Dynamic data for determining the accuracy of four open-circuit respiration chambers designed to quantify methane emissions from goats

Ophelie Dhumez, J. Tessier, Maguy Eugène, A.I. Martín-García, Alexandra Eymard, Sylvie Giger-Reverdin, Christine Duvaux-Ponter, Rafael Munoz Tamayo

animal - open space 1 (2022) 100006

Contents lists available at ScienceDirect

animal - open space

Dynamic data for determining the accuracy of four open-circuit respiration chambers designed to quantify methane emissions from goats

O. Dhumez[a,1], J. Tessier[a], M. Eugène[b], A.I. Martín-García[c], A. Eymard[a], S. Giger-Reverdin[a], C. Duvaux-Ponter[a], R. Muñoz-Tamayo[a,*]

[a] Université Paris-Saclay, INRAE, AgroParisTech, UMR Modélisation Systémique Appliquée aux Ruminants, 75005 Paris, France
[b] Université Clermont Auvergne, INRAE, VetAgro Sup, UMR 1213 Herbivores, Saint-Genès-Champanelle F 63122, France
[c] Estación Experimental del Zaidín (CSIC), Profesor Albareda 1, 18008 Granada, Spain

ARTICLE INFO

Article history:
Received 18 October 2021
Revised 28 January 2022
Accepted 30 January 2022

Handling editor: Antonella Baldi

Keywords:
Greenhouse gas emissions
Gas recovery test
Reproducibility
Respiration chambers
Ruminant emissions

ABSTRACT

Respiration chambers are the gold standard technique for measuring methane in ruminants provided that their gas recovery rates are close to 100%. The determination of the gas recovery rate of respiration chamber facilities is a central prerequisite to assess the accuracy of the methane emission quantification. However, data of recovery tests are seldom reported. This paper presents data from gas recovery tests applied to an experimental facility of four open-circuit respiration chambers designed to measure methane emissions from goats. The experimental facility is located at Thiverval-Grignon, France. The recovery test was assessed by placing a known source of methane emission at six locations in each chamber successively. For each chamber, the gas from the chamber and the ambient air were continuously sampled by a Multi-Gas Analyser 3500 gas analyser provided with a multiport unit that switches the sampling between the pipe from chamber and from the ambient air every 90 s. The analyser determines the concentration (ppm) of methane by infrared. The data were further imported in an R script for calculation of the methane recovery percentage. These data are useful resources for illustrating the protocol to assess the accuracy of respiration chambers.

Specification table

Subject	Livestock Farming Systems
Specific subject area	Ruminants
Type of data	Table R script
How data were acquired	For each of the four chambers, samplings for determining methane concentrations were taken from the ambient air (background outside the chamber) and from the chamber for each of the six locations of methane emissions. Methane concentrations (ppm) were measured using an Multi-Gas Analyser 3500 gas analyser. Mass flow (m^3/h) of the conduction system was measured by a mass flow meter Mass-Stream, Bronkhorst.
Data format	Raw data in XLSX format
Parameters for data collection	For each location of methane emission, the gas samples from the chamber and the ambient air were continuously sampled by the gas analyser using a multiport unit that switches the samples every 90 s during 30 min.

(*continued on next page*)

* Corresponding author.
E-mail address: rafael.munoz-tamayo@inrae.fr (R. Muñoz-Tamayo).
[1] Present address: PEGASE, INRAE, Institut Agro, 35590 Saint-Gilles, France.

https://doi.org/10.1016/j.anopes.2022.100006
2772-6940/

Description of data collection	For the recovery test, data were recorded by the Multi-Gas Analyser 3500 gas analyser that produced a csv file with information on the sampling times, the inlet analysed (ambient air or chamber) and the concentration of methane in ppm. We converted the resulted files into Excel files and added manually a column with the airflow rate (m^3/h) of the chamber provided by the mass flow meter Mass-Stream, Bronkhorst, and the location of the emission of methane. For the determination of the response time and stability of the gas analyser, the concentration of methane was registered every 5 s.
Data source location	Institution: INRAE, MoSAR team City: Thiverval-Grignon Country: France
Data accessibility	Repository name: data.inrae Data identification number: https://doi.org/10.15454/MFJXY3
Related research article	Not applicable

