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Comparison of methods to determine methane emissions from dairy cows in farm conditions

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ABSTRACT

Nutritional and animal-selection strategies to mitigate enteric methane (CH_4) depend on accurate, cost-effective methods to determine emissions from a large number of animals. The objective of the present study was to compare 2 spot-sampling methods to determine CH_4 emissions from dairy cows, using gas quantification equipment installed in concentrate feeders or automatic milking stalls. In the first method (sniffer method), CH_4 and carbon dioxide (CO_2) concentrations were measured in close proximity to the muzzle of the animal, and average CH_4 concentrations or CH_4/CO_2 ratio was calculated. In the second method (flux method), measurement of CH_4 and CO_2 concentration was combined with an active airflow inside the feed troughs for capture of emitted gas and measurements of CH_4 and CO_2 fluxes. A muzzle sensor was used allowing data to be filtered when the muzzle was not near the sampling inlet. In a laboratory study, a model cow head was built that emitted CO_2 at a constant rate. It was found that CO_2 concentrations using the sniffer method decreased up to 39% when the distance of the muzzle from the sampling inlet increased to 30 cm, but no muzzle-position effects were observed for the flux method. The methods were compared in 2 on-farm studies conducted using 32 (experiment 1) or 59 (experiment 2) cows in a switch-back design of 5 (experiment 1) or 4 (experiment 2) periods for replicated comparisons between methods. Between-cow coefficient of variation (CV) in CH_4 was smaller for the flux than the sniffer method (experiment 1, CV = 11.0 vs. 17.5%, and experiment 2, 17.6 vs. 28.0%). Repeatability of the measurements from both methods were high (0.72–0.88), but the relationship between the sniffer and flux methods was weak ($R^2 = 0.09$ in both experiments). With the flux method CH_4 was found to be correlated to dry matter intake or body weight, but this was not the case with the sniffer method. The CH_4/CO_2 ratio was more highly correlated between the flux and sniffer methods ($R^2 = 0.30$), and CV was similar (6.4–8.8%). In experiment 2, cow muzzle position was highly repeatable (0.82) and influenced sniffer and flux method results when not filtered for muzzle position. It was concluded that the flux method provides more reliable estimates of CH_4 emissions than the sniffer method. The sniffer method appears to be affected by variable air-mixing conditions created by geometry of feed trough, muzzle movement, and muzzle position.

Key words: concentration, dairy cow, flux, methane

INTRODUCTION

Ruminants are increasingly scrutinized for their contributions to greenhouse gas emissions. Ruminants account for up to one-third of the anthropogenic methane (CH_4) emissions worldwide (IPCC, 2006). Interest has increased in developing various mitigation strategies such as dietary manipulation, additives, and vaccines. In practice, dietary manipulation may still be the most promising. Genetic selection has also been proposed as a strategy to reduce CH_4 emissions from ruminant production systems (e.g., Hegarty et al., 2010; Pinares-Patiño et al., 2013).

Several methods have been developed to measure CH_4 emissions from ruminants. All methods have different scopes of applications, advantages, and disadvantages, and none of them is perfect in all aspects. Respiration chambers provide an accurate reference method used for research purposes. Individual animals are confined in chambers usually for 2 to 4 d, and CH_4 emissions are calculated from gas flow and changes in gas concentrations between air inlet and outlet (Yan et al., 2010; Hellwing et al., 2012). The chamber method has both high investment and labor costs, and it could be criticized of distorting feeding behavior. However, no effects on DMI were observed in studies using transparent chambers (Hellwing et al., 2012). The sulfur hexafluoride (SF_6) tracer technique (Johnson et al., 1994) generates values for CH_4 flux that are correlated with chamber measurements, but the between-cow variability was greater than with chamber measurements

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(Grainger et al., 2007; Pinares-Patiño et al., 2011). The method is also relatively labor intensive and, therefore, not suitable for ranking a large number of animals.

