DOI: 10.5433/1679-0359.2015v36n6Supl2p4589

Thermoregulatory responses and blood parameters of locally adapted ewes under natural weather conditions of Brazilian semiarid region

Respostas termorregulatórias e parâmetros sanguíneos de ovelhas nativas brasileiras criadas na região semiárida brasileira

Wirton Peixoto Costa[1*]; Débora Andréa Evangelista Façanha[1]; Jacinara Hody Gurgel Morais Leite[2]; Regina Cely Benício da Silva[3]; Carlos Henrique de Souza[2]; Dowglish Ferreira Chaves[4]; Angela Maria de Vasconcelos[5]; Benito Soto-Blanco[6]; André Menezes do Vale[2]; Edgard Cavalcanti Pimenta Filho[7]

Abstract

The effect of the natural weather conditions on respiratory rate, rectal temperature and hematologic parameters such as glucose, total cholesterol, triacylglycerol, total protein, albumin, globulin, red blood cells, microhematocrit, mean corpuscular volume, serum triiodothyronine (T_3) and thyroxine (T_4) levels was evaluated in red (RMN) and white (WMN) coat colored Morada Nova ewes, of different class of body condition score (CBCS), during the dry (from july to december) and wet (from january to june) seasons, which exhibited different ($P<0.05$) air temperature, relative humidity and radiant thermal load averages. Tukey's test was used and the difference considered was to $P<0.05$. Significant greater averages of respiratory rate were observed in the dry period compared to the rainy period (42.26±8.96 and 36.89±8.20 breaths min^{-1}, respectively), mainly in the RMN (45.54±8.23 breaths min^{-1}) compared with the WMN (39.27±8.57 breaths min^{-1}). No differences were observed in rectal temperature measurements between the dry and the wet periods (38.59±0.58 and 38.60±0.56 ^{o}C, respectively), but the WMN had higher values than the RMN (38.77±0.54 and 38.40±0.54 ^{o}C, respectively). The glucose and total cholesterol were higher in the wet season, with no variation due to breed variety and CBCS. The triacylglycerol did not change between breed varieties and seasons. The albumin was similar between varieties and in different seasons, being different in CBCS. Total protein and globulin serum were higher during the wet season, but total protein was higher and globulin was lower in better CBCS. T_3 and T_4 levels were higher in the rainy season (0.25±0.07 and 6.74±11.37 μg dL^{-1}, for T_3 and T_4, respectively) than in the dry season (0.18±0.08 and 6.31±1.64 μg dL^{-1}, for T_3 and T_4, respectively). The red blood cells showed no difference, but microhematocrit was higher in WMN and in the better CBCS and mean corpuscular volume was higher in the dry season. The concentration of T_3 was lower in the RMN than in the WMN (0.19±0.07 and 0.24±0.08 μg dL^{-1}, respectively), while T_4 did not differ between them (6.53±1.51 and

[1] Profs., Universidade Federal Rural do Semi-Árido, UFERSA, Campus Mossoró, RN, Brasil. E-mail: wirton@ufersa.edu.br; debora_ufersa@hotmail.com

[2] Discentes do Curso de Doutorado do Programa de Pós-Graduação em Ciência Animal, UFERSA, Campus Mossoró, RN, Brasil. E-mail: narinhazootecnista@hotmail.com; carloshsouzavet@hotmail.com; andre.vale@ufersa.edu.br

[3] Discente de Pós-Doutorado em Zootecnia no Programa Nacional de Pós-Doutorado da Universidade Federal Rural do Pernambuco, UFERSA, campus Recife, PE, Brasil. E-mail: reginaufrpe@hotmail.com

[4] Discente do Curso de Doutorado do Programa de Pós-Graduação em Ciências Veterinárias, Universidade Estadual do Ceará, UECE, Campus Fortaleza, CE, Brasil. E-mail: dowglish@yahoo.com.br

[5] Profª, Universidade Estadual Vale do Acaraú, UVA, Campus Sobral, CE, Brasil. E-mail: angv06@hotmail.com.br

[6] Prof., Universidade Federal de Minas Gerais, UFMG, Campus Belo Horizonte, MG, Brasil. E-mail: benito.blanco@pq.cnpq.br

[7] Prof., Universidade Federal da Paraíba, UFPB, Campus Areia, PB, Brasil. E-mail: edgardpimenta@hotmail.com

[*] Author for correspondence

Recebido para publicação 06/03/15 Aprovado em 22/06/15

6.52±1.46 µg dL^{-1}, respectively). The Morada Nova sheep showed positive physiological responses to the heat stress, notably an increase of respiratory rate and a reduction of T_3 and T_4 levels. All another hematologic parameters analyzed were within the normal range for all sheep, indicating a good ability to cope with the climatic changes of the Brazilian semiarid region. Both varieties were heat tolerant, but the red variety required major adjustments to maintain homeothermy.
Key words: Adaptation, blood metabolites, blood parameters, sheep, thermoregulatory responses, thyroid hormones

