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Methane Emissions from Dairy Cows Measured Using the Sulfur Hexafluoride (SF_6) Tracer and Chamber Techniques

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ABSTRACT

Our study compared methane (CH_4) emissions from lactating dairy cows measured using the sulfur hexafluoride (SF_6) tracer and open-circuit respiration chamber techniques. The study was conducted using 16 lactating Holstein-Friesian cows. In each chamber, the cow was fitted with the SF_6 tracer apparatus to measure total CH_4 emissions, including emissions from the rectum. Fresh ryegrass pasture was harvested daily and fed ad libitum to each cow with a supplement of 5 kg of grain/d. The CH_4 emissions measured using the SF_6 tracer technique were similar to those using the chamber technique: 331 vs. 322 g of CH_4/d per cow. The accuracy of the SF_6 tracer technique was indicated by considering the ratio of the CH_4 emission measured using the SF_6 tracer to the emission measured using the chamber for each cow on each day. The calculated ratio of 102.3% (SE = 1.51) was not different from 100%. A higher variability within cow between days was found for the SF_6 tracer technique [coefficient of variation (CV) = 6.1%] than for the chamber technique (CV = 4.3%). The variability among cows was substantially higher than within cows, and was higher for the SF_6 technique (CV = 19.6%) than for the chamber technique (CV = 17.8%). Our CH_4 emission data were compared with whole-animal chamber studies conducted in Canada and Ireland. In the Canadian study the SF_6 technique did not measure CH_4 emissions from the rectum and emissions were 8% lower than those measured using the chamber, indicating that emissions from the rectum may be greater than previously measured (1%). The relationship between CH_4 emission and dry matter intake was examined for our data and for that reported in the Canadian study. There was a difference in the slopes of the regressions derived from our data and that from Canada; 17.1 vs. 20.8 g of CH_4/kg of dry matter intake. A difference between the 2 locations was expected based on the difference in diet composition for these 2 studies. The SF_6 tracer technique is reasonably accurate for inventory purposes and for evaluating the effects of mitigation strategies on CH_4 emissions.
Key words: chamber, dairy cattle, methane, sulfur hexafluoride

INTRODUCTION

There is a need to accurately measure enteric methane (CH_4) emissions from cattle because these emissions account for about 15% of global CH_4 emissions (Lassey et al., 1997). Methane is an important greenhouse gas having many times the global warming potential of CO_2 (IPCC, 2001). Methane emissions can be accurately measured by placing animals in sealed chambers with appropriate measures of gas flow and composition (Blaxter and Clapperton, 1965; Moe and Tyrrell, 1979); however, diets eaten by cows in chambers may differ from that selected by grazing animals (Clark, 2002). The majority of ruminants graze under extensive conditions, are free ranging, and select a variety of forage types. Their CH_4 production must be determined to calculate inventory. The sulfur hexafluoride (**SF_6**) tracer technique is often used to measure CH_4 emissions from grazing ruminants (Johnson et al., 1994; Lassey et al., 1997; Woodward et al., 2006), and although data appear to be defensible and repeatable, additional validation would provide a degree of certainty to CH_4 inventory.

Studies with beef cattle and sheep indicate that CH_4 estimated with the SF_6 tracer technique is 93 to 95% of that measured using whole-animal chambers (Johnson et al., 1994; Ulyatt et al., 1999; McGinn et al., 2006) and 105% of that measured using hood chambers (Boadi et al., 2002). The lower estimates using the SF_6 tracer technique are partly explained by the CH_4 released

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Table 1. Mean DMI, BW, BCS, and production of milk and milk composition for cows during the calorimetry period (n = 16)

Item	Mean	SD
DMI, kg/d		
Grain	4.4	0.53
Forage	13.8	2.71
BW, kg	496	57.5
BCS[1]	4.5	0.09
Milk yield, kg/d	22.3	3.78
Protein yield, kg/d	0.72	0.099
Protein, %	3.24	0.175
Fat yield, kg/d	0.91	0.146
Fat, %	4.08	0.451

[1]Based on an 8-point scale (Earle, 1976).

via the rectum (Murray et al., 1976). No comparisons between SF_6 and chamber techniques have been made with dairy cows at higher intakes and including rectal methane.

