Livestock CH4 Emissions with the Laser Methane Detector

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The handheld, portable laser methane detector (LMD) was developed to detect gas leaks in industry from a safe distance. Since 2009, it has also been used to measure the methane (CH4) concentration in the breath of cattle, sheep, and goats to quantify their CH4 emissions.

methane emission laser methane detector ruminants sensor

1. The Laser Methane Detector

The measurement with the Laser Methane Detector (LMD) (**Figure 1**a) is based on infrared absorption spectroscopy: it uses a semiconductor laser as a collimated excitation source and employs the second harmonic detection of wavelength-modulation spectroscopy for the measurement [1]. A visible guiding laser (Class 3 R laser, 532 nm) helps to direct the invisible measuring laser (Class 1 laser, 1653 nm) to the desired target. The integrated CH_4 concentration between the LMD and the target is measured by detecting a fraction of the diffusely reflected laser beam [2]. The measured value is expressed as CH_4 column density (ppm × m), i.e., a cumulative CH_4 concentration along the laser path or the average CH_4 concentration (ppm) multiplied by the length of the path (m) [3]. The LMD measures CH_4 in the range of 1 to 50,000 ppm × m (up to 5 vol-%) with an accuracy of ±10%, and can be used from a distance between 0.5 and 30 m and in a temperature range from −17 to +50 °C. It autocalibrates via an internal reference cell [4]. The LMD shows the data in real time on its display and optionally issues an acoustic and visual alarm if a certain threshold is exceeded. Data can be stored in a csv file on a wirelessly connected Android device running the GasViewer app [5]. This can be, for example, a mobile phone (smartphone) worn in an armband sleeve so that one person can operate the LMD and the app at the same time. It has been originally designed to detect CH_4 from gas leaks in mining, the petrochemical industry, and landfills. The studies cited here used a “LaserMethane mini-g,” a similar model or a previous model of the same series of LMD from the same manufacturer (Tokyo Gas Engineering Solutions, Tokyo, Japan).