Value of the Data

- Dynamic data of methane concentration from recovery tests of four open-circuit respiration chambers are presented. The recovery tests were applied at six locations of methane emissions in the chambers
- The data are useful for illustrating the protocol to calculate the accuracy of respiration chambers
- The data are a useful resource for training courses on the operation of respiration chambers

Data Description

The data are available at https://doi.org/10.15454/MFJXY3. Tables Chamber1.xls, Chamber2.xls, Chamber3.xls and Chamber4.xls display methane (ppm) during the methane recovery test using a controlled source of methane emission (200 mL/min from a bottle with methane at 8%) during 30 min at six locations in each chamber (Fig. 1). The green and yellow colours in the rows of the Excel files indicate the times when the bottle of the methane source was opened and closed, respectively. The tables include information on the air outflow rate from the chamber. The R script recovery.r includes the code for the calculation of the percentage of recovery by determination of the area under the curve.

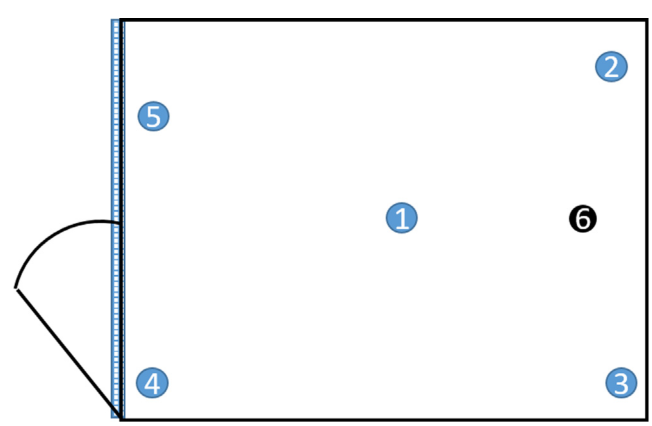

Fig. 1. Locations of the controlled methane emission sources used during the gas recovery test in a chamber designed to quantify methane emissions from goats. For the locations 1 to 4, the emission source was placed at 65 cm above the floor except. For location 5, the emission source was located on the ground with the emission flow oriented to the outside of the chamber. For location 6, the emission source was placed at the air extraction point on the top of the chamber.

The Excel file Analyser.xls shows dynamic data of the concentration of methane (ppm) and carbon dioxide (ppm) during a test to establish the response time and stability of the gas analyser.

Experimental design, materials and methods

Experimental facility

Our experimental facility was designed to quantify methane emissions from goats. It may also be used for other small ruminants like sheep, in accordance with the French regulation on the use of animals for experimental purposes. The facility consists of four open-circuit respiration chambers whose design was based on the respiration chambers of Hart et al. (2014), Pinares-Patiño et al. (2014), Eugène and Guyader (2016). Each chamber is made of a steel frame and polycarbonate walls (Fig. 2). The dimensions of each chamber are as follows: 1.57 m wide × 2.06 m deep × 1.85 m high. Each chamber has a surface of 3.22 m^2 and a volume of 5.98 m^3. At the bottom of the front of the chamber, there is an air gap of 10 cm high not covered by the polycarbonate along the width of the front. All chambers share a common pumping system that comprises two pumps (K06MS, FPZ Blower Technology) that continuously draw the air through the chambers. The extract duct is located on the top of the chamber. The ambient air is therefore drawn into the chamber and is mixed with the gas emitted by the controlled methane source. The extraction flow rate ranges from 14 to 80 m^3/h according to the number of turbines which are active and the number of valves open (there is one valve per chamber). The gases from the pumping system are exhausted through the building roof. Air flowing out of each chamber passes first to a F300 dust filter (Agilent, Valmadrera, Italy), and then, its flow rate is measured by a mass flow meter (Mass-Stream D-6380-DR, Bronkhorst). The pumping system, mass flow meters and analysers are integrated in a cabinet (ENVEA, France) to be protected from dust. Samples of air from each chamber are obtained before the mass flow meter by a multiport unit integrated in the infrared gas analyser Multi-Gas Analyser 3500 (ADC Gas Analysis Ltd). The analyser was equipped with both methane (**CH_4**) and carbon dioxide (**CO_2**) cells. Fig. 3 illustrates the scheme of the facility. The chambers are located in an enclosed barn with lateral windows. The barn is not insulated and operates at ambient pressure and temperature.

