

Methane production in different breeds, grazing different pastures or fed a total mixed ration, as measured by a Laser Methane Detector

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Abstract

Agriculture is responsible for 5% to 10% of the global anthropogenic greenhouse gas (GHG) emissions. Livestock contribute about 65% of agricultural GHG and enteric fermentation accounts for 90% of this. The global warming potential of CH₄ is known to be 23 times more than that of carbon dioxide, resulting in it being a significant role player in the greenhouse gas family. The laser methane detector (LMD) is an instrument that has the potential to measure enteric CH₄ emission from livestock under normal husbandry activities. This study was aimed at evaluating the efficiency and results, when using the LMD to measure CH₄ production under normal production conditions. Twelve heifers, four each from the Bonsmara, Nguni and Jersey breeds, were subjected to grazing natural veld, forage sorghum under irrigation, oats pasture under irrigation or a total mixed ration. Measurements were taken late afternoon (18:00) when the animals were ruminating. Four repeated measurements, lasting 60 seconds each, were taken on 10 consecutive days on each of the production systems. The animals were adapted for a period of 14 days on the specific feed, before the measurements were taken. The Jersey heifers produced significantly less CH₄ than the Bonsmara and Nguni on natural veld, with no significant differences between breeds on the forage sorghum. On natural veld the heifers generated 48% more CH₄. These results thus indicate that the LMD produce sensible and repeatable measurements that can be interpreted in respect of CH₄ production by cattle. The next step will be to increase the number of breeds, numbers per breed, and feeding strategies over all seasons in order to validate and build up a baseline data set on the use of the LMD to measure CH₄ emissions from cattle under different grazing conditions.

Keywords: Heifers, methane emission, pastures, total mixed ration

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Introduction

Agriculture is responsible for 5% to 10% of the global anthropogenic greenhouse gas (GHG) emissions. Livestock contributes about 65% of agricultural GHG, and enteric fermentation accounts for 90% of this (Meissner *et al.*, 2012). The global warming potential of methane is 23 times more than that of carbon dioxide (CO₂), resulting in it being a significant role player in greenhouse gas production (Scholtz *et al.*, 2013). Methane, as part of the GHG family, can affect the climate directly through its interaction with long-wave infra-red energy and indirectly through atmospheric oxidation reactions that produce CO₂, a potent GHG. More recently, attention has been given to CH₄'s potential contribution to climatic change and global warming (Johnson & Johnson, 1995).

Enteric methane production is a by-product of ruminant anaerobic fermentation in the rumen and large intestine by microbes in a process called methanogenesis or biomethanation. The animals then release the methane into the atmosphere mainly by exhaling the gas through the mouth and nostrils. Enteric methane produced by cattle can thus be seen as a loss of feed energy from the diet and reflects the inefficient utilization of the feed (Wood & Knipmeyer, 1998). The production rate of enteric methane can vary, depending on the digestive system and level of feed intake of the individual animals, as well as type of carbohydrate in the diet, feed processing, addition of lipids or ionophores to the diet, alterations in the ruminal microflora and different animal activities (Chagunda, 2013).

The need for accurate estimates of enteric methane production in ruminants in different systems has been emphasized in a number of reports. Understanding the differences in enteric methane production from

ruminants in different production systems is important for developing mitigation strategies for the contribution of agricultural activities to the anthropogenic methane emission (Chagunda *et al.*, 2009). Current methods to measure CH₄ emissions from livestock include the use of respiration calorimetry chambers (Kelly *et al.*, 1994; Murray *et al.*, 1999), which provide accurate measures of methane emissions for limited numbers of animals under controlled conditions, but are impractical for use in a farm environment (Garnsworthy *et al.*, 2012). Tracer techniques (Johnson *et al.*, 1994; McGinn *et al.*, 2006), which are used under semi-commercial conditions, require a gas collection apparatus attached to the cow, insertion of rumen boluses to release SF₆, and frequent cow handling, which generally interfere with the cow's behaviour (Johnston *et al.*, 1994). Mass balance/micro-meteorological techniques, which range from the use of aircraft to sample methane concentrations at different levels in the atmosphere to paddock scale applications as well as prediction equations, have also been developed (Judd *et al.*, 1999; Lassey *et al.*, 2000; Laubach *et al.*, 2008; Teeranavattanakul, 2010). Therefore, researchers identified a need for an inexpensive, convenient and practical method of quantifying the amount of enteric methane produced by ruminants.

