

# **Physiological and biochemical blood variables of goats subjected to heat stress – a review.**

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## **Abstract**

The aim of this review was to understand the role of physiological, hematological, biochemical and hormonal variables of the blood of goats raised in adverse environments. Scientific work in recent years has allowed for the evaluation of how goats of various breeds respond to edaphoclimatic effects to maintain homeothermy according to adaptability to the environment. The exposure of goats to heat stress causes changes in the physiological functions with impact on production and productivity of the animals. There is evidence that the central nervous system is sensitive to temperature changes, and some cells are agiler in the cold than in heat. In conclusion, we say that regardless of the breed, the raising environment and its climatic variables can trigger physiological, biochemical, hematological and hormonal alterations that result in a reduction of the heat production for maintenance of homeothermy. All these changes have a substantial impact on production and productivity.

Keywords: adaptability, cortisol, homeothermy, thermoregulation, tolerance to heat

## 1. Introduction

Stress is the body's reaction to stimuli that disturb homeostasis. These stimuli can be nutritional, chemical, psychological or thermal. These stimuli, heat stress, requires more attention, considering that the environmental temperature variations have major effects on animal production (Nardone et al. 2010; Salama et al., 2014). These effects have been greater nowadays, with the advent of global warming, by increasingly exposing animal species to stressful conditions worldwide.

High environmental temperatures in tropical and arid areas and low environmental temperatures in temperate areas range lethal, and this challenges the animal's ability to maintain the balance of its body (Silanikove 2000a). The interaction between the animals and the environment, the ability of each species and breed to adapt are essential characteristics because, based on them, decisions are made about the best system of raising and the best management strategy to be adopted to increase the production of the animals (Mirkena et al. 2010).

Climatic variations directly affect the animals, changing their physiology (Ribeiro et al. 2015). The impact of climatic changes has promoted much loss in livestock production as pointed out by Salama et al., (2014), a fact that generates the need for detailed studies to understand better the mechanisms of animals to adapt to extreme temperature changes. The description of the production environment is important since each breed has distinct adaptability features. Changes in biological functions of the animals due to exposure to heat stress include physiological, hormonal, hematological, and biochemical responses, which make the goats resistant and able to survive in adverse environments (Bernabucci et al. 2010). The aim of this review is to provide an

explanation of the physiological, hematological, biochemical and hormonal aspects in goats subjected to heat stress.

## **2. Physiological Variables**

Among the physiological variables commonly assessed in studies of adaptability in small ruminants are rectal temperature, heart rate, respiratory rate and surface temperature (Table 1). In general these variables will vary depending on the season, age, sex, time of day, physiological stage, exercise, water consumption, food intake and digestion (Otoikhian et al. 2009, Phulia et al. 2010, Sharma and Kataria 2011, Leite et al. 2012, Lucena et al. 2013, Ribeiro 2013).

According to Swenson and Reece (2006), the rectal temperature in goats varies from 38.3°C to 40.0°C and has frequently been used as an indicator of the body temperature of the animals, although there is a variation in body temperature in different parts of the body throughout the day. The daily variation in rectal temperature can be to ranges -0.3 to 1.9°C (Piccione and Refinetti 2003). In different environmental conditions, the rectal temperature is maintained within the proper range for goats (Rocha et al. 2009, Salles et al. 2009, Phulia et al. 2010, Aiura, Aiura and Silva 2010, Leite et al. 2012, Lucena et al. 2013, Ribeiro 2013).

The initial response of an animal to heat stress is the increasing of its respiratory rate, causing loss of heat by evaporation (Renaudeau et al. 2012). During heat exposure, animals use respiration as a mechanism to avoid increased rectal temperature, maintaining homeothermy. The increase in respiratory frequency can be an efficient way to lose heat for short periods of time. When the increased respiratory rate is maintained for several hours, it can result in serious problems for the animal. However, high values of respiratory rate do not indicate that the animal is under heat stress. That

is, if the animal has a high respiratory rate and excellent efficiency of heat loss to maintain homeothermy, heat stress may not occur (Berbigier and Cabello 1990). Several studies were developed on this issue as those reported by Rocha et al. (2009), Leite et al. (2012), Lucena et al. (2013), Ribeiro (2013).

