BREED COMPARISON FOR HEAT ADAPTATION IN RAMS USING MULTIVARIATE ANALYSIS

COMPARAÇÃO ENTRE RAÇAS PARA ADAPTAÇÃO AO CALOR EM CARNEIROS USANDO ANÁLISE MULTIVARIADA

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ABSTRACT: In this study, a multivariate analysis of morphological and physiological characteristics was performed on clinically healthy rams from six breeds (Santa Ines, Bergamasca, Dorper, Texel, Ile de France and Hampshire Down) to determine if these characteristics were able to separate and determine the most important variables in the differentiation of breeds for heat adaptation. To characterize the thermal environment, mean temperature was 23°C and relative humidity ranged between 30.6-55.6%. Morphological and physiological data were subjected to multivariate statistical tests including principal components (PRINCOMP), clustering (CLUSTER), discriminant (DISCRIM), step-by-step (STEPDISC) and canonical (CANDISC) analyses, using the Statistical Analysis System (SAS®). A multiple analysis of variance (MANOVA) was carried out with the variables defined as important by the discriminant analysis. The principal components analysis for biometric characteristics and scrotum-testicle, for physiological characteristics and body temperature as well as the characteristics of the skin and hair explained 60, 70 and 67 % of the total variation, respectively. The dendrogram showed a clear separation between the breeds studied and the existence of two distinct groups, one formed by the Texel and the other by the other breeds, considering all the characteristics used in the study. The most useful morphological parameters to explain heat tolerance were diameter of hair, layer thickness of hair at withers, 12th thoracic vertebra and rump, withers height, thoracic and scrotal circumferences, body weight, anterior and posterior shin perimeters, hair and epidermis brightness as well as the content of red and yellow in the epidermis. Among physiological characteristics, respiratory rate was better than rectal temperature and heart rate to explain changes caused by thermal stress. From the multivariate and variance analyzes it can be concluded that the Santa Ines breed was the most tolerant to heat stress as it presented a highly pigmented epidermis, a shorter hair of larger diameter, the lower layer thickness of hair at withers, 12th thoracic vertebra and rump, the lower temperatures in the testicle and at the 12th thoracic vertebra as well as the lower respiratory rate and rectal temperature value.

KEYWORDS: Canonical average. Discriminant. Principal components. Tree diagram.

INTRODUCTION

Heat is a major factor limiting the production of animals in the tropics, since the biological functions of the animal are impaired (SILANIKOVE, 2000; McMANUS et al., 2011). Sheep are well adapted to diverse ecosystems, however, temperature and relative humidity can influence animal husbandry, because under these conditions animals have difficulty in losing heat, and consequently, regulating the temperature of their organism, adapting to the environment and therefore maintain satisfactory production of wool, milk and meat (STARLING et al., 2002).

Individual susceptibility of an animal to heat stress is influenced by many factors, including species, fat score, skin and coat color, temperament, sex, and skin thickness (SCHOLTZ et al., 2013). Currently, the physiological characteristics most commonly used to evaluate the adaptation of animals to hot environments are respiratory rate, heart rate, rectal temperature and cutaneous evaporation (McMANUS et al., 2009). Other indicators include: volume of air exhaled, sweating rate, activity level, ruminal movement frequency, hematological and other physiological characteristics (SILVA, 2000; MARAI et al., 2007). Skin and coat properties such as color, density, diameter, depth, transmissivity and absorption also affect the heat exchanges (GEBREMEDHIN, 1985).

Despite the many characteristics that can be measured to assess heat tolerance, data collection is often time consuming and expensive, especially in developing countries, so there is a need to assess the usefulness of these characteristics in determining differences between breeds and individuals (McMANUS et al., 2011).

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Multivariate analysis enables the evaluation of a set of characteristics, taking into account the correlations among them, which allows inferences to be taken from the set of traits. Some authors used multivariate analysis to examine heat tolerance with bases in physiological characteristics and blood parameters (McMANUS et al., 2009) and physiological and hematological characteristics (ALVARENGA et al., 2013), in sheep, but there are no studies considering physical and physiological characteristics related to heat tolerance in sheep.

Therefore, the aim of this study was to use multivariate analyzes of the morphological and physiological characteristics of heat dissipation under thermal condition in sheep, to determine if the measured characteristics were able to separate six sheep breeds (Santa Ines, Bergamasca, Dorper, Texel, Ile de France and Hampshire Down) and determine the most important variables in the differentiation of groups in the adaptation to heat.

