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A comparison of methane emissions from sheep grazing pastures with differing management intensities

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Abstract

Methane emissions were measured from sheep grazing on pastures that received one of three managements, either 70 or 270 kg N fertiliser ha^{-1} or one which had a high proportion of white clover present. A system for measuring the emissions is described which enables measurements to be made under near natural grazing conditions. Continuous measurements of emissions were made over periods of 4 days. There were no significant differences in the amount of CH_4 produced per unit body weight over the study period. Animals feeding on both the grass pastures showed strong diurnal patterns of CH_4 emission with peak emissions between 15:00 and 17:00 h and levels gradually falling throughout the night before starting to rise at around 08:00 h. Those animals feeding on the clover swards also had peak emissions at around the same time in the afternoon, however, levels of CH_4 production did not decline over the night and peaked again in the morning before falling sharply to a low at noon. It is concluded from the present studies that the level of inputs to the sward tends to play little part in the overall levels of CH_4 emissions from grazing sheep, but can influence the diurnal part em of CH_4 production.

Introduction

Methane (CH_4) is second only to carbon dioxide (CO_2) in importance as a greenhouse gas. It is estimated that CH_4 contributes around 18% of the overall global warming potential globally. Atmospheric concentrations of CH_4 have been rising at the rate of approximately 1% per annum and have risen from around 800 to 1750 ppb since the industrial revolution and its associated population increase (Johnson et al., 1994). In the UK around 37% of the annual CH_4 emission (ca. 4.2 Tg) has been attributed to agriculture (Anon, 1993) where the primary source is ruminant animals.

In ruminant animals, CH_4 is generated as a by-product of microbial breakdown of carbohydrates, principally cellulose, to produce volatile fatty acids which are metabolised. In the animal 90% of the CH_4 is generated in the rumen and is released via the mouth and nostrils by eructation, the remaining 10% is generated in the large intestine. The vast majority of the CH_4 in the large intestine is absorbed into the blood stream and is released via the lungs in the animal's breath (Lassey et al., 1997).

Traditionally CH_4 emissions from animals have been measured under controlled environment and feeding conditions in respiration chambers (e.g., Kirchgessner et al., 1991; Leng, 1993; Moss 1992, and estimates of CH_4 production using such systems have been integrated into the national budgets. It is only recently that attempts have been made to evaluate CH_4 emissions under more natural grazing conditions. To this end three main experimental techniques have been utilised; micrometereological methods (e.g., Denmead, 1991, use of SF_6 as a tracer (e.g., Johnson et al., 1994; Lassey et al., 1997) and a tunnel system (Lockyer & Jarvis, 1995). The present work utilises a tunnel system to determine CH_4 release from sheep grazing on pastures of differing management intensity.

Materials and methods

Pasture management

Three different pastures were established at North Wyke Research Station, Devon, UK. Two were predominately perennial ryegrass swards which had received either the equivalent of 70 kg N ha^{-1} in one single fertiliser application in May 1997 (N70), or 270 kg N ha^{-1} in three applications in May, June and August 1997 (N270). From May to September these swards were managed to take three silage cuts prior to the start of the experimental periods. A third sward was sown to a white clover/perennial ryegrass mixture in autumn 1997 and given 100 kg N ha^{-1} in a single dressing at sowing. This sward was then grazed by sheep during the winter of 1997 and summer of 1998 (Clover).

CH_4 measurements

CH_4 emissions were measured using the system developed by Lockyer & Jarvis (1995). This system utilises a polythene clad tunnel of approximately 10 $\times$ 4.5 $\times$ 2 m. Air is drawn through the tunnel with a speed-controllable fan housed in a small wind tunnel. The velocity of the air flowing out of the large polytunnel was measured by an anemometer head in the small wind tunnel. This air was sampled using a pump attached, by 6 mm diameter plastic piping, to a sampling device in the air stream of the small wind tunnel. A second air sample is taken from outside the large tunnel to determine ambient CH_4 levels. These air streams were sampled every 2 min in turn via a gas handling device and the air streams passed either to waste or through an infra red gas analyser (IRGA) for CO_2 determination. A 2-ml sub-sample of the air was injected automatically onto a GC column fitted with a flame ionisation detector (FID). A data logger controlled the gas-handling unit and automatic sampling valve and collected output from the IRGA and GC. Air velocities were collected on a second data logger.

