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BRIEF COMMUNICATION: A versatile sheep respiration chamber system for measurement of methane emission

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INTRODUCTION

Globally, the single most important source of greenhouse gas emissions from grazing systems is enteric methane (CH_4) arising as a by-product of the fermentation of feed in the reticulo-rumen of ruminants (Clark *et al*., 2005). Methane is implicated in global warming and in countries where livestock constitutes a major emission source such as New Zealand, international commitments are driving research to develop emission reduction technologies, for which accurate measurements of CH_4 emissions are paramount.

Enteric CH_4 emissions from individual animals can be accurately measured by indirect calorimetry (respiration chambers). These methods are expensive and not easily related to less controlled systems such as under grazing conditions. The sulphur hexafluoride (SF_6) tracer technique (Johnson *et al*., 1994) suits free ranging conditions and it is widely used in New Zealand and other countries. This technique, however, is associated with larger variability than the emission values obtained using calorimetric methods (C.S. Pinares-Patiño, Unpublished data).

Whole-animal enclosed calorimetric chambers are the best choice when accurate measurements of total digestive tract CH_4 emissions including eructation and flatus, are required. Recent technological advances in gas analysis data acquisition systems and building materials have made it possible to build calorimetry systems relatively cheaply, while fulfilling accuracy and animal welfare requirements. AgResearch has recently built, commissioned and tested a four-chamber calorimetry facility for sheep, which is now in use. This paper describes the facility.

DESCRIPTION OF FACILITY

The chambers (Figure 1) were designed to provide a comfortable and safe environment for the animals, while enabling accurate measurement of CH_4 flows. The volume of each chamber is 1.84 m^3 (1.8 m long, 0.85 m wide, 1.2 m high). The frame was made of 25 × 25 × 3 mm square section aluminium tube with a 3 mm thick aluminium sheet floor. The walls and roof are 6 mm clear polycarbonate sheet, fixed to the aluminium frame using silicone sealant and rubber seated screws to form an air tight seal. The chambers have a front and back access door fitted with internal rubber seals. The front door is locked by two solenoid locks which open automatically in the event of power failure. The back door is locked by three adjustable latches. The chambers are mounted on castors with four levelling feet. The sheep are restrained in the chambers in modified metabolic crates with a feed bin, drinking water container and separate trays to collect faeces and urine.

FIGURE 1: Four-chamber open-circuit calorimetry facility for sheep at AgResearch Grasslands, Palmerston North, New Zealand.

Each chamber is fitted with a fresh air inlet at the front and an air outlet at the back made of flexible (38 mm outside diameter) polyurethane. The air inlet is piped from a ceiling vent in the building. The outlet hose from each chamber is connected to a diaphragm gas meter (AL425, American Meter Company) for wet gas flow measurement. All four outlets from the gas meters are connected to a common air pump system using the polyurethane hoses. Two air pumps (UNI-JET 40, ESAM, Parma, Italy), assembled in parallel provide air circulation throughout the chambers at continuous but adjustable flow rates (100 - 250 L/min). Air from the pumps is exhausted outside the building. Each chamber is fitted with two internal ventilation fans for mixing expired gases and incoming air. Sensors (Vaisala Oyj, Helsinki, Finland) for relative humidity and temperature (Vaisala Humicap® HMT100) and barometric

FIGURE 2: Rates of methane (CH_4) emission (g/d) by a sheep following feeding at 08:00 hours and afternoon 15:20 hours. Data points are at five minute intervals.

