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The Use of Sniffer Analyzer to Measure Enteric Methane Emissions Under Commercial Conditions in Dairy Cow

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Abstract

Enteric methane emissions are the largest source of agricultural greenhouse gases (GHGs), presenting a major challenge due to methane's high global warming potential and short atmospheric lifespan. Primarily produced in the rumen during fiber digestion by methanogenic archaea, methane (CH_4) emissions must be accurately quantified to develop effective mitigation strategies. While reference methods, such as the use of metabolic chambers (MC), offer high precision, they are impractical for use under commercial farm conditions. This study was conducted over 28 days and evaluates the use of a sniffer analyzer for continuous, non-invasive CH_4 measurement across 46 dairy cows under commercial conditions. The method allows the collection of a large dataset from a high number of productive animals (average milk yield 40.36 kg±11.15 kg) and demonstrates good accuracy in on-farm settings. Results show an average CH_4 emission of 368 ppm daily, with 32% variability between individual cows, allowing for the identification of "efficient" cows-those with high milk production and lower CH_4 emissions. Integrating further metrics like dry matter intake (DMI) and body weight (BW) would enrich insights into methane output. The sniffer analyzer thus shows promise as a scalable tool for methane monitoring, advancing environmental sustainability in dairy production.

Keywords: Methane; Emission; Sniffer; Ruminants

Abbreviations: AMS: Automatic dairy system BW: Body weight; CH4: Methane DIM: Days in milk; DMI: Dry matter intake GHG: Greenhouse gases MC: Metabolic chamber TMR: Total Mixed Ration

Introduction

Methane emissions from enteric fermentation account for a significant part of greenhouse gas (GHG) emissions in the livestock sector, comprising 46% of total emissions [1]. These emissions contribute from 2 to 4% to global warming [2]. In France, they represent 45% of livestock-related emissions [3]. Although released in smaller quantities than carbon dioxide (CO_2), methane (CH_4) has a global warming potential from 28 to 34 times greater over a 100-year period and a relatively short atmospheric lifespan of around 12 years [4].

Methane is produced in the rumen by methanogenic archaea during the digestion of carbohydrates, with 95% expelled through eructation (Glasson et al., 2022). Mitigating methane emissions is crucial for reducing livestock's environmental impact. Various strategies, such as genetic selection, diets changes, and feed additives inclusion, are being explored. Feed additives show promising impact due to their quick action, but their effects need to be validated in real-world conditions. However, large-scale in vivo studies in commercial farms are limited due to the lack of practical measurement tools.

Current reference methods for measuring methane emissions include respiratory chambers, the SF6 tracer gas method, and the Greenfeed system. While highly accurate, each method has significant limitations when applied to commercial farming. Respiratory chambers, considered the gold standard, require animals to be confined in a sealed environment, which not only disrupts normal behaviors but also limits the scale of testing to small groups and makes routine farm integration challenging. The SF_6 tracer gas method, though slightly more flexible, involves inserting a bolus into the animal's rumen to release the gas, which is then tracked to estimate methane output. However, SF_6 itself has a global warming potential far exceeding that of CO_2, raising environmental concerns. Furthermore, this method is costly and operationally complex, requiring specialized equipment and posing logistical challenges for on-farm applications. The greenfeed system, which combines a feeding station with gas measurement, is less invasive but requires extensive animal training, and some animals never interact with it, leading to incomplete data coverage. Additionally, visit frequencies can be inconsistent, leading to irregular sampling that may not fully capture daily methane emission patterns [5].

Given these limitations, there is a growing need for a practical, non-invasive, and cost-effective tool that can be readily implemented on commercial farms. Recently, sniffer analyzers, originally developed for industrial emission monitoring, have shown potential in dairy farm settings as a feasible alternative. Studies by Garnsworthy et al [6] et Lassen et al. [7] have demonstrated that sniffer analyzers can provide reliable, large-scale measurements of methane emissions, offering a scalable solution that maintains accuracy while reducing costs and operational complexities.

This study evaluates the use of a sniffer analyzer as a practical tool for measuring methane emissions in dairy cows under commercial conditions, aiming to facilitate data collection and improve environmental sustainability in dairy farming.

