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Research paper

Conditions to evaluate differences among individual sheep and goats in resilience to high heat load index

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ABSTRACT

Thirty-three yearling Katahdin sheep (KAT, 38.9 kg) and Boer (BOE, 28.6 kg) and Spanish goat wethers (SPA, 22.7 kg) were used to determine conditions appropriate for evaluating resilience to high heat load index (HLI). Grass hay (69% NDF and 9.5% CP) was consumed ad libitum with concentrate supplemented at 0.5% BW. Period 1 was 2 wk and periods 2–5 were each 1 wk. Target HLI for the five periods during the day/night was 70/70, 80/70, 90/76.5, 95/80.75, and 100/85, and measured HLI was 66/66, 80/75, 92/84, 97/86, and 101/89, respectively. Respiration rate increased with advancing period except from period 4–5 when there was a smaller decline for KAT than for BOE or SPA. Rectal temperature also increased as the experiment progressed until period 4 and was similar among animal types in period 5 when values for BOE and SPA were lower than in period 4, in contrast to similar values for KAT. Respiration rate at 13:00 and 17:00 h increased with advancing period up to a plateau at 150–155 breaths/min converse to much lower rates (i.e., 32–83) at 06:00 in periods 2–5. Respiration rate at 06:00 h differed more among days of period 5 than at 13:00 or 17:00 h, with values increasing from day 1–3 and thereafter generally declining from 118 to 37 breaths/min on day 7. Rectal temperature for KAT was lower than for goats early in period 5 but similar among animal types on days 6 and 7. In conclusion, a HLI in the range of 95/80.75 and 100/85 seems appropriate, periods longer than 1 wk appear necessary for full adaptation, and measures should occur during both night and day.

1. Introduction

In developed regions of the world, livestock production systems with well-controlled environmental conditions are common, particularly for swine, poultry, and dairy cattle. In such cases animals selected for high levels and efficiencies of production are used to achieve adequate profit, without great concern given to characteristics sometimes referred to as 'hardiness.' Relatedly, in some instances negative relationships have been noted between genetic potential for productivity with well-controlled environments and properties such as heat tolerance (Menéndez-Buxadera et al., 2012). However, the majority of ruminant livestock in the world are raised in production systems for which there is limited control of climatic conditions. Concomitantly, the degree of adaptation to those specific conditions is very important, although certainly production level remains a key consideration. In this regard, climate change may affect the suitability of particular livestock for specific environments.

One of the most significant and widespread environmental stress factors faced by ruminant livestock and their producers is high temperature and (or) humidity. Even in temperate regions there are frequently periods of very high heat load index (HLI), used to address combined effects of temperature, humidity, and wind. Heat stress can have a myriad of effects on ruminant livestock, including reduced ADG, milk yield, reproductive performance, and immunity (Finch, 1984; Lu, 1989; Silanikove, 2000; Sevi et al., 2001, 2002; Chedid et al., 2014). More variable climatic conditions throughout the year are expected in the future with climate change, and it is thought that some regions will experience increases in HLI and others decreases (Devendra, 2012; Silanikove and Koluman, 2015). Therefore, in addition to natural adaptation processes, selection of animals for resilience to high HLI may take on an increasing importance.

Breeds of ruminant livestock vary in tolerance to high HLI (Brown et al., 1988; Silanikove, 2000; Gaughan et al., 2010), and the same is true for animals of breeds adapted to specific environ-

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mental conditions, resulting in 'ecotypes' (Lee and Phillips, 1948; Silanikove, 2000). Moreover, considerable variability exists among individuals within ecotypes and breeds (Lee and Phillips, 1948; Finch, 1984; Gaughan et al., 2010; Menéndez-Buxadera et al., 2012). For most rapid selection progress, relationships between genetic characteristics and resilience should be identified, which would be facilitated by development of simple and standardized methods of determining resilience phenotypes. Ideally, such models would be conducive to use at different institutions and locations, allowing potential pooling of data and coupling with genetic characteristics of phenotyped animals to develop breeding programs in regards to changing and more variable expected future climatic conditions. In this regard, related research has been previously conducted to determine means of assessing the ability of individual animals to minimize energy use with limited feed intake (Goetsch et al., 2017) and conserve water with reduced availability (Mengistu et al., 2016), characteristics also thought to increase in importance with projections of future climate change. Objectives of the present experiment were to determine conditions appropriate for a method of evaluating resilience to high HLI of individual animals of one hair sheep breed and two breeds of meat goats. Conditions receiving most attention were suitable HLI for expression of physiological responses indicative of resilience such as increased respiration rate to prevent or minimize rise in core body temperature as assessed by rectal temperature, length of time at set HLI, and appropriate time(s) of measurement.

2. Materials and methods

2.1. Animals, feedstuffs, and housing

The protocol for the experiment was approved by the Langston University Animal Care and Use Committee. Thirty-three wethers were used, 11 Boer goats (BOE), 11 Spanish goats (SPA), and 11 Katahdin sheep (KAT). Average BW during the baseline period was 28.6, 38.9, and 22.7 kg (SE = 1.12) for BOE, KAT, and SPA, respectively. BOE and SPA were derived from herds of the American Institute for Goat Research of Langston University, with initial age of 541 (SE = 3.4) and 564 days (SE = 3.5), respectively. The KAT were purchased from a local farm, with a similar age as the goats based on producer comments. Before the preliminary period wethers were vaccinated against clostridial organisms and treated for internal parasites.