MATERIAL AND METHODS

The experiment was carried out on the Sucupira Farm belonging to Embrapa Genetic Resources and Biotechnology located southwest of the city of Brasilia-DF (15°47'S and 47°56'W), with altitudes ranging 1050-1250 m, during the dry season. The climate is Aw, according to Köppen classification system, characterized by two distinct seasons, with rainy summers and dry winters (SILVA et al., 2008).

To characterize the thermal environment, temperature ranged between 15.7 - 26.9°C and relative humidity ranged between 30.6 - 55.6%, obtained from the National Institute of Meteorology (INMET). The temperature and humidity index (THI) was calculated according to the following Marai et al. (2002) formula: $THI = ET - \{(0.31 - 0.31\ RH)\ (ET - 14.4)\}$; where ET is the environment temperature (°C) and RH is the relative humidity ((RH%)/100). The values of THI during the study period ranged between 15.40 and 23.94, which are compatible with absence of heat stress and severe heat stress, respectively (MARAI et al., 2002).

A total of eighteen adult purebred rams (with register in the Brazilian Sheep Breeder´s Association – ARCO) with no known kinship, clinically healthy, from six breeds (Santa Ines - SI, Bergamasca - BE, Dorper - DR, Texel - TX, Ile de France – IF and Hampshire Down - HD), three representatives from each breed, were used. This number was determined using the minimum number of replications formula in KAPS and LAMBERSON (2009) in accordance with CEUA regulations to detect differences between treatments at a level of 5% and 80% power of the test. Characterization of the sheep breeds studied was described by CARNEIRO et al. (2010).

The animals were managed in semi-intensive system and fed with *Brachiaria decumbens*, supplementation of concentrate for sheep (22.00% crude protein, 2.30% ether extract, 4.30% crude fiber, 1.20% calcium, 0.38% phosphorus and 71.50% TDN), mineral and water *ad libitum.*

Samples were collected on six separate occasions, in both the morning (07.00 hour) in the shade and the afternoon (14.00 hour) in the sunlight. The physiological parameters measured included: respiratory rate (RR), heart rate (HR) and rectal temperature (RT). RR and HR were measured using a stethoscope. RT was measured with a digital thermometer introduced into the animal's rectum. Animals were also weighed. Other measures included wither height (the highest point of the interscapular region); body length (from the tip of the palette to the ischial tuberosity), posterior shin bone perimeter and thoracic circumference, using a tape measure. Skin thickness was measured at the central portion of the right scapula using digital calipers. Hair coat thickness was measured in centimeters at the withers (LHW), 12th thoracic vertebra (T12) and rump using paquimeter. The thickness of the coat cover was the perpendicular distance between the epidermis and the surface layer of hair. Number, length and diameter of hair were collected according to LEE (1953). The hairs were placed in a plastic bag and then were spread on white paper and counted with the help of needle. The length of hair was measured according to UDO (1978). The diameter of the hair was measured using an optical microscope fitted with a graduated ocular piece and epidermis color was carried out to analyze brightness and hue using CIELa*b* method (CIE, 2004), using a spectophotometer (Byk-Gardner GMBH, Geretsried, Germany).

Skin temperature (ST) was measured using an infrared thermometer Raytek MX6 PhotoTemp™ (Burlington, VT, USA) at the following points: neck, rump, groin, 12th thoracic vertebra (T12) and scrotum. The temperature of the scrotal skin was also measured by infrared FLIR thermograph ThermaCAM ® model T400 (FLIR Systems Inc, Wilsonville, OR, USA) at a distance of 1 meter of the animal in five points: top, bottom, right, left and central region. Other temperatures measured with ThermaCAM® were: nose, mean neckline, axilla, groin, rump, and average temperature of the whole side of the body, and floor area at the side of the animal. This camera has infrared resolution 320 × 240 pixels, with thermal sensitivity of <0.05°C at 30°C (86°F)/50 mK.

Standard Quickreport® tools were used for analysis of the images: the "line" tool was used to obtain the average temperature in the neck region of the animals. The "point" tool was used to obtain the highest temperature in the axilla, groin, rump and testicle points of the animals and the "area" tool was used to measure the average temperature of the whole body and the temperature of the floor area near of the animals.

Testicular measurements included: scrotal circumference, testicular length, width and thickness, obtained with a paquimeter.

The statistical design was completely randomized factorial 6x2 (six breeds and two periods – morning and afternoon) with six replications. After standardization of data a principal component analysis (PRINCOMP) was carried out to identify the most important variables in the sample space, clustering (PROC TREE) to check the distances between the breeds, discriminant (PROC DISCRIM) to identify the quantitative variables able to separate individuals in their groups, step-by-step discriminant analyses (PROC STEPDISC) to define morphological and physiological variables that separated the breeds and canonical (PROC CANDISC) to clarify the sources of separation of breeds. A multiple analysis of variance (MANOVA) was carried out with those variables defined as important by the discriminant analysis. Analyses were carried out using the Statistical Analysis System® (SAS Inc, Cary, NC, USA) package, version 9.3.