Materials and Methods

Animal's characteristics

The study was carried out on a commercial farm located in Torce´, Brittany, France. A total of 46 Prim'Holstein cows were included in this study, with an average of 148 days in milk (DIM) (±85 days), averaging 2.7 lactations (± 1.6), and producing an average of 40.36 kg of milk per day (±11.15 kg). The cows were housed in a free-stall barn with ad libitum access to feeding. The diet consisted of a total mixed ration (TMR) based primarily on maize and grass silage, providing an intake of 27 kg of dry matter (DM) per cow per day. Additionally, a 80% maize and 20% barley concentrates were dispensed through the automatic milking system (AMS), with the quantity adjusted according to each cow's lactation stage and milk yield.

Methane measurements

Methane (CH_4) emissions were measured using a Gasmet DX4015 Fourier Transform Infrared (FTIR) gas analyzer, which was integrated into the feeding kiosk of an AMS on a commercial dairy farm. This setup allowed for continuous monitoring of gas emissions from individual cows. CH_4 was analyzed every 11.5 seconds per cycle. For each measurement, data including the cow's identification (ID), date, time, and gas concentrations were automatically recorded. In this study, methane concentration measurement was recorded for 28 days.

Results & Discussion

Profile of methane measurements

Given the average milking frequency of 2.5 visits per day per cow, and the average time spent inside the AMS of 7min45sec, multiple methane measurements were obtained from each animal daily, resulting in an average of 41.12 individual measurements per cow per day. Figure 1 presents sample data on CH_4 concentrations during milking sessions in the AMS, showing distinct eructation peaks for three cows. Variability in emission patterns between individuals is clearly observed. The black line (Cow 1) shows an irregular pattern with mostly low peaks and occasional higher peaks during the middle of milking. The dark grey line (Cow 2) exhibits a more regular pattern with consistent medium peaks, while the light grey line (Cow 3) displays an irregular pattern characterized by higher peaks. At the herd level, methane emissions show a variability of 32%. As observed in Bell et al [8], this variability can range from 22% to 67% depending on the farm.

Such individual variation in methane emission patterns, also noted by Jonker et al [9] and Negussie et al [10], may result from several factors. One key factor is the distance between the cow's head and the sniffer inlet. Since the AMS operates in a semi-open environment, cows are free to move their heads during milking. However, behavioral observations showed that only a few cows raised their heads during milking. Another possible factor is individual variability, including genetics, as all cows were on the same diet and measured at the same time of day [11].

Figure 2 illustrates how methane emissions vary within the day. Two significant peaks in CH_4 concentration occur following feed distribution at 7 a.m. and 7 p.m. Between these feeding times, as well as during the night, methane concentrations measured during milking were lower. These diurnal patterns align with findings from Huyen et al [12] and can be explained by the increased fiber digestion following feed distribution. The activity of methanogenic archaea spikes after feeding due to the greater availability of fermentable substrate, leading to higher methane emissions during these periods.

Herd characterization

Figure 3 shows the relationship between milk yield and methane emissions across all individuals, categorized by their stage of lactation. Circles represent cows in early lactation (<100 DIM), triangles those in mid-lactation (100-200 DIM), and cubes those in late lactation (>200 DIM). The figure identifies two distinct groups of high milk producers: one group that emits high concentrations of methane ("high emitters") and another group, referred to as "efficient," that produces high milk yields while emitting lower levels of methane. The threshold between these two groups is set at 368 ppm (±32 ppm) of average daily emitted CH4 concentration, as it represents the overall average of the group. Interestingly, the efficient cows are distributed across all lactation stages, with 4 in early lactation, 7 in mid-lactation, and 6 in late lactation, indicating that efficiency is independent from lactation stage.

