La F, Luanna S, Batista F, Af S, Elb S. Growth and Reproduction Hormones of Ruminants Subjected to Heat Stress. *Journal of Animal Behaviors and Biometeorology*. 2017; 5: 7-12. DOI <http://dx.doi.org/10.14269/2318-1265/jabb.v5n1p7-12>
- [7] Berihulay H, Abied A, He X, Jiang L, Ma Y. Adaptation Mechanisms of Small Ruminants to Environmental Heat Stress. *Animals*. 2019; 9(3): 75. DOI: 10.3390/ani9030075.
- [8] Nejad J G, Sung K I. Behavioral and Physiological Changes during Heat Stress in Corriedale Ewes Exposed to Water Deprivation. *Journal of Animal Sciences and Technology*. 2017; 59(13):1-6. DOI: 10.1186/s40781-017-0140-x
- [9] Kumar P, Giri A, Bharti V K, Kumar K, Chaurasia O P. Evaluation of various biochemical stress markers and morphological traits in different goat breeds at high-altitude environment, *Biological Rhythm Research*. 2019; 52(2): 1-12. DOI: 10.1080/09291016.2019.1594123.
- [10] Willmer P, Stone G, Johnstone I. *Environmental Physiology of animals*. 2nd ed. Wiley-Blackwell. 2004; 768p.
- [11] Shilja S, Sejian V, Bagath M, Mech A, David C G, Kurien E K, Varma G, Bhatta R. Adaptive capability as indicated by behavioural 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*. 2016; 60:1311-1323. DOI: 10.1007/s00484-015-1124-5.
- [12] de Melo Costa, C C, Campos Maia A S, Fontenele Neto J D, Oliveira S E O, Fernandes de Queiroz, J P A. Latent heat loss and sweat gland histology of male goats in an equatorial semi-arid environment. *International Journal of Biometeorology*. 2014 ;58(2):179-84.doi: 10.1007/s00484-013-0642-2.

- [13] Silanikove N. The Physiological Basis of Adaptation in Goats to Harsh Environments. Small Ruminant Research.2000; 35: pp.181-193. DOI. org/10.1016/S0921-4488(99)00096-6
- [14] Darcan N, Cedden F, Cankaya S. Spraying effects on some physiological and behavioural traits of goats in a subtropical climate. Italian Journal of Animal Science. 2008; 7(1); 77-85. DOI: 10.4081/ijas.2008.77.
- [15] Attia N E S. Physiological, Hematological and Biochemical Alterations in Heat Stressed Goats. Benha Veterinary Medical Journal. 2016; 131: 56-62.DOI. 5890dbac6a6f06.93550331
- [16] Koluman N, Boga M, Silanikove N, Gorgulu M. Performance and Eating Behaviour of Crossbred Goats in Mediterranean Climate of Turkey. Revista Brasileira de Zootecnia. 2016; 45: 768-772. DOI.org/10.1590/s1806-92902016001200006
- [17] Sejian V, Kumar D, Gaughan J B, Naqvi S M K. Effect of Multiple Environmental Stressors on the Adaptive Capability of Malpura Rams Based on Physiological Responses in a Semi-Arid Tropical Environment. Journal of Veterinary Behavior: Clinical Application. 2017; 17: 6-13. DOI: 10.1016/j.jveb.2016.10.009.
- [18] Bergmann, Carl"Über die Verhältnisse der Wärmeökonomie der Thiere zu ihrer Grösse". Göttinger Studien. 1847; 3 (1): 595-708.
- [19] Allen, Joel Asaph "The influence of Physical conditions in the genesis of species". Radical Review. 1877; 1: 108-140.
- [20] Elbeltagy A R, Aboul Naga A M, Hassen H, Solouma G M, Rischkowsky B, Mwacharo J M. Genetic Diversity and Structure of Goats within an Early Livestock Dispersal Area in Eastern North Africa. African Journal of Biotechnology. 2016; 15(2): 431-441 DOI.org/10.5897/AJB2015.14891
- [21] Epstein, H. The Origin of the Domestic Animals of Africa, vol II, Leipzig, Germany. 1971, 573p. https://hdl.handle.net/10568/70619
- [22] Daramola J O, Adeloye A A. Physiological Adaptation to the Humid Tropics with Special Reference to the West African Dwarf (WAD) Goat. Tropical Animal Health and Production. 2009; 41(7); 1005-1016. DOI: 10.1007/s11250-008-9267-6.
- [23] Asres A, Amha N. Physiological Adaptation of Animals to the Change of Environment: A Review. Journal of Biology, Agriculture and Healthcare. 2014; 4: 2224-3208.
- [24] Finch V A. Body temperature in beef cattle: its control and relevance to production in the tropics. Journal of Animal Science. 1986; 62: 531-542.
- [25] Ribeiro N L, Costa R G, Filho E C P, Ribeiro M N, Bozzi, R. Effects of the dry and the rainy season on endocrine and physiologic profiles of goats in the Brazilian semi-arid region. Italian Journal of Animal Science. 2018; 17(2):454-461. DOI.org/10.1080/1828051X.2017.1393320
- [26] da Silva W E, Leite J H G M, de Sousa J E R, Costa W P, da Silva W ST, Guilhermino M M, Façanha D A E. Daily rhythmicity of the thermoregulatory responses of locally adapted Brazilian sheep in a semiarid environment. International Journal of Biometeorology. 2017; 61 (7): 1221-1231. DOI: 10.1007/s00484-016-1300-2
- [27] Phulia S K, Upadhyay R C, Jindal S K, Misra R P. Alteration in surface body temperature and physiological responses in Sirohi goats during day time in summer season. Indian Journal of Animal Science. 2010; 80(4): 340-342.