Resumo

Neste estudo foram avaliados os efeitos da época do ano nas características fisiológicas de frequência respiratória e temperatura retal e nos parâmetros hematológicos glicose, colesterol total, triglicerídeos, proteínas totais, albumina, globulina, contagem total de hemácias, hematócrito, volume corpuscular médio, triiodotironina (T_3) e tiroxina (T_4) em ovelhas da raça Morada Nova das variedades vermelha (RMN) e branca (WMN), de diferentes classes de escore corporal (CBCS), durante os períodos seco (de julho a dezembro) e chuvoso (de janeiro a junho), assim caracterizados por exibirem diferenças estatísticas ($P<0,05$) na temperatura do ar, umidade relativa e carga térmica radiante. Na análise estatística foi usado o teste de Tukey a 5% de probabilidade ($P<0,05$). Diferenças significativas foram encontradas na frequência respiratória durante os períodos seco e chuvoso, sendo maior na variedade vermelha do que na branca. Não foram verificadas diferença na temperatura retal dos animais entre os períodos seco e chuvoso, mas a variedade vermelha apresentou maiores médias desta variável. A glicose e o colesterol total sérico foram maiores no período chuvoso, não apresentando diferença significativa entre as variedades nem entre animais de diferentes condições corporais. A dosagem sanguínea de triglicerídeos não foi diferente para nenhuma das fontes de variação. A albumina foi estatisticamente semelhante entre as variedades da raça e durante os períodos seco e chuvoso do ano, apresentando diferença somente em relação à condição corporal dos animais CBCS. A dosagem sérica de proteína total e globulina foram maiores durante o inverno, mas a proteína total foi maior e a globulina foi menor em animais com melhor CBCS. Os níveis séricos de T_3 e T_4 foram maiores no período chuvoso do que no seco e a concentração de T_3 nas ovelhas de pelagem vermelha, enquanto T_4 não diferiu entre as variedades. A contagem total de hemácias foi semelhante, mas o microhematócrito foi maior nos animais da variedade vermelha e em animais de melhor CBCS, e o volume corpuscular médio foi maior no período seco. Concluiu-se que as ovelhas Morada Nova apresentaram respostas fisiológicas positivas ao estresse calórico, notadamente no aumento da frequência respiratória e redução dos níveis séricos de T_3 e T_4. Todos os outros parâmetros sanguíneos analisados estavam dentro dos parâmetros normais para a espécie, indicando uma excelente capacidade adaptativa das ovelhas Morada Nova à região semiárida brasileira, sendo ambas tolerantes ao estresse calórico, mas a variedade vermelha necessitou realizar maiores ajustes para manter a homeotermia.
Palavras-chave: Adaptabilidade, hormônios tireoidianos, metabólitos sanguíneos, ovinos, respostas fisiológicas

Introduction

The adjustment between the animal and the environment is decisive for the success of animal performance, and it can be reached through the selection of breeds that have developed adaptive mechanisms to cope with specific environmental inputs. Heat tolerance is an important trait for deciding on which genetic resource to adopt in production systems in tropical regions (SILVA, 2008).

Sheep are strict homeotherms, i. e. animals strive to maintain their body temperature within a fairly narrow range, even under adverse conditions. However, the adoption of extensive thermoregulatory mechanisms to maintain homeothermy, can have negative effects on many organ functions, expressed by negative reproductive and productive performances. Failures in the adaptive and homeostatic processes are first indicated by physiological responses, such as changes in body temperature, metabolism and calorigenic hormones. The biological changes as a result of thermoregulation include a decrease in feed and water intake and utilization, the body fluid balance, the acid-base equilibrium, blood biochemical and hematological profile (OCAK et al., 2009; BRAUN et al., 2010; FADARE et al., 2012).

According to McManus et al. (2011), respiratory rate and rectal temperature (RT) are the most common traits observed for adaptability and heat tolerance evaluation in hot weather, because they are related to the most common mechanisms of heat exchange between the animals and the environment. RT vary between 38.3 and 39.0°C under thermoneutral conditions. Outside of the thermoneutral zone, animals must enable thermolysis mechanisms. However, when these mechanisms fail, the RT increases, leading to hyperthermia (MARAI et al., 2007). In fact, animals have different ways to control internal temperature; in ruminants, especially those raised under field conditions in tropical areas, the respiratory and cutaneous thermolysis are the only way to dissipate heat when the air temperature exceeds the body surface temperature (SILVA et al., 2010).

However, recent studies showed that other physiological parameters, such as circulating concentrations of thyroid hormones can change depending on the environmental conditions (VERÍSSIMO et al., 2009; MAURYA et al., 2010; KOLUMAN; DASKIRAN, 2011). These hormones are directly involved with metabolic rate regulation and obligatory thermogenesis, thus they have an essential role in thermoregulation and homeothermy. Koluman and Daskiran (2011) observed a reduction in the serum concentrations of thyroid hormones in sheep exposed to high temperatures, maybe to reduce the basal metabolic rate and avoiding an increase in endogenous heat production. The variation in concentrations of thyroid hormones can be high, and genetic factors may cause different responses, influencing the degree of adaptability to climatic stressors. For that reason, the study of RR and RT associated with T_3 and T_4 concentrations may highlight thermoregulatory processes in tropical environments.

The results of Helal et al. (2010) suggest that blood metabolites may be used as heat stress indicators. These authors reported that desert goats exposed to heat stress increased the total plasma protein, albumin, and globulin concentrations and decreased plasma volume, urea, cholesterol, triglyceride and glucose concentrations. The plasma concentrations of T_3 and T_4 decreased, perhaps due to the effect of heat on the hypothalamic pituitary axis, reducing thyrotropin releasing hormone which enabled the animal to reduce basal metabolism.

Morada Nova sheep is the only locally adapted breed Brazil, developed from unplanned crosses for over 500 years of European animals, exposed chronically to high levels of solar radiation, under environmental conditions in the Northeastern of Brazil. These animals were never within the thermoneutral zone referenced in the literature, and possibly for that reason, acquired morphological and physiological adaptations to cope efficiently with continuous heat stress. The breed can be further classified into two varieties: the White Morada Nova (WMN) and the Red Morada Nova (RMN), both used in extensive production systems (FACÓ et al., 2008). However, there is few information about the heat tolerance of these two groups, including during the critical dry season of the year.

