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Thermoregulatory response in hair sheep and shorn wool sheep

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ABSTRACT

This study's main goal was to evaluate the thermoregulatory responses velocity through the variation of rectal temperature (RT), related to the thermolytic pathways, respiratory rate (RR) and sweating rate (SR) among different sheep breeds. Ninety female sheep, eighteen of each breed: Santa Ines and Morada Nova (Brazilian hair breeds), Texel, Suffolk and Ile de France (wool breeds) were challenged during three non-consecutive summer days (22°42′S, 47°18′W, and 570 m of altitude, maximum air temperature of 33.5 °C, average relative humidity of 52 ± 6.9%). The physiological variables were registered at 0800 h (T1), 1300 h (T2: after 2 h of shade rest), 1400 h (T3) (after one hour of sun exposure) and in the shade at 1415 h (T4), 1430 h (T5), 1445 h (T6) and 1500 h (T7) and a thermotolerance index (TCI) was calculated as (10-(T7 to T4)-T1). The statistical analysis was performed by a mathematical model including the fixed effects of breeds and time frames, and the interaction between these effects, besides random effects such as animal and day. The Santa Ines breed presented the lowest RT after sun exposure (39.3 ± 0.12 °C; $P < 0.05$) and it was the only one to recover morning RT 60 min after heat stress (38.7 and 38.9 for 1300 h and 1500 h; $P > 0.05$). Hair breeds presented RR lower ($P < 0.05$) than wool breeds. Although thick wool or hair thickness differs among and within hair and wool breeds ($P < 0.05$), SR did not differ among breeds and time (227.7 ± 16.44 g m^{-2} h^{-1}; $P > 0.05$). The thermotolerance index did not differ among breeds, but it showed similar response ($P > 0.05$) 45 min or 1 h of shade after sun exposure. One week post shearing is not enough to wool breeds present to show thermotolerance similar to hair breeds.

1. Introduction

Hot environment impairs production, reproduction and welfare (Finocchiaro et al., 2005; Llonch et al., 2015; Marai et al., 2007; Silanikove, 2000). Regarding livestock systems, it will be strategic to optimize the productivity of crops and forage and to improve the ability of animals to cope with environmental stress by management and selection (Nardone et al., 2010).

Genetic selection program carried out in optimally controlled conditions clearly improved production traits. However, it may enhance the animal's susceptibility to high ambient temperature due to the strong relationship between production level and metabolic heat production (Mirkena et al., 2010).

Heat loss capacity varies with the species, among breeds and within the same breed (Renaudeau et al., 2012). Sheep appear to be less susceptible to heat stress than other domesticated ruminant species (Shkolnik and Choshniak, 2006). Nonetheless, it has a lack of information comparing the effects of heat stress on hair and shorn wool sheep available in the literature (Renaudeau et al., 2012). Wool acts as a protective barrier and difficult evaporation of water from the body, thus reducing heat loss trough sweating (Wojtas et al., 2014). Nevertheless, in shorn animals or hair sheep breeds, sweating may become much more important in the total heat loss (Marai et al., 2007).

Studies to know the physiological differences between hair sheep and wool breeds used in a tropical environment are a great step to help farmers who wish to sell breeders to hot regions and direct the choice of animals more adequate to hot weather.

The aim of this study was to determine the variations in rectal temperatures, respiratory rate and sweating rate on hair (Santa Ines and Morada Nova) and shorn wool sheep breeds (Ile de France, Suffolk e Texel), during a heat test to evaluate the thermoregulatory responses and the degree of thermotolerance.

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2. Material and methods

The experiment was conducted at the sheep unit of the Instituto de Zootecnia in Nova Odessa, SP, Brazil (22°42′S, 47°18′W, and 570 m of altitude). The region is known for being dry temperate during winter and hot and humid in the summer with average temperatures of 22 °C, ranging from 13 °C to 32 °C. Data were collected at the handling center of the sheep unit which has concrete floored pens, open area, individual pens, and containment area and squeeze shut in a covered area with ceramic shingles. All procedures were approved by the Research Ethics Committee of Faculdade de Zootecnia e Engenharia de Alimentos of Universidade de São Paulo and its protocol number is 13.1.456.74.2.

During the experimental period (0800–1500 h), the ambient air temperatures and relative humidity were recorded with a data logger (LogBox-RHT, Novus, Campinas, SP, Brazil). It was also registered black globe temperatures in the sun and in the shade were recorded with black globe thermometers held at 0,5 m above the surface. The black globe humidity indexes in the sun and in the shade (BGHIsun and BGHIsh) were calculated according to Buffington et al. (1981).

Morphological and physiological data were collected on 90 adult female non-lactating and non-pregnant sheep from five different breeds (18 animals per breed), including hair breeds and wool breeds. Santa Ines hair sheep (three groups with white, brown, or black coat, all with dark skin; 53 ± 1.6 kg), Morada Nova hair sheep (red coat, dark skin; 31.4 ± 1.3 kg), Ile de France (white wool, white hair, white skin; 57 ± 2.1 kg), Suffolk (white wool, black hair, dark skin; 59 ± 2.3 kg) and Texel (white wool, white hair, dark skin; 48 ± 1.8 kg) were selected with ages ranging from 1.5 to 4 years, with similar body condition score (3–3.5). The animals were kept on *Panicum maximum* cv. Aruana pasture with natural and artificial shaded areas, mineral mixture and water through near the handling center, where animals were evaluated. The wool breeds were shorn with average fleeces (4.96 ± 0.97 mm in length) one week before the experiment allowing the thickness to be similar to hair breeds.

