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A comparison of methane emissions from beef cattle measured using methane hoods with those measured using respiration chambers

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ABSTRACT

The methane hood (MH) system is a novel method of quantifying methane (CH_4) emissions from cattle during feeding. The MH system measures CH_4 concentrations exhausted from beneath a hood designed to partially enclose the volume above a feed bin. To test the system two experiments were conducted on two groups ($n = 84$ and 80) of finishing beef cattle of differing breeds, whereby CH_4 measurements taken over 56 days using the MH system were compared to CH_4 output measured subsequently on the same animals using respiration chambers (RC). The primary objective of this study was to compare the MH and RC measurements and to develop an equation to predict CH_4 measured in RC from measurements taken during group feeding. The second objective was to determine whether the MH system could detect dietary treatment effects from diets designed to reduce CH_4 emissions. In experiment 1, cross-bred Charolais and purebred Luing steers were offered 2 contrasting diets consisting of forage to concentrate ratios (g/kg DM) of 500:500 (Mixed, M1) and 80:920 (Concentrate, C1). Within each diet there were 3 treatments: (i) Control, (ii) Nitrate (calcium nitrate with 77% nitrate on a DM basis), and (iii) Rapeseed cake (higher fat content). Both the MH and RC measurements detected differences in CH_4 emissions between diets M1 and C1 ($P < 0.001$), and between the Control and Nitrate treatments within diet M1 ($P < 0.05$). In experiment 2, cross-bred Aberdeen Angus and cross-bred Limousin steers received the same Mixed diet (M2) with 4 treatments containing nitrate and/or high oil in a 2×2 factorial arrangement: (i) Control, (ii) Nitrate, (iii) Maize dark grains (higher fat content) and (iv) Combined (both nitrate and higher fat). Again, both the MH and RC measurements detected reductions in CH_4 emissions from animals receiving treatments amended with nitrate ($P < 0.001$). However, only the MH measurement technique detected differences when animals received treatments with higher fat contents ($P < 0.001$). Using the CH_4 concentrations measured by the MH system and the dry matter intake (DMI) measured during the 56 days test period prediction models for individual animal daily CH_4 output were developed and subsequently validated. The best prediction model produced a good correlation between predicted and measured CH_4 output ($R^2 = 0.77$, $P < 0.001$), with a concordance correlation coefficient of 0.84. We conclude that the MH system can be used to estimate the effects of dietary mitigation strategies on CH_4 emissions. Furthermore, the predicted CH_4 output from MH measurement supports the use of this system as a tool for the genetic selection of cattle based on CH_4 emissions.

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1. Introduction

Global atmospheric concentrations of methane (CH_4) are increasing, with a global average concentration of 1774 ppb CH_4 in 2005 compared with a 715 ppb pre-industrial value (IPCC, 2013). To meet the food demands of the increasing world population (expected to be 10.9 billion by 2100; United Nations, 2013), global meat production in 2050 is projected to be 75% higher than 2005 (Alexandratos and Bruinsma, 2012). Meeting this demand for food, whilst reducing the environmental impact of livestock, is a significant challenge; without additional policies CH_4 emissions are predicted to increase 1.6-fold from 2005 to 2030 (IPCC, 2013). Globally, emissions from livestock production are estimated at 7.1 Gt CO_2-equivalent per annum, with beef production responsible for 2.9 Gt CO_2-equivalent (Gerber et al., 2013). Methane emissions account for 44% of the total GHG emissions from beef production systems and are primarily affected by feed intake and quality. Mitigation strategies for enteric CH_4 emissions fall into 3 broad areas; nutrition (e.g., through feed additives and diet manipulation), breeding and management (Cottle et al., 2011; Grainger and Beauchemin, 2011). Nutritional strategies to reduce enteric CH_4 emissions are the most developed and most likely to be applied in the field (Martin et al., 2010). Accurate measurements of CH_4 emissions are therefore required in order to develop and test the effectiveness of CH_4 mitigation strategies.

