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Physiological parameters of male goats raised under tropical climate conditions (Brazil)

Parâmetros fisiológicos de machos caprinos criados em condições de clima tropical (Brasil)

Parámetros fisiológicos de machos caprinos criados en condiciones climáticas tropicales (Brasil)

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Júlio César Oliveira Dias
ORCID: https://orcid.org/0000-0002-9356-4264
Instituto Federal de Educação, Ciência e Tecnologia do Norte de Minas Gerais, Brasil
E-mail: julio.dias@ifnmg.edu.br
Cristina Mattos Veloso
ORCID: https://orcid.org/0000.0001.5811.8819
Universidade Federal de Viçosa, Brasil
E-mail: cristina.veloso@ufv.br
Madriano Christilis da Rocha Santos
ORCID: https://orcid.org/0000-0003-1400-1066
Agência Estadual de Defesa do Maranhão, Brasil
E-mail: madrianosantos@gmail.com.br
Carlos Thiago Silveira Alvim Mendes de Oliveira
ORCID: https://orcid.org/0000-0003-4413-7482
Centro Universitário Católica do Leste de Minas Gerais, Brasil
E-mail: ctsamo@gmail.com
Camila Oliveira Silveira
ORCID: https://orcid.org/0000-0002-4225-7192
Universidade Federal de Viçosa, Brasil
E-mail: camilasilveiravet@yahoo.com.br

Abstract

This study evaluated the adaptive capacity and variations in physiological parameters of four male goats originate from a temperate region (Alpine breed) in a tropical climate over twelve months. The ambient temperature, relative humidity, and temperature via a black globe thermometer were evaluated to calculate the black globe temperature and humidity index;

they were collected five times during the day, three times during the week, and during the four annual seasons. Every fortnight throughout the experimental period, respiratory and heart rates as well as rectal and surface temperatures of the animals were measured in the morning, and blood samples were acquired for hormonal levels (cortisol, T3, and T4) and complete blood count. There was a difference between the mean values of surface temperature, respiratory rate, hormones, and some hematological parameters (total protein and monocytes) between the seasons ($P<0.05$). However, no differences were observed in cases of heat stress, based on the fact that physiological parameters were within normal and expected limits for goats. Thus, it is concluded that the male goats of the Alpine breed, when reared intensively, maintain homeothermia and are greatly adaptable to the conditions of the tropical climate.

Keywords: Bioclimatology**;** Cortisol; Heat stress; Thyroxin; Triiodothyronine.

Resumo

Este estudo avaliou a capacidade adaptativa e as variações nos parâmetros fisiológicos de quatro caprinos machos originários de uma região temperada (raça Alpina) em um clima tropical ao longo de doze meses. A temperatura ambiente, a umidade relativa e a temperatura por meio de um termômetro de globo negro foram avaliadas para calcular a temperatura de globo negro e o índice de umidade; eles foram coletados cinco vezes ao dia, três vezes durante a semana e durante as quatro estações anuais. A cada quinze dias durante o período experimental, as frequências respiratória e cardíaca, bem como as temperaturas retal e superficial dos animais foram medidas pela manhã, e amostras de sangue foram coletadas para os níveis hormonais (cortisol, T3 e T4) e hemograma completo. Houve diferença entre os valores médios de temperatura superficial, frequência respiratória, hormônios e alguns parâmetros hematológicos (proteína total e monócitos) entre as estações ($P <0,05$). No entanto, não foram observadas diferenças nos casos de estresse por calor, devido ao fato dos parâmetros fisiológicos estarem dentro dos limites normais e esperados para cabras. Assim, conclui-se que os caprinos machos da raça Alpina, quando criados de forma intensiva, mantêm a homeotermia e são bastante adaptáveis às condições do clima tropical.

Palavras-chave: Bioclimatoloia; Cortisol; Estresse por calor; Tiroxina; Triiodotironina.