The thermoneutral zone for this breed is yet unknown and we believe that it is different of that obtained using woolled sheep. For that reason, it is important to highlight the mechanisms used by these animals to reach thermal equilibrium under the real combination of weather factors. Considering the need of models to predict thermoregulation of livestock in natural environments, the goal of this work was to evaluate the variation of thermoregulatory responses and adaptive indicators, such as thyroid hormones, blood metabolites and hematological parameters of two different varieties of Morada Nova breed in a semi-arid region, during the dry and wet seasons.

Materials and Methods

This research was conducted in a commercial farm located in a Brazilian semi-arid ecosystem at 07° 17’ 58’’ S, 35°28’43’’ W and 117 M.A.S.L. It is important clarify that the low latitude regions are characterized by high air temperatures and levels of solar radiation during all the year (SILVA et al., 2010). The mean environmental temperature varies from 25 °C to 35 °C, and the relative air humidity is approximately 70%. The mean rainfall varies from 300 to 1000 mm by year, and is normally concentrated from january to may (AESA, 2011).

Sixty adult Morada Nova ewes were utilized, 30 of the white variety (WMN) and 30 of the red variety (RMN). The animals analyzed during the trial were always the same, and were previously subjected to a clinical examination, to confirm that the physiological, hematological and endocrine responses were not modified due to any pathological processes. They were maintained during all the time of day in an extensive production system, in a typical Caatinga Bioma, a high biodiversity savannah, where these animals were kept grazing in a multispecies area, in native pasture, composed basically of *Leucaena leucocephala*, *Mimosa tenuiflora, Mimosa caesalpinifolia, Clitoria Ternatea, Cratylia molis, Cynodon dactylon, Andropogon gayanus*. They received mineral mix but no energy or protein supplementation, once daily, according to the feed management of the farm, as our propose was to evaluate the adaptative responses as well as the performance of the animals submitted to the local conditions.

Physiologic data were collected during one year, once a month, from 7:00 AM to 10:00 AM. To minimize the effect of sampling on thermoregulatory responses of different colored animals, they were always managed in three groups of 20 females, ten white and ten red, randomly chosen. On each sampling day, ewes were housed together. First, the respiratory rate was determined using a stethoscope and then, the rectal temperature was registered using a clinical thermometer.

In the same days, blood samples were collected by venipuncture in the jugular vein, using three types of tubes: without anticoagulant, to get serum for hormonal analysis, with anticoagulant, to get plasma for hematological and biochemical analyses, and with fluorite, to analyze the blood glucose levels. The samples were centrifuged at 5000 rpm/five minutes, and the serum or plasma was maintained in a freezer at -20°C for posterior hormonal and biochemical analysis. The hematological analyses and the glucose levels were determined in the same day of sampling.

Hormonal serum concentrations were determined using commercial kits of triiodothyronine (T_3) (sensibility = 0.05ng dL^{-1}) and thyroxine (T_4) (sensibility = 0.5µg dL^{-1}), in an automatic Elisa device (Elysis Uno®, Human®). The biochemical parameters concentrations analyzed were total cholesterol (Chol), triglyceride (Tri), glucose (Glu), total protein (TP), albumin (Alb) and globulin (Glo), all determined in a semi-automatic device for biochemical analysis (CELM SBA - 200®). The hematologic traits were measured in blood samples collected in bottles with ethylene-diamine-tetra-acetic acid (EDTA). The red blood cells counts (RBC) were performed visually in a Neubauer chamber, using an optical microscopy. The microhematocrit (Mh) was determined by the microhematocrit method. The Corpuscular Mean Volume (CMV) was calculated as follows: CMV = Ht (He 100mL^{-1} of blood), as pointed out by Kaneko et al. (2008).

Body Condition Score (BCS) was monitored on each data collection day, to evaluate the annual variations of nutritional status and its correlation with blood metabolites. Visual method scoring was employed, whereby ewes were scored on a scale from 1 (very thin) to 5 (very fat), according to Machado et al. (2008). For effects of statistical analysis, the BCS was grouped into three classes of Body Condition Score (CBCS): CBCS 1 (low BCS, less than 2.25), CBCS 2 (medium BCS, from 2.5 to 3.5) and CBCS 3 (high BCS, from 3.75 to 5).

The meteorological data were obtained from a weather station installed in the same local occupied by the animals. During the wet season, from january to june, and the dry season, from july to december, the air temperature, air humidity, wind speed and black globe temperature were registered, and the Black Globe Humidity Index (BGHI) and Radiant Heat Load (RHL) were used as environmental heat stress indices as suggested by Silva (2008).

The data were analyzed by the least-squares method (SAS, 2010), adopting a repeated measurement design, following the technical program pointed by Façanha et al. (2010). The linear model used was: $Y_{ijk} = \mu + V_i + S_j + VS_{ij} + CBCS_k + \varepsilon_{ijk}$, where: Y_{ijk} = the parameter of interest; μ = overall mean for the parameter of interest; V_i = fixed effect of variety (white or red); S_j = effect of season during collection; VS_{ij} = interaction effect of variety and season; $CBCS_k$ = effect of class of body condition score; ε_{ijk}= Random error.

Results

The results from Table 1 indicate differences between dry and wet seasons for almost all meteorological traits, except for the Black Globe Humidity Index (BGHI) and wind speed. The BGHI and the Radiant Heat Load (RHL) were always high, confirming the chronic stressful environment, according to Silva et al. (2010). The average wind speed were low throughout the year (VAREJÃO-SILVA, 2001).

