

**Thermoregulation in Sheep and Goats: Review**

**25 Abstract**

26 Thermoregulation is how mammals maintain their core internal temperature by returning the body to homeostasis.  
27 Sheep and goats are adaptable to different environmental changes and often perform better heat stress additivity  
28 compared to other ruminant animals. Adapting sheep and goats to extreme weather conditions occurs through  
29 behavioral, genetic, physiological, and morphological bases. They can minimize the adverse effects of thermal stress  
30 through behavioral responses such as increased water intake and shade seeking and other morphological mechanisms  
31 such as hair color and fat storage. Sheep and goats also respond to thermal changes through physiological mechanisms  
32 such as changes in the respiration rate, sweating rate, metabolic rate endocrine functions. In genetics, the authors report  
33 that animals can inherit traits that favor their survival in specific environmental conditions. The sheep or goat's size  
34 and shape determine the heat gain or loss rate and are crucial in adjusting water loss and heat gain in scorching  
35 environments. Goats and sheep exposed to high ambient temperature tend to have an elevated respiratory rate, pulse  
36 rate, and increased rectal temperature. Genetically, the adaptation of sheep and goats to different thermal environments  
37 is mediated by a complex network of genes with specific genome-wide DNA markers enhancing tolerance to heat  
38 stress.

39

40 **Keywords:** Thermoregulation, Sheep and Goats, Physiology, Behavior, Genetic, Heat stress

## 41 **Introduction**

42 Small ruminants, including sheep and goats, have been primarily kept in various environments and grazing systems,  
43 requiring multiple adaptations, especially concerning temperature changes through thermoregulation. From a  
44 biological perspective, thermoregulation can be defined as how mammals maintain their core internal temperature by  
45 returning the body to homeostasis. The influence of the thermal environment on animals is primarily exerted through  
46 energy exchange which involves convection, conduction radiation, and evaporation. Many animal factors (e.g., breed,  
47 genetics, health status, body condition, and coat color) determine metabolic intensity, the rate of thermal exchange,  
48 and thermal insulation, which contribute significantly to the heat balance of the animal. The optimal internal  
49 temperature ranges for different mammals are based on various factors, such as the temperature of the surrounding  
50 environment and energy requirements. Heat stress is one of the primary factors that can affect the growth of small  
51 ruminant animals such as sheep and goats in different parts of the world. As a limiting factor, excessive heat stress can  
52 lead to impaired production, reproduction, compromised natural immunity, and increased susceptibility to diseases.  
53 Heat stress affects ruminant animals through various environmental factors, including high ambient temperature,  
54 excessive solar radiation, relative humidity, wind, rainfall, and nutrition. However, sheep and goats are adaptable to  
55 different environmental changes and often perform better heat stress additivity compared to other ruminant animals.  
56 The current review explores the process of thermoregulation in sheep and goats. It describes the various physiological  
57 features of ruminant animals that enhance their ability to perform better stress additivity. The adaptation of sheep and  
58 goats to extreme weather conditions occurs through behavioral, genetic, physiological, and morphological bases. These  
59 mechanisms are divided into those that modulate heat production rates and the rate at which heat flows into and out of  
60 the organisms. From a morphological perspective, the coat color of the sheep or goat plays a vital role in the absorption  
61 of heat, with the light-colored coated animal absorbing less heat than those with darker coats.

62 Genetically, scientific evidence has shown that different genetic factors enable sheep and goats to live in heat-stressed  
63 environments. Other genes associated with adaptability to temperature changes have been found in sheep and goats,  
64 including HSP70, which are heat shock protein genes that protect the animals from heat stress, and the ENOX2 gene,  
65 which has been found in heat-stress susceptible goats. Other polymorphic genes, including MC1R, ASIP, and TYRP1,  
66 have been observed in different sheep breeds and are associated with wool color, which controls the rate of heat  
67 absorption. To this extent, therefore, it can be hypothesized that the adaptation of the ruminants to different  
68 environmental conditions is based on their ability to survive and reproduce under extreme living conditions.

69 Considering the lack of complete information on the adaptation and survival of these animals, the current review  
70 provides an integrative discussion on the various adaptative mechanisms of the ruminants in heat-stressed  
71 environments. It assesses the multiple genes that are involved in thermoregulation.