Resumen

Este estudio evaluó la capacidad adaptativa y las variaciones en los parámetros fisiológicos de cuatro machos cabríos de una región templada (raza alpina) en un clima tropical durante doce meses. Se evaluó la temperatura ambiente, la humedad relativa y la temperatura utilizando un termómetro de globo negro para calcular la temperatura del globo negro y el índice de humedad; se recolectaron cinco veces al día, tres veces a la semana y durante las cuatro estaciones anuales. Cada quince días durante el período experimental, se midió la frecuencia respiratoria y cardíaca, así como la temperatura rectal y superficial de los animales por la mañana, y se tomaron muestras de sangre para niveles hormonales (cortisol, T3 y T4) y hemograma completo. Hubo una diferencia entre los valores medios de temperatura superficial, frecuencia respiratoria, hormonas y algunos parámetros hematológicos (proteína total y monocitos) entre temporadas (P <0.05). Sin embargo, no se observaron diferencias en los casos de estrés por calor, debido a que los parámetros fisiológicos se encuentran dentro de los límites normales y esperados para las cabras. Así, se concluye que los machos cabríos de la raza alpina, cuando se crían de forma intensiva, mantienen la homeotermia y son bastante adaptables a las condiciones del clima tropical.

Palabras clave: Bioclimatolia; Cortisol; Estrés por calor; Tiroxina; Triyodotironina.

1. Introduction

Goats are considered to be rustic animals with a high ability for acclimation to climate changes. However, when exposed to high ambient temperatures, air humidity, and solar radiation, they suffer changes in physiological and productive behavior (Brasil, et al., 2000; Silva, et al., 2005).

Most of the time, tolerance and degree of adaptability of the animals to heat stress are determined by physiological measurements based on respiration, cardiac beats per minute, and body temperature (Silanikove, 2000; Marai, et al., 2008; Pereira, et al., 2011; Souza, et al., 2013). Nevertheless, the blood system can also be utilized to evaluate the relationship between the animals and heat stress in view of mechanisms of heat loss, which directly involve the blood (Delfino, et al., 2012). Thus, it is possible that quantitative and morphological changes occur in cells and the blood volume of the animals, which can be observed in values of erythrocytes and white blood cells (WBC; Iriadan, 2007). Thus, as the blood system is sensitive to temperature changes, it can be considered an important indicator of physiological responses to stressful situations (Delfino, et al., 2012), thereby complementing other physiological parameters.

Other important aspects to be considered since animal metabolism and heat stress are related are the hormones triiodothyronine (T3), thyroxin (T4), and cortisol. The activity of the thyroid gland is directly related to metabolism, which correlates with thermogenesis (Coelho, et al., 2008). Thus, heat stress induces the body to reduce the concentration of thyroid hormones in order to decrease the metabolic heat rate (Yousef, et al., 1967). Cortisol has the function of preserving the internal balance of the body, and when threatened, the body develops a biologic, defensive response through hyperactivity of the adrenal cortex to increase the hormones needed to restore homeostasis (Vasquez & Herrera, 2003). Therefore, the hormones T3, T4, and cortisol could indirectly help to verify situations of heat stress.

The majority of dairy goat breeds that are raised in tropical countries have origins in temperate regions; in a production system, the acclimation and the welfare of the animals in the ambient temperature affect not only the question of survival, but also influence productive and reproductive efficiency (Façanha, 2013). Thus, the objective of this study was to evaluate the adaptive ability and the variations of physiological parameters of male Alpine goats that are raised in highland tropical climate conditions over the course of twelve months.

All procedures of handling were approved by the Ethics Committee for Animal Use of the Animal Science Department of the Federal University of Viçosa (process number 32/2013) and were performed according to the Ethics principles of animal experimentation, as established by the Brazilian Animal Experimentation College and according to the current lawse o parágrafo como modelo.

2. Methodology

Regarding the methodology used in this work, the research has a quantitative nature and was carried out through data collection.

The animals were housed in the Goat Section of the Animal Science Department of the Universidade Federal de Viçosa, Viçosa, Minas Gerais, Brazil at 649 m of altitude, under the latitude of 20°45’20''S and longitude 42°52’40'' W. The average annual temperature was 20.9°C, with an average annual precipitation index of 1,221 mm^3, and a highland tropical climate Cwa type (dry winter and wet summer) based on the weather classification of Köeppen-Geiger. The experimental period was 12 months, comprised of the four seasons of the year (autumn, winter, spring, and summer).

