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Physiological responses and lactational performances of late-lactation dairy goats under heat stress conditions

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ABSTRACT

Eight Murciano-Granadina dairy goats in late lactation were exposed to different ambient conditions, using metabolic cages in a climatic chamber. The experimental design was a crossover (2 periods of 35 d and 4 goats each) and conditions were (1) thermal neutral (TN; 15 to 20°C day-night) and (2) heat stress (HS; 12-h day at 37°C and 12-h night at 30.5°C). Humidity was maintained at 40% and light-dark was constant (12–12 h). The forage:concentrate ratio was adjusted daily for maintaining similar value in TN and HS goats (70:30). Water was freely available at ambient temperature. Rectal temperature and respiratory rate (0800, 1200 and 1700 h) and milk yield were recorded daily, whereas milk composition, nonesterified fatty acids and haptoglobin in blood were analyzed weekly. At d 25, additional blood samples were taken for analysis of metabolites and indicators of the acid-base balance. Digestibility coefficients and N balance were determined (d 31 to 35) and body weight was recorded (d 35). Compared with TN goats, HS goats experienced greater rectal temperature (+0.58°C), respiratory rate (+48 breaths/min), water intake (+77%) and water evaporation (+207%). Intake of HS goats rapidly declined until d 7 (−40%), partially recovered from d 7 to 19, and steadied thereafter (−14%). No changes in digestibility or N balance were detected. Blood nonesterified fatty acids and haptoglobin peaked at d 7 in HS goats but did not vary thereafter. Although milk yield did not vary by treatment, milk of HS goats contained −12.5% protein and −11.5% casein than TN goats. Panting reduced concentration and pressure of CO_2 in the blood of HS goats, but they were able to maintain their blood pH similar to the TN group by lowering HCO_3^- and increasing Cl^- concentrations in their blood. In conclusion, HS dairy goats showed dramatic physiological changes during the first week of treatment and partially recovered thereafter. They were able to maintain milk yield by losing body mass, but milk protein content and protein yield were depressed. Further research is needed to assess the response of dairy goats to HS at earlier stages of lactation.

Key words: heat stress, lactation, digestibility, dairy goat

INTRODUCTION

Heat stress (**HS**) decreases milk production of dairy animals, and half of this reduction in milk yield is due to reduced DMI (Rhoads et al., 2009). The other half of milk yield losses could be explained by the increase in maintenance requirements (NRC, 2007), decreasing secretion of growth hormone (Mitra et al., 1972), lowering blood flow to the udder (Lough et al., 1990), downregulating milk protein genes, and upregulating apoptosis genes in the mammary gland (Collier et al., 2006). Cows under HS had greater levels of insulin with improved insulin sensitivity and lacked the ability of fat mobilization from adipose tissue to face the decreased DMI (Baumgard and Rhoads, 2013). The reduction in dairy farm profit associated with HS when the temperature-humidity index (**THI**) is extremely high is not only a result of decreased milk yield, but also includes impaired milk quality, reproduction problems, increased health care costs, and even animal death.

Despite the large number of studies carried out in dairy cows, little is known about the effects of HS in dairy goats. Goats are considered more tolerant to high THI values compared with dairy cows because of their metabolic size and high water-conservation capacity (Silanikove, 2000). When environmental temperatures increased from 20 to 40°C, respiration rate increased from 30 to over 200 breaths/min in East African goats (Maloiy and Taylor, 1971) and domestic Swedish goats (Olsson et al., 1995), indicating that water evaporation by respiration plays an important role in heat dissipation in goats.

Lactating Saanen goats exposed to moderate or severe HS for 4 d (THI = 81 or 89) lost milk yield by 3 or 13%, respectively (Sano et al., 1985). Brown et al. (1988) reported that the exposure of dairy goats

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to moderate HS conditions for 5 wk (34°C and 25% humidity; THI = 79) depressed milk yield in Alpine but not in Nubian goats, indicating that the response to HS varies according to breed.

The objective of the current study was to measure the physiological, lactational, and nutritional responses to extreme heat stress conditions in Spanish Murciano-Granadina dairy goats in late lactation. Moreover, blood acid-base status and stress indicators were also evaluated. No information is available on the effects of HS on this dairy breed, which is widely spread in the Mediterranean area.

MATERIALS AND METHODS

Animal and Management Conditions

Animal care conditions and management practices agreed with the procedures stated by the Ethical Committee of Animal and Human Experimentation of the Universitat Autònoma de Barcelona (Bellaterra, Spain; CEEAH reference 09/771) and the codes of recommendations for the welfare of livestock of the Ministry of Agriculture, Food and Environment of Spain (Madrid).