The experiment consisted of 2 wk for adaptation to housing conditions followed by a 2-wk period to determine baseline or thermonetural zone measures and then 4 wk with weekly stepwise increases in HLI. Wethers were housed individually in 1.05 × 0.55 m elevated pens with a plastic-coated expanded metal floor in one room. A moderate quality grass hay was fed free-choice at 120% of consumption on the preceding few days, along with 0.5% BW (DM) of concentrate that consisted of 80% ground corn and 20% soybean meal. Hay was given at 08:00 h after refusals had been collected and weighed. Concentrate was fed at 10:00 h in a bucket placed in the large plastic barrel containing hay and was completely consumed within a few minutes. Based on visual appearance before harvest, hay consisted primarily of equal quantities of Johnsongrass (*Sorghum halepense*) and bermudagrass (*Cynodon dactylon*) and was coarsely ground through a 3.8-cm screen. Feedstuffs were sampled daily following the preliminary period to form weekly composite samples, which were analyzed for DM, ash, (AOAC, 2006), CP (Leco TruMac CN, St. Joseph, MI), NDF with use of heat stable amylase and containing residual ash, ADF, and ADL (hay only) (filter bag technique of ANKOM Technology Corp., Fairport, NY, USA). A small amount (8–10 g/day; as fed basis) of a mixture of 95% soybean meal and 5% of a trace mineral premix (275 mg/kg Co, 2000 mg/kg I, 43,746 mg/kg Fe, 750 mg/kg Se, 18,748 mg/kg Cu, 68,744 mg/kg Zn, and 19,998 mg/kg Mn) was top-dressed on hay. Also, each wether had free access to a small trace mineralized salt block (NaCl: 96.5–99.5%; Zn: 4000 ppm; Fe: 1600 ppm; Mn: 1200 ppm; Cu: 260–390 ppm; I: 100 ppm; and Co: 40 ppm) in the bottom of each feeder.

2.2. Experimental periods

HLI was estimated as proposed by Gaughan et al. (2010) for temperatures above 25 °C: HLI = 8.62 + (0.38 × RH) + (1.55 × BG) − (0.5 × WS) + $e^{(2.4 - WS)}$, with BG = black globe temperature (° C), RH = relative humidity (%), WS = wind speed (m/s; assumed zero), and e = base of the natural logarithm. In addition to the measurement of temperature inside the 15-cm diameter black globe, there were four temperature and humidity monitors (Hobo® Temperature/RH Data Logger, model number U12-011; Onset Computer Corp., Bourne, MA, USA) present at different locations in the room. The temperature-humidity index (THI) of Amundson et al. (2006; (0.8 × °C) + (RH/100) × (°C − 14.4) + 46.4) was calculated as well, which is nearly the same as that of Salama et al. (2014), with a correlation coefficient of 0.99996 ($P < 0.001$). The correlation coefficient between the THI and HLI was 0.970 ($P < 0.001$). The experiment occurred in the late fall before temperatures became very low, which allowed condition control by adjustments of heating and humidifying units.

Target HLI were 70, 80, 90, 95, and 100 during daytime (07:00–19:00 h) and 70, 70, 76.5, 80.75, and 85 during nighttime (19:00 to 07:00 h) in periods 1 (baseline), 2, 3, 4, and 5, which are also referred to as target HLI of 70/70, 80/70, 90/76.5, 95/80.75, and 100/85, respectively. For periods 3–5, target HLI at night were 85% of that during the day. Actual values are in Table 1 and averaged 66, 80, 92, 97, and 101 during the day and 66, 75, 84, 86, and 89 at night in periods 1, 2, 3, 4, and 5, respectively. After period 5, thermoneutral zone conditions were maintained during days and nights for 1 wk.

2.3. Measures

At the beginning of the experiment, fiber in a 10 × 10 cm midside patch was clipped close to the skin using Öster clippers (McMinnville, TN, USA) fitted with a size 40 blade. The same area was clipped at the end of the study. Whole body fiber was calculated based on a surface area equation for Merino sheep, where surface area (m^2) = 0.094 × kg $BW^{0.67}$ (Bennett, 1973) and assuming 90% of the surface area to be fiber-producing. Clean and greasy fiber mass values were determined according to ASTM (1988) standards.

Intake of DM (DMI) was measured daily and BW was determined at the end of periods at 13:00 h, which includes both wk 1 and 2 of period 1 (i.e., baseline). BW was also determined on two other days each week, although these data are not presented. Respiration rate and rectal temperature were determined at the end of the weeks at 06:00, 13:00, and 17:00 h. In addition, in period 5 these measures occurred each day. Blood was collected via jugular venipuncture on the last day of the week once at 07:00 h into tubes with and without heparin and placed in ice. Packed cell volume (PCV) was determined with heparinized tubes (Clay Adams, Parsipany, NJ, USA).

2.4. Statistical analyses

Data were analyzed by mixed effects models with SAS (2004). Fiber mass at the beginning and end of the experiment was analyzed with a model consisting only of animal type. Other variables with one or more repeated measure were analyzed as split-plots. For BW, DMI, and PCV, the model consisted of animal type, target HLI or period, and their interaction, with HLI as a repeated mea-