The use of a recently-developed, proprietary, laser methane detector (LMD) in dairy cows was first initiated and explored by Chagunda *et al.* (2009). The LMD is a hand-held gas detector for the remote measurements of the column density for methane containing gases (Tokyo Gas Engineering). The LMD instrument is based on infrared absorption spectroscopy, using a semi-conductor laser, as a collimated excitation source and employing a second harmonic detection of wavelength modulation spectroscopy to establish a methane concentration measurement.

The integrated concentration of methane between the equipment and the target point is then digitally displayed. The measured value is expressed as methane concentration, while taking into account the thickness of any methane plume. Hence, the measurements are expressed in parts per million-meter (ppm-m). The instrument normally operates in a temperature range of between 0 and 40 °C and in humidity range of 20% - 90% (Chagunda *et al.*, 2009). The LMD has subsequently been used extensively in detection applications, such as gas transmission networks, landfill sites and other areas where methane leakage or build-up is a risk (Crowcon, 2006).

Chagunda & Yan (2011) tested the degree of accuracy between the LMD and the indirect open-circuit respiration calorimetric chamber. The test was based on two different methods, i.e. Pearson correlation and an analysis of agreement based on the Bland and Altman methodology. The correlation coefficient of the LMD and the calorimeter chamber was high ($r = 0.8$) and positive. The Bland and Altman methodology demonstrated high levels of correlation between measurements of the LMD and the calorimeter chamber. Furthermore, inverse regressions provided sufficiently close estimates of the chamber measurements, based on the LMD readings (Chagunda & Yan, 2011).

Previous studies have concentrated solely on testing the LMD under indoor conditions, while Teeranavattanakul (2010) reported the effect of different environmental factors on the LMD measurements performed under outdoor conditions. Taking into account all the environmental factors investigated by Teeranavattanakul (2010), the current study was aimed at examining the laser methane detector, under normal natural cattle feeding conditions.

Materials and methods

Twelve heifers, four each of the Bonsmara, Nguni and Jersey breeds, grazing on natural sour veld, forage sorghum under irrigation, oats pasture under irrigation or fed a total mixed ration (TMR), were used and measurements were taken late afternoon (18:00), when the animals were ruminating. Measurements were taken on individual animals with a minimum radius of 3 m from any other animal. Gas column density, at a distance of 3 m from the animal, was measured by directing the auxiliary LMD targeting laser beam at the nostrils of the heifer. The 3 m distance was used to be able to measure methane production from the animal, without creating a situation where the animal's activity was disturbed (Gibbons *et al.*, 2009). The animals were adapted for 14 days on the specific grazing or feed before the measurements were taken. All measurements were taken at the same time of the day (18:00) as it proved to be difficult to see the laser beam in direct sunlight and no or very little wind was experienced at this time of day. The measurements for each individual heifer were then taken every 5 seconds over a period of 60 seconds, to include the different stages of the tidal respiratory cycle. Four 60 second repeated measurements were taken on 10 consecutive days on each of the grazing or feeding conditions. Enteric methane production is normally reported per day or per unit of product produced; however, in the current study, enteric methane was expressed in ppm-m. One of the aims of this study was to evaluate the recording of measurements under applied farm conditions by using the LMD. Data was analyzed with the application of the Proc GLM of SAS (SAS, 2000).

Results and Discussion

The Jersey heifers produced significantly ($P < 0.05$) less methane than the Bonsmara and Nguni heifers on natural veld, as demonstrated in Table 1. No significant difference were recorded between breeds grazing forage sorghum ($P > 0.05$), although the Ngunis showed a tendency to produce more CH_4 than the Jersey heifers, especially. As expected, significantly less methane was produced when the animals were grazing on the forage sorghum under irrigation, compared to the natural veld ($P < 0.0001$), possibly due to the tannin content found in forage sorghum. On natural veld the animals produced on average 48% more methane, compared to grazing forage sorghum. The Bonsmara and Nguni heifers produced slightly less methane on the TMR than on natural veld, but the Jerseys produced more methane on the TMR than on natural veld. The Jerseys produced slightly less methane on the oats pasture than on the total mixed ration, but both the Bonsmara and Nguni heifers produced less methane on the total mixed ration than grazing the oats pasture under irrigation. There may be a possibility that dairy cattle may react differently than beef cattle on different feed sources, e.g. selective grazing by the Jersey heifers on natural veld.