Grazing management

The sheep used in the studies were all dry ewes of approximately the same age and weight. The sheep were allowed to graze for 2 weeks on the same sward to acclimate the rumen micro-flora to the food source which was typical of that in the tunnels. After the 2-week acclimation period, two sheep were introduced to the polytunnel and contained in an area of 33 m^2 by solid metal hurdles, and the ends of the tunnel closed down. Prior to the sheep being put into the tunnel, three quadrats (0.22 m^2) were cut to approximately 15 mm above ground level, from the sward in the tunnel and separated into grass, clover and weeds. Total dry matter (DM) was determined for each sample by oven drying at 80 °C for 24 h. The sheep were allowed to graze in the tunnel for a total of 4 days (usually 13:00 h Monday to 13:00 h Friday). After each grazing period, the sheep were removed and the tunnel moved to a fresh area of grass and the study repeated using different sheep. Three studies on each of the ryegrass swards were made between October and December 1997, and three on the clover sward between October and December 1998.

Testing system efficiency

At regular intervals tests were done to estimate the CH_4 recovery of the experimental system. Pure CH_4 was bled into the tunnel via a precision flow meter (200 ml min^{-1}) for a known length of time (usually 30 mm). The instrumentation was then used to determine the amount of CH_4 recovered from the tunnel and this was compared the amount released to give an estimate of the efficiency of the system.

Results

Recoveries

In 12 recovery tests carried out over the period of the experiment there was a good correlation between the amount added and the amount recovered (R^2=0.971) with a mean recovery of 102.3% ($\pm$ 4.41%), which was well within the errors inherent in the measurement equipment, regardless of any experimental variability.

Methane emissions

To take account of differences in body weight of the animals used in the studies, data were normalised and are presented as emissions per kg body weight of the animal.

There were no significant differences in the amounts of DM available on the three pastures (Table 1) or in the amount of CH_4 produced per unit body weight, either on a daily basis or in total over the study periods (Table 2). There was, however, significantly more CH_4 produced on the clover pasture than on either the N70 or N270 pastures (Table 1). Significantly less CH_4 was emitted by the animals grazing the N270 pasture when the data was corrected to a per unit body weight basis (Table 1).

Over the 4-day period that the animals were in the tunnel there was a gradual decline in CH_4 emission (Figure 1). Animals feeding on both the N270 and N70 pastures showed strong diurnal patterns of CH_4 emission (Figure 2) with peak emission rates between

Table 1. Available DM on grass pastures which had received either 70 or 270 kg N ha^{-1} (N70 and N270) or had a high white clover content (Clover) and calculated CH_4 emissions

	N270	N70	Clover	SED*
DM Available (kg)	7.73	9.07	5.71	1.022
CH_4 emissionper animal (g kg^{-1} DM)	6.3	4.5	12.7	1.11
CH_4 emission (g kg^{-1} DM kg^{-1} body wt.)	0.19	0.12	0.20	0.027

*SED, standard error of the difference between means.