Four male, clinically healthy Alpine goats with an age of 3.4 ± 1.9 years were selected and were maintained under natural lighting conditions. The animals were housed in covered individual pens with an uncovered exercise area (solarium) where they had free access to solar radiation. The animals received corn silage roughage, a protein and energy concentrate, as well as free access to mineral salt and water, thereby meeting the nutritional requirements of goats according to the National Research Council – NRC (2007). A unique diet was offered during the experiment to eliminate possible interference from changing offerings of feed on the studied characteristics.

Climatic data of ambient temperature and relative air humidity were obtained by digital thermo hygrometer, and the black globe temperature was obtained by using a black globe thermometer; the means that were obtained for each season are shown in Table 1. The equipment was installed at close to the animals and data were collected during the year three times a week (Monday, Wednesday, and Friday) at five times during the day (7h00, 9h30, 12h00, 14h30, and 17h00). The index to evaluate thermal comfort of the animals was the black globe temperature and humidity index (BGHI; Table 1), which was calculated according to the formula proposed by Buffington, et al., (1981):

$$BGHI = Bgt + 0.36\ (Dpt) + 41.5$$

Bgt = black globe temperature (°C); and Dpt = dew point temperature (°C).

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Table 1. Means and mean standard error of the average ambient temperature (°C), relative air humidity (%), and black globe and humidity index (BGHI) during the seasons of the year for a highland tropical climate (Viçosa, MG - Brazil).

Period	Ambient temperature (°C)				
	Morning		Afternoon		
	7h00	9h30	12h00	14h30	17h00
Autumn	16.97 ± 0.39	20.53 ± 0.39	23.80 ± 0.45	25.69 ± 0.75	23.15 ± 0.54
Winter	13.87 ± 0.45	18.73 ± 0.48	23.66 ± 0.48	26.03 ± 0.57	24.80 ± 0.62
Spring	19.43 ± 0.44	23.34 ± 0.46	26.37 ± 0.59	27.22 ± 0.67	26.79 ± 0.73
Summer	20.50 ± 0.20	23.88 ± 0.29	26.89 ± 0.44	28.35 ± 0.53	27.40 ± 0.60
	Relative air humidity (%)				
Period	Morning		Afternoon		
	7h00	9h30	12h00	14h30	17h00
Autumn	92 ± 0.2	87 ± 0.8	69 ± 1.4	61 ± 0.8	67 ± 1.7
Winter	89 ± 0.4	79 ± 1.9	55 ± 1.9	44 ± 2.0	47 ± 0.7
Spring	86 ± 1.0	68 ± 1.9	57 ± 2.3	53 ± 2.7	55 ± 3.4
Summer	90 ± 0.5	76 ± 1.2	63 ± 1.7	57 ± 2.0	59 ± 2.7
	BGHI				
Period	Morning		Afternoon		
	7h00	9h30	12h00	14h30	17h00
Autumn	64 ± 0.5	69 ± 0.5	72 ± 0.6	75 ± 0.3	72 ± 0.9
Winter	61 ± 0.6	66 ± 0.5	71 ± 0.5	73 ± 0.6	72 ± 2.5
Spring	68 ± 0.6	72 ± 0.6	75 ± 0.7	76 ± 0.8	76 ± 1.1
Summer	69 ± 0.3	74 ± 0.4	77 ± 0.5	78 ± 0.6	78 ± 0.9

Source: Authors (2020).

The physiological parameters were measured and collected inside the individual pens every fortnight at 7h00 in the morning.

The rectal temperature (°C) was measured with a veterinary clinic thermometer whose scale ranged up to 44°C; it was introduced directly in the rectum of the animal with the bulb in contact with the rectal mucosa of the animal for two minutes. The superficial temperature (°C) was the average of the superficial temperatures from the rib, flank, and scrotum as measured with an infra-red digital thermometer. The respiratory frequency was obtained by

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visual observation of the flank movements of the animals over the course of one minute, and the result was expressed in movement per minute (mov min^{-1}). The cardiac frequency was measured by using a flexible stethoscope (Rappaport Premium®) placed directly in the left thoracic region at the height of the aortic arch for a minute, and the result was expressed in beats per minute (beats min^{-1}).

