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Using wireless rumen sensors for evaluating the effects of diet and ambient temperature in nonlactating dairy goats

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ABSTRACT

Sixteen Murciano-Granadina dairy goats, provided with wireless rumen sensors for pH and temperature, were used to assess the rumen environment variations produced by extreme forage to concentrate diets (experiment 1) and climatic conditions (experiment 2). To avoid the interference of feed intake, goats were fed at maintenance level. Rumen sensors were inserted by surgery and programmed to collect and store rumen pH and temperature every 30 min. In experiment 1, 8 dry goats (38.6 ± 2.3 kg of body weight) in tiestalls were divided into 2 groups and fed at maintenance level with 2 diets varying in forage-to-concentrate ratio [high forage (HF) 70:30; low forage (LF) 30:70] according to a crossover design. Diets were offered once daily for 4 h and tap water (4 L, 9.8 ± 0.4°C) was offered for only 30 min at 6 h after feeding. Rectal temperatures were recorded 3 times during the day. Rumen pH fell immediately after feeding, reaching a nadir depending on the diet (HF = 6.35 ± 0.07 at 11 h after feeding; LF = 6.07 ± 0.07 at 6 h after feeding) and being on average greater (0.31 ± 0.06) in HF than LF goats. No diet effects were detected in rectal (38.2 ± 0.1°C) and ruminal (38.9 ± 0.1°C) mean temperatures, which were positively correlated. Rumen temperature dramatically changed by feeding (1.4 ± 0.1°C) and drinking (−3.4 ± 0.1°C), and 2 h were necessary to return to the fasting value (38.2 ± 0.1°C). In experiment 2, 8 dry goats (43.9 ± 1.0 kg of body weight) were kept in metabolic cages, fed a 50:50 diet and exposed to 2 climatic conditions following a crossover design. Conditions were thermoneutral (TN; 20 to 23°C day-night) and heat stress (HS; 12-h day at 37°C and 12-h night at 30°C). Humidity (40 ± 5%) and photoperiod (light-dark, 12–12 h) were similar. Goats were fed at maintenance level, the feed being offered once daily and water at ambient temperature was freely available. Intake, rectal temperature, and respiratory rate were recorded 3 times daily. Despite no differing in dry matter intake, rumen pH was lower in HS than in TN goats (−0.12 ± 0.04). On the contrary, rumen temperature (0.3 ± 0.1°C), rectal temperature (0.4 ± 0.1°C), respiratory rate (77 ± 5 breaths/min), and water intake (3.2 ± 0.7 L/d) had a greater increase in HS than TN, which might indicate an altered microbial fermentation under high temperature conditions. In conclusion, wireless bolus sensors proved to be a useful tool to monitor rumen pH and temperature as affected by different feeding and climatic conditions.

Key words: pH, radiofrequency, rumen sensor, temperature

INTRODUCTION

Continuous data acquisition by telemetry allows dynamic measuring of responses and helps to define associations with management and environmental variables (Eigenberg et al., 2008; Rutten et al., 2013). Using wireless rumen boluses based on the use of radiofrequency, variation of rumen temperature by estrus and parturition (Cooper-Prado et al., 2011), viral diarrhea infection (Rose-Dye et al., 2011), SARA (AlZahal et al., 2009), and IMI (AlZahal et al., 2011) have been reported in cattle.

Changes in ambient temperature induce different responses in the nervous, circulatory, respiratory, renal, and endocrine systems, which allow the animal to cope with the altered environment. Different physiological, lactational, and nutritional responses to heat stress have been reported in ruminants: by Baumgard and Rhoads (2013) in dairy cows, and by Hamzaoui et al. (2013a) and Salama et al. (2014) in dairy goats. However, little is known about changes in rumen pH and temperature due to heat stress.

When feed intake was held constant in thermoneutral (**TN**) and heat stress (**HS**) environments, HS reduced

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the concentration of VFA in the rumen of cattle (Kelley et al., 1967), increased the concentration of lactic acid, and reduced ruminal pH (Mishra et al., 1970). Moreover, profiling the rumen microbiota by 16s RNA gene cloning confirmed that HS induces significant changes in microbial diversity in heifers, resulting in a decrease of acetate and acetate-to-propionate ratio and an increase of butyrate, which substantially decreases the efficiency of absorption of VFA and the overall rumen pH (Tajima et al., 2007).

