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Technical note: Assessment of the oxygen pulse and heart rate method using respiration chambers and comparative slaughter for measuring heat production of cattle

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ABSTRACT

The objective of this study was to assess the oxygen pulse and heart rate (O_2P-HR) technique using the respiration chamber (RC) and comparative slaughter (CS) methods for measuring the heat production (HP) of crossbred (Holstein × Gyr) yearling bulls. Twenty-four bulls were used. Six bulls were slaughtered at the beginning of the experiment as a reference group to estimate the initial empty body weight (BW) and energy content of the remaining animals. The remaining bulls were assigned to a completely randomized design with 3 levels of dry matter intake, with 6 replicates. The levels of dry matter intake were 1.2% of BW, 1.8% of BW and ad libitum, with target orts of 5%. The bulls were fed a diet consisting of 59.6% corn silage and 40.4% concentrate on a dry matter basis. The HP (kcal/$BW^{0.75}$) was measured using 3 techniques, first using O_2P-HR, followed by the RC and CS methods. The HP did not differ among assessed techniques, averaging 162.7 kcal/$BW^{0.75}$. The intercepts of the linear regressions (mean ± SE) were 64.82 ± 25.515 (H_0: intercept = 0; P = 0.024), 33.77 ± 13.418 (H_0: intercept = 0), and 50.02 ± 27.495 (H_0: intercept = 0) for O_2P-HR versus RC, CS versus RC, and O_2P-HR versus CS, respectively. The slopes of the linear regressions were 0.59 ± 0.153 (H_0: slope = 1), 0.88 ± 0.081 (H_0: slope = 1), and 0.62 ± 0.155 (H_0: slope = 1) for O_2P-HR versus RC, CS versus RC, and O_2P-HR versus CS, respectively. The coefficients of determination were 0.52, 0.90, and 0.52 for O_2P-HR versus RC, CS versus RC, and O_2P-HR versus CS, respectively. The concordance correlation coefficients, 0.70 and 0.68, were moderate for O_2P-HR versus RC and O_2P-HR versus CS, respectively, but high, 0.90, for CS versus RC. The between-animal coefficient of variation was greater for the O_2P-HR method (16.6%) compared with RC (7.7%) or CS (6.7%). We conclude that there was an agreement among the HP measurements detected using the assessed methods and that O_2P-HR is able to predict HP in cattle with great accuracy but only moderate precision. Therefore, the O_2P-HR method may have limitations in terms of assessing HP in low numbers of replications due to greater between-animal coefficient of variation than either the RC or CS methods.

Key words: heart rate, heat production, oxygen pulse

Technical Note

Heat production (**HP**) of cattle can be determined under controlled and confined conditions by using the respiration chamber (**RC**) method; however, these conditions do not reflect free-ranging animals or commercial cattle in feedlots or pastures. Also, capital investment for RC is high, training of animals is required, and the behavior of animal may be altered from that which occurs under most production settings (e.g., low activity and reductions in DMI). In an attempt to overcome the limitations of measuring HP in the environment of cattle, HP can also be measured using the comparative slaughter method (**CS**), as this technique allows the evaluation of animals that are being raised in several production conditions. However, CS is terminal, laborious, and requires accurate estimates of DMI and metabolizable energy intake (**MEI**) and thus can introduce significant errors; besides, it is able to provide only one HP value on average for all of the experiment.

The O_2P-HR method is an alternative technique for measuring HP that is based on long-term measurements (24-h periods) of the heart rate (**HR**) of free-range animals and on short-term measurements of oxygen pulse (**O_2P**; mL of O_2 consumed/heart beat), which are measured by attaching a face mask (**FM**) to the animal's nose (Brosh, 2007).

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Few experiments have been conducted to examine the reliability of the O_2P-HR method in measuring the HP of cows (Arieli et al., 2002; Brosh et al., 2002). However, to our knowledge, no studies have compared O_2P-HR with the more traditional techniques (RC and CS) of determining HP in cattle energetics research (Arieli et al., 2002; compared O_2P-HR with CS in sheep rather than cattle). The use of O_2P-HR method as an alternative method can be useful in studies including genetic and efficiency selection, evaluation of physiological stage or growth stage and also different feeding paradigms.