Table 1. Means ± standard deviation for Air Temperature (AT), Relative Humidity (RH), Wind Speed (WS), Black Globe Humidity Index (BGHI) and Radiant Heat Load (RHL). Mogeiro, PB, BR, 2011.

Season	AT(°C)	RH (%)	WS (m s^{-1})	BGHI	RHL (W $m^{2(-1)}$)
Dry	32.1^a ±1.68	49.4^b ±6.41	1.5±1.07	84.5±6.00	502.9^b±97.85
Wet	28.4^b±2.05	79.0^a ±7.20	1.6±0.96	82.1±3.12	583.6^a±54.32

[a,b] Means within column, are significantly different (P<0.05). Source: author data.

The Table 2 shows that the ewes exhibited normal values for RT and RR, which are compatible with low stress responses: RR lower than 60 breaths min^{-1}, and RT less than 40.5°C, as reported by Silva (2008). The study also indicated higher RR values among the ewes of RMN type, when compared to those of WMN type, while no significant differences were observed during the rainy season.

The serum concentrations of triiodothyronine (T_3) and thyroxine (T_4) were lower in the dry season in the red animals, but no variations were observed in different BCS in both varieties (Table 3). During the rainy season, the variation of T_3 concentrations in red variety ewes was higher than in white ewes.

Table 2. Means ± standard deviation for Respiratory Rate (RR) and Rectal Temperature (RT) of Red (RMN) and White (WMN) Morada Nova ewes, according to the seasons and the class of body condition score (CBCS). Mogeiro, PB, BR, 2011.

Variable	Sheep type	Dry Season	Wet Season	Mean
RR (breaths min^{-1})	RMN (n=30)	45.54^{a}±8.23	38.49±7.34	42.23^{a}±8.57
	WMN (n=30)	39.27^{b}±8.57	35.41±8.68	37.47^{b}±8.20
	Mean	42.26^{A}±8.96	36.89^{B}±8.20	39.75±9.02
RT (°C)	RMN (n=30)	38.41^{b}±0.56	38.39^{b}±0.52	38.40^{b}±0.54
	WMN (n=30)	38.76^{a}±0.56	38.79^{a}±0.52	38.77^{a}±0.54
	Mean	38.59±0.58	38.60±0.56	38.59±0.57
CBCS		1 (1.5 to 2.5)	2 (2.75 to 3.5)	3 (3.75 to 5.0)
RT (°C)		38.45^{C}±0.63	38.60^{B}±0.57	38.81^{A} ±0.33
RR (breaths min^{-1})		38.17±9.54	40.32±8.79	39.57 ±9.00

[A,B] Means within row, are significantly different (P<0.05); [a,b] Means within column, are significantly different (P<0.05).

Table 3. Means ± standard deviation for serum concentrations of thyroid hormones in Red (RMN, n=30) and White (WMN, n=30) types of Morada Nova ewes, of different class of body condition scores (CBCS), in different seasons. Mogeiro, PB, BR, 2011.

		Season		Class of Body Condition Score (CBCS)			General Mean
		Dry	Wet	1	2	3	
T_3 (µg dL^{-1})	RMN	0.15^{bB}±0.07	0.23^{aA}±0.06	0.15^{b}±0.09	0.15^{b}±0.09	0.16^{b}±0.08	0.19^{b}±0.07
	WMN	0.21^{aB}±0.08	0.26^{aA}±0.08	0.24^{a}±0.08	0.26^{a}±0.10	0.25^{a}±0.08	0.24^{a} ± 0.08
T_4 (µg dL^{-1})	RMN	6.31^{bB}±1.66	6.76^{aA}±1.39	6.51±1.41	6.53±1.46	6.55±1.29	6.53 ± 1.51
	WMN	6.30^{bB}±1.62	6.72^{aA}±1.34	6.50±1.33	6.52±1.38	6.53±1.57	6.52 ± 1.46

T_3 = triiodothyronine; T_4 = thyroxine; BCS 1 = 1.5-2.5; BCS 2 = 2.75-3.5; BCS 3 = 3.75-5.0. [a,b] Means within column, are significantly different (P<0.05). Source: author data.

The changes in the biological functions of sheep due to exposure to heat stress include disturbance in and blood metabolites (MARAI et al., 2007), however, in Table 4 can be seen that both varieties exhibited similar levels of protein and energetic metabolites.

The serum concentrations of TP did not differ between the RMN and WMN varieties and are considered normal when compared with the reference values of 6.0 to 7.9 g dL^{-1}, described by Kaneko et al. (2008). In the rainy season, there was an increase in TP, maybe due to an increased globulinemy. On the other hand, during the wet season, were observed superior levels of Glu, Chol, TP and Glo.

The total count of red blood cells (RBC) did not differ (P>0.05) with established sources of variation. The determination of microhematocrit (Mh) was higher (P<0.05) in RMN and in the animals with greater CBCS, but did not differ between seasons. The mean corpuscular volume (MCV) was higher in the dry season (P<0.05), but no difference with other sources of variation.

These findings can be explained for the greater feed intake associated to the better roughage quality found in the native pastures during the rainy season and this certainly contributed to the better energy and protein balance.

Table 4. Means ± standard deviation for serum glucose (Glu), total cholesterol (Chol), triglycerides (Tri), total protein (TP), albumin (Alb) and globulin (Glo), total red cell counts (Er), Hematocrit (Mh) mean corpuscular volume (MCV) of red Morada Nova (RMN; n=30) and white (WMN; n=30) ewes, of different class of body condition scores (CBCS), in the dry and wet seasons. Mogeiro, PB, BR, 2011.