72

### 73 **Literature Review**

74 Different environmental conditions differently affect the productivity of livestock while also having an impact on  
75 various physiological parameters. Temperatures above the thermoneutral zone trigger a chain of physiological,  
76 anatomical, and behavioral changes in the animal's body, such as a reduction of feed intake, a decline in performance  
77 (milk production, growth, and reproduction), a decrease in activity, an increase of respiratory rate and body  
78 temperature, the addition of peripheral blood flow and sweating and change in endocrine function (Fuquay, 1981;  
79 Kadzere et al., 2002; Farooq et al., 2010; Renaudeau et al., 2012). Thermal stress affects the dynamic characteristics  
80 of digestion and neuroendocrine factors influencing metabolism. Declining feed intake has been identified as a  
81 significant cause of reduced milk production in livestock species (Farooq et al., 2010). Various research studies have  
82 investigated the relationship between ecological changes and animal response. However, quite limited extensive  
83 research has been conducted to determine how sheep and goats respond to temperature changes through  
84 thermoregulatory processes. According to a research study by Leite et al. (2017), livestock tends to show reduced  
85 productivity levels in environments with high levels of thermal radiation due to changes in their physiological  
86 processes. As expected, animals often develop adaptive features to cope with environmental changes to guarantee  
87 survival. In their research study, Leite et al. (2017) highlight hair characteristics as one of the features directly  
88 associated with heat exchanges with the environment. According to Leite et al. (2017), the hair structure serves two  
89 primary roles: protecting the skin from direct solar radiation and promoting the processes of convection and heat loss  
90 through evaporation. The efficiency of the performance of these roles is entirely dependent on the physical structure  
91 of the hair coat. Therefore, the form of the hair coat is considered a prominent physical thermoregulatory feature of  
92 livestock, especially in sheep and goats.

93 Berihulay et al. (2019) conducted a review to investigate the adaptation of small ruminants, specifically sheep  
94 and goats, to environmental heat stress. According to the study, sheep and goats are among the livestock that can  
95 quickly adapt to changes in environmental temperature through a combination of physiology, morphology, and genetic

96 makeup (Berihulay et al., 2019). The review notes that sheep and goats can minimize the adverse effects of thermal  
97 stress through behavioral responses such as increased water intake and shade seeking as well as other morphological  
98 mechanisms such as hair color and the amount of fat they keep (Berihulay et al., 2019). Other physiological changes  
99 involved the reduction of the basal metabolic rate, modifications in the acid-base balance, and hormonal balance  
100 changes (Farooq et al., 2010; Renaudeau et al., 2012). Heat stress significantly induces the secretion of hormones  
101 connected with metabolism (thyroxine, somatotropin, and glucocorticoids) and water balance (antidiuretic hormone  
102 and aldosterone). Several days after heat stress begins, the secretion rate of thyroid hormones is reduced. Growth  
103 hormone secretion rates are reduced during prolonged heat stress after an initial rise (Farooq et al., 2010). Adrenal  
104 corticoids, mainly cortisol, immediate physiological changes that allow animals to undergo stressful conditions  
105 (Hansen, 2004; Beatty et al., 2006; Renaudeau et al., 2012). Therefore, thermoregulation is part of a homeostatic  
106 mechanism to keep the organism at an optimum operating temperature within certain boundaries, even when the  
107 surrounding temperature is very different (Ruben, 1995; Grigg et al., 2004). In terms of physiology, Berihulay et al.  
108 (2019) report that sheep and goats respond to thermal changes through changes in the respiration rate, sweating rate,  
109 metabolic rate endocrine functions. Regarding genetics, the authors report that animals can inherit traits that favor their  
110 survival in specific environmental conditions (Berihulay et al., 2019). The authors note that sheep and goats are rustic  
111 animals that can easily cope with different environments and are less susceptible to heat-stressed environments than  
112 other ruminants.

### 113 **Morphological Thermoregulation in Sheep and Goats**

114 Morphological thermoregulation in sheep and goats occurs through physical changes that enhance their fitness  
115 in their operational environment. According to Berihulay et al. (2019), the central morphological adaptations of sheep  
116 and goats to differences in thermal conditions include body size and shape, coat and skin color, hair type, and fat  
117 storage. To be specific, Leite et al. (2017) mention different breeds of sheep and goats that uses the mentioned  
118 adaptations to survive in thermally stressed conditions. According to Leite et al. (2017), the Sudanese Saleh and  
119 Egyptian Zaraiby goats have long legs and ears as a thermoregulatory morphological adaptation, while West African  
120 goats have short legs. The authors report that the Awassi sheep have loose coarse wool and adipose tissue reserves as  
121 a thermoregulatory morphological adaptation to heat changes in their environment.

