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Thermoregulation of nutrient-restricted hair ewes subjected to heat stress during late pregnancy

U. Macías-Cruz [a], F.D. Álvarez-Valenzuela [a], A. Correa-Calderón [a], R. Díaz-Molina [b], M. Mellado [c], C. Meza-Herrera [d], L. Avendaño-Reyes [a,*]

[a] Instituto de Ciencias Agrícolas, Universidad Autónoma de Baja California, Ej. Nuevo León, Mexicali, Baja California 21705, México
[b] Facultad de Medicina, Universidad Autónoma de Baja California, Mexicali, Baja California 21000, México
[c] Departamento de Producción Animal, Universidad Autónoma Agraria Antonio Narro, Saltillo, Coahuila, México
[d] Unidad Regional de Zonas Áridas, Universidad Autónoma de Chapingo, Durango, México

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ABSTRACT

In summers with severe hot environmental temperatures, thermoregulation is expected to be critical during the last third of gestation of hair ewes, and this effect can be overstated by suboptimal feeding conditions. Twenty-four multiparous hair sheep ewes with approximately 100 d of pregnancy were randomly assigned to two treatments to evaluate the effects of nutritional restriction (NR) during late gestation on some serum metabolites, physiological variables, and thyroid hormone concentrations under intense heat load (maximum temperature 42–45 °C). Treatments were as follows: (1) control, ewes fed free choice wheat straw plus a concentrate at a rate of 500 g/d, and (2) nutritionally-restricted (NR) ewes, which were offered wheat straw only *ad libitum*. Body weight of NR ewes dropped 5.1 kg ($P<0.05$), while control ewes gained 4.7 kg during the study period. Rectal temperature was not affected ($P>0.05$) by feeding regime either in the morning or afternoon hours. Respiration rate was greater ($P<0.05$) in control ewes (20 and 40 breaths/min higher in the day and night, respectively) on *d* 130 and 145 of pregnancy compared to NR ewes. Skin temperatures during the morning and afternoon were affected ($P<0.05$) by feeding regime at *d* 130 and 145 of pregnancy. In the morning, NR ewes presented greater ($P<0.05$) head and rump temperature at day 145 of gestation, and lower ($P<0.05$) udder temperatures at *d* 130 and 145 than control ewes. In the afternoon, skin temperatures of NR ewes were higher ($P<0.05$) in head and right flank on *d* 130 and 145 of pregnancy, and in udder at day 145 compared to control ewes. Serum glucose was higher ($P<0.05$) in NR ewes than control animals at day 145 of pregnancy. Serum cholesterol, triglyceride and thyroid hormones were not affected by nutritional restriction. Overall, it was found that nutritionally restricted ewes were less affected by intense heat loads than well-fed ewes, apparently due to the lower metabolic heat produced by this underfed animals. Also, it was apparent that the lower respiration rate of NR ewes was compensated by a greater body surface temperature.

1. Introduction

Arid and semiarid regions of the world are characterized by extreme climate with few rains throughout the year, which negatively impact forage production and quality. This situation brings out that livestock are underfed during prolonged periods due to scarcity of fodder. High ambient temperatures and forage scarcity are factors that significantly impact the productivity and well-being of ewes during summer in these regions world-wide. Several studies have shown that both heat stress (McCrabb and Bortolussi, 1996; Laburn et al., 2002; Marai et al., 2008) and sub-optimal feeding (Gao et al., 2007; Tygesen et al., 2008; Ford et al., 2007) during gestation of ewes are associated with fetal growth retardation and consequently, lighter lambs at parturition are produced, which compromise their survival.

Low birth weights in lambs born from heat-stressed ewes are the result of physiological, metabolic, and hormonal adjustments of the ewe in order to dissipate their heat load or to reduce its generation. The immediate physiological responses to heat load are increased respiration rate, decreased feed intake, and increased water intake (Bernabucci et al., 2009). An apparent physiological explanation for fetal dwarfing as a result of heat stress during pregnancy is that as ambient temperature increases, blood flow is redirected to the lungs or to superficial tissues of the mother, in an attempt to dissipate excess of heat load (Marai et al., 2008). This may result in a reduction of energy supply to the

* Corresponding author. Tel.: +52 686 523 0088; fax: +52 686 523 0217.
E-mail address: lar62@hotmail.com (L. Avendaño-Reyes).

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internal organs, including the placenta, with the consequent undernutrition of fetuses (Bauman and Currie, 1980). Thermoregulatory mechanisms during the last third of gestation have not been studied in heat-stressed hair sheep with nutritional restriction, while in wool sheep the information available is scarce (Brown et al., 1977).

Pregnant ewes maintained in hot and dry arid environments are generally subjected to more than one stress at a time, nevertheless, studies on thermoregulation involving the effects of more than one type of stress on farm animals are limited. Targhee x Suffolk crossbred ewes under heat and nutritional stress during late gestation produced lambs with lower birth weight than ewes maintained only under heat or nutritional stress, even so rectal temperature in these ewes was similar among treatments (Brown et al., 1977). On the other hand, Sejian et al. (2010a) reported lower feed intake and greater water intake, rectal temperature, respiration rate, pulse rate and body weight in heat-stressed non-pregnant Malpura ewes compared with heat-stressed and underfed ewes. Also, Sejian et al. (2010b) found an important reduction in serum metabolites and metabolic hormones in non-pregnant Malpura ewes subjected to the combined effect of heat and undernutrition relative to those only subjected to heat stress. These studies have shown that when both thermal and nutritional stresses are coupled, ewes exhibit different thermoregulatory strategies in contrast to what would normally occur when sheep are exposed to only a high ambient temperature. Therefore, the objective of this study was to determine the effects of nutritional restriction on the heat tolerance of pregnant hair sheep ewes by evaluating changes in serum metabolites and hormones, respiration rate and skin surface temperatures.