- [28] Hamzaoui S, Salama A A K, Albanell E, Such X, Caja G. Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions. *Journal of Dairy Sciences*. 2013; 96(10): 6355-6365. DOI.org/10.3168/jds.2013-6665
- [29] Kumar S, Yadav B, Choudhury S, Kumari P, Madan A K, Singh S P, Rout P K, Ramchandran N, Yadav S. 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*. 2017; 48(3):466-478. DOI.org/10.1080/09291016.2017.1377984.
- [30] Banerjee D, Upadhyay R C, Chaudhary U B, Kumar R, Singh S, Ashutosh, Das TK, De S. Seasonal variations in physio-biochemical profiles of Indian goats in the paradigm of hot and cold climate. *Biological Rhythm Research*. 2015; 46(2):221-236. DOI: 10.1080/09291016.2014.984999.
- [31] Yadav V P, Dangi S S, Chouhan V S, Gupta M, Dangi S K, Singh G, Maurya V P, Kumar P, Sarkar M. Expression analysis of NOS family and HSP genes during thermal stress in goat (*Capra hircus*). *International Journal of Biometeorology*. 2016; 60: 381-389. DOI: 10.1007/s00484-015-1035-5.
- [32] Marai I F M, El-Darawany A A, Abou-Fandoud E I, Abdel-Hafez M A M. Tunica dartos index as a parameter for measurement of adaptability of rams to subtropical conditions of Egypt. *Animal Science Journal (Jpn)*. 2006;77:487-494. DOI. org/10.1111/j.1740-0929.2006.00376.x
- [33] Adedeji T A. Effect of some qualitative traits and non-genetic factors on heat tolerance attributes of extensively reared West African Dwarf (WAD) goats. *International Journal of Applied Agricultural Research*. 2012; 8:68-81.
- [34] Facanha D A E, Sammicelli L, Bozzi R, Silva W S T, Morais J H G, Lucena R M O, *et al*. Performance of Brazilian native goats submitted to a mix supply under thermal stress conditions. *Proc. XI International Conference on Goats*, Gran Canaria, Spain. 2012; 343.
- [35] Finch V A, Dmi'el R, Boxman R, Shkolnik A, Taylor, R. Why black goats in hot deserts? Effects of coat color on heat exchanges of wild and domestic goats. *Physiological Zoology*. 1980;53(1): 19-25. DOI/abs/10.1086/physzool.53.1.30155771.
- [36] Salama A A K, Caja G, Hamzaoui S, Badaoui B, Castro Costa A, Facanha D A E. *et al*. Different levels of response to heat stress in dairy goats. *Small Ruminant Research*. 2014; 121: 73-79. DOI. org/10.1016/j.smallrumres.2013.11.021
- [37] Shkolni A, Choshniak, I. Physiological response and productivity of goat. In: Yousef M. K. editors. *Stress physiology in livestock*, Vol. II, Ungulates, CRC Press, Inc, Boca Raton. 1985. 357-358. DOI.org/10.1002/smi.2460020413.
- [38] Sarangi, S. Adaptability of goats to heat stress: A review *The Pharma Innovation Journal*. 2018; 7(4):1114-1126.
- [39] Alam M M, Hashem M A, Rahman M M, Hossain M M, Haque M R, Sobhan Z, Islam M S. Effect of heat stress on behavior, physiological and blood parameters of goat. *Progressive Agriculture*. 2011; 22 (1&2):37-45. DOI. org/10.3329/pa.v22i1-2.16465
- [40] Upadhyay R C, Rao M V N. Haematological and biochemical constituents of blood in goats upto the one year age. *Indian Journal of Dairy Science*. 1985; 38:168-173. <https://agris.fao.org/agris-search/search.do?recordID=US201301460059>.
- [41] Abdelatif A M, Ibrahim M Y, Hassan Y Y. Seasonal variation in

erythrocytic and leukocytic indices and serum proteins of female nubian goats. Middle East Journal of Science Research.2009; 4: 168-174. 9a59b5c21b47950cc53f697f37ee35c2935223c5