122 In contrast, the Damar sheep have fat tails. On the other hand, Massese, Xalda, and Soay sheep use coat color as the  
123 thermoregulatory morphological adaptive feature, during Barki sheep and goat use skin pigmentation. Therefore,  
124 Berihulay et al. (2019); Leite et al. (2017) reported that sheep and goats have different thermoregulatory morphological  
125 adaptive features such as body size and shape, coat and skin color, hair type, and fat storage. An animal's body  
126 size and shape is a dominant morphological feature that influences the thermoregulatory mechanisms of sheep and  
127 goats in scorching environments. According to Joy et al. (2020), the size and shape of the sheep or goat determine the  
128 heat gain or loss rate and can be crucial in adjusting water loss and heat gain in scorching environments.

129 Biologically, any animal with larger body size is expected to have a reduced metabolic rate and gain heat slower than  
130 smaller animals (Berihulay et al., 2019). As such, sheep and goats in scorching environments are expected to have a  
131 larger body size to reduce the rate of metabolism and heat absorption. Also, as reported by Joy et al. (2020), taller  
132 animals are expected to release more heat compared to short and squat-bodied animals, which explains why the  
133 Sudanese Saleh and Egyptian Zaraiby goats have long legs and ears as thermoregulatory morphological adaptive  
134 features for evaporative heat loss. In terms of fat storage, Berihulay et al. (2019) report that one-quarter of the global  
135 sheep population are fat-tailed breeds and are extensively in tropical environmental conditions, and can accumulate  
136 and mobilize the body fat in the internal fat depots. It is important to note that sheep and goats use fat tails and fat  
137 rumps as a thermoregulatory morphological feature based on their operational environmental condition. Therefore,  
138 body size, shape, and fat storage are important thermoregulatory morphological features and mechanisms for sheep  
139 and goats. It is thought that the evolution of subcutaneous (fatty tissue) or supercutaneous (hair) thermal insulation  
140 affects heat flow to and from the organism along the thermal gradient from the organism to the environment (Schmidt  
141 -Nielsen, 1997; Bligh, 1998). This implies that sheep fleece morphology affects heat dissipation from their skin surface  
142 through thermoregulatory mechanisms.

143 The sheep's coat morphology changed significantly during domestication. There are primitive sheep breeds that still  
144 possess a double coat of coarse outer hairs (produced by primary hair follicles) and fine inner hairs (derived from  
145 secondary hair follicles), like Soay sheep. Rather than having two follicles, modern woolled sheep (e.g., Merino) have  
146 a single coat containing both primary and secondary follicles (Sumner and Bigham, 1993, Galbraith, 2010). However,  
147 there is a wide variation in skin and coat morphology across different body regions. Skin thickness decreases from  
148 dorsally to ventrally on the trunk and from proximally to distally on the limbs (Scott, 1988).

149 There is a positive correlation between skin thickness, mean fiber diameter, and staple length (Gregory, 1982). Among  
150 sheep, the pinnae and the axillary, inguinal, and perianal regions have the thinnest skin, with an average thickness of  
151 2.6 mm in adults (Lyne and Hollis, 1968). These areas with thinner skin and shorter hair act as "thermal windows" for  
152 the dissipation of heat (Fowler, 1994; Mauck et al., 2003). Infrared electromagnetic waves can measure the flow of  
153 thermal energy between the skin and the environment. For detecting this infrared radiation in the boundary layer of an  
154 animal, infrared thermography is an excellent non-invasive tool (Gerken, 2010; AL-Ramamneh et al., 2012).