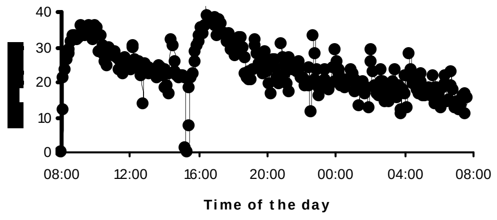
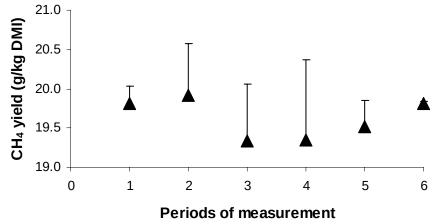


FIGURE 3: Mean and standard deviation of methane (CH_4) yield (g/kg dry matter intake (DMI)) by a sheep fed a fixed amount of a consistent diet over six measurement periods.



pressure (PTB 110) are fitted in each chamber and provide data enabling air flows to be adjusted to standard temperature and pressure.

Outlet gas from each chamber is continuously sampled at a rate of 0.5 L/min into a multiport gas switching unit (S.W. and W.S. Burrage, Ashford, Kent, UK) using 1/8 inch polyurethane tubing with an in-line 7 µm filter. The multiport unit switches the samples taken from each of the four chambers and an ambient sample every minute. Sample gas is delivered to the gas analyser by a means of a micro diaphragm pump (NMP 09L, KNF Neuberger Inc, Freiburg, Germany) at 0.5 L/min flow. Before entering the anaylser each sample is filtered through a 0.5 µm pore filter and conditioned using a heated gas drier (MDH-110-96, Perma Pure, New Jersey) which uses dry air as counter flow at 1.0 L/min. A non-dispersion infrared gas analyser (ZKJ-1, Fuji Electric Systems Co., Ltd., Tokyo, Japan) able to detect CH_4 in the range 0 to 200 and 0-5,000 ppm is used for CH_4 analysis.

The CH_4 analyser is calibrated every morning using 99.99% pure nitrogen as a zero CH_4 baseline and a CH_4 standard with 170 ± 3 ppm of CH_4 (BOC Limited, New Zealand). The gas analyser has 1 ppm resolution for concentrations in the range 0 to 200 ppm. The data acquisition system records data for CH_4 concentrations and gas conditions every 10 seconds providing six estimates per sample. To compensate for the time delay between sampling point and analysis, only the last of the six readings for each sample are used for CH_4 emission calculations (Figure 2). Daily emissions are calculated by averaging the 5-min data points

The chambers operate under a slight negative pressure so that no respiratory gases are lost from the system. Consequently, there is a risk that power failure or malfunctioning of air pumps could cause suffocation if the air flow ceased. Safety measures to remove this risk include the front door of the chamber being able to open automatically in the case of a power failure, the parallel assembly of the two vacuum pumps responsible for continuous air flow to maintain air circulation even if one pump fails. In addition, since the four chambers are piped into a single air pumping system and one chamber is fitted with a highly accurate CO_2 sensor (GMP222, Vaisala Oyj, Helsinki, Finland), any failure in the air pumping system will increase CO_2 concentrations in all chambers, and concentrations of CO_2 reaching 4000 ppm trigger power cut to the solenoids, releasing the front doors. The respiratory chamber system is also connected to alarms for abnormal CO_2 and CH_4 concentrations, temperature, relative humidity and pressure and to the AgResearch computer network to facilitate remote monitoring of the chambers.

The respiratory chamber system has been tested by metering ultra pure CH_4 using a metered flow of 20 mL/min, to deliver the mean concentration of about 100 ppm. These tests revealed recovery rates of CH_4 of 99.4%, 99.5%, 99.7% and 98.4% in chambers 1, 2, 3 and 4, respectively.

The transparent walls of the respiration system enable the sheep to acclimatise to the system almost immediately as shown by their eating, ruminating and lying behaviour. Usually animals remain in a chamber for three days. Figure 2 shows a typical within-day pattern of CH_4 emissions for forage fed sheep. When a single diet of consistent quality was fed to sheep during a 2-month period, the respiration chamber system showed CH_4 emissions per unit of feed intake that were highly repeatable both between-days with a coefficient of variation of less than 5.0% and between-periods with a coefficient of variation of less than 1.5% (Figure 3).

ACKNOWLEDGEMENTS

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