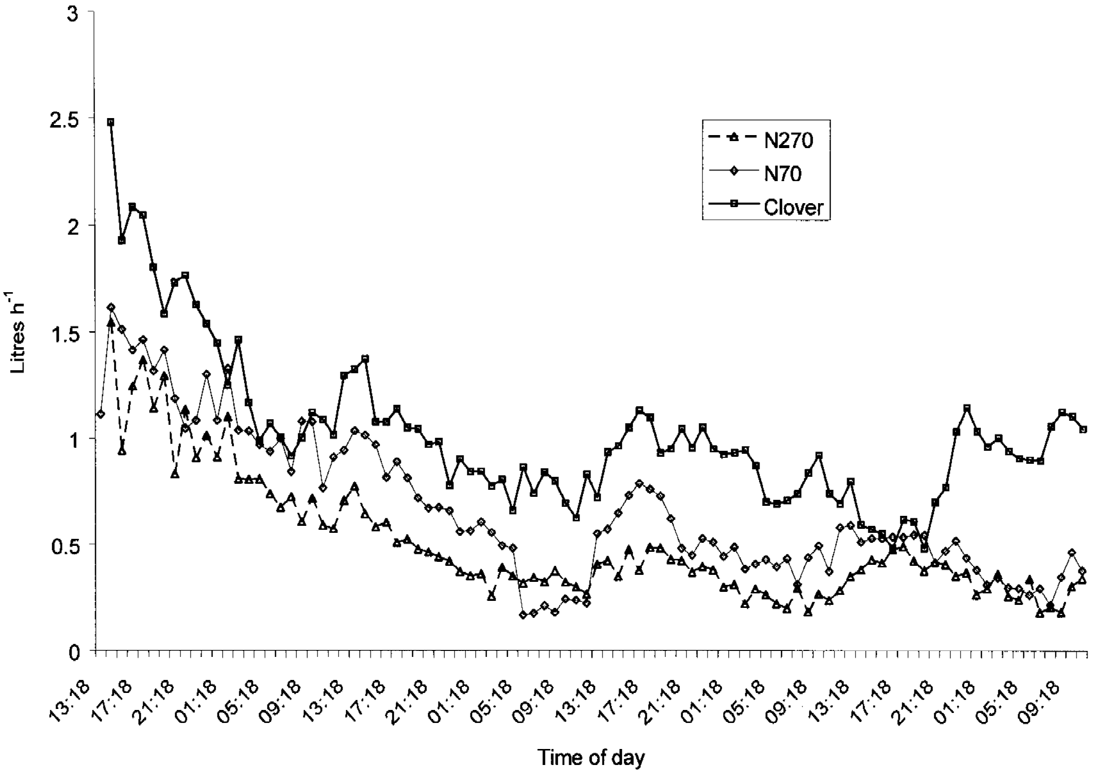

Figure 1. Emission of CH_4 (1 h^{-1}) over 4 days by sheep grazing pastures which had received either 70 or 270 kg N ha^{-1} (N70 and N270) or had a high white clover content (clover) (error bars not shown to aid clarity). Standard errors ranged from ±0.0048 to ±0.0956 (mean ±0.4201) for N270; ±0.00241 to ±0.1642 (mean ±0.3144) for N70; ±0.0024 to ±0.1744 (mean 0.5353) for clover).

15:00 and 17:00 h which gradually fell throughout the night before starting to rise at around 08:– h. Those animals feeding on the Clover swards also had peak emissions at around the same time in the afternoon, however, levels of CH_4 production did not tend to decline over the night and peaked again in the morning before falling sharply to a low at noon (Figure 1).

Discussion

The polytunnel system described in this work is a system which is a halfway-house between the traditional calorimeter methods of determining CH_4 emissions from confined ruminants, and the free-grazing SF_6 and micrometereological methods. In the tunnel the animals are allowed to graze freely and to interact with each other, which is not possible using the calorimeter methods, and the system allows easy determination of diumal and other structure within the emission patterns, which is difficult with the free-grazing tech-