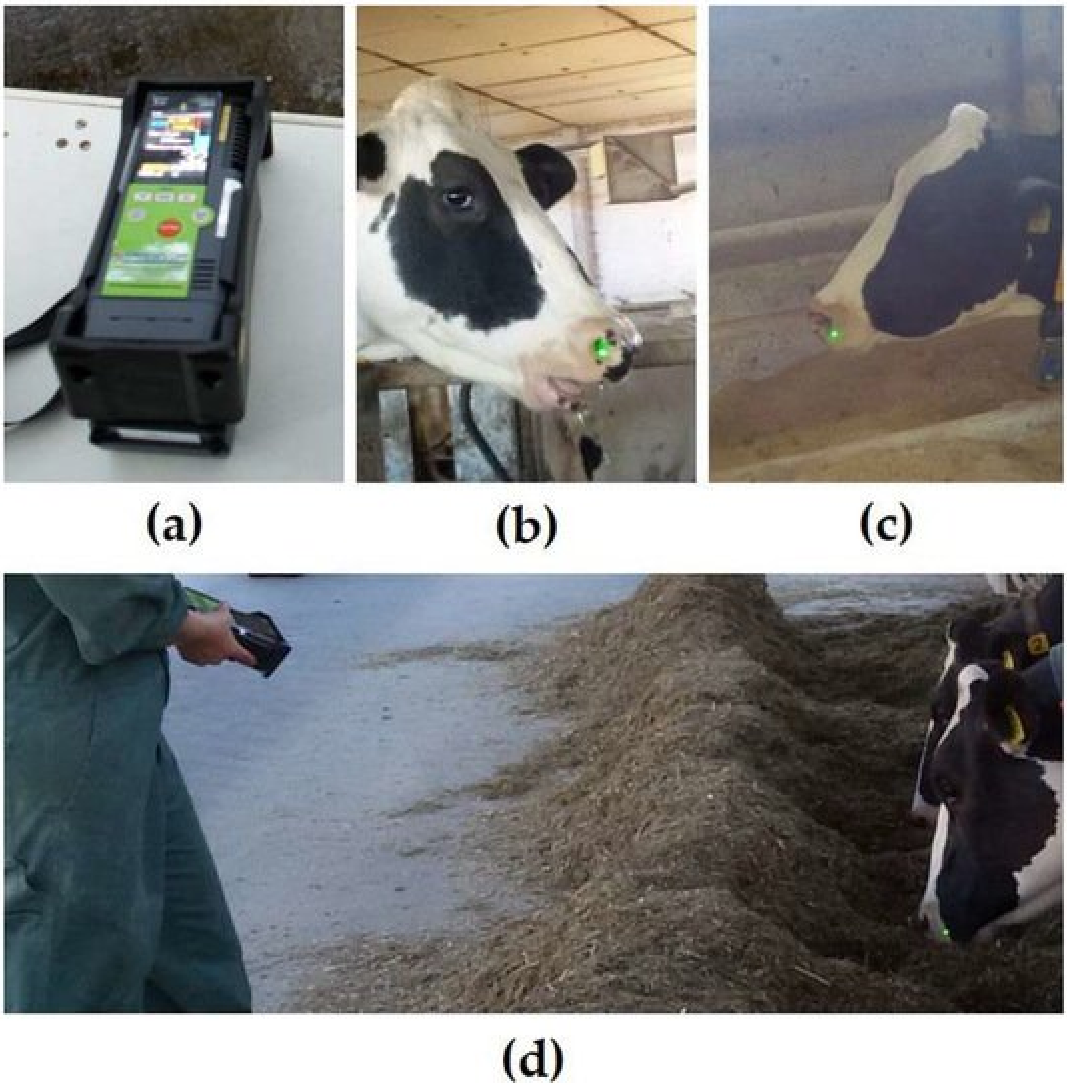

Figure 1. (**a**) A laser methane detector (LMD, Tokyo Gas Engineering Solutions, Tokyo, Japan). (**b**,**c**) cows in different positions with the visible guiding laser pointed at their nostrils. (**d**) measurement with the LMD (source: D. Sorg).

2. Applications

In several areas of ruminant research, there is a need to assess CH_4 emissions in order to develop mitigation measures or to obtain valuable information on the physiological and metabolic status of animals. Hence, the LMD has been successfully used for studies in various fields of animal science:

2.1. Genetics

In addition to the established and well-studied traits for animal performance, conformation, health and fertility, traits for feed efficiency and environmental impact have been studied for some time. Selective breeding for lower CH_4 emissions could make a valuable contribution to the set of mitigation strategies to achieve climate targets but requires data from a sufficient number of animals that are phenotyped and genotyped [6]. Such data must be obtained under on-farm conditions from a large sample of animals. Therefore, complex or invasive techniques with high accuracy such as the respiration chamber or sulphur heaxafluoride (SF_6) tracer gas methods are not suitable. The LMD is able to classify animals according to their CH_4 production and has therefore been used to calculate estimates of heritability (h^2) for several CH_4 phenotypes [7][8][9]. The results (0.01–0.23) are in the range of those obtained with other on-farm methods [10], although the standard errors are higher. The measurements with the LMD are more influenced by environmental conditions, resulting in higher variability of the recorded values. Furthermore, the number of animals that have been included in genetic evaluations based on LMD data so far is limited. With larger samples and a more standardised protocol for measurement and data analysis, estimates of h^2 are likely to improve.

2.2. Nutrition

Novel feeds and natural and synthetic feed additives are emerging CH_4-mitigation technologies with high commercialisation potential and a potentially large impact on CH_4 emissions in the future [11]. The effect of these feeds and feed additives needs to be validated in a large sample of animals under on-farm conditions. Among other methods, the LMD could be a valuable technique for their investigation. A few studies have successfully used the LMD to discriminate between different rations and feeding strategies at the group level [12][13][14]. Cameron et al. [15] measured the CH_4 production of dairy cows with the LMD and concluded that adding fresh grass or pasture to a total mixed ration reduced it by 17% and 39%, respectively, and could be a valuable tool to reduce CH_4 emissions. However, some researchers were unable to detect differences in CH_4 concentration or production measured with the LMD due to dietary components [16][17] despite their well-studied effect on methanogenesis [18].

Vrancken et al. [19] demonstrated the effectiveness of a novel feed additive to decrease CH_4 emissions from cows using LMD measurements. If such feed additives are to be used as mitigation measures in the future, their effect must be extensively demonstrated at the farm level. For this, the LMD could be a useful application.

2.3. Farming Systems and Breeds

Due to its relatively low cost, flexibility, and portability, the LMD can be used to systematically compare farms and farming systems in regions with limited access to research infrastructure or with animals on pasture. This was demonstrated by Pinto et al. [16], who were able to characterise access to pasture and different husbandry systems along an urban–rural gradient in India using CH_4 phenotypes obtained with the LMD. Grobler et al. [20] found breed differences ($p < 0.05$) in the CH_4 production of South African Jersey, Bonsmara, and Nguni cattle, while in the study by Mapfumo et al. [21] extensively reared African Boran and Nguni heifers showed no difference in CH_4 output per DMI. If the breed differences in CH_4 production are too small, the LMD may not be able to detect them.

2.4. Health and Metabolism

The correlation of physiological blood parameters with CH_4 production measured with the LMD has been investigated by Reintke et al. [22]: the blood concentrations of zinc, β-hydroxybutyrate, and unesterified fatty acids had a partly breed-specific significant ($p < 0.05$) influence on CH_4 concentrations.

For the applications described above, the LMD can be a complement to other established methods or an alternative in environments where more sophisticated and complex methods are not suitable. The LMD meets the requirement to measure variation over time (especially whole and consecutive lactation periods) in large numbers of animals without disrupting normal animal behaviour or farm management on commercial farms and limiting investment and maintenance costs [23] (pp. 34–35). It can be used for experiments where animals are to be categorized or ranked according to their CH_4 concentration—especially in genetic analyses—or where average values of CH_4 concentration or estimated CH_4 production at a group level are sufficient. For these purposes, large samples are recommended: many replicates per animal and/or many animals. A common protocol specific to each purpose would further improve the comparability of such studies and is also suggested by other researchers [24]. If possible, external validation with another on-farm method (e.g., GF, sniffer, or SF_6) or the newly developed “artificial cow” [25] should be attempted. It is not recommended to use the LMD if accurate values for absolute CH_4 production of individual animals are needed.

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