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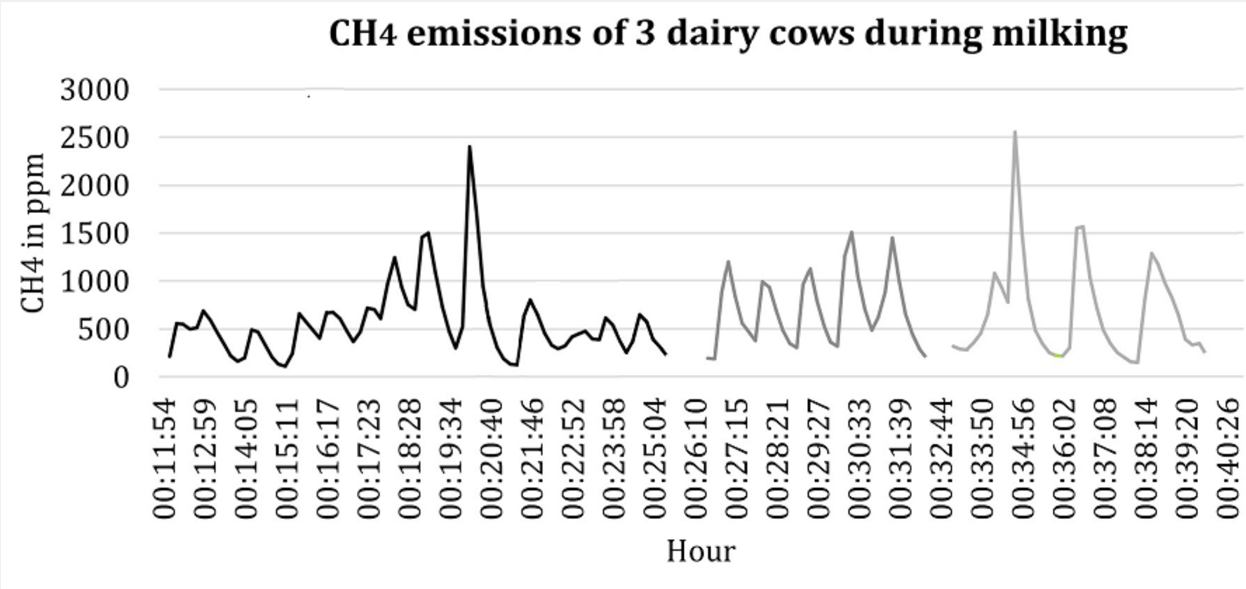

Figure 1: Data point of CH4 measured in ppm of 3 cows milked in the AMS, one color of spectra corresponding to one individual.

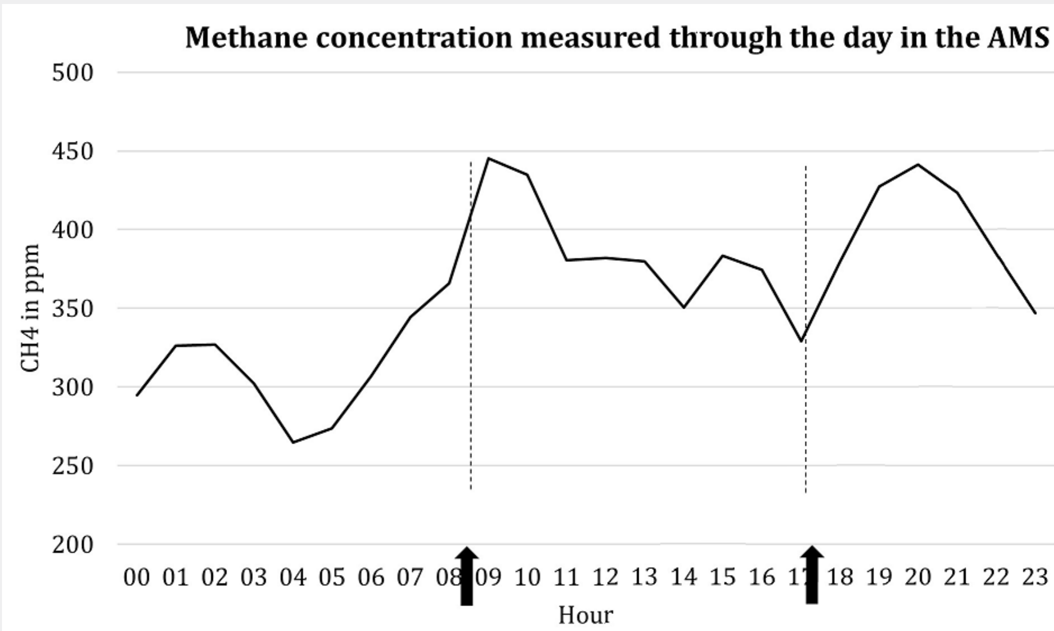

Figure 2: Evolution of the methane concentration sampled at different hour of the day

An analysis of variance (ANOVA) comparing methane emissions with lactation stage (DIM) variance revealed no significant correlation (p-value > 0.5), across the sampled dairy cows. The result suggests that DIM does not substantially impact methane emissions, pointing to other factors as primary influencers of emission variability.