Blood samples were collected after analyses of the physiological parameters every fortnight at 7h00 by jugular venipuncture in two 10-mL vacutainer tubes, with one containing heparin (tube 1) and the other without an anticoagulant (tube 2). In tube 1, the CBC of the animal (erythrocyte and white blood cell count – WBC) was immediately performed, while tube 2 was immediately centrifuged at 1500 g for 10 minutes in an ambient temperature and the blood serum was stored in 2-mL polyethylene tubes at -20 °C. The assays for the hormone levels (ng/mL) of T4, T3, and cortisol were performed by chemiluminescence through the immune-enzymatic technique by using commercial kits from Beckman Coulter® (Beckman Coulter, EUA) and the Access® equipment (Beckman Coulter, EUA) according to the specifications of the manufacturer.

Data were analyzed using the Statistical Analysis System (SAS, 2002). The quantitative variables were evaluated by variance analysis while considering the effect of animals and while using the PROC GLM; the means were compared by the Ryan-Einot-Gabriel-Welsh test. The qualitative variables were analyzed by the Kruskal-Wallis test using the PROC NPAR1WAY. The correlations between the quantitative variables were analyzed by simple Pearson correlation and the qualitative variables were analyzed by the Spearman correlation (PROC CORR). Data were presented as the mean ± mean standard error, and the adopted significance was $\alpha = 0.05$.

3. Results and Discussion

The values of the ambient temperature (°C; Table 1) were different from those recorded in studies that were performed in regions of semiarid and Mediterranean tropical climates, which were generally greater than 30°C (Shinde, et al., 2002; Darcan & Güney 2008; Rocha, et al., 2009; Pereira, et al., 2011; Silva, et al., 2011). Considering the fact that the interval from 20 to 30°C is the interval that comprises the ambient temperature values of the Thermal Comfort Zone (TCZ) for goats (Baêta & Souza, 2010), it can be inferred that during the experimental period, the animals were not exposed to heat stress. Some ambient temperature values were below this limit at 7h00 (autumn, winter, and spring) and at 9h00 (winter); however, the values were within the range of the thermal comfort modest zone (TCMZ), which is between -20 to 34°C for goats (Baêta & Souza, 2010). Thus, there was no cold or heat detected by the animals during the periods that were analyzed.

The relative air humidity (%) presented with a greater value in the morning and a decreased value associated with the increased ambient temperature during the day, according to observations by Shinde, et al., (2002) and Rocha, et al., (2009) who worked with dairy goats in semiarid regions and found average values of 90% and 30% during the morning and the afternoon respectively. In addition to solar radiation and wind, the ambient temperature and relative air humidity are the main ambient factors that determine the occurrence of heat stress in the animals (Medeiros, et al., 1998; Souza, et al., 2008), especially if they are high (Nardone, et al., 2006). In hot regions where the temperature is greater than the body surface, the elimination of the body heat of warm-blooded animals by radiation, conduction, and convection is impaired, while evaporation is the main process of heat dissipation. However, its efficiency is impaired when the relative air humidity is excessive since evapotranspiration is regulated by the ambient humidity (Marai, et al., 2008).

In this study, the increased ambient temperatures during the day throughout the four seasons were followed by a decreased relative air humidity (Table 1). Thus, the negative effect on the mechanism of heat dissipation via evaporation was reduced, as was the possibility of heat stress. This was also observed by Martins Júnior, et al., (2007) who worked with Boer goats in semiarid regions.

Buffington, et al., (1981) concluded that in ambience where the animals are exposed to solar radiation, the black globe temperature and humidity index (BGHI) is the most precise indicator of heat stress and allows us to evaluate thermal ambient comfort where the animals are housed. We observed that the BGHI presented in Table 1 were greater in the spring and summer, mainly in the afternoon. The values of BGHI were below those recorded for semiarid tropical regions; in the morning and in the afternoon, the values of BGHI were above 77 and 82 respectively (Silva, et al., 2006; Rocha, et al., 2009; Pereira, et al., 2011; Silva, et al., 2011; Souza, et al., 2013). According to Baêta & Souza (2010), values of BGHI up to 74 indicate thermal comfort conditions, from 74 to 78 as an alert condition, from 79 to 84 as a dangerous condition, and higher than 84 as an emergency condition. Thus, the values that were obtained in this study for BGHI did not indicate a situation of thermal discomfort, only that there was risk of homeothermia during the afternoon (alert condition) mainly during the hottest seasons (spring and summer), probably due to the greater incidence of solar radiation inside of the shelters.

