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Laser and thermographic infrared temperatures associated with heat tolerance in adult rams

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ABSTRACT

Heat is a major factor limiting the production of animals in the tropics. Sheep are well adapted to diverse ecosystems, however, temperature and relative humidity can influence animal husbandry. Therefore, this study was carried out to verify the thermoregulation in rams of six breeds (Bergamasca, Dorper, Ile de France, Hampshire Down, Santa Ines and Texel) through the evaluation of physiological traits, body measures, laser and thermographic infrared temperatures as well as testicle morphometry associated with heat tolerance. Animals were measured and weighed, coat and hair colour determined, as well as physiological traits and laser and thermographic infrared temperatures measured twice a day. Data were analyzed with the Statistical Analysis System®. There were differences among breeds for most of the traits linked to heat tolerance, with the Santa Ines showing better adaptation to heat stress compared to other breeds. The Dorper was not significantly better than Bergamasca or Hampshire Down breeds, while Texel and Ile de France were less well adapted. Scrotal temperatures were lowest in Hampshire Down and Dorper, while highest in Texel. Temperature gradient measured by thermography identified Hampshire Down as the least heat tolerant breed. Traits linked to heat tolerance should be taken into consideration when choosing breeds for lamb production in tropical regions.

1. Introduction

In the central-west Brazil, sheep farming is predominantly extensive, where pastures have little shade, and animals are exposed to high solar radiation and low levels of relative humidity in the dry season, which runs from late March to early October. Despite this, the climate of this region is favorable compared to other regions where sheep production is developed (McManus et al., 2009) which has led to growth of the sheep flock in this region (McManus et al., 2013).

Climate changes may lead to an increase in thermal stress due to changes in thermal energy balance between animal and environment, which is influenced by environmental characteristics (radiation, temperature, relative humidity and wind velocity) and heat exchange (conduction, radiation, convection and evaporation) (Sirohi and Michaelowa, 2007). Any changes in these factors may modify the thermoneutral zone and trigger changes in biological functions of sheep, including decrease in food consumption and use, disturbances in water, energy, protein and mineral metabolism, enzymatic reactions, hormonal secretions and metabolites in the blood (Marai et al., 2006).

Factors such as species, body condition, hair coat and skin characteristics, temperament and gender influence the response to heat stress (Scholtz et al., 2013). Physiological measures (heart, sweating and respiratory rate, and rectal temperature) as well as body measurements (cannon bone and thoracic circumference, body length and shoulder height, number of hairs per cm^2, hair length and skin and hair characteristics) have been used to investigate heat tolerance in sheep (McManus et al., 2009, 2011).

Data collection is often time consuming and expensive, especially in developing countries, where laboratory facilities and trained human resources are scarce, so there is a need to assess the usefulness of these characteristics in determining differences between breeds and individuals (McManus et al., 2011). Infrared thermography is a modern, non-invasive and safe technique that is

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used to measure the surface temperature of the body of the animals (Montanholi et al., 2008) that has been shown be related to several physiological processes associated with heat tolerance (Paim et al., 2013, 2014; Silva et al., 2014). Considering that animals react differently to the environment to which they are exposed, this technology can help to identify animals and breeds of sheep more adapted to the heat under the same management conditions.

As heat stress can greatly affect the productive and reproductive life of sheep (Veríssimo et al., 2009), this study was carried out to verify the thermoregulation in rams of six breeds, through the evaluation of the physiological traits, body measures, laser and thermographic temperatures as well as testicle morphometry associated with heat tolerance.

2. Material and methods

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

2.1. Local and animal data

The experiment was carried out on the Sucupira Farm bellowing 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).