Source of Variation	Glu (mg dL^{-1})	Chol (mg dL^{-1})	Tri (mg dL^{-1})
Dry season	45.33^{b}±11.96	47.34^{b}±10.43	26.96±7.87
Wet season	53.77^{a}±11.52	55.25^{a}±8.81	25.55±6.46
RMN	47.88±12.47	49.80±11.03	26.52±7.34
WMN	50.57±12.37	52.09±9.83	26.11±7.21
BCS1	47.90±14.53	49.84±15.64	27.18±7.32
BCS2	48.13±14.82	50.63±13.41	25.97±8.61
BCS3	50.62±13.62	52.49±9.69	25.73±8.31
Source of Variation	**TP (g dL^{-1})**	**Alb (g dL^{-1})**	**Glo (g dL^{-1})**
Dry season	5.93^{b}±0.66	3.05±0.37	2.88^{b}±0.59
Wet season	6.48^{a}±0.55	3.12±0.35	3.36^{a}±0.51
RMN	6.13±0.69	3.09±0.36	3.04±0.60
WMN	6.24±0.64	3.08±0.37	3.16±0.59
CBCS1	6.05^{b}±0.61	2.90^{c}±0.39	3.15^{a}±0.59
CBCS2	6.20^{a}±0.73	3.18^{b}±0.34	3.02^{b}±0.62
CBCS3	6.28^{a}±0.53	3.28^{a}±0.34	3.00^{b}±0.57
Source of Variation	**Ere (10^{6} $mm^{3(-1)}$)**	**Mh (%)**	**VCM (fl)**
Dry season	8.66±1.96	33.56±6.41	38.74^{a}±8.12
Wet season	9.20±2.14	31.28±4.63	33.99^{b}±7.37
RMN	9.39±2.14	34.15^{a}±5.71	36.37±9.17
WMN	8.48±1.90	30.97^{b}±5.37	36.51±8.78
CBCS1	8.28±2.02	29.60^{b}±5.45	35.75±7.12
CBCS2	9.02±2.03	33.13^{a}±5.63	36.72±8.83
CBCS3	9.46±2.05	34.10^{a}±5.30	36.04±12.09

[a,b] Means within column, are significantly different (P<0.05). Source: author data.

Discussion

The AT was always outside of the environmental comfort zone for sheep, of 24°C to 27°C, reported by Dickson (2006). In the Northeastern of Brazil, during the hottest season approximately 65% of the total short-wave radiation is due to direct solar exposition. In these cases, the evaporative losses are the only efficient way for heat exchange (SILVA et al., 2010). However, in the rainy season, the high RH associated with the high AT certainly reduces evaporative losses. The low wind speeds registered during the trial can make the thermal environment more stressful, because a good air circulation is important to promote heat loss by convection and also to increase cutaneous evaporation in an environment with a high incidence of solar radiation. It has been observed that the difference of 4 °C between the dry and the wet seasons, which normally occurs in the Brazilian semi-arid region, can cause differences in thermoregulatory responses (MCMANUS et al., 2009; SILVA et al., 2010; GARIGLIO et al., 2010).

The elevated RHL averages confirmed the stressful situation, also during the dry period, which can increase heat absorption, leading to a rise of thermolysis mechanisms and as a consequence, the performance of less adapted animals may drop. Despite the elevated RHL, during the dry season the low RH could favors evaporative heat exchanges, thereby causing less stress in the animals and improving the performance. The observations are in accordance with the findings of Façanha et al. (2010).

The higher RR in the red ewes can be explained by the large amount of solar radiation absorbed due to dark color. The observations are similar to those observed by Façanha et al. (2010). Moreover, animals raised in extensive systems are directly exposed to short-wave solar radiation. It can be concluded that RMN type exhibited a major necessity to increase respiratory thermolysis with the aim of maintaining homeothermy. McManus et al. (2009) observed a similar behavior in Santa Ines sheep, with lower RR exhibited by white animals when compared with brown and black animals or Bergamasca breed of sheep. The observations are also in accordance with the findings of Fadare et al. (2012), who observed that sheep with black coat showed the highest means of RT and RR than white ones. In the present study, the white ewes exhibited a higher RT, however, it does not mean that these animals absorbed more radiation. Despite of the statistical difference ($P<0.05$) in RT between varieties, is very important emphasize, that both varieties presented normal RT, in all seasons evaluated. The red ewes probably had lower RT as a result of the increased activation of respiratory thermolysis. These findings suggest that both varieties are adapted, and even the greater warmth that occurred in red ewes was offset by the efficient utilization of the thermoregulatory mechanisms by this breed.

The heat stress can be characterized by an increase in RR, on this account, about 60% of the total heat loss can be observed by respiratory via at ambient temperatures above 35°C (MARAI et al., 2007). In this study the RMN had to enable respiratory thermolysis during the dry season because of the greater amount of radiation and the excessive warmth of the animals. The RT was similar between the seasons, however, the red animals presented lower average RT in the dry season. The weather conditions during the dry season were stressful, nevertheless the RT was always within the physiological range. Anderson and Jonasson (2006) affirmed that the RT exceeds the normal values when the environmental temperature is over 32^{o}C, but even in this case, the animals maintained homeothermy.

The CBCS did not influence the RR, but it promoted an alteration in the RT. This can be related to the increased metabolic rate, with a consequent increase in endogenous heat production. Sejian et al. (2009) observed that sheep with a body condition score (BCS) of 2.5 presented lower RR than animals with a BCS between 3.0 and 3.5 and 4.0, these last two being statistically similar.

