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Locally adapted brazilian sheep: a model of adaptation to Semiarid region

Ovelha brasileira localmente adaptada: um modelo de adaptação para o semiárido

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Abstract

Well adapted animals are characterized by maintain homeostasis under natural conditions. The present study aimed to evaluate physiological and morphological responses, as well as identify the relationship between these parameters in order to maintain homoeothermic status, in the dry and rainy season. Measurements were taken from 383 Morada Nova hair ewes, under dry and rainy season. The studied variables included rectal temperature (RT), respiratory rate (RR), coat thickness (CT), hair length (HL), hair diameter (HD) and hair density (D). Blood samples were collected for determining biochemical, erythrogam and hormone concentration. The evaluated blood parameters from the Morada Nova breed did not demonstrate any variation from the reference interval established for sheep, confirming its adaptability profile even under high radiation and air temperatures. Multivariate analyses were performed in order to determine relationship between morphological, biochemical, erythrocyte and hormonal traits in each season. Differences correlations were observed according to season of the year. In the dry season, the correlations were significant among RT, RR, Packed cell volume (PCV), thyroxine (T4), Glucose (GLU), CT, HL, Globulin (GLO) and Total Protein (TP), whereas in dry season the characteristics that showed greater correlation were Mean corpuscular volume (MCV), thyroid hormones, Creatinine, GLO, TP, PCV and GLU. In conclusion, Morada Nova ewes was able to maintain homeothermy, even in the most stressful environmental conditions. Their hematological, biochemical and hormonal profile were within the normal range for sheep, confirming the adaptability of this local breed to the Brazilian semiarid environment.

Key words: Adaptability. Coat traits. Genetic resources. Natural conditions. Thyroid hormones. Serum biochemistry.

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Resumo

Os animais bem adaptados são caracterizados por manter a homeostase em condições naturais. O presente estudo teve como objetivo avaliar as respostas fisiológicas e morfológicas, bem como identificar a relação entre esses parâmetros a fim de, manter o estado homeotérmico, na estação seca e chuvosa. As medições foram tomadas em 383 ovelhas da raça Morada Nova, na época seca e chuvosa. As variáveis estudadas incluíram temperatura retal (TR), frequência respiratória (FR), espessura do pelame (EP), comprimento do pelo (CP), diâmetro do pelo (D) e densidade numérica (DN). Foram coletadas amostras de sangue para determinar a concentração bioquímica, eritrogama e hormonal. Os parâmetros de sangue avaliados da raça Morada Nova não demonstraram variação do intervalo de referência estabelecido para ovinos, confirmando que seu perfil de adaptabilidade, mesmo sob alta radiação e temperaturas do ar. Foram realizadas análises multivariadas para determinar a relação entre características morfológicas, bioquímicas, eritrocitárias e hormonais em cada estação. As correlações de diferenças foram observadas de acordo com a estação do ano. Na estação seca, as correlações foram significativas entre TR, FR, PCV, T4, GLU, CT, HL, GLO e TP, enquanto que na estação seca as características que apresentaram maior correlação foram MCV, T4, T3, CRE, GLO, TP PCV e GLU. Em conclusão, as ovelhas Morada Nova conseguem manter a homeotermia, mesmo nas condições ambientais mais estressantes. Seu perfil hematológico, bioquímico e hormonal permanecem dentro da faixa de normalidade para ovinos, confirmando a adaptabilidade dessa raça local ao ambiente semiárido brasileiro.

Palavras-chave: Adaptabilidade. Características do pelame. Recursos genéticos. Condições naturais. Hormônios tireoidianos. Bioquímica sérica.

Introduction

Animal adaptation is the result of the action of many different factors, such as anatomy, physiology, hormones, biochemistry and behaviour (BRIDI, 2001). Animals are often strongly linked to the environment in which they live (MARAI et al., 2007). Thus, climate change observed in recent years, with high levels of solar radiation and air temperature (IPCC, 2007), could have a profound effect on animal health, reproductive efficiency and production (BOHMANOVA et al., 2007; RHOADS et al., 2009; RUST; RUST, 2013; SCHOLTZ et al., 2013).