Animal care procedures throughout the study followed protocols approved by the Ethics Committee for Animal Use (CEUA) at the University of Brasilia, number 44568/2009.

RESULTS AND DISCUSSION

Means, coefficients of variation and standard deviation of the variables analyzed in this study is shown in Table 1.

The principal components analysis for biometric characteristics and scrotum-testicle (Figure 1) explained 60% of the total variation. The first autovector indicated that the increase in perimeter of the anterior shin (PAS), thoracic circumference (TC), weight, body length (BL) and perimeter of the posterior shin (PPS) were accompanied by an increase in scrotal circumference (SC), testicular length (TL), testicular width (TW), and testicular thickness (TT) as expected.

The scrotum-testicle biometrics is directly related to body weight and seminal production in several species being a reliable parameter for selection for breeding (PANT et al., 2003). In a study of biometrics and shape of testicles in Santa Ines lambs managed in an intensive management, PACHECO et al. (2010) also observed that heavier males have higher testicular development.

With an increase in testicular morphometry (SC, TL, TT, TW) there was a decrease in testicular temperatures measured by thermography and infrared. Scrotal conformation and the ambient temperature have considerable influence on testicular temperature. An increase in testicular biometric parameters provides greater surface exposure of each testicle to the environment, which improves heat dissipation, sperm quality and reproductive efficiency (ALMEIDA, et al. 2003). Improved heat exchange decreased testicular temperature.

Using the first two autovectors for physiological characteristics and body temperature (Figure 1), it was seen that an increase in maximum ambient temperature was accompanied by an increase in physiological characteristics and body temperatures measured by infrared, explaining 70% of the total variation. NEIVA et al. (2004) evaluating the effect of environmental stress on productive and physiological parameters of Santa Ines sheep, found that an increase in the temperature in the afternoon led to increased rectal temperature and respiratory rate. McMANUS et al. (2009), working with sheep in the Federal District, also found differences between the physiological parameters during the morning and afternoon. During the morning, when ambient temperature was lower and humidity higher, heart and breathing frequencies and rectal temperature were lower, and increased with increasing ambient temperature and decrease in humidity during the afternoon. The higher the air humidity, the less evaporative water loss, making animal cooling slower. The lower water concentration in the air provides quicker animal cooling, due to the increased water evaporation rate through the skin and the respiratory system (NEIVA et al., 2004; SILVA; MAIA, 2011). The region where the experiment was carried out has high daily temperatures but very low humidity; therefore, unlike the humid tropics, moisture evaporation from the animal body surface is still possible.

Table 1. Mean, coefficients of variation and standard deviation of the variables analyzed in this study

Variables	Abbreviation	Mean	Coefficient of variation	Standard deviation
Biometrics characteristics				
Body weight (kg)	BW	77.43	17.23	13.34
Withers Height (cm)	WH	71.86	8.09	5.81
Thoracic circumference (cm)	TC	95.84	7.29	6.98
Body Length (cm)	BL	84.98	7.50	6.38
Perimeter of the anterior shin (cm)	PAS	9.38	9.09	0.85
Perimeter of the posterior shin (cm)	PPS	10.68	11.27	1.20
Physiological characteristics				
Heart rate (beats/mim)	HR	22.00	26.07	5.73
Respiratory rate (mov/mim)	RR	22.00	47.16	10.37
Rectal temperature (^{o}C)	RT	38.87	2.09	0.81
Skin and hair characteristics				
Layer thickness of hair in Withers (cm)	LTHW	4.96	68.82	3.41
Layer thickness of hair in T12 (cm)	LTHT12	3.94	70.86	2.79
Layer thickness of hair in rump (cm)	LTHR	3.58	73.18	2.62
Number of hair (cm^2)	NH	2902.10	46.56	1351.28
Diameter of hair (mm)	DH	0.52	133.27	0.70
Length of hair (cm)	LH	12.28	57.76	7.09
Skin thickness (mm)	ST	6.49	21.48	1.39
Hair L	HL	45.21	25.10	11.34
Hair a*	HA	1.27	172.56	2.19
Hair b*	HB	8.70	47.45	4.13
Epidermis L	EL	53.17	19.48	10.35
Epidermis a*	EA	0.42	499.48	2.09
Epidermis b*	EB	6.69	59.29	3.96
Body temperatures				
Temperature in the testicle - Infrared (°C)	TTI	30.39	3.81	0.99
Temperature in the back - Infrared (°C)	IBI	34.75	8.41	2,92
Temperature in the neck -Infrared (°C)	TNI	33.73	5.30	1.78
Temperature in the rump -Infrared (°C)	TRI	34.76	8.36	2.90
Temperature in the groin -Infrared (°C)	TGI	35.78	5.01	1.79
Temperature in the T12 -Infrared (°C)	TT12I	33.23	8.58	2.85
Body side temperature- Thermography (°C)	BSTT	31.48	20.81	6.55