Table 1 The mean (\pm SD) methane production (parts per million per meter) of 12-month-old Jersey, Nguni and Bonsmara heifers utilizing different feed sources

	Natural veld	Total mixed ration	Oats grazing	Forage sorghum
Bonsmara	32.7 ^{a,b} \pm 5.3	31.3 ^{a,b,c} \pm 9.8	26.3 ^{c,d} \pm 7.3	15.3 ^e \pm 1.6
Jersey	25.8 ^{c,d} \pm 1.1	36.6 ^a \pm 3.4	30.7 ^{b,c} \pm 7.0	14.5 ^e \pm 1.7
Nguni	30.6 ^{b,c} \pm 1.4	26.4 ^{c,d} \pm 4.0	24.6 ^d \pm 3.0	16.5 ^e \pm 2.8

^{a,b,c,d} Means in both rows and columns with different superscripts are significantly different ($P \leq 0.05$).

There were significant differences between methane production from the different breeds (Table 2), with a slight interaction between breed and feed source, although not significant.

Table 2 Analysis of variance of animal, feed source, breed and feed source/breed interaction

Source	DF	Mean square	F value	Pr > F
Animal	3	87.30	5.56	0.0035
Feed source	3	598.13	38.07	<.0001
Breed	2	23.43	1.49	0.2402
Feed source x breed	6	59.66	3.80	0.0057

From Table 3 it would seem that the feeding of a TMR produced more methane than in heifers grazing on natural veld, oats or forage sorghum. These results are in contrast with most other studies which show a lower methane production from high quality feed. However, this phenomenon has been recorded in a few unpublished studies and need further investigation.

It would seem as if individual animals have a tendency to emit higher or lower quantities of methane, irrespective of the feed source. This tendency is evident in Table 4, where the Bonsmara heifer number 3 emitted the most methane on 3 feed sources (veld, total mixed ration and oats), whereas the Bonsmara number 4 emitted the least methane on these feed sources, compared to the other Bonsmara heifers in the group.

Table 3 Mean (\pm SD) methane production (parts per million per meter) of Jersey, Nguni and Bonsmara heifers on different feed sources

Feed source	Mean \pm standard deviation
Natural veld	29.70 ^a \pm 4.23
Total mixed ration	31.42 ^a \pm 7.26
Oat grazing	27.20 ^b \pm 6.12
Forage sorghum	15.55 ^c \pm 2.10

^{a,b,c,d} Means with different superscripts are significantly different ($P \leq 0.05$).

Table 4 Average methane production (parts per million per meter) measured from four Bonsmara heifers on different feed sources

Bonsmara	Natural veld	Total mixed ration	Oats pasture	Forage sorghum
1	29.48	26.67	28.50	13.51 ⁽⁴⁾
2	35.83	30.54	23.58	14.52
3	38.53 ⁽¹⁾	45.19 ⁽¹⁾	35.22 ⁽¹⁾	16.25
4	27.08 ⁽⁴⁾	22.75 ⁽⁴⁾	18.07 ⁽⁴⁾	17.06 ⁽¹⁾

⁽¹⁾ Bonsmara heifer with the highest methane emission in the group.

⁽⁴⁾ Bonsmara heifer with the lowest methane emission in the group.

Conclusion

From these results it is clear that the LMD produced recordable measurements, which can be interpreted in respect to enteric methane emission in cattle. The next step should be to increase the number of breeds, number of animals per breed, and feeding strategies over all seasons, in order to validate and build a baseline data set, regarding the use of the LMD to measure methane emissions from cattle on different feed sources and grazing conditions.

The possibility of differences in methane production between animals of the same breed indicates that it may be possible to identify genetic differences between animals using the LMD and it is recommended that this be investigated.

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