The procedure took place during 18 days on summer of December 2006 on hot and cloudless days with low airspeed observed at morning and at least 45 °C in black globe thermometer at 1300 h. To ensure that all animals were evaluated in the 15-min break, each day a group of 15 sheep (3 of each breed randomly chosen) were analyzed and the test was repeated three times in non-consecutive days for each group. The animals were taken to the handling center in the morning, around 0730 h and rested in the shade. At 0800 h the first rectal temperature (RT1) and respiratory rate (RR1) were taken and registered. At 1100 h, the same animals returned to the handling center where they rested for 2 h under the shade; RT2 and RR2 were recorded at 1300 h. The next procedure was to take these animals to a concrete floor pen, with no shaded area where they were completely exposed to the sun, for one hour (1300–1400 h). At 1400 h the animals were moved to the shade area and the registration of RT3 and RR3 was made and repeated every 15 min until one hour of shade was completed (RT4, RT5, RT6, RT7, RR4, RR5, RR6, and RR7). From 1100 to 1500 h the animals were deprived of food and water. The heat challenge was adapted from Titto et al. (2011), which is usually used for cattle. The Thermotolerance Index (TCI) was calculated using the rectal temperatures by the following formula: 10–(RTa − RT2). RTa was registered every 15 min interval after sun exposure: 1415 (RT4), 1430 (RT5), 1445 (RT6) and 1500 h (RT7). Lower TCIs characterizes the less heat-tolerant animals.

Firstly, RR was measured by a trained person through visual observation of rib movement for 60 s at 1 m distance and these data were expressed as movements per minute (mov min^{-1}). Then, a second operator collected RT with a clinical thermometer (Instrutherm, Sao Paulo, SP, Brazil) inserted into the rectum with a minimal animal disturbance.

Sweating rates (SR) were measured at 0800 h and 1500 h by the Schleger and Turner (1965) method. It is based on the utilization of three filter paper discs impregnated with cobalt chloride in an adhesive tape to fix the filter paper discs onto the animal's skin on the shoulder. The time taken for the cobalt chloride colour change from blue to pink allows measurement of the sweating rate. As faster the colour change the greater the SR. All measurements were performed by the same operator using a chronometer to avoid subjectivity. The maximum test time was 5 min, after that the measure was declined. An area on the shoulder was shaved to allow the tape to be fixed. SR was calculated and is displayed in g m^{-2} h^{-1} using the formula: SR = (22 × 3600)/(2.06 × t), where t is the time to change colour in seconds.

The model for RT, RR, SR and TCI included breed, times of samples as a repeated measurement and the interactions breed × times as main effects, and random effects on animals and day. Means were compared by Tukey-Kramer test. Significance was set at $P \leq 0.05$ and all values were presented as the mean (μ) and one standard error of the mean (SEM). Data were tested for normality, homoscedasticity and sphericity by Kolmogorov-Smirnov, Levene and Mauchly tests, respectively, and the data of the 3 days were compared to assume they are similar (P > 0.05; SAS Institute, Inc. 2013, Cary, NC, USA).

3. Results

Concerning the meteorological data (Table 1), the warmest periods of the day were at 1400 and 1415 h. The highest values of BGT at the sun were at 1400 (48.2 °C) and in the shade were at 1415 (32.0 °C) consequently, the highest BGHI occurred in those periods (97.7 and 81.4, respectively).

The RT variations throughout the different periods of the day according to the animal's breed are present in Table 2. There were differences among breed and time factors and interaction breed-time on RT (P < 0.05). Within Santa Ines different coat colors no differences were found for RT and RR (P > 0.05), so all group colors were considered just for the breed.

In the morning (at 0800 h), the only breeds with major differences in relation to RT (P < 0.05) were Santa Ines and Texel. At 1300 h, the lowest mean for RT was from Santa Ines breed (38.68 ± 0.11 °C) and it was different from the others breeds (P < 0.05) except for Morada Nova breed (38.8 ± 0.13 °C; P > 0.05). On the other hand, the highest RT was found for Ile de France breed (39.15 ± 0.14 °C). After one hour of sun exposure (1400 h), the average RT of Santa Ines was still the lowest (39.15 ± 0.14 °C) and different (P < 0.05) from all of the others breeds but the highest was from Suffolk sheep (39.96 ± 0.13 °C). At 1415, 1430 and 1445 h there were differences registered between the RT means of Santa Ines and Ile de France, Suffolk and Texel breeds (P < 0.05), with Santa Ines showing the lowest values (39.17 ± 0.12 °C, 39.02 ± 0.11 °C, 38.93 ± 0.10 °C, respectively for each hour). However, the highest values at 1415 and 1430 h were for Suffolk sheep (39.67 ± 0.11 and 39.51 ± 0.11 °C), and at 1445 and 1500 h for Texel sheep (39.43 ± 0.11 °C and 39.40 ± 0.11 °C). It was observed that only one hair breed (Santa Ines) could dissipate all heat stored after one hour in the sun preceded by 45 min in the shade. At this time, Santa Ines sheep presented a similar RT value to the period before sun exposure (P > 0.05). On the other hand, none of the others breeds recovered the RT values (P < 0.05).

As expected, the RT increased in all breeds after heat stress (1400 h) and varied (P < 0.05) from the ones observed before the heat stress (at 0800 and 1300 h).