Brain temperature - Thermography (°C)	BTT	32.72	12.72	4.16
Nose temperature- Thermography (°C)	NTT	32.83	10.40	3.41
Neck temperature- Thermography (°C)	NeTT	31.90	14.01	4.47
Axilla temperature- Thermography (°C)	ATT	30.75	17.05	5.24
Rump temperature- Thermography (°C)	RTT	32.15	22.80	7.33
Groin temperature- Thermography (°C)	GTT	30.62	17.38	5.32
Infrared scrotum temperature (°C)	IST	30.41	7.40	2.25
Top testicle temperature -Thermography (°C)	TTTT	33.91	6.10	2.67
Bottom testicle temperature - Thermography (°C)	BTTT	30.34	6.63	2.01
Left testicle temperature - Thermography (°C)	LTTT	31.97	6.07	1.94
Right testicle temperature -Thermography (°C)	RTTT	32.15	6.53	2.10
Central testicle temperature -Thermography (°C)	CTTT	32.69	6.29	2.05
Scrotum-testicular characteristics				
Scrotal circumference (cm)	SC	31.82	11.56	3.68
Testicle length (cm)	TL	9.23	11.95	1.10
Testicle width (cm)	TW	6.35	10.18	0.63
Testicle thickness (cm)	TT	11.41	11.20	1.27
Maximum environment temperature (°C)	MET	26.00	7.36	2.23
Floor temperature- Thermography (°C)	FTT	25.75	17.58	4.52

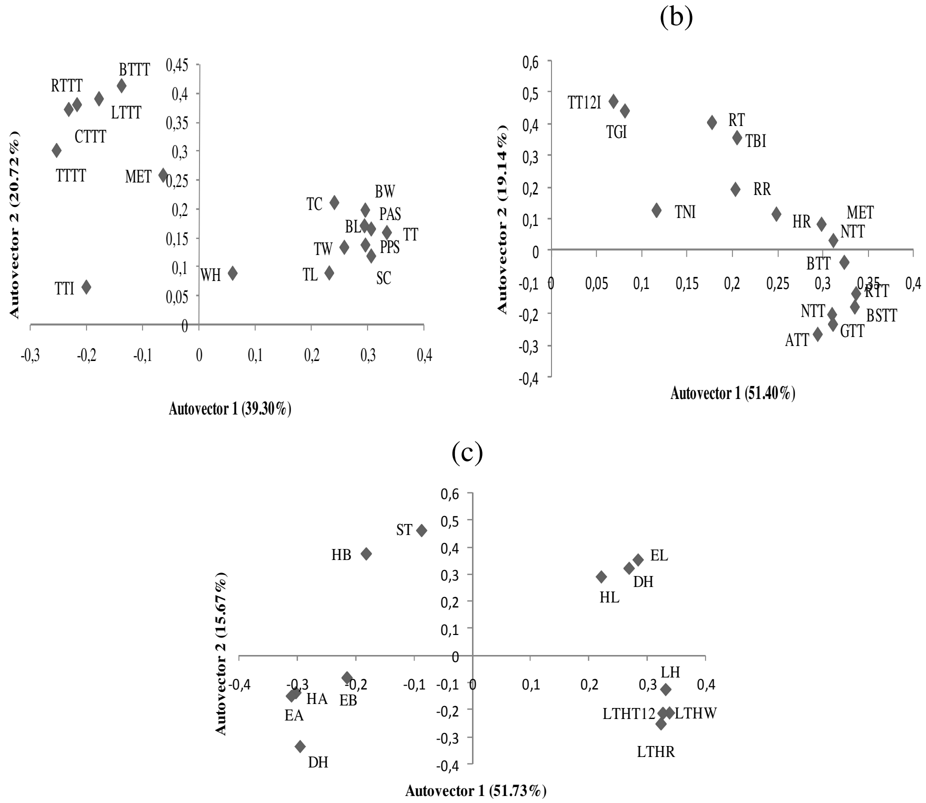

Figure 1. Graphical representation of the first two autovectors of (a) biometrics and scrotum-testicular characteristics, (b) physiological characteristics and body temperature and (c) characteristics of the skin and hair of rams. Abbreviations are shown in Table 1.

