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Factors influencing estimates of heat energy associated with activity by grazing meat goats

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ABSTRACT

Ten yearling Boer goat wethers (45.4 ± 0.92 kg) grazed a 0.8-ha grass pasture or were individually confined in a crossover experiment with 3-wk periods to evaluate factors influencing heat energy (HE) associated with activity (AEC) when grazing and to evaluate different methods of estimating the AEC. Fresh forage offered to confined wethers was 15.9% and 13.4% CP and 65.0% and 67.4% NDF in periods 1 and 2, respectively. Based on forage and fecal acid detergent insoluble ash, digestibility of gross energy in forage by confined wethers averaged 67.9% and 56.5% in periods 1 and 2, respectively. From these values and fecal DM, least squares means of ME intake were 405 and 484 kJ/kg $BW^{0.75}$ for confined and grazing wethers, respectively (SE =15.4). HE determined from heart rate (HR) measured over 1 d and the ratio of HE to HR estimated earlier was less ($P < 0.001$) for confined than for grazing wethers (482 and 642 kJ/kg $BW^{0.75}$; SE =17.2). The AEC estimated by subtraction from HE of ME required for maintenance (ME_m; 427 kJ/kg $BW^{0.75}$), HE expended for tissue energy gain based on recovered energy (RE) when greater than 0, an efficiency of ME use for gain (i.e., [0.0423× forage ME in MJ/kg DM] +0.006; 0.40 ± 0.009), and the same efficiency of use for maintenance (k_m; [0.019× forage ME in MJ/kg DM] +0.503; 0.68 ± 0.004) of energy from forage and mobilized tissue with RE less than 0 was 39 and 213 kJ/kg $BW^{0.75}$ for confined and grazing wethers, respectively (SE =21.9; Partitioning approach). The AEC determined as the difference between HE by grazing and confined wethers was 165 ± 19.3 kJ/kg $BW^{0.75}$ (Confinement approach), and that based on time spent in different activities (i.e., lying, standing, grazing, and walking) multiplied by corresponding HE and assuming that AEC resulted from HE when standing, grazing, and walking was 46 ± 4.85 kJ/kg $BW^{0.75}$ (Lying approach). In conclusion, method of estimation can have marked impact on the AEC, with a relatively low value for the Lying method because of lower HE while lying when confined than on pasture. Determining the AEC by the Confinement approach relies on similar conditions to minimize confounding, and the Partitioning method is influenced by specific assumptions of energy requirements and efficiencies of use for different physiological functions.

1. Introduction

It is commonly assumed that approximately 10% of the energy required by confined ruminants for maintenance is used for activity (AFRC, 1998; NRC, 2007). However, grazing ruminants use considerably more energy for activity, and the amount can be even as much as a confined animal requires for maintenance (Lachica and Aguilera, 2003). Therefore, accurate means of predicting this energetic expense would be very useful. But, the difficulty in determining the activity energy cost (AEC) has limited the number of estimates available and resulted in high variability.

Goetsch et al. (2010) addressed three methods of determining the AEC that have been employed recently. One used with cattle is based on differences in heat energy (HE) between times when animals are lying compared with periods while eating, standing, and walking. These differences are multiplied by the lengths of time spent in the activities (Brosh et al., 2006). Such estimates are frequently expressed as a percentage or proportion of the ME requirement for maintenance (ME_m) of animals in confinement (NRC, 2007). This may necessitate an assumption that HE while lying is constant regardless of specific conditions, even for animals when grazing and confined. Another approach to determine the AEC is to compare HE by grazing animals with that by ones confined (Lachica and Aguilera, 2005), which requires similar conditions between the two settings to minimize confounding. A third approach is to subtract the various components of the estimate of total HE in order to derive the AEC by difference

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(Beker et al., 2009, 2010; Tovar-Luna et al., 2011). The accuracy of assumptions employed is very important for this method. Therefore, objectives of the present study were to evaluate factors influencing the AEC when grazing, particularly time spent in different behaviors, and compare different methods of estimation.

2. Materials and methods

2.1. Animals, phases, and experimental design

The experimental protocol was approved by the Langston University Animal Care and Use Committee. Ten yearling Boer goat wethers were used, with an average BW during the experiment of 45.4 ± 0.92 kg and age of approximately 18 months. Wethers were weighed at the beginning and end of each phase and calorimetry measurement period. The wethers were treated for internal and external parasites before the study, which consisted of a preliminary or stationary calorimetry system phase 2 wk in length followed by a crossover experiment of two 3-wk periods. Measures during the crossover occurred in a pasture and in pens and stanchions located in an alleyway adjacent to the pasture at the Langston University campus. The experiment occurred during August and September of 2013, with temperature and humidity from Weather Underground (http://www.wunderground.com) for the Guthrie, Oklahoma airport summarized in Table 1.

2.2. Stationary calorimetry system phase

Animals were adapted to housing in a room with metabolism crates (0.7×1.2 m) with plastic-coated expanded metal floors during the first week; the facility was located approximately 250 m from the pasture site. In the second week, the ratio of HE to heart rate (HR) was determined for 24 h after 1 d of adaptation to housing in an adjacent room in four metabolism crates fitted with head-boxes of an indirect, open-circuit respiration calorimetry system (Sable Systems International, Las Vegas, NV, USA). A coarsely ground moderate quality grass hay (Table 2) was fed free-choice for ad libitum consumption. The HE: HR ratio was determined as in other studies (Puchala et al., 2007, 2009). O_2 concentration was analyzed using a fuel cell FC-1B O_2 analyzer (Sable Systems International), and CH_4 and CO_2 concentrations were measured with infrared analyzers (CA-1B for CO_2 and MA-1 for CH_4; Sable Systems International). Prior to gas exchange measurements, analyzers were calibrated with gases of known concentrations. Ethanol combustion tests were performed to ensure complete recovery of O_2 and CO_2 produced with the same flow rates as used during measurements. HE was determined according to the Brouwer (1965) equation without consideration of urinary N.