The increased muscle activity to control the simultaneous increase in respiratory rate and a reduction in peripheral vascular resistance promotes greater blood circulation to dissipate heat through the skin, which are attributes that make the heart rate increase (Al-Tamimi 2007). Increase in the pulse rate will increase the flow of blood from the core to the periphery of the body, resulting in higher heat loss by sensible means (loss by conduction, convection, and radiation) and insensible means (loss of water by diffusion from the skin) (Marai et al. 2007). According to Swenson and Reece (2006), the average heart rate for goats is 90 beats per  $\text{min}^{-1}$ , and can vary from 70 to 120 beats per  $\text{min}^{-1}$ .

In mammals, the skin is an important route for the exchange of heat between the body surface and the environment. The blood flow to the skin is variable and is modified as necessary to regulate the rectal temperature. The redirecting of blood flow and vasodilation facilitate the dissipation of heat by sensible means, reducing the superficial temperature. The efficiency of heat dissipation through the skin depends on the temperature gradient between the animal's body and the environment. The dissipation of heat by insensible means is used when the superficial temperature increase occurs and is caused by the redirecting of blood flow to the body's surface and by vasodilation (Habeeb et al. 1992).

Under thermally comfortable conditions, the surface temperature is approximately 5 to 6 °C lower than the temperature of the central core. A cold stimulus leads to peripheral vasoconstriction mediated by the sympathetic nervous system and the conservation of

heat; a hot stimulus leads to peripheral vessel dilation and loss of heat. In extreme environmental temperatures, the surface temperature may approximate the temperature of the central core (Campbell 2011). The variation of the surface temperature depends on climatic variables (season and time of day) and physiological conditions (vascularization and sweating) and becomes higher with increasing temperature. Therefore, exposure of the goats to elevated temperatures causes increased dissipation of the excess heat from the body, to balance the body. The increase in heat loss of the skin as an immediate response to an increase in skin temperature may be more important in goats than in large ungulates. Due to the smaller body size, goats expose more surface area to solar radiation about their body mass (Ligeiro et al. 2006). Because they are homeothermic animals, when they are exposed to high temperatures, goats maintain the body in balance by dissipating excess body heat. The dissipation of excess heat is performed by the respiratory tract and by the skin surface. When it cannot dissipate the surplus heat, rectal temperature changes and the animal uses mechanisms morphological, hematological, and biochemical to maintain rectal temperature.

### **3. Blood Variables**

#### ***3.1 Hematological Variables***

The blood system is sensitive to temperature changes and is an important indicator of physiological responses to stressors. Several factors such as species, breed, sex, age, nutrition, diseases, physiological stage and seasonal variations can affect the pattern of hematological values (Bezerra et al. 2008, Abdelatif et al. 2009, Piccione et al. 2010, Bhat et al. 2011, Al-Eissa et al. 2012). Quantitative and morphological changes in blood cells are associated to heat stress (Table 2). These results show the variations in hematocrit values, mean erythrocytes count and hemoglobin (Iriadam 2007, Luz et al.

2010, Oliveira et al. 2012, Souza et al. 2011, Souza et al. 2008, Ribeiro 2013). Erythrocytes vary in diameter and thickness according to the breed and the nutritional status of the animal; however, they are capable of being modified in form as they pass through capillaries. During physical exercise, the release of oxygen is processed more quickly, helping to increase the rate of oxygen consumption and, consequently, to increase hemoglobin. Poor nutrition, which is observed in animals under long-term heat stress, reduces the number of erythrocytes and hemoglobin level, resulting in a decrease of red blood cells in the bloodstream (Swenson and Reece, 2006).

With the rise in environmental temperature, the animal loses liquid through the respiratory tract, reducing the blood plasma volume and increasing the concentration of hematocrit. If physical exertion is prolonged, dehydration occurs, and thus, loss of fluids by the evaporative process, resulting in increased hematocrit. During heat stress, significant depression in hematocrit may also occur due to the effect of hemodilution (El-Nouty et al. 1990). Animals raised under different environmental and management conditions can show noticeable variations in the constituents of the erythrogram, which creates the need to determine it for each breed in the various regions.

### ***3.2 Blood Biochemical Variables***

The knowledge of blood biochemical variables is necessary to define the biochemical profile, the energy metabolism, metabolism disorders, liver function, bone abnormalities and, based on them to assess the adaptation level of animals to climatic adversities (Swenson and Reece, 2006).