The elevation of the RR coincided with the increase of the AT, confirming that the weather data from the hottest and driest periods was incremental to the RR to maintain homeothermy, as also reported by Sejian et al. (2010). However, the low correlation coefficient confirmed that even in stressful climatic conditions, the Morada Nova ewes could maintain homeothermy, demonstrating their adaptability to hot environments. It was observed that respiratory thermolysis was made difficult by the high humidity (RH) during the rainy season. The correlation coefficient between RR and RH ($r=-0.26$) confirmed that in the months with high RH and AT the respiratory heat losses were lowest. In the present study the Morada Nova sheep utilized efficiently the RR to dissipate body heat, confirmed by the normal RT. Therefore, it is a mistake to consider the RT and RR separately as heat stress indicators. These parameters must be considered along with metabolic, endocrine and other homeostatic responses.

The mean values of thyroid hormones were always into the normal range, reported by Dias et al. (2004), who established normal values of T_3 between 0.09 and 0.23 μg dL^{-1}. During the dry period there was a drop in the concentration of T_3, and in Northeastern region of Brazil it normally coincides with the food scarcity period, which can causes lower inputs of nutrients, specially energy. Todini (2007) reported higher T_3 concentration in goats fed with high energy diets and these findings highlight the relationships between thyroid activity and energy balance, confirming that thyroid hormones represent a relevant metabolic index.

During the dry period the levels of solar radiation are greater and it's absorption through the skin surface can causes an increase of heat stock and as a consequence the body temperature is elevated. According to Todini (2007) the major exogenous regulator of thyroid gland activity is the environmental temperature, so an inverse relationship between ambient temperature and blood T_3 and T_4 concentrations can be expected in sheep under hot weather conditions. Lower serum levels of T_3 in hot environments can be expected due to the decisive role of T_3 and T_4 in thermogenesis, energy and proteins metabolism, as well as in metabolic responses of the animals to different nutritional and environmental changes (KOLUMAN; DASKIRAN, 2011). The fall in T_3 concentrations was greater in red ewes, compared with the white colored ones maybe can be due to the higher absorption of solar radiation.

The T_4 serum concentration indicated that the both varieties were able to maintain normal thyroid activity, in agreement to Dias et al. (2004) who found normal serum concentrations of T_4 about 3.8 and 7.7µg dL^{-1}. These means of T_4 could not be considered high, because the animals did not present symptoms of hyperthyroidism, such as muscle weakness and circulatory insufficiency, which prompts the duplicate need of oxygen and other nutrients to maintain metabolic activity (DICKSON, 2006), damages not found in this study.

Both varieties of Morada Nova ewes showed a similar T_4 plasma concentrations, despite of the higher amount of environmental radiation, as indicated by high Black Globe Humidity Index (BGHI) and Radiant Heat Load (RHL), probably absorbed by the red ones, because dark color of skin. The strategies utilized for the animals to maintain homeothermy, in addition to increased RR, is normally a decrease of thyroid hormones secretion, with a consequent drop of metabolic rate and endogenous heat production, however in the present paper, it wasn't found. These characteristics can confirm high adaptability to hot environments, and it can play an important role in physiological activities related to health, reproductive and productive patterns. A major T_4 plasma concentration was registered during the rainy season, probably as a way to face the increased availability of food, as pointed by Todini (2007).

The biological power of T_3 is superior to T_4, and approximately 30% of free T_4 is converted to T_3 in the cells of the peripheral tissues (DICKSON, 2006). The decrease of T_3 during the dry season, leads to a greater conversion of T_4 to T_3 with the aim of maintaining the metabolic activities (MORAIS et al., 2008). Therefore, it can be suggested that there were no increase in T_4 secretion during the dry season but a greater conversion of T_4 to T_3 in the wet season, thus causing this difference. The similar concentrations of T_3 and T_4 observed in the three classes of BCS can partly explain the elevated productive and reproductive efficiency of Morada Nova ewes. Maurya et al. (2010) observed that serum concentrations of thyroid hormones were higher in animals with better BCS. The authors concluded that the reproductive efficiency was directly related to the high T_3 and T_4 concentrations.

As pointed by Ocak et al. (2009), the adjustments in biological functions as a reflection of thermoregulation, including a reduction in feed and water intake and utilization, energy and mineral balance, decreased metabolic rate and changes blood biochemical parameters and haematological profile, body fluid balance, acid-basic equilibrium, hormonal secretions and enzymatic reactions related to anabolic and catabolic ways.

Related to hematological parameters, the values for RBC counts were normal and similar between the white and red varieties, as described Kaneko et al. (2008). This similarity was important to confirm the good adaptability to the Brazilian semi-arid region, because the normal RBC count was observed in nearly every month and it characterizes sufficient supply of oxygen to all body cells, providing suitable conditions for development. McManus et al. (2009) studying in Santa Ines, Bergasmasca and Santa Ines versus Bergamasca sheep, did not find differences in the He between native breeds (10.9, 10.7 and $10.5x10^6$ $mm^{3(-1)}$ for black, white and brown Santa Ines sheep, respectively) and crosses (11.6 $x10^6$ $mm^{3(-1)}$), but observed lower values for Bergamasca sheep ($8.5x10^6$ $mm^{3(-1)}$).

The RBC count and MCV were similar (P>0.05) between the white and red varieties (8.48 and 9.39 10^6 $mm^{3\ (-1)}$, 36.51 and 36.37 fl respectively) and according Silveira (1988), they had normal values (8 to 16 10^6 $mm^{3\ (-1)}$ 23 to 48 fl, respectively).