According to Souza et al. (2014), one way to evaluate the physiological capacity of animals to better tolerate heat is their efficiency in dissipating it, which varies among species, breeds and individuals. The skin surface is formed by the epidermis and its annexes (hair, wool, sweat glands and sebaceous glands) and represents the most extensive line of contact between the body and the environment. The increase of all body temperatures measured with thermography jointly suggests that there is need for dissipation of excess heat across the entire skin surface at the same time.

The first autovector of the skin and hair characteristics showed that the increase in hair length is accompanied by increase of the thicknesses of the hair layers at the rump, withers and 12th thoracic vertebrae. The second autovector showed that the increase in the number and thickness of hair was accompanied by a decrease in diameter and increase in length of the hair (Figure 1). According BIANCHINI et al. (2006), the coat of the animal is related to the ability to adapt to the environment, due to the boundary function between the animal and the surrounding physical environment that interferes with the response of animals to the environment. According to Holmes (1981), animals with thicker and denser coat have more difficulty in eliminating latent heat by dermal evaporation. This problem would be much more pronounced with thicker coats. However, the number of hairs per unit area is extremely important for the protection of the skin against ultraviolet radiation (GEBREMEDHIN et al., 1997).

According to Silva(2000), a dark pigmented coat has a higher absorption for solar short wave radiation, and thus stores greater amount of thermal energy than a light colored coat, which has a higher reflectivity. However, this difference is diluted in skin temperature, because, in white coats, the radiation that is not reflected penetrates deep, reaching the epidermis, especially when the coat is not very thick and the hairs are upright.

The second autovector also indicated that, with increasing level of the skin and hair brightness, there was a decrease in all color levels of skin and hair measured by this study. This fact is due to the brightness represent the black scale (black to white) and the a* and b* scales being primary colors such as red, green, yellow and blue. McManus et al. (2009) found that white Santa Ines ewes had lower heart rate, breathing and body temperature than the other groups, thus presenting better adaptation to heat. Veríssimo et al. (2009) found that Santa Ines ewes with light coat with brown spots had skin pigmentation that accompanied the hair coat, unlike the tropical cattle breeds that tend to have highly pigmented skin in combination with white or light coat. This is a consequence of natural selection, which aims to protect the deep tissues of the dangerous action of ultraviolet radiation of short wavelength (<300 nm), which readily crosses the thin layer of coat of these animals (SILVA; STARLING, 2003).

The tree diagram (Figure 2) showed a clear separation between the breeds studied and the existence of two distinct groups, one formed by the Texel and the other by Dorper, Hampshire Down, Ile de France Santa Ines and Bergamasca, considering all the characteristics of the study.

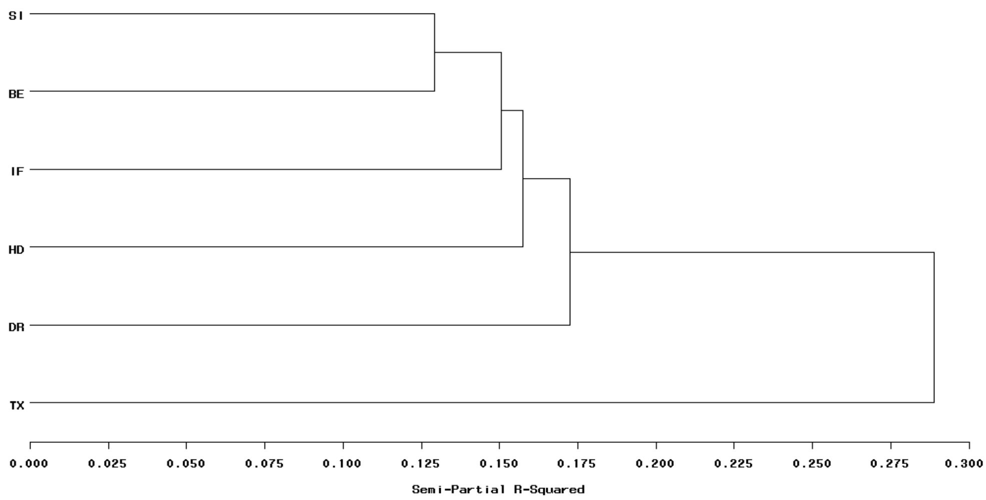

Figure 2. Tree diagram with the Euclidean distances between the breeds of rams studied. SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel and HD: Hampshire Down.