Various methods of measuring CH_4 emissions from ruminants have been developed, each with their own advantages and disadvantages. Housing animals in respiration chambers (RC) has long been used to precisely measure the emissions from individual ruminants. However, this method is time consuming and expensive, and the animal's behaviour may be altered while confined individually in the RC resulting in emissions values that do not accurately relate to emissions from their normal environment. There is interest in developing new methods of estimating CH_4 emissions from ruminants which have a larger throughput than RC and can be used without removing the animals from the regular production systems. The sulphur hexafluoride (SF_6) technique is used successfully to estimate CH_4 emissions from individual ruminants at grazing (Hulshof et al., 2012; McGeough et al., 2010). However, this technique requires the insertion of a permeation tube containing SF_6 gas into the rumen, the attachment of a gas collection apparatus to each animal. It is also labour intensive and requires daily handling of the animals. Other methods such as micro-meteorological dispersion methods can be used to estimate emissions from groups of animals in outdoor conditions (Tomkins et al., 2011). However, these techniques cannot measure emissions from individual animals, nor can they be used for indoor housed animals. Furthermore, the scale of micro-meteorological techniques makes their use difficult for testing mitigation options (McAllister et al., 2011).

Recently, a number of studies have attempted to directly measure exhaled CH_4 concentrations to estimate CH_4 output (g/d) and yield (g/kg DMI) from dairy and beef cattle. Chagunda et al. (2013) and Ricci et al. (2014) successfully estimated CH_4 emissions using a hand-held laser CH_4 detector based on infra-red absorption spectroscopy, targeted at the nostrils of dairy cows and beef steers, respectively. This method is relatively inexpensive and large groups of animals can be measured in a short time period. However, it requires a trained person to stand and point the detector at individual animals, and it can be affected by atmospheric conditions, particularly wind. Recently, a number of studies comparing CH_4 emissions measured using the GreenFeed system (C-Lock Inc. Rapid City, USA) with subsequent RC measurements from the same animals (Hammond et al., 2015; Velazco et al., 2015) found that the average CH_4 output measured using both techniques were similar. Other studies have exploited the fact that dairy cows are confined a number of times daily during milking to their advantage (Garnsworthy et al., 2012; Lassen et al., 2012). Garnsworthy et al. (2012) accurately predicted the CH_4 yield of dairy cows by measuring CH_4 concentrations in breath samples taken regularly in a semi-enclosed headspace during milking. Supplements are offered to the cows at milking and air samples are taken from close to the animals head. However, this technique is not directly applicable to beef animals in group housing.

A novel methane hood (MH) technique has been developed to measure CH_4 concentrations from group-housed animals during feeding. The primary objective of this study was to compare CH_4 measurements for large groups of finishing beef cattle across two experiments from this MH system to CH_4 output measured using RC, in order to develop a CH_4 output prediction equation from MH measurements. The second objective was to investigate whether differences in CH_4 emissions resulting from dietary CH_4 mitigation strategies could be detected by the MH system.

2. Materials and methods

Respiration chamber data from two experiments were used in this study (Troy et al., 2015 and unpublished) in which finishing beef steers were fed a range of dietary treatments. In both experiments CH_4 measurements were taken over a period of 8 weeks using the MH system while the animals were housed in groups. Following the MH measurement phase, individual animal daily CH_4 outputs from the same animals were measured using 6 respiration chambers. Throughout both

Abbreviations: C1, high concentrate diet of experiment 1; CH_4, methane; CMB, combined dietary treatment; CTL, control dietary treatment; DMI, dry matter intake; GHG, greenhouse gas; M1, mixed forage and concentrate diet on experiment 1; M2, mixed forage and concentrate diet on experiment 2; MDG, maize dark grains dietary treatment; MH, methane hood; MH-MPR, methane production rate measured by the methane hood system; MH-Yld, methane production rate corrected for dry matter intake; NIT, nitrate dietary treatment; RC, respiration chamber; RSC, rapeseed cake dietary treatment.

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