The physiological parameters of the animals are shown in Table 2. Differences were observed (P<0.05) only for superficial temperature and respiratory frequency, as the means were greater during the seasons with greater ambient temperatures. According to Kabuga & Agyemang (1992) and Abi Saab & Sleiman (1995), the respiratory frequency, the cardiac frequency, and the body temperature (rectal) can indicate whether the animal is in a heat stress condition. The influence of heat on physiological parameters can increase the rectal temperature by 3.3% and the respiratory frequency by 194% (McDOWELL, 1972).

Table 2. Means and mean standard error of the physiological parameters of male Alpine goats during different seasons for a highland tropical climate (Viçosa, MG – Brazil).

Period	Physiological parameters			
	Body temperature		Frequency	
	Rectal (°C)	Superficial (°C)	Respiratory (mov min^{-1})	Cardiac (beat min^{-1})
Autumn	38.09 ± 0.05 ^{a}	28.06 ± 0.24 ^{ab}	33.04 ± 2.72 ^{ab}	73.07 ± 2.85 ^{a}
Winter	37.35 ± 0.04 ^{a}	26.47 ± 0.49 ^{b}	23.36 ± 2.04 ^{b}	76.91 ± 1.69 ^{a}
Spring	37.94 ± 0.06 ^{a}	29.85 ± 0.29 ^{a}	23.21 ± 1.28 ^{b}	77.29 ± 2.23 ^{a}
Summer	38.05 ± 0.06 ^{a}	29.32 ± 0.27 ^{a}	38.50 ± 6.05 ^{a}	74.86 ± 3.65 ^{a}

Different letters in the same column differ among them by the Ryan-Einot-Gabriel-Welsh test (P<0.05).
Source: Authors (2020).

Warm-blooded animals have body temperatures that vary in different parts of the body due to acclimation to external ambient temperatures in order to control and regulate their physiology. However, the temperature of the body's core for goats is 40°C, which is constantly maintained independently of ambient variation (Baêta & Souza, 2010).

The average rectal temperature for goats at rest and in shade is 39.1°C (Robertshaw, 2006) and above 42°C is considered to be a risk for animal health and welfare (Brown-Brandl, et al., 2003; Marai, et al., 2008). In this study, the rectal temperatures did not present with differences among the four seasons, nor did they present with clues of heat stress since they were close to the average recognized by Pereira, et al., (2011) and Souza, et al., (2013) for goats in semiarid tropical climates. When animals are within their Thermal Comfort Zone, they maintain the body temperatures constantly with minimal efforts from their thermoregulatory mechanisms (Baêta & Souza, 2010). According to Hopkins, et al., (1978), rectal temperature values close to the temperature considered to be normal for the species can be considered as an adaptability index.

Another important parameter in the evaluation of heat dissipation is the superficial temperature (Santos, et al., 2005). The superficial temperature (°C) had a correlation (r= 0.65) with the ambient temperature (°C) and presented with greater values during the spring (29.85 ± 0.29) and summer (29.32 ± 0.27) (P<0.05), which were the hottest seasons of the experimental period. These values for superficial temperature were close to those recorded by Silva, et al., (2006) and Souza, et al., (2013), which were 29.50 and 29.47°C respectively. In the mechanisms to eliminate excess body heat, evaporation can occur either through the surface of an animal's body through evaporation of sweat released by sweat glands or through evaporation from the respiratory system due to expiration of water vapor into the air (Silva, 2000). Therefore, the greatest values of superficial temperature during the hottest seasons reveal the physiological need of animals to eliminate internal heat to the environment, thereby increasing blood flow in the peripheral tissues and sweat production by the sweat glands (Ligeiro, et al., 2006). Moreover, when there is an increase in peripheral vasodilatation, the losses of sensible heat increase via radiation, conduction, and convection (Silva, 2000). Although, the lowest value of superficial temperature (Table 2; P<0.05) during winter (26.47 ± 0.49) is evidence of the need for greater retention of body heat during this season that presents with lower ambient temperatures and values of humidity, which in turn favors heat loss to the external environment as sensitive and latent ways.