Calibration, response time and stability test of the gas analyser

The gas analyser was calibrated with three reference gases: high purity N_2 (Linde, >99.9990% purity), CH_4 at 150 ppm (Q.S. synthetic air) and CO_2 at 5 000 ppm (Q.S. synthetic air). The calibration was firstly done with N_2 to set the zero value of the analyser for CH_4 and CO_2 determination. Afterwards, the reference gases were connected to the analyser to set the span values for CH_4 and CO_2. The response time and stability of the gas analyser were tested following the protocol of Gardiner et al. (2015) by sampling the reference gases. The procedure was repeated three times in a row. The response time T90 was determined as the time taken to reach 90% of the final stable plateau reading. The stable plateau is reached

Fig. 2. Experimental facility with the four open-circuit respiration chambers designed to quantify methane (CH_4) emissions from goats, the cabinet with the gas analyser, the pumps for air extraction and the mass flow meters.

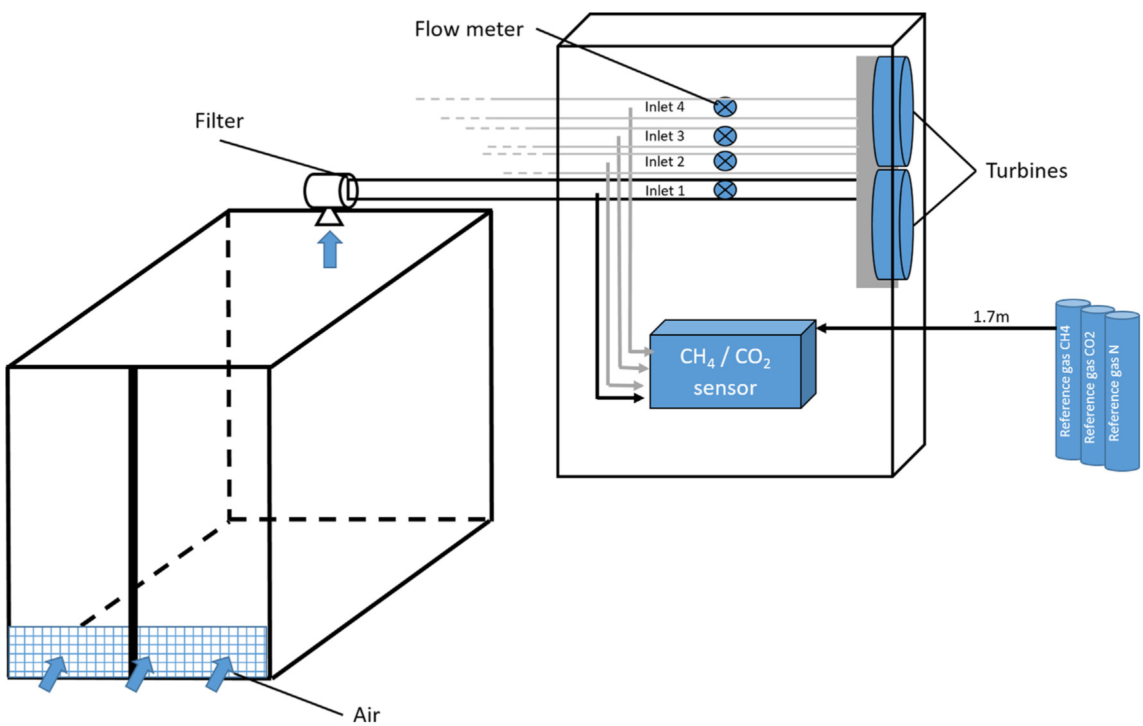

Fig. 3. Scheme of the open-circuit respiration chamber facility designed to quantify methane (CH_4) emissions from goats.

when the concentration is at steady state. For CH_4, the average T90 was 62 s. For CO_2, the average T90 was 46 s. The analyser stability was taken as the coefficient of variation of the records of methane concentration during 90 s once the stable plateau was reached. For CH_4, the values varied from 0.15 to 0.27% (mean 0.21%). For CO_2, the values varied from 0.13 to 0.16% (mean 0.14%).