[42] Gupta M, Kumar S, Dangi S S, Jangir B L. Physiological, biochemical and molecular responses to thermal stress in goats. International Journal of Livestock Research. 2013; 2(2); 27-38. DOI: 10.5455/ijlr.20130502081121

[43] Mohamad SS. Effect of level of feeding and season on rectal temperature and blood metabolites in desert rams. Academic journal of Nutrition. 2012;1:14-18. DOI: 10.5829/idosi.ajnr.2012.1.2.71100

[44] Dangi S S, Gupta M, Maurya D, Yadav V P, Panda R P, Singh, G et al. Expression profile of HSP genes during different seasons in goats (*Capra hircus*). Tropical Animal Health and production. 2012; 44(8):1905-1912. DOI.org/10.1007/s11250-012-0155-8

[45] Helal A, Hashem A L S, Abdel-Fattah M S, El-Shaer H M. Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. American Journal of Environmental Sciences.2010; 7(1):60-69.<http://www.idosi.org/.../10.pdf>

[46] Okoruwa M I. Effect of heat stress on thermoregulatory, live bodyweight and physiological responses of dwarf goats in southern Nigeria. European Science Journal. 2014; 10: 255-264. DOI. org/10.19044/esj.2014.v10n27p%25p

[47] Madhusoodan A P, Sejian V, Rashamol V P, Savitha S T, Bagath M, Krishnan G, Bhatta, R. Resilient capacity of cattle to environmental challenges – An updated review. Journal of Animal Behaviors and Biometeorology. 2019; 7(3):104-118.

DOI: 10.31893/2318-1265jabb.v7n3p104-118.

[48] Shilja S, Sejian V, Bagath M, Manjunathareddy G B, Kurien E K, Varma G, Bhatta R. Summer season related heat and nutritional stresses on the adaptive capability of goats basedon blood biochemical response and hepatic HSP70 gene expression. Biological Rhythms Research. 2017; 48: 65-83. DOI.org/10.1080/09291016.2016.1232340.

[49] Ocak S, Darcan N, C, ankaya S, Inal T C. Physiological and biochemical responses in German fawn kids subjected to cooling treatments under Mediterranean climate conditions. Turkish journal of veterinary and Animal Sciences, 2009: 33(6)455-461. DOI: 10.3906/vet-0708-3

[50] Johnson H D. Physiological responses and productivity of cattle. In: Stress physiology in livestock, Yousef M.K. editors. Ungulates. CRC Press Inc., Boca Raton, FL, USA. II: 1985; 3-24. DOI.org/10.1002/smi.2460020413.

[51] West, J.W. Nutritional strategies for managing the heat stressed dairy cow. Journal of Animal Sciences, 1999; 77: 21-35. DOI: 10.2527/1997.77suppl_221x.

[52] Todini L. Thyroid hormones in small ruminants: effects of endogenous, environmental and nutritional factors. Animals, 2007; 1: 997-1008. DOI: 10.1017/S1751731107000262.

[53] Pragna P, Sejian V, Soren N M, Bagath M, Krishnan G, Beena V, Devi P I, Bhatta R. Summer season induced rhythmic alterations in metabolic activities to adapt to heat stress in three indigenous (Osmanabadi, Malabari and Salem Black) goat breeds. Biological Rhythm Research, 2018; 49(4):551-565. DOI.org/10.1080/09291016.2017.1386891.