However, in the case of goats who have a lower number of sweat glands in relation to cattle, the evaporation mechanism by respiration is utilized more than sweating for heat dissipation (Arruda, et al., 1984). In normal conditions, 20% of heat losses in sheep are performed by respiration, and this value increases to 60% when the animals are submitted to ambient temperatures above 35°C (Quesada, et al., 2001) due to a drop in the efficiency of sensible heat losses by decreasing the temperature gradient between the animal's skin and the environment (Silva, et al., 2006). The values considered to be a normal respiratory frequency for goats are between 12 to 25 respiratory movements/minute (Reece, 2006). Thus, when ruminants present with a frequency of 40-60, 60-80, or 80-120 movements/minute, they are considered to be in a low, medium-high, or high stress condition, respectively (Silanikove, 2000).

Data presented in Table 2 show that the respiratory frequency (mov min^{-1}) of the animals did not reach the range indicative of stress; greater values were observed only for summer (38.50 ± 6.05) and autumn (33.04 ± 2.72) (P<0.05), and were close to those observed by Souza, et al., (2013) but lower than those verified by Pereira, et al., (2011), which were 37.18 and 77.62 respectively. Moreover, the values of relative air humidity were greater (Table 1) during summer and autumn, during which times heat loss through the skin of the animals was difficult, which let them to dissipate heat via respiration. According to Buffingon, et al., (1981), the respiration rate is directly related to BGHI; during this study, thermal discomfort (BGHI in the Table 1) was possibly observed, mainly during the summer, which can increase the respiratory frequency (Table 2). Thus, it can be inferred that the respiratory frequency of the animals varied according to the ambient temperature associated with the elimination of excessive internal heat acquired during the hottest seasons and needed to reach homeothermia, a fact that was also observed by Martins Junior (2007). According to Baccari Junior (1986), animals such as those in this experiment that present with a lower increase in the rectal temperature and a lower respiratory frequency when submitted to high temperatures are considered more tolerant to heat.

The values of cardiac frequency were within the limits recognized for goats (from 70 to 80 beats/minute) (Erickson & Detweiler, 2006) and did not present with differences among seasons, similar to the results verified by Souza, et al., (2008).

The average values (ng/mL) of cortisol, triiodothyronine (T3), and thyroxin (T4) in the animals during the four seasons are shown in Table 3.

Table 3. Means and mean standard error of serum concentrations of the hormones cortisol, triiodothyronine (T3), and thyroxin (T4) of male Alpine goats during different seasons in highland tropical conditions (Viçosa, MG – Brazil).

Period	Physiological parameters		
	Cortisol (ng/mL)	T3 (ng/mL)	T4 (ng/mL)
Autumn	17.57 ± 1.09 ^{a}	0.58 ± 0.02 ^{c}	61.61 ± 2.62 ^{b}
Winter	13.11 ± 1.05 ^{b}	0.72 ± 0.03 ^{a}	81.76 ± 4.23 ^{a}
Spring	14.40 ± 1.23 ^{ab}	0.65 ± 0.02 ^{b}	74.73 ± 2.54 ^{a}
Summer	17.20 ± 1.18 ^{a}	0.56 ± 0.01 ^{c}	61.57 ± 2.16 ^{b}

Different letters in the same column differ among them by the Ryan-Einot-Gabriel-Welsh test (P<0.05).
Source: Authors (2020).