The interpretation of biochemical profiles is complex due to both the mechanisms that control the blood level of various metabolites and to the considerable variation in these

levels promoted several factors. Among these factors we can highlight the breed, age, physiological stage, diet, and management of the animal and, the climate (Gomide et al. 2004). Some studies have shown that in a high-temperature environment, the levels of glucose and cholesterol in the blood decrease, which is an indicator of failure in homeostasis (Ocak et al. 2010, Ribeiro 2013). The maintenance of stable levels of glucose in the blood is regulated by the liver, extrahepatic tissues and hormones namely insulin, glucagon, adrenaline, cortisol and thyroid hormones (Swenson and Reece, 2006).

The lipids found in blood plasma are divided into three major groups: cholesterol, phospholipids, and triglycerides. When failures in energy requirements of glucose occur, triglycerides are mobilized to serve as a source of energy (Payne and Payne, 1987). Heat stress has a greater effect on the total cholesterol levels, which may be due to increased use of fatty acids for energy production as a consequence of the reduction of glucose concentration in animals undergoing heat stress (Mundim et al. 2007).

Regarding the proteins, in general the researchers pointed out an increasing of them when the animals are subjected to heat stress (Abdelatif et al. 2009, Helal et al. 2010, Al-Eissa et al., 2012 and Ribeiro, 2013). However, Helal et al. (2010) performed a study with Balady goat breed subjected to heat stress and observed a decreased in total plasma protein, albumin, and globulin.

The enzyme concentration is necessary to assess the welfare of animals. During heat stress, the level of the aspartate aminotransferase, gamma glutamyl transferase, and alanine aminotransferase reflects the metabolic activities. In animals subjected to heat stress, a decrease in the concentration of these enzymes may occur due to decreased thyroid activity. A study performed by Ribeiro (2013) in goats indicated high levels of those related enzymes during heat stress. However, Sharma and Kataria (2011)

observed no significant changes in the degree of aspartate aminotransferase in goats during heat stress.

However, little importance has been given to the study of the possible effects of high effective environmental temperature on blood biochemical variables. The study of the biochemical profile requires the correct interpretation of blood variables; it is important to use appropriate reference values for each population and region studied.

### ***3.3 Thyroid Hormones***

Thyroid hormones (triiodothyronine (T<sub>3</sub>) and thyroxine (T<sub>4</sub>) act in all tissues of the body. The main effect of those hormones is to increase the metabolic activity of most tissues, increasing the rate of vital processes such as oxygen consumption and heat production in the body cells. The overall effects are an increase in basal metabolic rate, making more glucose available to the cells, with stimulation of protein synthesis and increased lipid metabolism, stimulating cardiac and neural functions (Todini 2007).

The levels of hormones in the thyroid gland vary according to the physiological stage, growth, breed, age, environmental temperature, and sex. The thyroid gland is one of the most sensitive organs to the variation of environmental temperature since its hormones are related to thermogenesis (Morais et al. 2008).

The intensity of the adverse effects of high environmental temperatures on the animals depends on the efficiency of thermoregulatory mechanisms. In the heat, the activity of the thyroid gland is reduced and in the cold, it is increased. Well-adapted animals respond quickly to environmental changes and thus can make the necessary physiological adjustments (Starling et al. 2005). The thyroid and adrenal glands play important roles in the adaptation of animals by controlling heat production in the organism. In animals exposed to high temperatures, the decrease in the secretion of



thyroxine occurs due to decreased need for thermogenesis, as an important step to heat stress (Coelho et al. 2008). The reduction of heat stress is due to the effect of heat on the hypothalamic-pituitary-adrenal (HPA) axis, thus decreasing the release of thyroid hormones, causing the animal to reduce basal metabolism. Likewise the increased level of T3 and T4 during cold stress results in increased oxygen consumption and heat production by cells to increase basal metabolism (Bernabucci et al. 2010).

Seasonal variation in serum concentrations of thyroxine (T4) and triiodothyronine (T3) of goats has been widely reported in the literature (Uribe-Velasquez et al. 1998, Starling et al. 2005, Todini et al. 2007, Sivakumar et al. 2010, Ribeiro 2013). In these studies variation in the behavior of the thyroid hormones were observed and it was due to changes in temperature. In some breeds (Azul, Graúna, Boer, Savana, Saanen) the effect of temperature changes are more noticeable than in others and depend on the physiological stage of animals (Berbegier and Cabello 1990, Coelho et al. 2008, Helal et al. 2010, Salles et al. 2009).

