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Technical note: A facility for respiration measurements in cattle

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ABSTRACT

A respiration system consisting of 4 climate-controlled chambers and 1 set of flowmeters and analyzers was constructed and validated. Each chamber had volume of 21.10 m^3 (3.68 × 2.56 × 2.24 m) and was made from steel with double-glazed windows on either side enabling visual contact between animals. The chambers are independently climate-controlled and can maintain temperature and relative humidity in a range from 5 to 45°C and 30 to 80%, respectively. A flow generator and mass flowmeter continuously pull air from each chamber and a slight negative pressure inside the chamber is ensured. Air from all chambers and ambient air share a common gas analysis and data acquisition system for monitoring O_2, CO_2, and CH_4 concentrations over the measurement period, with the cycle time set to 20 min. Analyzers are regularly calibrated and the chambers have mean recoveries of 99.0 and 98.0% for CO_2 and CH_4, respectively. The chambers are equipped with infrared cameras and electronic feed and water bins for intake measurements, as well as sensors for monitoring animal position and heart rate. Data acquisition and analysis software is used to calculate the rate of consumption of O_2 and production of CO_2 and CH_4. The dynamic respiration measurements are integrated with feed intake data and other sensors. The daily gas exchanges are estimated by integration to determine methane emission and heat production. We conducted a trial with 12 lactating 3/4 Holstein × 1/4 Gyr crossbred dairy cows (6 multiparous and 6 primiparous) under 2 feeding regimens (ad libitum or restricted) to validate the system. Two 22-h respiration measurements were obtained from each cow. Restricted-fed cows showed lower values for milk yield, methane emission, and heat production compared with ad libitum-fed animals. We found no difference between groups for CH_4 produced per kilogram of dry matter intake. Repeatability for CH_4 emission and heat production was high (0.97 and 0.92, respectively). The respiration system described herein is a useful tool for measuring the dynamic and accumulated data of heat production, methane emission, and feed intake.

Key words: bioenergetics, energy, indirect calorimetry, methane

Technical Note

Historically, open-circuit respiration chambers have been widely used in North America and Europe for determination of feed evaluation and energy requirements for dairy and beef cattle (Yan et al., 1997; Derno et al., 2005). Over the last decade, the increased demand for finding strategies to mitigate methane emission by ruminant animals has renewed interest in respirometry studies around the world. In addition, there is a need to understand the mechanisms that regulate energy expenditure in beef and dairy cattle to improve the efficiency of production and animal health (Derno et al., 2009), and to identify variation in energy metabolism of more-efficient animals as a phenotypic feature for breeding programs (Arndt et al., 2015; Moraes et al., 2015). The search for knowledge about the effects of heat stress on animal metabolism also motivates the use of climate-controlled respiration chambers. The respiration chambers for cattle described herein were designed to allow the study of interactions and dynamics among feed intake, climatic conditions, methane emission, and energy metabolism. The aim of this technical note is to describe and validate this facility as a useful and repeatable tool for respiration measurements.

The respiration system is located in Bioenergetic Laboratory of Multi-use Complex on Livestock Bioefficiency and Sustainability of the Brazilian Agricultural Research Corporation, Embrapa (Coronel Pacheco, Minas Gerais, Brazil). All chambers are located in the same building and a dedicated level on the second floor contains the air-conditioning units. A separate air-conditioned room, annexed to the chamber build-