155 According to Berihulay et al. (2019), coat and skin color are critical morphological features used for thermoregulation  
156 by different animals, including sheep and goats. The characteristics of the coat and skin of sheep and goats in tropical  
157 and desert environmental conditions are entirely different from those in temperate environments (Joy et al., 2020). A  
158 hair coat's ability to absorb radiant heat depends on its surface area, pigmentation, structure, length, and condition.  
159 Several studies have shown that black-pigmented hair in strong sunshine has a greater surface temperature than hair  
160 with other colors, whether in sheep or goats. The coat color is an important feature that determines the radiant heat  
161 load and the amount of solar radiation that is reflected and absorbed by the animal. Those with light coat coloring  
162 absorb less heat than those with dark coat coloring (Berihulay et al., 2019). According to Leite et al. (2017), sheep  
163 with dark pigments are more prone to areas with heat stress than those with light pigmentation. The coloration of  
164 surfaces is caused by differential reflection or transmission of shortwave radiation. Sensible heat is generated whenever  
165 the surface doesn't reflect or transmit the radiation (Walsberg, 1983; Gerken, 2010). A darker coat color absorbs solar  
166 radiation more efficiently, providing more heat and emitting more energy (Galvan and Solano, 2016).

167 Consequently, animals adapted to hot climates have been observed to change their hair coat colors to alter their solar  
168 absorption (Acharya et al., 1995; Kadzere et al., 2002). Therefore, selecting animals with a light color is essential for  
169 the welfare and production efficiency of the sheep. According to the review by Berihulay et al. (2019), the effects of  
170 coat coloring that are related to climatic-stress-tolerance traits in the west African dwarf sheep include the rate of  
171 respiration, the rectal temperature, the pulse rate packed red cell volume (PRCV), plasma sodium (Na<sup>+</sup>), and potassium  
172 (K<sup>+</sup>). It has also been reported that sheep with carpet-type wool, thinner skin, and shorter hairs are well adapted to hot  
173 environments due to the improved heat dissipation rate (Berihulay et al., 2019). Therefore, coat and skin color are  
174 essential thermoregulatory morphological features used by sheep and goats to survive in different thermal  
175 environments.

## 176 **Behavioral and Physiological Mechanisms of Thermoregulation**

177           The behavioral adaptation of sheep and goats to different environments is based on their instinctive reaction  
178 to changes in their external environment by performing various activities to control their body temperature. According  
179 to Berihulay et al. (2019), the behavioral adaptation of small ruminants is meant to protect themselves from extreme  
180 environmental factors through the shedding of hair, water restriction, and control of feed intake. Also, it is essential to  
181 note that ruminants are active during the day and rest during the night to control the amount of heat and energy  
182 requirements based on their operation environment (Okoruwa, 2014). When small ruminants like sheep and goats have  
183 exposed to excessively high-temperature conditions, there shall be a reduced intake of feed as a means of adaptation  
184 to reduce heat production since the heat increment of feeding is a crucial source of heat production. According to Joy  
185 et al. (2020), goats are better adapted to heat stress than other ruminants because they have a dynamic eating behavior  
186 in hot environmental conditions. For example, the Saanen goats exposed to highly severe heat stress have a larger meal  
187 size but a reduced number of meals compared to the German Improved Fawn (GIF) goats (Berihulay et al., 2019).  
188 Goats exposed to highly stressful conditions have a reduced feed intake, body weight, and growth rate to maintain their  
189 thermoregulatory mechanisms and average body temperature.

190           Goats and sheep possess various physiological thermoregulatory mechanisms to adapt to different  
191 environmental conditions. When the physiological mechanisms of the animals fail to address the effect of various heat  
192 changes, the body temperature can change to a point where its well-being is compromised (Berihulay et al., 2019). The  
193 body temperature of an animal is essential in gauging its heat tolerance as it represents the net amount of heat as a  
194 result of the heat gain and loss processes in the body. The critical physiological adaptation mechanisms in small  
195 ruminants, including sheep and goats, include the change in heart rate, respiration rate, and rectal temperature. The  
196 rectal temperature of sheep and goats is a standard tool of measurement of the body temperature, even if there is a  
197 significant variation in the temperature of other body parts at various times of the day. In areas of high heat stress, the  
198 respiratory rate is the primary thermoregulatory mechanism used by sheep and goats to maintain an average body  
199 temperature. Another physiological thermoregulatory mechanism sheep and goats use is panting, resulting from an  
200 increased respiratory rate (Berihulay et al., 2019). It is important to note that sheep and goats experience various  
201 complex physiological changes in response to varying changes in temperature. In most cases, animals exposed to high  
202 ambient temperatures tend to have an elevated respiratory rate, pulse rate, and increased rectal temperature. Therefore,

203 physiological mechanisms are necessary for the thermoregulatory adaptations of sheep and goats to different  
204 environments.