The highest Euclidean distance was observed between Texel and Santa Ines, the latter demonstrating greater ability for thermoregulation, while Santa Ines and Bergamasca showed smallest distance. A similar result was found by Carneiro et al. (2010) in an UPGMA dendrogram based on physical traits, where the Santa Ines breed from Midwestern region was closer to the Bergamasca breed. The genetic makeup of Santa Ines breed is still unclear, and it was officially established in 1977, encompassing crossing with different phenotypes. According to Paiva et al. (2005), Santa Ines animals are genetically close to the Bergamasca breed, but also to Rabo Largo (Fat Tail) and Morada Nova hair sheep (PAIVA et al., 2011).

It was possible to correctly classify at least 50% of animals of each breed in the correct group using respiratory rate, heart rate and rectal temperature, infrared temperature on the back, neck, and groin, temperatures measured with thermography in the line of the brain, nose, neck, armpits, buttocks and groin characteristics (Table 2).

Table 2. Percentage of animals classified in each breed using respiratory rate, heart rate and rectal temperature, infrared temperature on the back, neck and groin, and temperatures measured with thermography in the line of the brain, nose, neck, armpits, buttocks and groin characteristics

Breed	BE	DR	HD	IF	SI	TX
BE	66.67	11.11	11.11	11.11	0.00	0.00
DR	0.00	72.22	5.56	11.11	11.11	0.00
HD	5.56	11.11	50.00	11.11	0.00	22.22
IF	16.67	5.56	16.67	55.56	0.00	5.56
SI	0.00	11.11	0.00	0.00	88.89	0.00
TX	5.56	5.56	11.11	0.00	0.00	77.78
Priors	0.16	0.16	0.16	0.16	0.16	0.16

SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel, HD: Hampshire Down

The highest ranked breed was the Santa Ines (88.89), while the worst was the Hampshire Down (50.00), which showed animals classified in all other breeds except in Santa Ines, probably due to the close genetic relationship between exotics breeds (BE, DR, HD, IF and TX) in comparison with naturalized breed (SI). No trends in misclassification errors were observed.

It was possible to correctly classify 100% of the animals in Bergamasca and Texel breeds using testicular temperature measured with infrared and thermography as well as the morphometric scrotum-testicles characteristics and temperature measured with infrared in T12 (Table 3). The second best breed classified was Hampshire Down (94.44), followed by Ile de France and Santa Ines. The worst classified was the Dorper breed (55.56) having 33.33% of the Dorper animals classified as Texel. No trends in misclassification errors were observed.

Table 3. Percentage of animals classified in each breed using testicular temperature measured with the infrared and thermography as well as the morphometric scrotum-testicle characteristics and temperature measured with infrared in T12

Breed	BE	DR	HD	IF	SI	TX
BE	100.00	0.00	0.00	0.00	0.00	0.00
DR	0.00	55.56	0.00	11.11	0.00	33.33
HD	0.00	0.00	94.44	5.56	0.00	0.00
IF	0.00	11.11	0.00	88.89	0.00	0.00
SI	0.00	0.00	0.00	11.11	88.89	0.00
TX	0.00	0.00	0.00	0.00	0.00	100.00
Priors	0.17	0.17	0.17	0.17	0.17	0.17

SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel, HD: Hampshire Down

Canonical means used to evaluate the relationships of (co)variances among morphological and physiological characteristics to separate the breeds are presented in Figure 3. The most useful morphological parameters to explain heat tolerance were diameter of hair, layer thickness of hair in withers, T12 and rump, withers height, thoracic and scrotal circumferences, body weight, anterior and posterior shin perimeters, hair and epidermis brightness as well as the content of red and yellow in the epidermis.