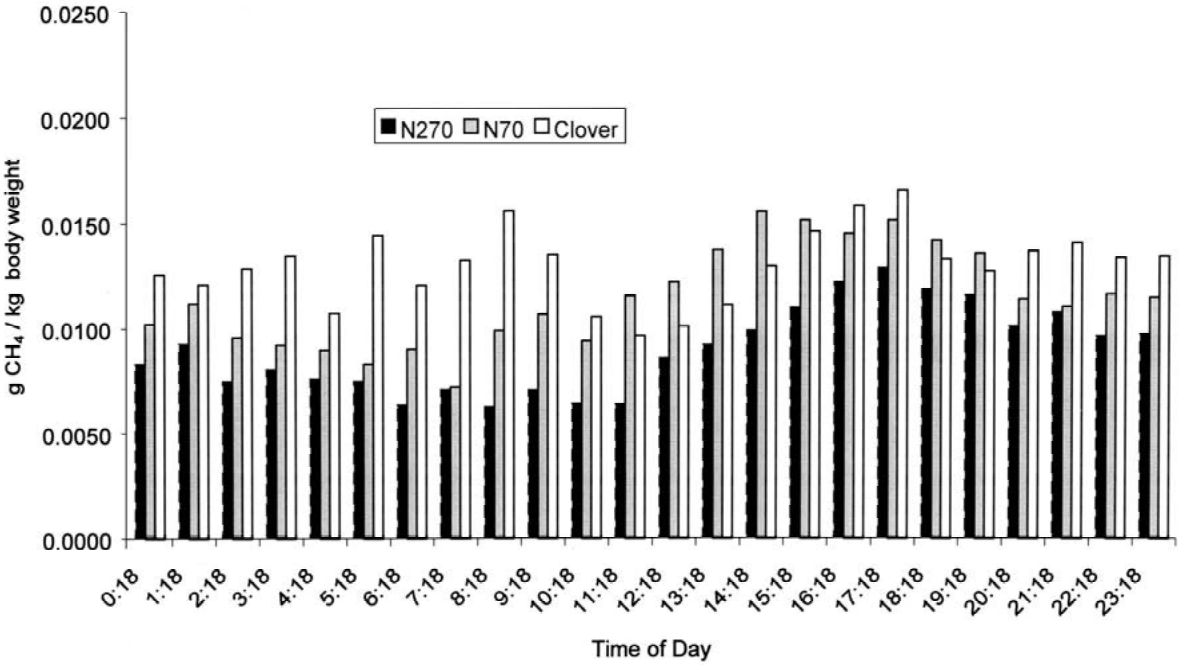

Figure 2. Diurnal pattern of CH_4 emission from sheep grazing pastures which had received either 70 or 270 kg N ha^{-1} (N70 and N270) or had a high white clover content (Clover).

Table 2. Daily CH_4 emissions* from sheep grazing pastures which had received either 70 or 270 kg N ha^{-1} (N70 and N270) or had a high white clover content (Clover)

	N70	N270	Clover	SED*
Day 1 (mg kg^{-1} body weight)	590	430	380	78
Day 2 (mg kg^{-1} body weight)	310	250	270	57
Day 3 (mg kg^{-1} body weight)	300	200	260	47
Day 4 (mg kg^{-1} body weight)	240	190	240	46
Total (mg kg^{-1} bodyweight)	1440	1060	1190	152

*Here and in the text conversion from volumetric units to mass is corrected to 20 °C, but no adjustment for changes in atmospheric pressure are made. *SED, standard error of the difference between means.

niques. The measurements of CH_4 production seen in these studies are broadly in line with those found by other workers (a mean of 20.5 g per animal on day 1) (e.g., Crutzen et al., 1986; Lockyer, 1997; Lockyer and Jarvis, 1995; Moss, 1992). The pattern of emission over the 4-day period of the present study is characteristic of that seen in previous studies using a similar tunnel system and mimics the findings of Lockyer (1997) who also recorded similar high emission rates on the first day of each study. This was explained by changes in the ingestive behaviour of sheep, under a rotational grazing management system, in response to changes in the ratio of leaf to stem in the sward; intake falling as green leaf mass was reduced below a 1500 kg ha^{-1} (Penning et al., 1994). The polytunnel system is akin to a rotational grazing situation where there is a relatively high stocking rate for a limited period of time. It can be assumed that at the outset of the present studies that the amount of DM available to the animals was not limiting intake and that as grazing continued during the 4-day period, the leaf: stem ratio of the available sward declined. Emission of CH_4 from the animal is linked to food intake and has been shown to rise sharply immediately after ingestion (Mathers & Walters, 1982; Murray et al., 1999).

The diurnal pattern of emission seen from the sheep grazing the N70 and N270 swards is similar to that seen by Lockyer (1997). Penning et al., (1991) studying sheep behaviour found that 72% of sheep grazing occurred in daylight and especially during a 4 h period immediately prior to sunset. Judd et al. (1999) found that during the daytime a concentrated period of grazing occurred for 3 h after sunrise and 3 h before sunset, and that in the middle of the day the sheep were relatively inactive and ruminating. This period corresponded with his highest periods of CH_4 emission rates, at night CH_4 emission rates reduced with declining grazing activity. On the clover swards a different pattern of emission was seen (Figure 2) where approximately 48% of the CH_4 was produced in the period from midnight to noon, whereas the sheep on the grass swards produce approximately 41% of the total in the same period. Parsons et al. (1994) found a strong diurnal pattern of preference for clover rather than grass in the mornings. This could explain the disparity in the diurnal pattern of CH_4 production seen in these studies, although further studies to determine CH_4 output from clover based diets is necessary.

From the present studies it appears that sward composition can influence the diumal pattern of CH_4 production. There is a need to investigate the interaction between animal behaviour and CH_4 emission in grazing studies to determine the wider implications for estimating the national inventories of greenhouse gasses.

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