Evaluation of animals adapted to stressful thermal environmental conditions has been increasing. For many years, adaptability tests were linked to only a few variables, such as rectal temperature, respiratory rate and heart rate (BACCARI JUNIOR, 1985). However, other characteristics related to homeostasis should be included. According to a theory by Bridi (2001), adaptation is the result of the action of different factors, such as anatomy, physiology, hormones, biochemistry and behaviour. There are different kinds of exposure to heat stress: rapid heat stress can trigger animal homeostatic mechanisms, including increased water intake, sweating, respiration rate, reduced heart hate and feed intake (McMANUS et al., 2009; FAÇANHA et al., 2013; SALAMA et al., 2014). On the other hand, animals can be frequently exposed to thermal stress; in this case, heat acclimation is achieved via the process of acclimatory homeostasis characterized by changes in physiological parameters, such as decreased thyroid hormones, and changes in biochemical and hematological parameters (BERNABUCCI et al., 2010). Castanheira et al. (2010) used physical and physiological characteristics of different crosses of sheep to evaluate which would be better adapted to heat stress. Al-Haidary et al. (2012), observed changes in biochemical constituents during the summer season in native sheep adapted to the hot environment of Arabian desert. Acclimatization to the hot environment may also be achieved by changing the pituitary-thyroid profile (PEZZI et al., 2003; PEREIRA et al., 2008; SEJIAN et al., 2010a).

Locally adapted breeds are very important to local farming systems, probably because these animals have genes linked to adaptation, disease resistance and survival. Correa et al. (2012)

evaluated different genetic groups of native breeds of sheep from tropical and temperate environments, and found that locally adapted animals showed better values for characteristics linked to adaptation, such as coat traits, as well as physiological and blood parameters.

It is important to understand the relationship among locally adapted animals and the natural environmental conditions in which they evolved. Morada Nova is a locally adapted breed from Brazilian semi-arid region. It is characterized by good reproductive efficiency, such as high fertility and high prolificacy (QUESADA et al., 2001; FACÓ, 2008), even in the hottest climatic conditions. However, there is scarce information about the adaptive profiles of these animals. Therefore, the aim of this study was to analyse the adaptive profile, such as coat traits, blood and physiological parameters and determine which variables have been influenced by season, rainy or dry, in Morada Nova sheep managed under natural environmental conditions of the semi-arid region of Brazil.

Materials and Methods

The experiment, approved by the University Ethics Committee on the use of animals, CEUA-UFERSA, number 23091003895/2014-71, was carried out on commercial farms registered with the Brazilian Association of Morada Nova Sheep Breeders (ABMOVA). Data were collected from 383 adult ewes of reproductive age as estimated by dental chronology (PUGH, 2002), non-pregnant and non-lactating. Data were recorded from 23 commercial herds in the northeastern region of Brazil. During the rainy season were analyzed 139 ewes and 244 during the dry season. The animals were evaluated always in the early morning, after feeding around 8h00min, there was made one sample by animal that were evaluated on the same place that were daily managed, under natural weather conditions. The region was classified as BSWh, according to Köppen classification, characterized as very dry and hot with a short rainy season (GUERRA, 1955), commonly from February to May, as well as a low annual variation in photoperiod. The ewes were managed on open pasture of native vegetation of the semi-arid region.

Environmental data were recorded using a digital thermohygrometer and a black globe temperature (T_G; °C) in the same place occupied by ewes. Air temperature (Air T; °C) and relative humidity (RH; %) were recorded at the same time as morphological and physiological data. These data, indexes of environmental comfort, such as the black globe-humidity index (BGHI) and the radiant thermal load (RTL), were estimated according to Silva (2008).

Examined traits included coat thickness, determined in situ in the middle of the thorax of each animal, approximately 20 cm below the dorsal line, with a caliper. Hair samples were taken from the same region where coat thickness was measured, then the samples were stored in plastic envelopes, and measurements of hair length, hair density and hair diameter were taken at the laboratory.