Eight open multiparous Murciano-Granadina dairy goats (43.5 ± 2.6 kg of BW) with healthy and symmetrical udders, from the herd of the experimental farm of the Universitat Autònoma de Barcelona were blocked in 2 balanced groups and used at late lactation (194 ± 3 DIM; 1.53 ± 0.04 L/d). The experimental design was a crossover with 2 treatments in 2 periods, lasting 35 d, and 4 goats each. Goats were switched to the opposite treatment in the second period. Climatic conditions were (1) thermal neutral (**TN**; 15 to 20°C and 45% relative humidity; THI = 59 to 65) and (2) HS (12-h day at 37°C and 40% relative humidity; THI = 85; and 12-h night at 30.5°C and 40% relative humidity; THI = 77). The order of treatments on each goat was recorded and taken into account in the statistical analyses. The THI values were calculated according to NRC (1971) as follows:

$$\text{THI} = (1.8 \times \text{T}_{\text{db}} + 32) - [(0.55 - 0.0055 \times \text{RH}) \times (1.8 \times \text{T}_{\text{db}} - 26.8)],$$

where T_{db} is the dry bulb temperature (°C) and RH is the relative humidity (%).

Throughout the experiment, (mid-January to mid-April), the TN goats were kept indoors and the temperature was maintained at 15 to 20°C with the help of an electric heather equipped with a thermostat (3.5 kW; General Electric, Barcelona, Spain). The temperature and relative humidity averaged 16.7 ± 0.3°C and 45 ± 5% (THI = 61) for the TN goats. The HS goats were kept in a 4 × 6 × 2.3-m climatic chamber (Euroshield; ETS Lindgren-Euroshield Oy, Eura, Finland) provided with a temperature and humidity controlling system (Carel Controls Ibérica, S.L., Barcelona, Spain). A continuous 90 m^3/h air turnover was maintained throughout the experiment.

Goats had a 4-wk preexperimental period under TN conditions for adaptation to the diet and to metabolic cages. When goats were switched from TN to HS conditions, a transition period of 2 d was allowed (1 d at 25°C and 1 d at 30°C), but no transition was applied for the change from HS to TN. Photoperiod was maintained constant at 12-h light:12-h dark (0900 to 2100 h) and data of environmental temperature and humidity were recorded every 10 min by using 2 data loggers (Opus 10; Lufft Mess- und Regeltechnik GmbH, Fellbach, Germany).

Daily ration of the goats consisted of (as-fed) dehydrated fescue hay ad libitum (20% daily refusal), 0.65 kg of alfalfa pellets, and 0.8 kg of concentrate mixture (30% corn, 25.8% barley, 25% soybean meal, 8.5% sunflower meal, 5% FA sodium salts, 2.5% dicalcium phosphate, 2% calcium carbonate, 1% sodium chloride, and 0.2% vitamins A, E, and D_3; as fed). Mineralized salt blocks were freely available in each metabolic cage (composition: 36.74% Na, 0.32% Ca, 1.09% Mg, 5 g of Zn/kg, 1.5 g of Mn/kg. 912 mg of S/kg, 304 mg of Fe/kg, 75 mg of I/kg, 50 mg of Co/kg, and 25 mg of Se/kg; Ovi Bloc; Sal Cupido, Terrassa, Spain). The concentrate mixture was offered in 2 daily portions at 0900 and 1600 h. Changes in the forage intake of the HS goats were taken into account throughout the experiment and the amount of concentrate offered was daily modified to maintain a constant and similar forage:concentrate ratio to that of the TN goats. Clean water was permanently available at ambient temperature, according to treatment.

Goats were milked once daily (0800 h) with a portable milking machine (Westfalia Separator Ibérica SA, Granollers, Spain) set at 42 kPa, 90 pulses/min, and 66% pulsation ratio, provided with recording jars (2 L ± 5%). Milking routine included cluster attachment without udder preparation or teat cleaning, machine milking, machine stripping before cluster removal, and teat dipping in an iodine solution (P3-io shield; Ecolab Hispano-Portuguesa S. L., Barcelona, Spain).

Sample Collection, Analyses, and Measurements

Body Temperature and Respiration Rate. Rectal temperatures and respiration rates were recorded at 0800, 1200, and 1700 h. Rectal temperature was mea-