Soysal et al. (2011) did not observe significant differences (P>0.05) in the number of RBC count between Merino and Kivirck breed sheep, raised in Turkey (13.8 and 14.7 10^6 $mm^{3\ (-1)}$, respectively). These researchers suggest have consistent results that confirm similar values even in different races, provided that the animals are adapted to local conditions.

The Mh means were higher in red ewes, and in those with a better CBCS. A monthly evaluation of Ht confirmed the highest values for the red variety and revealed that equality observed between dry and wet periods was due, primarily to the high values obtained the first month of the rainy season in this study, which could causes water restriction and consequent hemoconcentration, as emphasized by McManus et al. (2011). During the wet season there was a greater uniformity of Ht, probably due to greater availability of food and water.

These results showed that even in thermal stressful situations both RMN and WMN were able to maintain homeostasis, indicated by the homeothermy, normal serum thyroid hormones and normal blood biochemistry and hematology. It can improve the health and, as a consequence, the performance of the animals. These findings confirm that Morada Nova breed can be recommended for meat production systems in hot regions due to their thermotolerance; nevertheless, it is essential to provide shadow with the goal of reducing the overheating of dark animals and to prevent damage to the epidermis of white colored sheep that may be de-pigmented.

Conclusions

The Morada Nova ewes presented respiratory rate and rectal temperature within the normal range, considered a good adaptation indexes. The red variety showed an increase of the respiratory activity during the hot and dry period, as a reaction to an excessive environmental heat.

Despite of the normal serum concentrations of thyroxine and triiodothyronine, a thyroid response to increased heat load was observed with the reduction of hormonal concentrations during the hottest season.

The serum biochemical and hematological concentrations were mostly within normal levels, with practically no differences between the varieties and in different classes of body condition scores, but in the wet season, normally were greater.

These findings suggests that the values obtained in the present study can be used as a pattern for Morada Nova sheep under similar environmental conditions. Nevertheless, the blood parameters reflect the adaptability of Morada Nova sheep to the Brazilian semi-arid region.

Acknowledgments

Thanks to Embrapa - Caprinos e Ovinos, Universidade Federal Rural de Semiárido and Fazenda Fazendinha, Mogeiro, PB, Brazil.

References

AGÊNCIA EXECUTIVA DE GESTÃO DAS ÁGUAS DO ESTADO DA PARAÍBA - AESA. Monitoramento pluviométrico mensal do Estado da Paraíba. João Pessoa: AESA, 2011. Disponível em: <http://site2.aesa.pb.gov.br/aesa/monitoramentoPluviometria.do?metodo=listarMesesChuvasMensais>. Acesso em: 28 set. 2011.

ANDERSON, B. E.; JONASSON, H. Regulação da temperatura e fisiologia ambiental. In: SWENSON, M. J.; REECE, W. O. *Dukes:* fisiologia dos animais domésticos. 12. ed. Rio de Janeiro: Guanabara Koogan S. A, 2006. p. 805-813.

BRAUN, J. P.; TRUMEL, C.; BÉZILLE, P. Clinical biochemistry in sheep: a selected review. *Small Ruminant Research*, Amsterdam, v. 92, n. 1, p. 10-18, 2010.

DIAS, M. I. R.; CARNEIRO, M. J. R.; AZEVEDO, J. M. T.; FERREIRA, A. J.; CABRITA, A. M. S. Parâmetros hematológicos, de bioquímica sanguínea geral, electrólitos plasmáticos e das hormonas relacionadas com a função da tiróide na ovelha da raça Churra da Terra Quente. *Revista Portuguesa de Ciências Veterinárias*, Lisboa, v. 99, n. 550, p. 99-107, 2004.

DICKSON, W. M. Endocrinologia, reprodução e lactação. In: SWENSON, M. J.; REECE, W. O. *Dukes:* fisiologia dos animais domésticos. 12. ed. Rio de Janeiro: Guanabara Koogan S. A, 2006. p. 667-671.

FAÇANHA, D. A. E.; SILVA, R. G.; MAIA, A. S. C.; GUILHERMINO, M. M.; VASCONCELOS, A. M. Anual variation of morphologic traits and hair coat surface temperature of Holstein cows in semi-arid environment. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 39, n. 4, p. 837-844, 2010.

FACÓ, O.; PAIVA, S. R.; ALVES, L. R. N.; LOBO, R. N. B.; VILELA, L. C. V. *Raça Morada Nova*: origem, características e perspectivas. Sobral: Embrapa Caprinos, 2008. 43 p.

FADARE, A. O.; PETERS, S. O.; YAKUBU, A.; SONIBARE, A. O.; ADELEKE, M. A.; OZOJE, M. O.; IMUMORIN, I. G. Physiological and haematological indices suggest superior heat tolerance of white-coloured West African Dwarf sheep in the hot humid tropics. *Tropical Animal Health and Production*, Roslin, v. 45, n. 1, p. 157-165, 2012.

GARIGLIO, M. A.; SAMPAIO, E. V. S. B.; CESTARO, L. A.; KAGEYAMA. P. Y. *Uso sustentável e conservação dos recursos florestais da Caatinga*. Brasília: Serviço Florestal Brasileiro, 2010. 368 p.

HELAL, A.; HASHEM, A. L. S.; ABDEL-FATTAH, M. S.; EL-SHAER, H. M. Effect of heat stress on coat characteristics and physiological responses of Balady and Damascus goats in Sinai, Egypt. *American-Eurasian Journal of Agricultural & Environmental Sciences*, Deira, v. 7, n. 1, p. 60-69, 2010.