Hair density was obtained by counting the number of hairs removed in 0.1399 cm^2 using pliers and then converted into 1 cm^2, according to Lee (1953). Hair length (mm) and hair diameter were taken as the average length of the 10 longest hairs in the sample, according Udo (1978). The number of hairs per unit area ($hair.cm^{-2}$) was obtained by directly counting all hairs in the sample. A digital micrometer (Mitutoyo model®), with scale 0 to 25 µm, was used to measure hair diameter (µm); the hairs were the same used for the measurement of hair length (UDO, 1978).

Rectal temperature (RT, °C) was measured using a digital thermometer inserted into the animal's rectum. Respiratory rate (RR, $breaths.minute^{-1}$) was recorded by counting flank movements during one minute.

On the same days as the collection of thermoregulatory data in the animals, during the morning, blood samples were collected from each animal by puncturing the jugular vein. Three types of tubes were used: i) without anticoagulant, to obtain serum for hormonal analysis; ii) with the anticoagulant sodium ethylene diamine tetraacetic acid (EDTA), to measure hematological parameters and biochemical analyses; and iii) with sodium fluoride, to analyze blood glucose concentration. Thereafter, the blood samples were centrifuged at 5000 rpm for five minutes, and the serum or plasma was maintained at -20°C for posterior hormonal and biochemical analysis in the Laboratory of Biometeorology and Animal Welfare of Federal Rural University of the Semi-arid (UFERSA).

Hematological traits of blood sample were determined especially those related to oxygen transportation, such as red cell series. It were measured red blood cell counts (He) by adding 1.0 ml of blood to 4.0 ml of He diluent in test tubes, which were then corked and mixed. The mixed suspension was placed in a Neubauer-type chamber by diluting 20 µl of the cells using a semi-automatic pipette. The cells were then counted with an optical microscope. Packed cell volume (PCV) was determined using capillary tubes in a micro-centrifuge as described by Ayres et al. (2001). The hematological index mean corpuscular volume (MCV) was calculated as described by Ferreira Neto and Viana (1981).

The serum concentrations of total cholesterol (Chol), triglyceride (Tri), glucose (Glu), urea (Ur), creatinine (Cr), gama glutamyl transferase (GGT), amino glutamyl transferase (GOT) total protein (TP) and albumin (Alb) were determined with specific reagents for each metabolite and were analysed in an automatic device for biochemical determinations (Sba-200®/celm®). Globulin concentration was obtained by calculating the difference between total protein and albumin concentrations.

Serum concentration of thyroxine (T_4) and triiodothyronine (T_3) were determined in duplicate using commercial Human in vitro® (HUMAN, GmbH Max-Planck-Ring 21, Germany) in an automatic Elisa (Elisys Uno®, HUMAN®).

Statistical analysis was carried out using Primer 6 and PERMANOVA+ (PRIMER-E Ltd., Plymouth, UK). To test the effect of season on the studied variables, a distance-based permutation ANOVA was fitted, with season used as a fixed factor and farm as a nested random factor. Principal component analysis was performed for each season separately.

Results

The environmental conditions (Table 1) showed that the animals were evaluated under high levels of radiation and air temperature, independent of the season. These conditions represent heat stress conditions for animals, which could affect homeostasis. The dry season was characterized by higher air temperature and black globe temperature, as well as lower air humidity. These conditions characterized a dry and hot environment, confirmed by the highest Radiant Thermal Load (RTL) and black globe-humidity index (BGHI).

Table 1. Means, maximum and minimum of the environmental conditions during experimental data of dry and rainy season in Semiarid environment.

	Minimum	Maximum	Rainy Season	Dry Season
Air Temperature(°C)	25.8	42.1	30.60^b	35.46^a
Relative Humidity (%)	20.0	78.0	50.49^a	36.76^b
Black globe temperature (°C)	28.0	54.2	36.32^b	44.33^a
Radiant thermal Load (w m^{-2})	442.7	843.7	579.11^b	666.41^a
Black Globe Humidity Index	70.2	94.6	82.50^b	90.46^a

Different letter in each line represent difference using *t* student test ($P<0.05$).