### ***3.4 Cortisol***

The cortisol is considered one of the main hormones involved in stress response, and its main function is to favor protein metabolism to convert protein into amino acids, supporting gluconeogenesis. The cortisol synthesized by the adrenal cortex stimulates the degradation and release of glucose, amino acid, and fat in the liver, muscle and adipose tissue (Sejian, Srivastava and Varshney 2010). The cortisol concentrations can vary according to several factors, such as circadian rhythm, season, photoperiod and diet composition. The cortisol level reported in different breeds of goats ranges from 3 to 15 ng/ml (Ortiz-de-Montellano et al. 2007, Al-Busaidi et al. 2008, Aoyama et al. 2008, Sejian and Srivastava, 2010, Ribeiro 2013). In stressed animals, some authors

observed cortisol levels between 4.5 and 15.6 ng/ml (Ronchi et al. 2001), and values between 21.5 - 43.0 ng/ml (Du Preez et al. 2000). The levels of cortisol increase during the initial phase of the active cycle of animals, according to the circadian rhythm and also during stress. During heat stress, one of the main functions of cortisol is to promote protein catabolism, converting the protein into amino acids to support gluconeogenesis (Sejian, Srivastava and Varshney 2010).

The hormones secreted from the hypothalamic-pituitary-adrenal axis have a broad and lasting effect on the body. Virtually all biological functions that are affected by stress, including immune capacity, reproduction, metabolism, and behavior are regulated by cortisol. These endocrine responses aim to improve the ability of the individual to tolerate the stress. The increase in cortisol cannot be seen only as a negative response to the organism because this is essential to life and is responsible for various processes. The minimum release of cortisol has the objective of maintaining homeostasis, preserving the internal balance of the body, a fact which varies from individual to individual (Meij and Mol, 2008; Ribeiro et al., 2015).

The secretion of cortisol is useful despite its variability and short life. The cortisol stimulates physiological adjustments that allow the animal to tolerate stress caused by hot environments. Since threatening situations require vigorous action, anatomical and endocrine responses to stress are catabolic. That is, they help mobilize the organism's energy reserves, influencing the metabolism of carbohydrates, lipids, electrolytes and water (Silanikove 2000b).

The association between heat stress and increased cortisol secretion is sparsely documented in ruminants. High temperatures (acute heat stress) cause elevation of blood cortisol concentration, decreasing the rate of metabolic heat production (Sejian and Srivastava 2010). Increased level of cortisol occurs in goats after acute heat stress

when compared to animals that live in situations of chronic heat stress. Severe chronic stress can result in periods of high concentrations of cortisol, reducing individual fitness by causing immunosuppression and atrophy of the body's defense tissues. Furthermore, cortisol reduces the energy available to the immune system by increasing the susceptibility of animals to infectious diseases (Al-Busaidi et al. 2008).

The study showed that regardless of the breed, the breeding environment, and its climatic variables can trigger physiological, biochemical, hematological and hormonal alterations that result in a reduction in the heat production to maintain homeothermy. Although goats are considered animals of greater hardiness than other ruminants, little is known about the adaptive aspects of these animals. It is noticed that the Creole goat breeds have greater ability to maintain the rectal temperature within the ideal limit, with little variation in respiratory rate and heart rate, unlike what happens with exotic breeds. The environmental temperature has a predominant effect on the activity of blood biochemical variables in different physiological periods. The metabolism is reduced during heat stress and is controlled by hormones. The use of hormones makes it easier to understand the physiological variables involved in the process of adaptation.

#### **4. Conclusion**

The study showed that regardless of the breed, the breeding environment, and its climatic variables can trigger physiological, biochemical, hematological and hormonal alterations that result in a reduction in the heat production to maintain homeothermy. Although goats are considered animals of greater hardiness than other ruminants, little is known about the adaptive aspects of these animals. It is noticed that Creole goat breeds have greater ability to maintain the rectal temperature within the ideal limit, with little variation in respiratory rate and heart rate, unlike what happens with exotic breeds.

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