Methane recovery test

The determination of the gas recovery rate of respiration chamber facilities is a central prerequisite to assess the accuracy of the methane emission quantification (Hammond et al., 2016; Gerrits et al., 2018). Procedures for recovery tests are documented, for

Table 1
Percentage of methane (CH_4) recovery at six locations of methane emissions in four open-circuit respiration chambers designed to quantify methane emissions from goats.

Location	Chamber 1	Chamber 2	Chamber 3	Chamber 4
1	107.5	98.6	87.6	97.1
2	97.2	97.6	98.7	98.4
3	108.9	103.4	94.9	99.5
4	110.9	94.4	93.3	104.8
5	98.1	100.2	96.4	96.5
6	110	101.6	99.6	98.8

example, in Gerrits and Labussière (2015). We performed the recovery test of our facility following the protocol of Gardiner et al. (2015). A bottle of CH_4 at 8% was connected to a mass flow controller (Aera FC-R7700CD) to provide a controlled methane emission inside the chamber. The emission rate was set to 200 mL/min for 30 min. The emission source was placed successively at five locations (Fig. 1) inside the chamber (centre and corners) at 65 cm above the floor except for location 5, where the emission source was located on the ground with the emission flow oriented to the outside of the chamber. These locations are meant to cover the movement of the animal inside the chamber, including standing (locations 1 to 4) and lying (location 5). A sixth location was tested with the emission source placed at the air extraction point on the top of the chamber. This location allows to characterise the recovery of the ducting. The recovery test was done with the following steps:

(i) place the gas emission source at the desired location of methane emission, close the chamber and wait few minutes to equilibrate the chamber.
(ii) open the mass flow controller for 30 min.
(iii) close the mass flow controller and wait 15–20 min until the concentration of the chamber is almost equal to the concentration in the ambient.

The time between independent measurements (chamber and ambient) of the analyser was set to 90 s (about 1.5 × T90 of the gas analyser). After data collection, the concentration of methane in the chamber was subtracted from the methane concentration measured in the ambient air for each time point. The total amount of methane measured was further calculated by determination of the area under the curve using the trapezoidal rule implemented in the R software (https://www.r-project.org/) (see the script recovery.R in the data repository). The methane recovery was calculated as the ratio between the total amount of methane measured and the known amount of methane emitted. The results are presented in Table 1. Fig. 4 shows the example of the dynamics of measured methane for chamber 4.

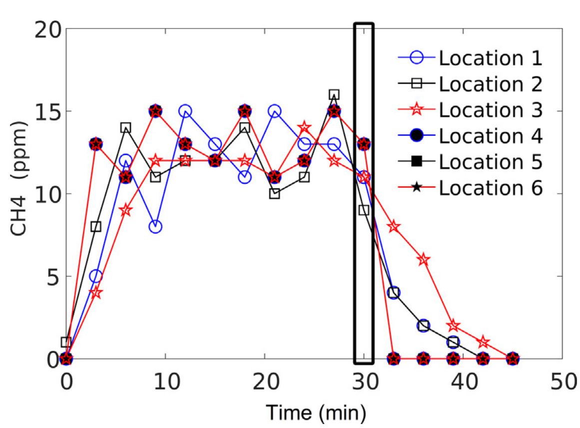

Fig. 4. Example of the dynamics of methane (CH_4) concentration at six locations of CH_4 emission during the recovery test for chamber 4. The emission starts at t = 0. The rectangle indicates the time at which the emission source stopped (30 min).

Ethics approval

NA.