KANEKO, J. J.; HARVEY, J. W.; BRUSS, M. L. *Clinical biochemistry of domestic animals*. 6th ed. San Diego: Academic Press, 2008. 928 p.

KOLUMAN, N.; DASKIRAN, I. Effects of ventilation of the sheep house on heat stress, growth and thyroid hormones of lambs. *Tropical Animal Health and Production*, Roslin, v. 43, n. 6, p. 1123-1127, 2011.

MACHADO, R.; CORRÊA, R. F.; BARBOSA, R. T.; BERGAMASCHI, M. A. C. M. *Escore de condição corporal e sua aplicação de manejo reprodutivo de ruminantes*. São Carlos: Embrapa Pecuária Sudeste, 2008. 16 p. (Circular técnica, 57).

MARAI, I. F. M.; EL-DARAWANY, A. A.; FADIEL, A.; ABDEL-HAFEZ, M. A. M. Physiological traits as affected by heat stress in sheep - a review. *Small Ruminant Research*, Amsterdam, v. 71, n. 1, p. 1-12, 2007.

MAURYA, V. P.; SEJIAN, V.; KUMAR, D.; NAQVI, S. M. K. Effect of induced body condition score differences on sexual behavior, scrotal measurements, semen attributes and endocrine responses in Malpura rams under hot semi-arid environment. *Journal of Animal Physiology and Animal Nutrition*, Berlin, v. 94, n. 3, p. 308-317, 2010.

MCMANUS, C.; LOUVANDINI, H.; GUGEL, R.; SASAKI, L. C. B.; BIANCHINI, E.; BERNAL, F. E. M.; PAIVA, S. R.; PAIM, T. P. Skin and coat traits in sheep in Brazil and their relation with heat tolerance. *Tropical Animal Health and Production*, Roslin, v. 43, n. 1, p. 121-126, 2011.

MCMANUS, C.; PALUDO, G. R.; LOUVANDINI, H.; GUGEL, R.; SASAKI, L. C. B.; PAIVA, S. R. Heat tolerance in Brazilian sheep: physiological and blood parameters. *Tropical Animal Health and Production*, Roslin, v. 41, n. 1, p. 95-101, 2009.

MORAIS, D. A. E. F.; MAIA, A. S. C.; SILVA, R. G.; VASCONCELOS, A. M.; LIMA, P. O.; GUILHERMINO, M. M. Variação anual de hormônios tireoideanos e características termorreguladoras de vacas leiteiras em ambiente quente. *Revista Brasileira de Zootecnia*, Viçosa, MG, v. 37, n. 3, p. 538-545, 2008.

OCAK, S.; DARCAN, N.; CANKAYA, S; INAL, T. C. Physiological and biochemical responses in German fawn kids subjected to cooling treatments under Mediterranean climate conditions. *Turkish Journal of Veterinary and Animal Sciences*, Ankara, v. 33, n. 6, p. 455-461, 2009.

SEJIAN, V.; MAURYA, V. P.; NAQVI, S. M. K. Adaptability and growth of Malpura ewes subjected to thermal and nutritional stress. *Tropical and Animal Health and Production*, Roslin, v. 42, n. 8, p. 1763-1770, 2010.

SEJIAN, V.; MAURYA, V. P.; NAQVI, S. M. K.; KUMAR, D.; JOSHI, A. Effect of induced body condition score differences on physiological response, productive and reproductive performance of Malpura ewes kept in a hot, semi-arid environment. *Journal of Animal Physiology and Animal Nutrition*, Berlin, v. 94, n. 2, p. 154-161, 2009.

SILVA, R. G. *Biofísica ambiental*: os animais e seu ambiente. São Paulo: FUNEP, 2008. 386 p.

SILVA, R. G.; GUILHERMINO, M. M.; FAÇANHA-MORAIS, D. A. E. Thermal radiation absorbed by dairy cows in the pasture. *International Journal of Biometeorology*, Kent, v. 54, n. 1, p. 5-11, 2010.

SILVEIRA, J. M. *Interpretação de exames laboratoriais em veterinária*: 100 casos clínicos. Rio de Janeiro: Editora Guanabara, 1988. 196 p.

SOYSAL, D.; CIBIK, R.; AYDIN, C.; AK, I. Comparison of conventional and organic management conditions on growth performance, carcass characteristics and haematological parameters in Karacabey Merino and Kivircik breeds. *Tropical Animal Health and Production*, Roslin, v. 43, n. 4, p. 817-823, 2011.

STATISTICAL ANALYSES SYSTEM - SAS. SAS user's guide: statistics. Ver. 6,12. 4th ed. Cary: SAS Institute, 2010. 842 p.

TODINI, L. Thyroid hormones in small ruminants: effects of endogenous, environmental and nutritional factors. *Animal*, Cambridge, v. 1, n. 7, p. 997-1008, 2007.

VAREJÃO-SILVA, M. A. *Meteorologia e climatologia*. 2. ed. Recife: Pax Gráfica e Editora Ltda., 2001. 532 p.

VERÍSSIMO, C. J.; TITTO, C. G.; KATIKI, L. M.; BUENO, M. S.; CUNHA, E. A.; MOURÃO, G. B.; OTSUK, I. P.; PEREIRA, A. M. F.; NOGUEIRA FILHO, J. C. M.; TITTO, E. A. L. Tolerância ao calor em ovelhas Santa Inês de pelagem clara e escura. *Revista Brasileira de Saúde e Produção Animal*, Salvador, v. 10, n. 1, p. 159-167, 2009.