The objective of this study was to compare the SF_6 tracer gas technique to the chamber technique for measuring total enteric CH_4 emissions from lactating dairy cows. The use of the SF_6 tracer gas technique within the chambers enabled a direct comparison between the 2 techniques and included CH_4 both respired and released from the rectum.

MATERIALS AND METHODS

Cows and Experimental Design

Sixteen Holstein-Friesian cows were used to compare CH_4 emissions estimated using the respiration chamber and SF_6 tracer techniques. The cows were from the experimental herd at the Department of Primary Industries, Victoria, Ellinbank Research Centre (latitude 38°14′36.4″, longitude 145°56′09.5″) and were part of a larger study to evaluate the effects of monensin sodium on methanogenesis. They were normally pastured year round on a predominantly ryegrass sward and milked twice daily. Cows chosen for the experiment were of mixed age and had previously been trained to accept halters and headstall restraint. The experiment was conducted during November and December (late spring to early summer) 2005. Half of the cows had controlled-release monensin capsules placed into their rumens (Elanco Animal Health, Greenfield, IN) before starting the experiment. The effect of monensin on methane emissions will be reported elsewhere. Mean BW, BCS (according to the 8-point scale described by Earle, 1976), and milk yield and composition for cows used in the experiments are presented in Table 1.

Methane measurements were undertaken on pairs of cows (one with and one without a monensin slow-release capsule) over a 36-d period, with animals moved from the main herd to a metabolism facility and then placed in individual chambers. The cows were initially held in metabolism stalls for 4 d and each cow was fitted with a body harness and collection apparatus to enable separate collection of urine and feces. This adaptation period facilitated a smooth transition into the chambers where CH_4, intake, milk, feces, and urine production were measured over 3 d. There were 2 chambers and cows progressed through the experiment in pairs, 1 in each chamber. Every fourth day was reserved for cleaning and servicing the chambers. While one pair of cows was in the chambers, the next scheduled pair was brought into the metabolism stalls in readiness.

Animal Husbandry

Inside the chambers, cows were restrained by neck halters anchored to the floor. The harnessing device permitted feces and urine to be collected at the rear of the cow into separate collection vessels that were emptied each day. The apparatus allowed the cow to lie down on a padded mattress within the stall. Windows between the chambers enabled visual contact with the cow in the adjacent chamber and the surrounding environment.

Cows were milked twice daily using a portable milking apparatus in both the metabolism stalls and the chambers. Milking and feeding the cows in the chambers necessitated opening the chamber doors, thereby disrupting gas measurements. Milk weights were measured and subsampled into bronopol (0.5% wt/wt) preservative and analyzed for concentrations of fat and protein using a near-infrared milk analyzer (model 2000, Bentley Instruments, Chaska, MN).

The bulk of the cows' diet was fresh ryegrass pasture that was harvested daily. When cows were in the metabolism stalls or chambers, fresh pasture was placed in the feed bins twice daily to ensure ad libitum intake. When cows were in the chambers, the feed was provided while the chamber doors were open for milking. Cows also received 5 kg/d of cracked barley (as-fed basis) in 2 feedings. All feed offered and refused was weighed daily. Samples of feed and refusals were dried to determine DM content, and total daily DMI was calculated per cow (Table 1). Representative samples of the pasture and grain were collected daily and pooled to form 4 samples of each feed over the 32-d measurement period. The samples were oven dried and ground through a 0.5-mm sieve, then analyzed by near-infrared spectroscopy by a commercial laboratory (FeedTest, Hamilton, Victoria, Australia). The pasture contained 71.1 ± 1.2% apparently digestible DM, 16.4 ± 1.0% CP, and 54.4 ± 0.9% NDF, on a DM basis. The grain contained 85.8 ±