205           As aforementioned, Berihulay et al. (2019) reported that the physiological adaptation of sheep and goats in a  
206 heat-stressed environment occurs through an increased respiratory rate, increased sweating rate, reduced metabolic  
207 rate, and changes in the functioning of the endocrine system. Various research studies and literature have shown that  
208 the respiratory rate and the rectal temperature are good indicators of thermal stress and can effectively assess the  
209 adversity of the operational thermal environment. According to Gupta et al. (2013), an increase in the rectal  
210 temperature of goats from 38<sup>0</sup> to 39<sup>0</sup> indicates that the animal has been kept at a hot ambient temperature for more than  
211 six hours. Another research study by Al-Dawood (2017) reported that an increase in rectal temperature above 44<sup>0</sup>C  
212 indicates that the animal has been exposed to higher temperatures. According to Al-Dawood (2017), the respiration  
213 rate of goats increases significantly at a temperature above 40<sup>0</sup>C, and ewes also report significant increases in the  
214 respiratory rate and rectal temperature when subjected to walking stress of more than 14km in a day which increases  
215 their body temperatures. An increase in the temperature of sheep and goats above the thermal comfort leads to the  
216 activation of evaporative cooling mechanisms, and the rate of sensible heat loss gets reduced (Berihulay et al., 2019).  
217 Therefore, the respiratory rate and rectal temperature can be considered critical physiological indicators of the thermal  
218 conditions of the environment.

### 219 **Genetic Mechanisms of Thermoregulation**

220 Performance traits are antagonistic with heat tolerance and, therefore, the use of heat-resistant individuals in goat  
221 breeding programs should be one of the main strategies to improve both animal welfare and productivity in hot climates  
222

223 Adaptation concerning genetic aspects is associated with the inheritable traits of animal characteristics or features that  
224 enhance their survival or tolerance to their external environment. In most cases, adaptive features are characterized by  
225 reduced heritability with the genetic variation within a population, providing the flexibility of adaptation to various  
226 environments, which is crucial for the population's long-term survival. Research studies and literature have indicated  
227 that genes' role in determining the capability of sheep and goats to survive in a heat-stress environment is complicated  
228 mainly because the mitochondrial genes have a high association with adaptability to temperature changes as it plays a

229 central role in energy metabolism. Most organelles in small ruminants like sheep and goats have a specific genome  
230 with one particular modified genetic code, with the mitochondrial genome being a circular and double-stranded  
231 molecule. Some outstanding characteristics of the mitochondrial DNA that play a role in thermal regulation include  
232 the relatively conservative gene content and organization, the reduced size, and the limited recombination. As  
233 Berihulay et al. (2019) reported, the adaptation of sheep and goats to different thermal environments is mediated by a  
234 complex network of genes with specific genome-wide DNA markers enhancing tolerance to heat stress, as is the case  
235 in the case of Egypt Baraki desert sheep and goats. Some possible genes that play a role in heat tolerance in sheep and  
236 goats include ANXA6, GPX3, GPX7, and PTGS2. Therefore, genes play a critical role in thermoregulation in sheep  
237 and goats.

### 238 **Endocrine and Metabolic Thermoregulatory Adaptation**

239 Heat stress generally affects livestock productivity, but very little information is available regarding their response to  
240 heat at a cellular level. Stress affects both innate and adaptive immune responses in animals. The immune system does  
241 not respond directly to stress but acts via the neuroendocrine system. The stress-related hormones act on the immune  
242 cell receptors to modulate the immune response. The innate immune response is one of the primary immune responses  
243 that help tackle the pathogens that enter the host animals. According to Roach et al. (2005), most vertebrate genomes  
244 contain one gene for each of the six major TLR families (TLR1, TLR3, TLR4, TLR5, TLR7, and TLR11). The heat  
245 shock response confers transient thermal tolerance, partly due to the expression of heat shock proteins (HSPs). HSP70  
246 plays the most dominant role among all the HSPs in protecting cells from damage caused by acute thermal stress  
247 (Dangi et al., 2014). Several kinds of the literature showed that heat shock proteins (HSPs) are rapidly synthesized in  
248 tissues subjected to thermal stressors.