The values of cortisol were greater during the summer, autumn, and spring (P<0.05), which were the seasons with greater values of temperature, relative humidity (Table 1), and

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respiratory frequency (Table 2). However, the recorded values are within the expected interval for small ruminants, varying from 14 to 31 ng/mL (Radostits, et al., 2002). In stressful conditions, one of the first physiological reactions of animals is the activation of the hypothalamic-pituitary-adrenal axis to release glucocorticoids in the blood, especially cortisol, which has the main function of regulating and/or acclimating the internal metabolism (Vasquez & Herrera, 2003; Eiler, 2006). In times of acute stress, there is an increase in the concentrations of serum cortisol and thus, an increase in the degradation of reserve tissues that provide greater glucose concentrations to the heart, nervous system, and skeletal muscle. Although, in periods of chronic stress, there is a reduction in the activity of this axis, which decreases excessive tissue mobilization and has a negative effect on animal production and reproduction (Schimidt-Nielsen, 2002).

The serum concentrations of the hormones T4 and T3 also presented a difference ($P<0.05$) among seasons, although they were close to (T4) or below (T3) the average values that are expected for small ruminants which are 79 ng/mL and 0.98 ng/mL respectively (Anderson, et al., 1988). In the summer when the ambient temperatures are higher, a reduction in hormonal values can be observed, while in winter, an increase in these values was verified ($P<0.05$). This blood change based on season was also observed by other authors working with goats (Prakash & Rathore, 1991), sheep (Taha, et al., 2000; Zamiri & Khodaei, 2005), and cattle (Rasooli, et al., 2004). T3 and T4 are characterized by heat production that controls the thermogenesis of the animals (Eiler, 2006; Coelho, et al., 2008) to maintain homeostasis and constant internal temperatures. The hormonal response in a possible condition of heat stress takes the form of a reduction in thyroid hormones synthesis and thus, a decrease in metabolism and internal heat production (Yousef, et al., 1967; Eiler, 2006). Moreover, it is possible that the exposure to heat can directly influence the hypothalamic-pituitary axis and allow for the reduction of TSH secretion (Tal & Sulman, 1973).

However, the values of respiratory frequency and other physiological parameters (Table 2) within the pre-established and expected limits for goats show that besides the increase in the stress indicator hormone (cortisol) and annual variations in thermogenic hormones (T3 and T4) between the seasons, the animals were able to dissipate the excess internal heat and reach homeostasis. Also, the increased T3 and T4 during the winter help to efficiently increase and maintain the internal body temperature within the physiological limits.

The values of hematocrit, total blood protein, and white blood cell count (WBC) that were observed for male Alpine goats during different seasons in a highland tropical climate can be seen in Table 4.

Table 4. Means and standard error of hematocrit, total protein, and WBC of male Alpine goats during different seasons for a highland tropical climate (Viçosa, MG – Brazil).

Period	Physiological parameters		
	Hematocrit (%)	Total protein (g/dL)	Leukocytes (mm³)
Autumn	31.04 ± 0.94 [a]	7.96 ± 0.09 [ab]	6.189 ± 201 [a]
Winter	31.25 ± 1.15 [a]	7.81 ± 0.09 [b]	6.621 ± 577 [a]
Spring	31.75 ± 0.62 [a]	8.20 ± 0.12 [a]	6.693 ± 346 [a]
Summer	30.85 ± 1.00 [a]	7.98 ± 0.12 [ab]	5.771 ± 270 [a]

Different letters in the same column differ among them by the Ryan-Einot-Gabriel-Welsh test (P<0.05).
Source: Authors (2020).

Table 4. Continuation.

Period	Physiological parameters				
	Basophils (%)	Eosinophils (%)	Neutrophils (%)	Lymphocytes (%)	Monocytes (%)
Autumn	0	4.39 ± 0.87 [a]	47.19 ± 2.09 [a]	43.81 ± 1.92 [a]	3.31 ± 0.40 [b]
Winter	0	5.75 ± 1.46 [a]	44.08 ± 2.08 [a]	44.17 ± 1.95 [a]	5.92 ± 0.95 [a]
Spring	0	4.18 ± 0.73 [a]	46.04 ± 1.61 [a]	45.50 ± 1.69 [a]	3.96 ± 0.37 [a]
Summer	0	4.21 ± 0.82 [a]	50.04 ± 2.33 [a]	41.58 ± 1.92 [a]	3.29 ± 0.43 [b]

Different letters in the same column differ among them by the Ryan-Einot-Gabriel-Welsh test (P<0.05).
Source: Authors (2020).