The sniffer analyzer, used in this commercial setting, successfully classifies and identifies cows with different methane emission profiles. Identifying efficient animals—those producing high milk yields with lower methane output—could be valuable for breeding and management strategies. Additional data, such as dry matter intake (DMI) and body weight (BW), would allow for a

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deeper understanding and characterization of these low-emission individuals, though obtaining such data in commercial settings is challenging. Furthermore, this study covers a limited time frame of 28 days and did not measure potential diet variability, extending measurements over a longer period would provide a more comprehensive understanding of methane efficiency throughout lactation and contribute to more robust statistical results.

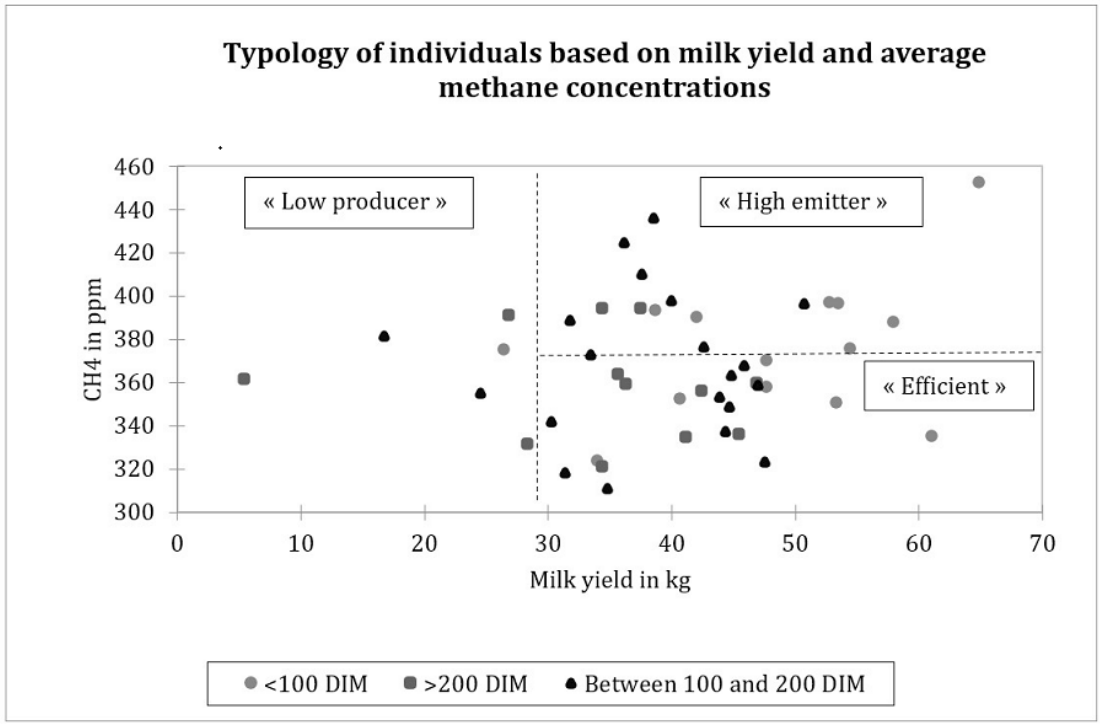

Figure 3: Typology of the individuals based on their methane emissions and their lactation stage; circles represent individual at early stage of lactation (<100 DIM), Squares represents individuals in late stage of lactation (>200 DIM) and triangle represents individuals between 100 and 200 DIM

Conclusion

This study highlights the potential of the sniffer analyzer as a practical, non-invasive tool for measuring enteric methane emissions in dairy cows under commercial conditions. The method successfully identified variations in methane emissions between cows, offering insights for strategies to improve environmental sustainability. While less invasive and costly than traditional methods, further research integrating additional data and long-term measurements, and potential diet variability is needed to improve the accuracy of the method. Overall, the sniffer analyzer provides a scalable solution for methane monitoring in commercial dairy farming.

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