During the dry season, animals had an increased rectal temperature (RT), since environmental conditions were more stressful. These animals triggered a higher respiratory rate (RR) in order to dissipate heat for maintaining inner temperature in the normal range (Table 2). The remaining variables, physiological and morphological, did not show differences between the two seasons evaluated (Table 2). Only creatinine and albumin varied between seasons, and showed higher values during the dry season.

Table 2. Means ± standard error of the adaptive variable during dry and rainy season in Morada Nova sheep in Semiarid environment.

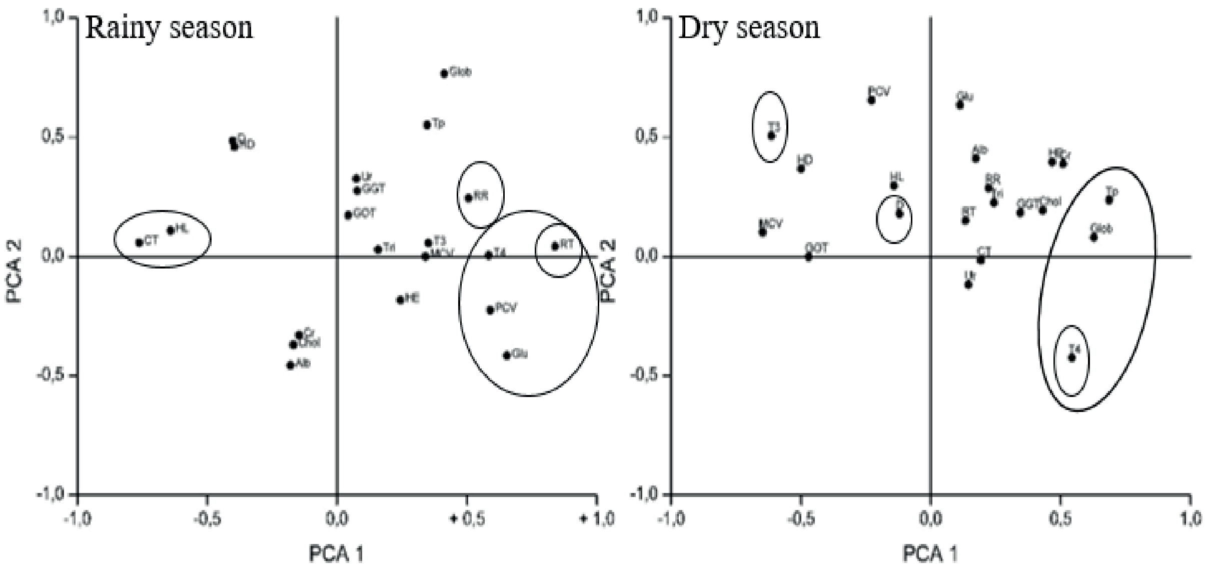
	Rainy season	Dry season	P-Value	Reference values
Rectal Temperature (°c)	38.8^{b}±0.11	39.1^{a}±0.04	<0.0001	38.3-39.9[3]
Respiratory Rate (breath minute^{-1})	40.0^{b}±1.77	44.0^{a}±0.08	<0.0001	-
Erythocytes (x10^{6}/ml)	9.1 ±0.19	9.9±0.14	0.2502	10.9±0.36[1]
Packed Cell Volume (%)	31.3±0.59	34.2±0.37	0.4719	32.9±0.27[1]
Means Corpuscular Volume (fl)	35.1±0.62	36.5±0.66	0.0650	31.7±0.41[1]
Thyroxine (µg/dl)	5.6±0.20	4.0±0.15	0.0702	4.41±1.13[5]
Triiodothyronine (µg/dl)	1.9 ±0.14	2.8 ±0.12	0.3401	1.25±0.27[6]
Glucose (mg/dl)	43.8±2.51	55.3±1.15	0.0571	50.0-80.0[2]
Cholesterol (mg/dl)	60.7±2.51	59.6±1.27	0.0601	52.0-76.0[2]
Triglycerides (mg/dl)	32.6±2.08	30.3±0.68	0.0913	36.2±18.5[4]
Urea (mg/dl)	38.8±1.38	49.8±1.02	0.0646	36.6-92.0[2]
Creatinine (mg/dl)	0.6^{b} ±0.02	1.1^{a}±0.04	<0.0001	1.2-1.9[2]
Albumin (g/dl)	2.7^{b}±0.06	3.0^{a}±0.03	0.0028	2.4-3.0[2]
Globulins (g/dl)	4.0±0.09	3.0±0.09	0.0746	3.5-5.7[2]
Total Protein (g/dl)	6.0±0.08	6.7±0.09	0.0654	6.0-7.9[2]
GOT (u/l)	108.1±3.5	105.8±1.50	0.7601	60-280[2]
GGT (u/l)	21.0±0.7	26.2±0.57	0.2978	22-38[2]
Coat Thickness (mm)	4.5±0.01	4.7 ±0.01	0.0781	-
Hair Lenght (mm)	11.9±0.03	12.5±0.01	0.0271	-
Hair Diameter (µm)	5.0±0.01	5.0±0.02	0.0275	
Hair Density (hair per cm²)	813.6 ±38.8	833.8±21.2	0.6082	-