- [54] Barnes A, Beatty D, Taylor E, Stockman C, Maloney S, McCarthy M. Physiology of heat stress in cattle and sheep. Project number LIVE.209, Australia. Meat and Livestock Australia Limited, 2004, 35.
- [55] Mwacharo J M, Kim E, Elbeltagy A, Aboul Naga M, Rischkowsky B, Rothschild M F. Genome Wide Scans Reveal Multiple Selection Sweep Regions in Indigenous Sheep (*Ovis Aries*) from a Hot Arid Tropical Environment. In: Proceedings of the Plant and Animal Genome Conference XXIV, San Diego, CA, USA, 9-13 January 2016; Addis Ababa, Ethiopia.2016.p.
- [56] Lanneau D, Wettstein G, Bonniaud P, Garrido C. Heat shock proteins: cell protection through protein triage. The Science World Journal. 2010; 10 (3):1543-1552. DOI: 10.1100/tsw.2010.152
- [57] Neuer A, Spandorfer S D, Giraldo P, Dieterle S, Rosenwaks Z, Witkin S S. The role of heat shock proteins in reproduction. Human Reproduction Update. 2000; 6(2):149-159. DOI: 10.1093/humupd/6.2.149.
- [58] Madhusoodan A P, Bagath M, Sejian V, Krishnan G, Rashamol V P, Savitha S T, Awachat V B, Bhatta, R. Summer season induced changes in quantitative expression patterns of different heat shock response genes in Salem black goats. Tropical Animal Health and Production. 2020; 52: 2725-2730. DOI.org/10.1007/s11250-020-02242-5
- [59] Aleena J, Sejian V, Bagath M, Krishnan G, Beena V, Bhatta R. Resilience of three indigenous goat breeds to heat stress based on phenotypic traits and PBMC HSP70 expression. International Journal of Biometeorology. 2018; 62(11):1995-2005. DOI: 10.1007/s00484-018-1604-5.
- [60] Collier R J, Collier J L, Rhoads R P, Baumgard L H. Invited review: Genes involved in the bovine heat stress response. Journal of Dairy Science, 2008; 91: 445-454. DOI.org/10.3168/jds.2007-0540
- [61] Bernabucci U, Lacetera N, Baumgard L H, Rhoads R P, Ronchi B, Nardone A. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal, 2010; 4:1167-1183. DOI: 10.1017/S175173111000090X.
- [62] Collier R J, Gebremedhin K, Macko A R, Roy K S. Genes involved in the thermal tolerance of livestock. In Environmental stress and amelioration in livestock production (ed. V Sejian, SMK Naqvi, T Ezeji, J Lakritz and R Lal), 2012: 379-410. Springer-Verlag, Berlin/Heidelberg/New York, NY, USA
- [63] Ganai T A S, Mishra S S, Sheikh F D. Characterization and evaluation of Pashmina producing Changthangi goat of Ladakh. Indian Journal of Animal Science. 2011; 81:592-599. DOI: 10.1017/S1014233900001826.
- [64] Abdul Niyas P A, Chaidanya K, Shaji S, Sejian V, Bhatta R, Bagath M, Rao G S L H V P, Kurien E K, Girish V. Adaptation of Livestock to Environmental Challenges. Journal of Veterinary Science & Medical Diagnosis, 2015;4: 1-7. DOI: 10.4172/2325-9590.1000162.
- [65] Verma P, Sharma A, Sodhi M, Thakur K, Kataria R S, Niranjan S K, Bharti V K, Kumar P, Giri A, Kalia S, et al. Transcriptome analysis of circulating PBMCs to understand mechanism of high altitude adaptation in native cattle of Ladakh Region. Science Report, 2018;7681:1-8. DOI: 10.21767/2471-8084-C1-024
- [66] Kim E, Elbeltagy A R, Aboul-naga A M, Rischkowsky B, Sayre B,

Mwacharo J M, Rothschild M F. Multiple Genomic Signatures of Selection in Goats and Sheep Indigenous to a Hot Arid Environment. *Heredity*, 2016; 116: 255-264. DOI: 10.1038/hdy.2015.94

[67] Meza-Herrera C A, Martine L, Archiga C, Bafielos R, Rincon R M, Urrutia J, Salinas H, Mellado, M. Circannual Identification and Quantification of Constitutive Heat Shock Proteins (HSP70) in Goats. *Journal of Applied Animal Research*. 2006; 29(1): 9-12. DOI: 10.1080/09712119.2006.9706560.

[68] Wang X, Liu J, Zhou G, Guo J, Yan H, Niu, Y. Whole-Genome Sequencing of Eight Goat Populations for the Detection of Selection Signatures Underlying Production and Adaptive Traits. *Science Reproduction*. 2016; 6: 38932. DOI: 10.1038/srep38932.

[69] Onzima R B, Upadhyay M R, Doekes H P, Brito L F, Bosse M, Kanis E, Groenen M A M, Crooijmans R P M A. Genome-Wide Characterization of Selection Signatures and Runs of Homozygosity in Ugandan Goat Breeds. *Frontier in Genetic*. 2018; 9:1-13. DOI. org/10.3389/fgene.2018.00318.