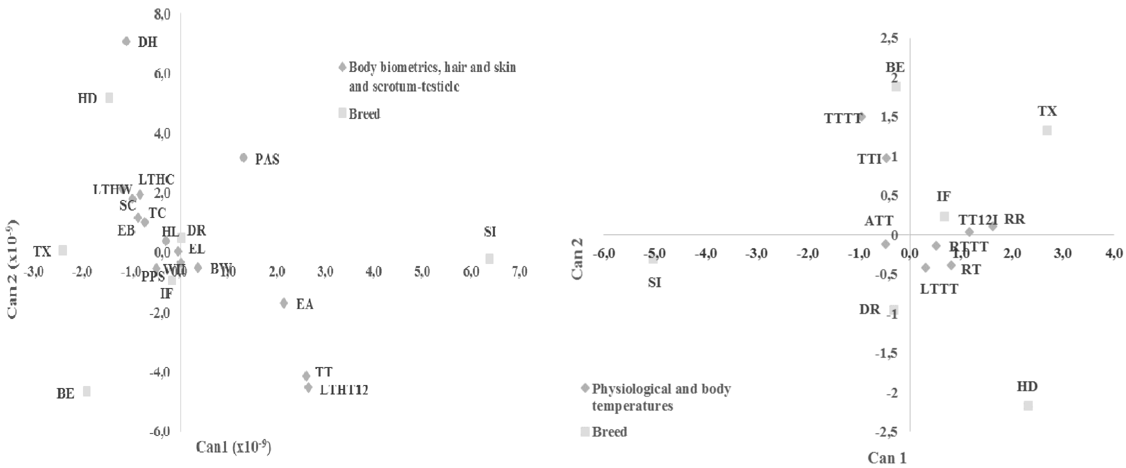

Figure 3. Graphical representation of the canonical average for (a) body biometrics, hair and skin characteristics and scrotum-testicle characteristics (b) physiological characteristics and body temperatures for the breeds evaluated. SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel, HD: Hampshire Down.

Among physiological characteristics, respiratory rate was better than rectal temperature and heart rate to explain physiological changes caused by thermal stress, corroborating with McManus et al. (2009), who found that an increase in respiratory frequency can be considered the main control mechanism of endothermia under the environmental conditions imposed, followed by other mechanisms, such as increased in heart rate. Heart rate was not useful as a physiological parameter in predicting heat tolerance, as it can be influenced by various environmental factors, unrelated to temperature, such as stress management caused at the time of measurement.

The Santa Ines breed was separated from other breeds of animals for morphological characteristics as well for physiological characteristics and body temperatures (Figure 3) as it presented a highly pigmented epidermis, which makes the penetration of ultraviolet rays difficult as well as showing shorter hair of larger diameter and shallower hair layer thickness at the withers, T12 and rump which favors the elimination of latent heat via skin evaporation (Table 4), corroborating with YEATES (1955), who confirmed the hair length as an important characteristic related to animal adaptation in the tropics, as longer the hair the worse is the animal adaptation to heat stress. Müller (1989) also stated that the length and diameter of the hair influence the heat adaptation, since, short, smooth and thin hair provides better heat dissipation, and among the breeds with long, thick coats, the Dorper and Texel breeds had the highest values of brightness (Table 4) which favors greater absorption for solar short-wave radiation, and therefore holds greater amount of thermal energy.

Also, the Santa Ines breed presented the higher withers height, that according with MÜLLER (1989) larger animals generally dissipate heat better presenting higher thermoregulatory capacity, as evidenced by the lower respiratory rate and rectal temperature value as well as lower temperatures in the testicle and in the T12 observed in this breed (Table 5).

Table 4. Mean of body biometrics, hair and skin and scrotum-testicle characteristics for the breeds evaluated in the ram breeds.

Breed	DH	LTHT12	SC	WH	PAS	EB	TC	EL	TT	TTHW	EA	PPS	BW	HL	LTHR
BE	0.24^{b}	4.33^{b}	27.00^{e}	73.83^{b}	8.33^{d}	4.78^{b}	88.33^{d}	59.50^{a}	10.33^{c}	6.83^{b}	-1.27^{d}	9.16^{c}	61.76^{d}	44.70^{a}	4.83^{b}
DR	0.23^{b}	1.33^{c}	35.50^{b}	64.33^{c}	9.66^{b}	6.16^{b}	92.00^{cd}	58.66^{a}	11.83^{b}	2.16^{d}	0.29^{bc}	11.26^{a}	78.73^{bc}	52.11^{a}	1.00^{d}
HD	0.30^{b}	3.90^{b}	36.66^{a}	76.16^{b}	10.33^{a}	7.58^{ab}	103.00^{a}	50.27^{b}	13.16^{a}	6.06^{b}	1.12^{b}	11.66^{a}	92.33^{a}	46.38^{a}	4.06^{b}
IF	0.19^{b}	4.32^{b}	33.32^{b}	69.55^{c}	10.17^{a}	6.44^{b}	99.11^{ab}	56.90^{a}	11.85^{b}	3.82^{c}	-0.40^{cd}	11.85^{a}	83.00^{ab}	48.01^{a}	2.94^{c}
SI	2.02^{a}	0.80^{c}	31.35^{c}	79.44^{a}	8.81^{c}	10.83^{a}	94.38^{bc}	34.31^{c}	10.97^{c}	0.76^{d}	3.99^{a}	9.85^{bc}	71.70^{c}	29.01^{b}	0.65^{d}
TX	0.22^{b}	8.83^{a}	29.16^{d}	68.16^{c}	9.06^{c}	4.54^{b}	98.33^{ab}	58.52^{a}	10.33^{c}	9.83^{a}	-1.06^{d}	10.30^{b}	77.06^{bc}	50.30^{a}	7.83^{a}
SE	0.057	0.23	0.44	0.67	0.10	0.81	1.20	1.30	0.18	0.37	0.27	0.16	2.25	2.05	0.22

Means with different letters in the column differ at 5% by Tukey test. SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel, HD: Hampshire Down. SE: standard error. Abbreviations are shown in Table 1.