[1]Radostits et al. (2002); [2] Kaneko et al. (2008); [3] Reece (2008), [4] Silveira (1988), [5] Cunningham (1993), [6] Canola (1986)
Different letter in each line represent difference using *t* student test ($p<0.05$)
GOT-amino glutamyl trasnferase; GGT- gama glutamyl transferase.

Animals were able to maintain physiological parameters in the normal range for sheep, even when the environmental conditions were more stressful, as seen in the dry season (Table 2). The average of mean corpuscular volume (MCV) and triiodothyronine (T_3) were higher than reference values, while creatinine and albumin average were below of reference values.

The animal response differed among seasons. This was likely due to the use of different mechanisms to maintain thermal equilibrium with the environment. The principal component analysis showed that, during the rainy season, animals with longer hair and a thicker coat tended to have lower rectal temperature (RT), thyroxin (T_4) concentration, packet cell volume and glucose (Figure 1). However, during the dry season, animals with lower hair density tended to show higher T_4, total protein and globulin concentration. During this season, an inverse relationship among the thyroid hormone concentrations was observed, since the animals that showed high concentration of T_4 also tended to present lower concentrations of T_3.

Figure 1. Principal Component Analyses for coat, biochemical, hematological and hormonal traits of Brazilian locally adapted hair sheep, respiratory rate (RR; breaths per minute), rectal temperature (RT;°C), PCV packed cell volume (PVC; %), Erythocyte (Er; x10^6/ml), MCV means corpuscular volume (MCV; fl), Thyroxine (T_4; µg/dl), triiodothyronine (T_3; µg/dl), Glucose (Glu; mg/dl), cholesterol (Cho; mg/dl), triglycerides (Tri; mg/dl), Urea (Ur; mg/dl), creatinine (CRE; mg/dl), Albumin (Alb; g/dl), globulina (Glo; g/dl), total protein (TP; g/dl), amino glutamyl transferase (GOT; U/l), gama glutamyl transferase (GGT; U/l), coat thickness (CT;mm), hair length(HL; mm), hair diameter (HD; µm) and hair density (D; hair per cm²).



Discussion

The environmental conditions to which Morada Nova sheep were exposed represent a hot and dry environment where, even during the rainy season, air humidity was low (50.49%) and air temperature was high (30.60°C). These conditions are certain to impose heat stress on farm animals. The average of air temperature was higher. during the dry season (35.46°C), with higher levels of Radiant Thermal Load (666.41 W m-²) confirming the more stressful conditions. However, lower air humidity (36.76%) favors evaporative heat loss, the main way to trigger thermoregulation when air temperature exceeds body surface temperature (MAIA et al., 2014). High air temperature may affect production, reproduction and health of animals (NAQUI; SEJIAN, 2010a). During the dry period, air temperature was above the comfort zone for sheep, according to Baeta and Souza (1997), which are from 20 to 30°C, with an upper critical temperature of 34°C.