2. Materials and methods

2.1. Experimental location

The study was conducted during summer at the Sheep Experimental Unit of the Instituto de Ciencias Agrícolas, Universidad Autónoma de Baja California, in Mexicali Valley, northwestern Mexico (32.8 °N, 114.6 °W). This region is characterized as dry and arid with extreme temperatures in summer ($\geq$42 °C) and winter ($\leq$0 °C), and an average annual precipitation of 85 mm (García, 1985).

2.2. Animal management and treatments

Thirty Katahdin x Pelibuey crossbred multiparous ewes were subjected to an estrus synchronization protocol in mid-April in order to have late pregnant ewes in August and September (severe heat stress conditions). The protocol consisted in the application of progesterone impregnated intravaginal sponges during 10 d (20 mg; Chronogest, Intervet, D.F., México) and 24 h before sponge removal, one intramuscular injection of 300 IU of pregnant mare serum gonadotropin (PMSG; Folligon, Intervet, D.F., México) was applied. All treated ewes exhibited estrus signs and all were bred to 3 Dorper rams. On *d* 90 post-mating, ultrasonography (50S Tringa Vet, Pie Medical, Maastricht, The Netherlands; transducer of 3.5/5.0 MHz) was used to detect pregnancy. Twenty-four pregnant ewes with a body condition score (BCS) of around 3.0 (5-points scale; 1 = emaciated to 5 = fat; Russel et al., 1969) were selected for the study.

All selected ewes were weighted at *d* 94 of gestation and randomly assigned to 2 treatments (n=12) using a randomized complete block design, where body weight (BW) and BCS were used as block factors. Treatments were: (1) control, ewes offered free choice wheat straw and supplemented with 500 g/d of concentrate (240 g wheat meal, 240 g soybean meal, and 20 g premix; Table 1), and (2) nutritional restriction (NR), ewes were fed with only wheat straw *ad libitum*. The concentrate was formulated to met nutritional requirements for the last third of gestation in sheep (12% crude protein and 2.4 Mcal/Kg DM metabolizable energy) indicated by NRC (1985). Wheat straw was considered as feed base because is a roughage source very similar to the grasses available during summer in arid regions. Feeding regimens were applied from *d* 100 of pregnancy until lambing; previously, ewes had a 6-d adaptation period to the feeding regimens. Concentrate in the control group was offered in the morning before serving the wheat straw to ensure its total consumption. Wheat straw was offered during the morning and afternoon (0800 and 1800), and water was available all the time for both groups. Individual daily feed intake was not measured given that ewes were not placed in individual pens. However, there was observed that control ewes consumed 100% of the concentrate offered daily, and the amount of straw offered and rejected was weighed twice a week in each corral. Average feed intake per ewe of wheat straw in control group was 811 ± 95 g and for NR 1148 ± 117 g.

Table 1
Chemical composition (DM basis) of wheat straw and concentrate feed offered to pregnant hair sheep in an arid-hot environment.

	Wheat straw	Concentrate
Dry matter (%)	98.0	97.5
Organic matter (%)	81.7	91.8
Crude protein (%)	1.4	26.9
Ether extract (%)	0.38	0.86
Neutral detergent fiber (%)	77.8	12.7
Acid detergent fiber (%)	56.1	5.7
Hemicellulose (%)	21.7	7.0
Ash (%)	16.4	5.7
Gross energy (Mcal/kg DM)	3.9	4.2

DM = Dry matter.

Ewes were maintained outdoors under standard husbandry conditions during all the study at the Sheep Unit. From the application of the synchronization protocol until *d* 94 post-mating, ewes were together in the same corral, but during the experimental period (*d* 94 to lambing), they were housed in 2 corrals (5 × 5 m), one for each treatment, with feed and drinking troughs, and provided with shade made of galvanized sheet located in the center of each corral to a height of 2.5 m (12.5 m^2/pen). Feed troughs were collocated under the shade and had an appropriate space per ewe to prevent competition (0.7 m). The air flow was excellent as woven wire was used as fence.

2.3. Sampling and measurements

Blood samplings, body weights, body condition scores and physiological measurements were recorded at 15-d interval from *d* 100 until 145 of gestation. Likewise, rectal temperature, respiration rate, and skin temperatures (head, right flank, left flank, rump and udder) were recorded in the morning (0900 h) and afternoon (1500 h) during the sampling days. Rectal temperature was measured with a transrectal digital thermometer (Delta Trak, CA®, USA), while skin temperatures were measured with an infrared thermometer gun (Raytek®, Model ST20, CA, USA), which has an accuracy of ±1 °C for targets above 23 °C, at a distance of around 2 m, and repeatability of $\leq \pm$1 °C. These skin temperature measurements were taken when the ewes were standing, following instructions of the operation manual. Respiration rate was measured by recording the number of breaths per