Purebred rams from six breeds (Bergamasca, Dorper, Ile de France, Hampshire Down, Santa Ines and Texel) were used. Within breed there was no genetic relationship between animals for at least three generations. All were clinically healthy, sexually mature, with an average age of six years and average body weight of 77.43 ± 1.27 kg, with good reproductive history and fertility. The number of rams per breed (3) was determined using the minimum number of replications formula in Kaps and Lamberson (2009) in accordance with ECAU regulations to detect differences between treatments at a level of 5% and 80% power of the test. All animals were reared at pasture. The animals were kept 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% total digestible nutrient), mineral and water *ad libitum*.

2.2. Data collection

Samples were collected in both the morning (7:00) in the shade and the afternoon (14:00) in the sunlight. The physiological parameters 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. Coat thickness was measured in centimeters at the withers (LHW), 12th thoracic vertebra (T12) and rump using a paquimeter. The thickness of the coat was the perpendicular distance between the epidermis and the surface. Number, length and diameter of coat fibers were collected according to Lee (1953). These were placed in a plastic bag and then were spread on white paper and counted with the help of needle. The coat length were measured according to Udo (1978). The diameter of the fiber was measured using an optical microscope fitted with a graduated ocular piece. Coat and epidermis colour were measured using a spectrophotometer (Byk-Gardner GMBH, Geretsried, Germany), through the CIELAB, L*, a* and b* system, which determines the coordinates: L* (brightness), a* (red colour intensity) and b* (yellow colour intensity). Three measurements were taken and the mean calculated for each animal.

Skin surface temperature (SST) was measured using a laser infrared thermometer Raytek MX6 PhotoTemp™ (Burlington, VT, USA) at the following points: neck, rump, groin, 12th thoracic vertebra (T12) and scrotum. This thermometer uses a 635 nm laser with an accuracy of 0.75% and a resolution of 0.1 °C. The temperature of the scrotal skin was also measured by infrared FLIR thermograph ThermaCAM® (FLIR Systems Inc, Wilsonville, OR, USA) at a distance of 1 meter of the animal in five points: top, bottom, right, left and central regions.This camera has infrared resolution 320×240 pixels, with thermal sensitivity of <0.05 °C at 30 °C (86 °F)/50 mK. The temperature gradient (TG) was carried out in accordance with Menegassi et al. (2015) where the line tool was used to draw a one pixel wide line in Quickreport® software to create two temperature measurements—one at 1 cm from the top and the other 1 cm from the bottom of the testicle. The mean temperature on each of these lines was taken and the gradient (TG) from the top to the bottom of the temperature calculated by difference.

Other temperatures measured with ThermaCAM® were: muzzle, neck, axilla, croup, groin and average temperature of side of the body, and floor area at the side of the animal. No measures were taken on regions covered with wool.

Testicular measurements included scrotal circumference, testicular length, width and thickness, obtained with a paquimeter, and the temperature gradient variation per cm was calculated by dividing temperature gradient by testicle length.

2.3. Environment characterization and temperature-humidity index calculation

The environmental temperature (°C), relative humidity (%) and wind speed (km/h) were obtained from the National Institute of Meteorology (INMET). The minimum and maximum environment temperatures obtained in the morning and afternoon during the experiment were 15.7 °C and 23.5 °C; 25.0 and 26.9, respectively. Relative humidity ranged between 30.6–55.6% and the wind speed average was 3.8 km/h. The floor temperature average was 25.7 °C.

The temperature and humidity index (THI) was calculated according to the following Marai et al. (2002) formula: $\text{THI} = \text{ET} - \{(0.31 - 0.31\ \text{RH})(\text{ET} - 14.4)\}$; 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).

2.4. Statistics analyses

The statistical design was completely randomized factorial 6×2 (six breeds and two periods—morning and afternoon) with six replications. The collected data were analyzed with the Statistical Analysis System® (SAS Inc, Cary, NC, USA) package, using the methods of analysis of variance (MIXED) with repeated measures and correlations. Means were compared using Duncan test with a significance level of 5%.

3. Results

Breed influenced ($P < 0.001$) the body measurements (Table 1) such as the weight, wither height, thoracic circumference, body length and shin bone perimeter. The Bergamasca breed presented