The Black Globe Humidity Index (BGHI) recorded in the dry and rainy season were above thermal comfort conditions proposed by the National Weather Service, USA (BGHI < 74). However, this is the only index that considers radiation and air humidity, and although it was developed for cows adapted to a temperate environment, it is possible that the high means, considered stressors for dairy cows, are not deleterious for hair sheep breeds living in low latitude regions.

The Radiant Thermal Load (RTL) is linked to heat exchange by radiation between the animal and environment, and this characteristic can differentiate a tolerable environment from an unbearable environment (SILVA, 2008). The RTL values showed that animals were exposed to a high incidence of radiation throughout the year, even during the wet season, despite major cloud cover. Silva et al. (2010), recorded high radiation in semi-arid region, and Façanha et al. (2010) recorded a maximum RTL of 768.77 W m^{-2}, at a low latitude in the semi-arid region and confirmed that animals were exposed to high incidence of radiation throughout the year, and that this influenced coat traits, increasing hair density and hair length. Neiva et al. (2004) reported negative effects of the RTL on the weight of the animals and found that sheep without access to shaded areas showed a 30% reduction in weight gain compared to animals protected from direct sunlight.

Environmental conditions during the dry season resulted in an increase of RT and RR (Table 2), which could lead to serious damage to organic function and changes in serum biochemical and hormonal concentration (SEJIAN et al., 2010b). This increase in RR is a primary response to heat stress and suggests that respiratory rate was triggered in order to reduce inner temperature. This is a very important mechanism to cope with stressful conditions, especially in sheep because it is a panting species (PANAGAKIS, 2011). Maia et al. (2008) observed that when air temperature was above 30°C, animals activated latent heat loss to dissipate heat from animal to environment. However, maintaining high respiratory rates for a long period of time could cause some physiological disturbance, such as acid-basic disequilibrium (SRIKANDAKUMAR et al., 2003; HAMAZAOUI et al., 2013) and changes in blood cell count caused by dehydration (SCHIMIDT-NIELSEN, 2002). In the present study, despite the increase in RR and RT, no differences were found in relation to biochemical, hormonal and hematological parameters through the year. This result may be indicative of the adaptive capability of these animals and reinforces the importance of local breed conservation, aiming to maintain biodiversity and provide alternatives for high quality food production. Different results were found by Al-Haidary et al. (2012) who reported an increase in the serum concentration of total protein, globulin, glucose, sodium and chloride in sheep under summer conditions, which suggest environmental and nutritional modifications to alleviate the impact of heat stress. Nevertheless, in the present study even under harsh climatic conditions, with air temperature above the comfort zone, native sheep were able to maintain all assessed values within normal range for sheep, similar to those found by Carlos et al. (2015).

Alterations in secretion of thyroid hormones may occur depending on the environmental conditions (VERÍSSIMO et al., 2009). The thyroid gland is sensitive to heat stress, and can increase or decrease metabolic rate, according to environment situations (BIANCO et al., 1999). The reduction of these hormones can lead to other changes, such as reduced feed intake, milk secretion and growth as well as measured loss (PEZZI et al., 2003; TODINI et al., 2007). We found that the weather conditions to which animals were exposed did not affect circulating levels of thyroid hormones, confirmed by the maintenance of T_3 and T_4 within the reference values (Table 2). These results also can be considered as having great adaptive significance by which thyroid hormones can act synergically with hormones that improve animal performance. Starling et al. (2005) studied Corriedale sheep in a tropical environment and found a significant reduction in thyroid hormone concentrations, probably associated with high air temperatures and radiation.