HR was monitored generally as described by Puchala et al. (2009). Wethers were fitted with 10×10 cm electrodes prepared from stretch conductive fabric (Less EMF, Albany, NY, USA), glued to Vermed PerformancePlus ECG electrodes (Bellows Falls, VT, USA), and attached to the chest just behind and slightly below the left elbow and behind the shoulder blade on the right side. Electrodes were connected by ECG snap leads (Bioconnect, San Diego, CA, USA) to T61 coded transmitters (Polar, Lake Success, NY, USA). Human S610 HR (Polar) monitors with wireless connection to the transmitters were used to collect HR data at a 1-min interval. HR data were analyzed using Polar Precision Performance SW software.

2.3. Crossover experiment

Five wethers grazed a 0.8-ha pasture and five were confined in period 1, and treatments were switched in period 2. The pasture consisted of Sudangrass (*Sorghum bicolor*) planted in the late spring/early summer, and grazing occurred in August and September. The pasture had not been previously grazed and, thus, available forage mass was high (i.e., >3000 kg/ha). There was a shelter located in the pasture, and trace mineralized salt blocks and fresh water were available on pasture and in confinement. When confined, wethers resided individually in 1.2×1.2 m pens under a shelter. Grazing wethers were observed each morning, after which pasture forage similar to that being grazed was harvested by hand and fed at 08:00 h to confined wethers at approximately 110% of consumption on the preceding few days. The composition of forage samples collected daily in week 2 and 3 of each period is shown in Table 2.

The first week of each period was for adaptation to confinement and grazing conditions. In wk 2 of period 1 and wk 3 of period 2, canvas bags were used to collect excreted feces for 5 days. After weighing feces daily, a 10% aliquot sample was saved to form a composite that was kept frozen between and after days of sampling. Samples of the forage and feces were stored frozen at −20 °C. Later, forage samples were dried by lyophilization and fecal samples at 55 °C in a forced-air oven. Samples were ground to pass a 1-mm screen and analyzed for DM, ash (AOAC, 2006), nitrogen (Leco TruMac CN, St. Joseph, MI, USA), NDF with use of heat stable amylase (Van Soest et al., 1991) and containing residual ash, ADF, acid detergent insoluble ash (ADIA; filter bag technique of ANKOM Technology Corp., Fairport, NY), and gross energy using a bomb calorimeter (Parr 6300; Parr Instrument Co., Inc., Moline, IL, USA; AOAC, 2006). Feed intake was based on fecal output and digestibility in confined wethers that was determined from concentrations of ADIA in forage and feces. Intake of ME was determined as 82% of DE intake (NRC, 1984).

In the first few days of wk 3 of period 1 and of wk 2 of period 2, HR was measured for 24 h as described earlier. At the same time, wethers on pasture were fitted with GPS collars (Model 3300SL GPS unit with x-y motion sensors; Lotek Wireless, Newmarket, Ontario, Canada) and an IceTag activity monitor (IceRobotics Limited, Midlothian, Scotland, UK) on the rear left leg. The GPS collars were used to estimate horizontal distance traveled and time the head was in a ‘down’ position. The ‘head down’ determination from GPS collars arises from a motion/position sensor. The collars were scheduled to acquire a GPS fix every 5 min. Fixes were downloaded and post-differentially corrected using proprietary software (N4, Lotek Wireless) and base station files from the Perry, OK, USA continuously operating reference station (OKPR, 36°16′34.46428″ N, 97°19′17.97610″ W). Corrected fixes were then imported into ArcMap 9.3 (ESRI, Redlands, CA, USA). Boundaries of the pasture, including a 7-m external buffer, were constructed as shapefiles using a coordinate system of WGS 1984 UTM 14N. The x and y coordinates in meters were calculated for each fix. Only fixes within the boundary and buffer shapefiles were exported. Distance between consecutive fixes was calculated using Euclidean geometry. The area within the pasture did not markedly vary in elevation; therefore, vertical distance traveled was not computed. Time standing from IceTags encompasses both grazing/eating and non-grazing/eating periods, and ‘active’ is walking at a relatively fast pace presumably without grazing/eating. Lying time is solely or predominantly without grazing.

Table 1
Temperature and humidity during the experimental period.

Month	Item	Mean	SE	Minimum	Maximum
August	Mean daily temperature (°C)	27.2	0.45	21.8	31.3
	Minimum daily temperature (°C)	21.7	0.38	17.8	25.8
	Maximum daily temperature (°C)	33.1	0.51	28.3	38.9
	Daily relative humidity (%)	64.9	1.51	47.7	84.1
September	Mean temperature (°C)	24.6	0.60	17.7	28.7
	Minimum temperature (°C)	18.6	0.72	9.4	23.3
	Maximum temperature (°C)	31.3	0.66	22.2	36.1
	Relative humidity (%)	58.8	1.52	43.0	77.4