249 In living tissues, HSP maintains the integrity of structural proteins, prevents protein aggregation, and aids the folding–  
250 refolding of damaged proteins (Morimoto, 1998b, 2008). Hsp90 is necessary for the viability of eukaryotes. It has been  
251 proved that Hsp90 direct folding, structural integrity, and proper regulation of a subset of cytosolic proteins (Carver et  
252 al., 1994; Matsumiya et al., 2009; Nguyen et al., 2009; Te et al., 2007). Besides, a decrease in intracellular Hsp90  
253 concentration has been reported to increase the mortality of mammalian cells at high temperatures (Barnes et al.,  
254 2001). Hsp60 is believed to protect the structure and function of native macromolecules, particularly as they traffic  
255 across membranes (Gupta et al., 2010).

256 The plasma cortisol concentration in the blood determines the endocrine adaptation of sheep and goats to different  
257 thermal environments. According to Archana et al. (2018), the Salem Black goats have reduced plasma cortisol  
258 concentrations, which indicates their superiority in adaptability to stressful conditions compared to the Osmanabadi  
259 goats, with a relatively high concentration of plasma cortisol in their blood during the summer. The plasma T3/T4  
260 concentrations also determine the variations in the breeds of sheep and goats with their response to different heat  
261 conditions. According to Joy et al. (2020), the cross-bred Chokla sheep have high plasma T3 concentrations during the  
262 summer compared to other pure breeds, which indicates aberrant thyroid gland activity and poor thermoregulation in  
263 heat-stressed environments. Joy et al. (2020) further report that sheep breeds with low plasma thyroid hormone  
264 concentrations are more adapted to heat-stressed environments as a result of the reduction in the rate of production of  
265 metabolic heat. It is further reported that heat stress significantly increased the concentrations of plasma growth  
266 hormones in various goat breeds, including Osmanabadi, Salem Black, and Malabari. The Osmanabadi goats have  
267 higher plasma concentrations associated with increased thermotolerance to excessively heat-stressed environments.  
268 Therefore, the endocrine system plays a crucial role in thermoregulation in sheep and goats.

269         Regarding metabolism, the size of sheep and goats often determines the natural selection for the genotypes of  
270 adaptability to different environments. According to Joy et al. (2020), metabolism is a crucial determinant of  
271 thermoregulation which determines the net temperature of the animal. Sheep and goats with relatively small sizes have  
272 reduced metabolic requirements and reduced heat production, which helps them to survive in heat-stressed  
273 environments. The reduced size of sheep and goats often confers an advantage to the tropical breeds, ensuring their  
274 survival in such environmental conditions. Also, another important determinant of the amount of heat in ruminants is  
275 the volatile fatty acids profiles in the rumen, which are important determinants of energy supply in the animals. The  
276 fatty acids determine the amount of heat gained or lost which determines the animal's net temperature (Joy et al., 2020).  
277 According to Pragna et al. (2018), the Salem goat breeds have a higher propionate production than the Osmanabadi  
278 and Malabari, leading to reduced methane synthesis. Also, the differences in the concentration of the proportion of  
279 volatile fatty acids determine the digestibility of diets and the population of rumen microbes in goats exposed to heat  
280 stress challenges (Pragna et al., 2018). Therefore, metabolic activities in sheep and goats are important determinants  
281 of the temperature of the animals and their response to different thermal environments.

## Conclusions

The current review explored the processes of thermoregulation in sheep and goats and described the various physiological features of the ruminant animals that enhance their ability to perform better stress additivity. Numerous studies have investigated the relationship between environmental changes and animal response. However, quite limited extensive research has been conducted to determine how sheep and goats respond to temperature changes through thermoregulatory processes. According to the review, heat stress is one of the primary factors that can affect the growth of small ruminant animals such as sheep and goats and can lead to impaired production, reproduction, compromised natural immunity, and increased susceptibility to diseases. The article further reports that the adaptation of sheep and goats to different thermal conditions occurs through behavioral, genetic, physiological, and morphological bases. Morphologically, the coat color of the sheep or goat plays an essential role in the absorption of heat, with the light-colored coated animal absorbing less heat as compared to those with darker coats. The behavioral adaptation of sheep and goats to different environments is based on their instinctive reaction to changes in their external environment by performing various activities to control their body temperature. Sheep and goats use fat tails and fat rumps as a thermoregulatory morphological features based on their operational environmental conditions. Also, sheep and goats exposed to high ambient temperature tend to have an elevated respiratory rate, pulse rate, and increased rectal temperature. Therefore, thermoregulation in sheep and goats occurs through behavioral, genetic, physiological, and morphological bases.

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