Table 5. Mean of physiological characteristics and body temperature in the ram breeds.

Breed	RR	TT12I	TTTT	RTTT	TTI	RT	LTTT	ATT
BE	21.00^{ab}	34.94^{ab}	35.48^{a}	32.67^{ab}	31.66^{ab}	38.86^{ab}	31.77^{b}	28.98^{b}
DR	21.50^{ab}	32.23^{c}	32.62^{bc}	30.90^{b}	28.71^{c}	38.64^{bc}	30.73^{b}	32.56^{ab}
HD	21.66^{ab}	33.76a^{bc}	31.57^{c}	32.78^{ab}	29.67^{c}	39.17^{ab}	31.73^{ab}	28.43^{b}
IF	22.17^{ab}	33.48^{bc}	34.20^{ab}	31.45^{b}	30.19^{bc}	39.08^{ab}	32.23^{ab}	30.39^{b}
SI	19.58^{b}	29.17^{d}	34.47^{ab}	32.66^{ab}	29.70^{c}	38.02^{c}	32.25^{ab}	35.20^{a}
TX	26.00^{a}	35.59^{a}	35.22^{a}	33.41^{a}	32.50^{a}	39.41^{a}	33.33^{a}	29.14^{b}
SE	1.30	0.46	0.54	0.46	0.44	0.16	0.42	1.12

Means with different letters in the column differ at 5% by Tukey test. SI: Santa Ines, BE: Bergamasca, IF: Ile de France, DR: Dorper, TX: Texel, HD: Hampshire Down. SE: standard error. Abbreviations are shown in Table 1.

CONCLUSION

Multivariate analyses were capable of separating sheep breeds for heat tolerance with respiratory rate, scrotum temperatures, skin and hair brightness, as well as biometric characteristics, being important in determining the more resistant breeds.

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RESUMO: Neste estudo, foram realizadas análises multivariadas das características fisiológicas e morfológicas em carneiros clinicamente saudáveis de seis raças (Santa Inês, Bergamácia, Dorper, Texel, Ile de France e Hampshire Down) para determinar se essas características foram capazes de separar as raças e determinar as variáveis mais importantes na diferenciação das raças na adaptação ao calor. Os dados foram submetidos a testes estatísticos multivariados, incluindo as análises de componentes principais (PINCOMP), agrupamento (CLUSTER), discriminante (DISCRIM), step-by-step (STEPDISC) e canônica (CANDISC), utilizando o pacote estatístico SAS®. A análise variância de múltipla (MANOVA) foi realizada com as variáveis definidas como importante pela análise discriminante. A análise dos componentes principais para características biométricas e escroto-testiculares, para as características fisiológicas e de temperatura corporal e para as características da pele e pelo explicaram 60, 70 e 67% da variação total, respectivamente. O dendrograma mostrou uma clara separação entre as raças estudadas e a existência de dois grupos distintos, um formado pela raça Texel e o outro pelas raças Dorper, Hampshire Down, Ile de France, Santa Inês e Bergamácia, considerando todas as características avaliadas. As características morfológicas mais importantes para explicar a tolerância ao calor foram o diâmetro do pelo, as espessuras das camadas de pelo na cernelha, na décima segunda vértebra torácica e na garupa, a altura da cernelha, as circunferências torácica e escrotal, o peso corporal, os perímetros das canelas anterior e posterior, as luminosidades da pele e do pelo, bem como os teores de pigmentação vermelho e amarelo na epiderme. Entre as características fisiológicas a frequência respiratória foi melhor que a temperatura retal e a frequência cardíaca para explicar as mudanças causadas pelo estresse térmico. A partir das análises multivariada e de variância pode-se concluir que a raça Santa Inês foi a mais tolerante ao estresse térmico, uma vez que apresentou epiderme altamente pigmentada, pelo mais curto e de diâmetro maior, menores espessuras das camadas de pelo na cernelha, na décima segunda vértebra torácica e na garupa, menores temperaturas no testículo e na décima segunda vértebra torácica, bem como as menores frequência respiratória e temperatura retal.

PALAVRAS-CHAVE: Componentes principais. Diagrama de árvore. Discriminante. Média canônica.

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