To our knowledge, telemetry has not been used to continuously measure changes in rumen environment in goats. Therefore, the objective of the present study was to evaluate the use of wireless sensors to assess the ruminal variations produced by diets with different forage-to-concentrate ratios and to monitor the effects of climatic conditions on the rumen environment of nonlactating dairy goats. To avoid confusion between reduced DMI and HS effects, both TN and HS goats were kept at the same level of feed intake to meet maintenance requirements.

MATERIALS AND METHODS

The experimental procedures and animal care conditions were reviewed and approved by the Ethical Committee on Animal and Human Experimentation of the Universitat Autònoma de Barcelona (reference CEEAH 11/1166) and the codes of recommendations for the welfare of livestock of the Ministry of Agriculture, Food and Environment of Spain.

Wireless Rumen Sensors

Wireless rumen boluses (model KB1001, Kahne, Auckland, New Zealand), designed for cattle heavier than 300 kg of BW, were used for recording rumen pH and temperature in goats. Measurement ranges for temperature and pH were 0 to 45°C (accuracy = ±0.08°C) and 4.00 to 8.00 (accuracy = ±0.02), respectively. The whole telemetric Khane system included (1) rumen boluses (27 mm diameter × 145 mm height, 70 g weight); (2) magnet blocker, to turn on and off the boluses; (3) top receiver, for capturing the data signals sent by the boluses (frequency = 433.9 MHz); (4) field receiver, with a directional antenna Yagi-Uda type (frequency = 400 to 500 MHz); (5) trigger device, for transmitting the data to the storage device through radio frequency (Kahne wand); and (6) software (Kahne Data Processing System, v.5.2.4), for enabling the configuration and communication between the boluses and transceivers via a computer.

Boluses were calibrated before use according to the manufacturer instructions (Kahne, 2010) using deionized water at 40.0 ± 0.5°C and pH buffer standard solutions of 4.01 and 7.00 (pH25, Crison Instruments, Barcelona, Spain). Measured and reference pH values correlated ($R^2 = 0.99$; $P < 0.001$). Before the insertion of boluses into the rumen, previously stored data were erased and they were configured to record pH and temperature values every 30 min.

In vivo validation was conducted using a rumen-cannulated dairy cow fed a maintenance diet (alfalfa hay ad libitum and 3 kg/d of concentrate). Rumen content was sampled beside the bolus sensor at 10 time points (0, 2, 6, 10, and 24 h during 2 d), filtered through a cheesecloth for rumen liquor and pH measured using the previously indicated pH meter, to register extreme pH daily variations.

Boluses (n = 8) were inserted into the rumen of goats through surgery (Dehghani and Ghadrdani, 1995). Goats were fasted for 24 h and were sedated by an i.m. injection of 0.3 mL of xylazine (Rompun 50 mg/mL; Bayer Hispania, Barcelona, Spain) and 1 mL of ketamine (Ketamina 50 mg/mL; Holliday-Scott, Buenos Aires, Argentina) before surgery. After washing, clipping, and disinfecting, a vertical incision of approximately 10 cm was made in the left flank, between the last rib and the iliac tuberosity. After pulling out the rumen wall to the incision with the help of towel clamps, a ruminotomy of 8 cm was done and the bolus was introduced into the rumen with its wings folded and tied to prevent damage to the rumen wall. After suturing the rumen wall, muscle layer, and skin, 2 mL of meloxicam anti-inflammatory (Metacam 20 mg/mL; Boehringer-Ingelheim, Barcelona, Spain) and 4 mL of amoxicillin (Invemox 1.5 mg/mL; Invesa, Barcelona, Spain) were i.m. injected for 5 d. Goats were allowed to recover after surgery for 2 wk in straw-bedded pens and fed alfalfa hay ad libitum.

A similar surgical procedure was followed to remove the boluses from the rumen at the end of the experiments. With this aim, the goats were lodged in straw-bedded pens and fed alfalfa hay ad libitum for a resting period of 1 wk before surgery. Retrieved rumen sensors were washed with tap water and recalibrated as above indicated to calculate the drift error of the pH and temperature measurements.

Experiment 1

Animals, Management, and Treatments. Eight multiparous (4.5 ± 0.6 yr) nonlactating female Murciano-Granadina goats (38.6 ± 2.3 kg of BW) from the herd of the Experimental Farm of the Servei de Granges i Camps Experiments of the Universitat Autònoma de Barcelona (Bellaterra, Barcelona, Spain) were used. Does were kept indoors in straw-bedded tiestalls at