The concentration of total protein in the blood plasma was greater than the reference value (6.5-7.5 g/dL; Reece & Swenson, 2006), mainly in the spring (P<0.05), which was one of the periods with high ambient temperatures (Table 1). This can cause greater dehydration and thus lead to a greater protein plasmatic concentration.

The values that were obtained in this study for hematocrit are according to the reference values, which are from 27 to 35% for goats (Bhargava, 1980). The hematocrit is the percentage of erythrocytes in relation to the total blood volume (Delfino, et al., 2012) and can be very important in diagnosing heat stress. Beyond the total plasmatic protein, the hematocrit can increase dehydration due to liquid loss by evaporative mechanisms of heat dissipation (respiration and sweating) (Lee, et al., 1974; Souza, et al., 2011). In this study, there was a correlation between hematocrit and cortisol (r= 0.26) and therefore, cortisol could be considered a parameter that can indicate heat stress conditions.

In determining the value of hematocrit, not only does the red blood cell (RBC) volume play a role, but so does the number of RBC, and therefore, an increase in the number of RBC can also increase the hematocrit. In prolonged conditions of heat stress, pulmonary evaporation happens with greater intensity, and this chronic hyperventilation can decrease the oxygen tension in the body while stimulating erythropoiesis in the bone marrow (Reece & Swenson, 2006). Thus, in a condition of chronic heat stress, the number of RBC can increase and consequently so can the hematocrit. However, some authors believe that the hematocrit can decrease in a condition of prolonged heat stress due to the reduction in the number of RBC as a function of lower feed intake (Herz & Steinhaut, 1978; Bezerra, et al., 2008; Souza, et al., 2008).

The values of WBC according to Pugh (2004) and Reece & Swenson (2006) vary from 4,000 to 13,000 leucocytes/mm^3, from 0 to 1% basophils, from 1 to 5% eosinophils, from 0 to 2% bands, from 30 to 55% segmented neutrophils, from 50 to 69% lymphocytes, and from 0 to 4% monocytes. Souza, et al., (2008), when working with goats of different genetic groups in the Paraiba semiarid, found greater values for leukocytes and lymphocytes and lower values for segmented neutrophils and monocytes. According to Broucek, et al., (2009), in cattle under heat stress, there is an increase in neutrophils (bands and segmented) and a decrease in eosinophils. However, in this study, the average values that were obtained in the different seasons were within the range of normality, even for bands (%) and monocytes (%) presented with differences among seasons ($P<0.05$).

The acclimation to several stressful ambient conditions can change the hematological and hormonal standards of animals (Yousef, et al., 1967; Iridian, 2007; Delfino, et al., 2012), which could be utilized as indicators of stress, as can respiratory frequencies, cardiac frequencies, and rectal temperature. The observation of drastic changes in these parameters can indicate a physiological unbalance and a lower adaptive efficiency (Broucek, et al., 2009) of the animals.

Thus, physiological indicators of thermal stress in the animals were not observed during this experiment since the physiological mechanisms that regulate body temperature were efficient during the experimental period and allowed for the internal balance; this was observed mainly via rectal and superficial temperatures and cardiac and respiratory frequencies. Despite the fact that Alpine goats have origins in temperate regions, data that were observed in this study using goats in an intensive system showed that there is a physiological and/or structural acclimation to highland tropical climates. Although, in grazing conditions, the physiological parameters can present with differences because other climatic variables such as direct heat stroke, shade, and wind can alter the physiology and homeostasis of the animals.

4. Final Considerations

Male Alpine goats maintained homeostasis during four seasons and presented with physiological parameters within the normal ranges expected for goats, which reveals that they are physiologically adapted to highland tropical climates.

The authors of the work suggest that in later researches the physiological parameters are measured more often during the day or at intervals shorter than fifteen days to try to understand more the physiology of these breeds in tropical climate, and also, to certify the absence of thermal stress.

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Percentage of contribution of each author in the manuscript

Júlio César Oliveira Dias – 60%

Cristina Mattos Veloso – 5%

Madriano Christilis da Rocha Santos – 15%

Carlos Thiago Silveira Alvim Mendes de Oliveira – 10%

Camila Oliveira Silveira – 10%