Therefore, the objective of this study was to compare the O_2P-HR, RC, and CS methods of measuring and assessing variation in HP in cattle. We hypothesized that the O_2P-HR method would predict HP comparable to the RC and CS techniques for these same growing bulls.

The present study followed the guidelines of the Ethics Committee in Animal Use of the Universidade Federal de Viçosa (process number 44/2012). The experiment was conducted at the Multi-Use Complex on Livestock Bioefficiency and Sustainability at Embrapa Gado de Leite, in Coronel Pacheco, MG, Brazil, from August 2013 to February 2014.

Twenty-four Holstein × Gyr crossbred 10-mo-old bulls (initial BW = 155 ± 24.6 kg) were used. All bulls were adapted to the experimental diet before the initial slaughter over 30 d being fed the same level of DM: 2.0% of BW. After the adaptation period, bulls (184 ± 23.4 kg) were randomly subdivided into 4 groups of 6 animals. One of those groups was designated as a baseline reference group and was slaughtered at the beginning of the experiment to measure the initial body energy content in their empty BW (**EBW**) to facilitate the CS method. The 3 remaining groups were fed at 3 different DMI: (1) restricted to 1.2% of BW, (2) restricted to 1.8% of BW, or (3) ad libitum with target 5% orts. These treatments were selected to introduce the necessary variation in MEI to assess the validity of the method. One bull from the ad libitum group had to be removed from the experiment due to health issues. Throughout the experiment, bulls were housed in a tie stall barn with free access to water and fed a diet consisting of corn silage and concentrate (59.6: 40.4 DM basis) once daily (0830 h). The concentrate was composed of soybean meal (24.8%), ground corn (67.9%), urea (2.4%), mineral mix (3.5%), and limestone (1.4%). The DM feed offered and refused was weighed to determine total daily DMI. The estimated ME content of the diet was 2.4 Mcal/kg of DM on average. The ME content of the diet was determined by multiplying digestible energy by 0.82 (NRC, 1996) taking into account the DM digestibility coefficients of each animal. Although the fixed ratio ME:digestible energy (**DE**) of 0.82 (NRC, 1996) has been accepted in many publications, this ratio might change as MEI increases [i.e., Chaokaur et al., 2015, who determined energy balance of Brahman bulls raised on increasing dietary allocations observed ME:DE ratio of 0.82, 0.86, 0.87, and 0.88 for maintenance (**M**), 1.4 × M, 1.8 × M, and ad libitum groups, respectively]. The digestibility coefficients in our study were obtained from 2 digestibility trials conducted at 2 points throughout the experiment: 2 mo after the reference slaughter and 2 mo before the final slaughter. The DM digestibility coefficients did not differ between trials. The digestibility trial consisted of 3 d of total feces and urine collection as described by Costa e Silva et al. (2015).

Treated bulls were slaughtered at the end of the experiment to measure the final body energy content in their final EBW for CS calculations. The experiment lasted 173, 171, and 168 d for the 1.2% of BW, 1.8% of BW and ad libitum groups, respectively, after which the animals were slaughtered. The slaughters followed the same procedures described by Costa e Silva et al. (2015).

The bulls were accustomed to the FM for a period of 2 wk before measurements. Bulls were placed in a squeeze chute and the FM was fitted for two 20-min periods (morning and afternoon). Following the training period, 3 O_2P (mL/heart beat) measurements were collected over a 3-d period with measurements made about 6 h after feeding, separated by 3 d of HR (beats/min) measurements at the tie stall.

The O_2 consumption data were recorded using a Sable System (Sable Systems International, Las Vegas, NV) attached to the FM. Details about the gas measurements were described by Oss et al. (2016). Samples from the FM were collected at 20-s intervals and recorded at 1-min intervals over 20 min, with ambient air collected 5 min before and after the 20-min measurements to establish baseline gas levels. All data were recorded using an automated data acquisition program (Expedata, Sable Systems International). The O_2 consumption (VO_2; mL/min) was calculated from the product of mass flow measurements of the atmospheric air corrected for standard temperature (273.5 K) and pressure (101.325 kPa) conditions (STP) and difference in average from FM [O_2fm, % and baseline (O_2b; %), O_2 concentration measurements over 30 min] as follows:

$$VO_2 = [STP \times (O_2fm - O_2b].$$

The HR was recorded using a Polar equine transmitter and monitor (model RS800CX, Polar Electro Inc.,