Author ORCIDs

RMT: https://orcid.org/0000-0002-9266-4132
ME: https://orcid.org/0000-0002-2111-0597
AIMG: https://orcid.org/0000-0002-5366-3938
SGR: https://orcid.org/0000-0003-2549-7511
CDP: https://orcid.org/0000-0003-3803-0662

Author contributions

All authors contributed to the design of the open-circuit respiration chambers. JT constructed the chambers. OD and RMT performed the recovery tests and collected the data. OD and RMT drafted the paper. All authors read and approved the final manuscript.

Declaration of interest

NA.

Acknowledgements

Sylvie Giger-Reverdin, Rafael Muñoz-Tamayo and Joseph Tessier are very grateful to Dr. David Yañez-Ruiz (CSIC, Spain) and Dr. Carlos Fernández Martínez (UPV, Spain) who kindly allowed them to visit their methane experimental facilities. These visits were central in providing key elements for the design of the experimental facility at INRAE. Ophélie Dhumez and Rafael Muñoz-Tamayo thank Mr Sylvain Poullette (Gruter & Marchand, France) for his valuable technical support and timely expert advice in the setting up of our experimental facility.

Financial support statement

Rafael Muñoz-Tamayo acknowledges the financial support provided by AgroParisTech and INRAE Phase department for the construction of the experimental facility.

Reader comments

We invite you to comment on the article on the PubPeer platform by clicking on this link discuss this article.

References

Eugène, M., Guyader, J., 2016. Application note 17 - Measuring CH4 and CO2 emissions from ruminants in partially open enclosures. In: Hassouna, M., Eglin, T. (Eds.), Measuring Emissions from Livestock Farming: Greenhouse Gases, Ammonia and Nitrogen Oxides. INRA-ADEME, France, pp. 103–105.

Gardiner, T.D., Coleman, M.D., Innocenti, F., Tompkins, J., Connor, A., Garnsworthy, P. C., Moorby, J.M., Reynolds, C.K., Waterhouse, A., Wills, D., 2015. Determination of the absolute accuracy of UK chamber facilities used in measuring methane emissions from livestock. Measurement 66, 272–279. https://doi.org/10.1016/j.measurement.2015.02.029.

Gerrits, W., Labussière, E., Dijkstra, J., Reynolds, C., Metges, C., Kuhla, B., Lund, P., Weisbjerg, M.R., 2018. Recovery test results as a prerequisite for publication of gaseous exchange measurements. Animal 12, 4. https://doi.org/10.1017/S1751731117002397.

Gerrits, W.J.J., Labussière, E., 2015. Indirect calorimetry: Techniques, computations and applications. Wageningen Academic Publishers, Wageningen, The Netherlands. 10.3920/978-90-8686-809-4.

Hammond, K., Crompton, L.A., Bannink, A., Dijkstra, J., Yanez-Ruiz, D.R., O'Kiely, P., Kebreab, E., Eugene, M.A., Yu, Z., Shingfield, K.J., Schwarm, A., Hristov, A.N., Reynolds, C.K., 2016. Review of current in vivo measurement techniques for quantifying enteric methane emission from ruminants. Animal Feed Science and Technology 219, 13–30. https://doi.org/10.1016/j.anifeedsci.2016.05.018.

Hart, K., Yañez-Ruiz, D., Martin-Garcia, A., Newbold, C., 2014. Chapter 5: Sheep Methane Chambers at Aberystwyth University (UK) and CSIC (Spain). In: Pinares, C., Waghorn, G. (Eds.), Technical Manual on Respiration Chamber Designs. Ministry of Agriculture and Forestry, Wellington, New Zealand, pp. 77–88.

Pinares-Patiño, C., Hunt, C., Martin, R., West, J., Lovejoy, P., Waghorn, G., 2014. Chapter 1: New Zealand Ruminant Methane Measurement Centre, AgResearch, Palmerston North. In: Pinares, C., Waghorn, G. (Eds.), Technical Manual on Respiration Chamber Designs. Ministry of Agriculture and Forestry, Wellington, New Zealand, pp. 10–28.