Blood parameters are used to indicate health of animals and can serve as indicators of heat stress (CORREA et al., 2012). There were no differences in biochemical constituents in relation to season, and this result agrees with previous studies (NAZIFI et al., 2003; SRIKANDAKUMAR et al., 2003). However, only creatinine and albumin levels were different between seasons. The creatinine increase during the dry season may have occurred due to the increase in respiratory rate, which can result in high muscle activity and oxygen consumption, leading to an increase of this enzyme (MENDEL et al., 2005; BROSNAN; BROSNAN, 2010). Different results were found by Al-Haidary et al. (2015) who observed a reduction in creatinine concentration during the hottest season of the year. The increase in albumin concentration may be due to vasoconstriction and decreasing plasma volume. Helal et al. (2010) found similar results, in which an increase in concentrations of albumin, total protein and glucose were observed in animals exposed to thermal stress conditions.

The principal component analysis showed that, during the rainy season, animals with longer hair and thicker coats tended to have lower T_4 concentration, packet cell volume and glucose. The short coats (CT) and hair (HL) are considered favorable for heat exchange. The coat traits can indicate how well animals are adapted to their environment (MAIA et al., 2009; McMANUS et al., 2009; HELAL et al., 2010). Maia et al. (2003) state that suitable hair traits are important for rearing animals in the tropics. Moreover, McManus et al. (2009) analyzed the relationship among coat and physiological traits in five sheep groups, and found that white coat color and shorter hair were related to lower rectal temperature, respiratory rate and heart rate, which suggest better adaptation to heat stress. In the present study, RT tended to increase in the rainy season, which could influence respiratory rate due to activation of control mechanisms for maintaining homeostasis functions.

The multivariate analyses showed that, during the dry season, coat traits were also linked to physiological parameters, since animals with lower hair density tended to show high T_4, total protein, globulin and glucose concentrations. Denser coats may lead to greater difficulty in eliminating latent heat via cutaneous evaporation (HOLMES, 1981). The thermal conductivity of hair is associated with physical characteristics of the air, in addition to air trapped between hairs. The metabolic heat generated in the inner body is conducted through the hair coat to the atmosphere by free convection in the air among the hairs and by molecular conduction along the hair (MAIA et al., 2008). It is possible that coat traits influenced some physiological responses; animals that showed coat characteristics more desirable for heat dissipation, such as less dense coat with short hair and thinner coat (MAIA et al., 2003; SILVA, 2008), tended to present more favorable values of biochemical and hormonal parameters. Similar results were found by McManus et al. (2011), where animals with longer hair and thicker coat represented a group of animals that suffered more with heat stress and tend to show higher rectal temperature, respiratory rate and sweating. Correa et al. (2013) reported that the best characteristics to evaluate heat tolerance were heart and respiratory rate, packed cell volume and coat thickness. This research shows the importance of analyzing morphological and physiological parameters together, as a way of ensuring adaptability of the animals, and reinforces the potential use of coat traits as phenotypical markers in selection for breeding programs.

An inverse relationship between T_3 and T_4 was found in the dry season. This suggests that there was a decrease in the T_4 to T_3 conversion rate. This suggests that the hypothalamic-hypophysis-thyroid profile was not reduced in order to maintain T_4 concentration. Because T_3 has around three times higher thermogenic power than T_4 (SWENSON; REECE, 2006), animals tend to reduce T_3 concentration in the dry season, allowing the T_4 concentration to remain constant, in order to maintain physiological functions such as milk secretion, milk production, and growth (RANDALL et al., 1997).

Thus it is clear that the environment can cause changes in the physical and physiological parameters of the animal, and that they should exhibit a plasticity to adapt to different weather conditions throughout the year, especially for animals that are exposed to solar radiation.

Conclusions

The Morada Nova breed were able to maintain homeothermy under semiarid conditions. However, particular responses were triggered in different seasons. The hematological, biochemical and hormonal profile were within the normal range for sheep, even in the most stressful environmental conditions, confirming the adaptability of this local breed to the Brazilian semi-arid environment.

Conflict of interest

The authors declare no conflicts of interest.

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