More recently, several alternative methods for on-farm measurements based on spot sampling have been proposed. These methods are based on continuous breath analysis of exhaled air from the feed troughs in automatic milking systems (**AMS**) or concentrate feeders (**CF**). In one application (sniffer method), a sampling inlet is placed in the feed trough of an AMS, and gas concentrations in exhaled air are continuously sampled. Following this principle, Garnsworthy et al. (2012) developed an on-farm method based on an index of CH_4 emission that is calculated during each milking as the product of peak frequency and mean peak area of CH_4 concentration. In another similar application of the sniffer method, CH_4 and CO_2 concentrations are used to derive a CH_4/CO_2 ratio, which is then multiplied by estimated CO_2 production to predict CH_4 fluxes (Madsen et al., 2010; Lassen et al., 2012). A recently patented gas-flux quantification system (GreenFeed; C-Lock Inc., Rapid City, SD) was implemented in feed troughs of AMS or in CF. This system uses a similar principle for measuring gas emissions as for respiration chambers (flux method) where an active airflow is induced to capture emitted air. This system integrates measurements of air flow, gas concentrations, and detection of muzzle position to allow direct measurement of CH_4 and CO_2 fluxes to be measured during each animal visit to the feed trough.

Studies using the sniffer method have reported emissions with relatively high between-animal CV (Garnsworthy et al., 2012; Lassen and Løvendahl, 2013; Bell et al., 2014a) compared with data from studies using respiration chambers (Blaxter and Clapperton, 1965; Yan et al., 2010) or the flux method (Zimmerman et al., 2013). These results suggest that the sniffer method may result in a greater CV compared with the flux method based on spot sampling. The objective of this study was to evaluate CH_4 emissions estimated by the sniffer and flux methods. Specific objectives were to assess relationships of emissions between the 2 methods, repeatability of gas measurements, and suitability of methods to sort or rank animals according to CH_4 emissions.

MATERIALS AND METHODS

A laboratory verification study and 2 on-farm studies were conducted to compare the sniffer and flux methods. The laboratory study assessed the influence of various animal- and environment-related factors that can influence the measurements of captured gas under controlled laboratory conditions. The 2 on-farm studies were conducted to assess methods under typical farm conditions. One farm study implemented a CF (experiment 1) that provided concentrates to each animal multiple times per day. The other farm study implemented the same gas quantification system retrofitted in the feed trough of an AMS (experiment 2).

Equipment

A data-acquisition system was used (C-Lock Inc.) that recorded ambient pressure, temperature, humidity, CH_4 and CO_2 concentrations by nondispersive infrared sensors (max span: CO_2 = 0–4%, CH_4 = 0–2%), muzzle position, pipe airflow rate (flux method only), and radiofrequency identification ear tags specific to each cow. All variables were logged at 1-s intervals.

For the laboratory study, and one farm study (experiment 1), the data-acquisition system was built into a specialized semienclosed CF manufactured by C-Lock Inc. (Figure 1). In the AMS farm study (experiment 2), the data-acquisition system and sensors were custom fit into the existing feed trough of an A3 Astronaut milking unit (Lely Industries N. V., Maassluis, the Netherlands), using a specially designed air-collection manifold (Figure 2). All gas sensors were the same between the CF and AMS, with the primary difference being the geometry of the feed trough.

The volume of the feed trough was larger in the AMS than in the CF (70 vs. 30 L). Therefore, while a cow is using the AMS, the cow can more easily move its muzzle out of the feed trough by lifting it quickly upward or side to side. In contrast, in the CF, the cow must step backward to remove the muzzle, therefore limiting the in–out head movement. In an AMS, the cows are locked in the milking stall until milking is complete. In most cases cows may not eat all of the delivered concentrates, or they may eat all delivered concentrate before milking is finished. Because of the difference in geometry of manifolds and muzzle movement, different sensors were used to determine muzzle position relative to the air-sampling inlet. In the CF, an infrared distance sensor was placed inside the feed trough just above the sampling inlet to scan outward and measure the distance between the muzzle and sampling inlet. In the AMS, an infrared beam sensor was positioned inside the trough so when the muzzle of the cow broke the beam a signal was sent to the data logger (Figure 2), which allowed for the determination of the duration of time the head was inside the feed trough during each milking period.

Equipment Setup. Subsampling of air for the sniffer method was extracted at approximately 1 L/min close to the muzzle of the cow, either directly in the middle of the feed trough for the CF (Figure 3) or on the left side