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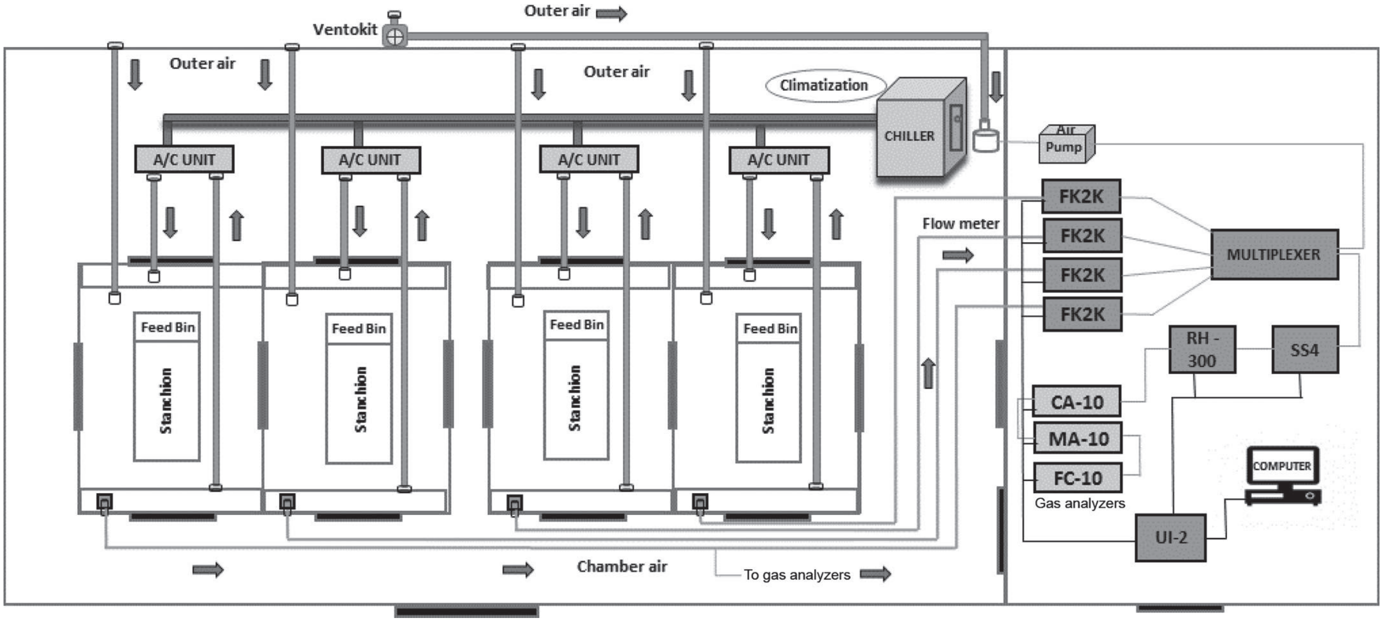

Figure 1. General scheme of the respiration system. FK2K = flow meter and control, SS4 = sub-sampler pump, RH-300 = water vapor analyzer, CA-10 = CO_2 analyzer, MA-10 = CH_4 analyzer, FC-10 = O_2 analyzer, UI-2 = universal interface. All components are from Sable Systems International (Las Vegas, NV).

ing, houses the equipment for gas analysis, calibration, chamber control, and data acquisition and processing (Figure 1). The respiration system is configured in an open-circuit arrangement (Aguilera and Prieto, 1986) and consists of 4 chambers assembled in pairs. The net volume of each chamber is 21.10 m^3, with dimensions (m) of 3.68 long × 2.56 wide × 2.24 high, containing a 2.26- × 1.26-m pen, which provides a safe environment for one animal and allows technicians walk around to manipulate it. The construction company was No Pollution Industrial Systems Ltd. (Edinburgh, UK). The chambers are made from steel with thermo-insulating and sound-insulating wall panels made from AISI 304 stainless steel sheets (CPC Inox S.P.A., Basiano, Italy), with polyurethane injected in between. Joints between panels were sealed with polyurethane sealant (Sikaflex, Sika S/A, São Paulo, Brazil). The chambers have large double-glazed windows (150 cm high, 150 cm wide) to guarantee visual communication between animals. Each chamber is fitted with one large back door for animal access and a smaller front door for operator access and for feeding, both fitted with rubber seals (Figure 2A). The floor is concrete painted with epoxy to prevent CO_2 exchange. An epoxy sealant ensures no leakage between the walls and concrete floor. A slurry grate located behind each animal is emptied twice a day by a flushing system operated from outside the chambers (Figure 2C). The slurry system is sealed with a wafer cast iron butterfly valve to prevent gas leaks. The pen floor is covered with a Rubber Plus mat (WingFlex, Kraiburg TPE GmbH & Co., Waldkraiburg, Germany) to optimize the animal's comfort. Each chamber is fitted with an emergency hatch, which is closed by an electromagnet lock. In the event of a power failure, flooding due to a leak in the water supply system, extreme temperatures, or a CO_2 build-up to 10,000 ppm, the hatch is automatically opened, ensuring animal safety.

Chambers are climate-controlled and designed to keep ambient temperature and relative humidity (**RH**) from 5 to 45 ± 0.5°C and 30 to 80 ± 5%, respectively. The temperature and RH inside the chambers are continuously measured over the measurement period, and the climate control and climatic conditions are recorded using Metasys software (version 5.1.3.0400; Johnson Controls Inc., Milwaukee, WI). Each chamber has an independent regulation system, a separate air treatment unit with a recirculating fan (800–1,600 m^3/h), and an air filter section, which is integrated to the chamber through 350-mm-diameter flexible thermo-insulating tubes. For recirculation, air leaves the chamber through openings at the bottom corners of the chambers. The air is then recycled into the chamber through openings at the front end of the chamber ceiling.

Four separate streams of ambient air are drawn through 75-mm-diameter polyvinyl chloride (**PVC**) pipes from outside the shed and are connected to each chamber's fresh air inlet in the front ceiling (Figure 1).