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Methane emissions from growing beef cattle grazing hill country pasture

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ABSTRACT

Methane (CH_4) emissions from 12 Hereford x Friesian steers grazing hill country were measured on six occasions (6, 11, 13, 15, 23, and 26 months of age) during the months of February, July, September, November 2003, and October and November 2004 using the sulphur hexafluoride (SF_6) tracer gas technique. These data are the first serial measurements of CH_4/kg DMI on growing dairy beef cattle in New Zealand. Average daily methane (± s.d.) emissions increased from 89 (10) g/head/d for 6 month old steers to 222 (46) g/head/d for 26 month old steers. The corresponding dry matter intake (DMI), predicted from energy requirements using the Feeding Standards for Australian Livestock, also increased from 3.6 kg/head/d to 12.0 kg/head/d for 6 and 26 month old steers, respectively. In contrast to the increasing DMI and daily methane emissions with age of the steers, the mean methane emission per unit of estimated intake was relatively constant at 17.3 (3.7) to 19.0 (5.6) g CH_4/kg DMI from 11 to 26 months of age with a higher value of to 26.1 (7.0) g CH_4/kg DMI for the 6 month old steers. The overall mean value of 19.5 (± 5.2) g CH_4/kg DMI is lower than that used in the current national inventory calculations.

Keywords: steers; methane; grazing hill country.

INTRODUCTION

Methane (CH_4) emissions from beef cattle are estimated to make up almost 25% of the total emissions from the New Zealand agriculture sector (Clark *et al.*, 2003). Direct measurements of CH_4 emissions in New Zealand have been made on dairy cattle and sheep but, in the absence of any data on emissions from beef cattle, in the national CH_4 inventory the beef cattle emissions rates are assumed to be the same as for dairy cattle (Clark *et al.*, 2003). This paper presents the first data on measurements of CH_4 emissions from beef cattle grazing typical New Zealand hill country pastures, and is the first presentation of CH_4 measurements from the same animals over their productive lifetime.

MATERIALS AND METHODS

Twelve Hereford x Friesian (HxF) bull calves born in August 2003 were hand reared from birth to 10 weeks of age at AgResearch Grasslands, Palmerston North. At an average age of four months they were castrated and at six months of age they were transferred to the AgResearch Ballantrae Farm in the Manawatu region, which is a typical New Zealand hill country farm. The steers were grazed together as a single mob and separate from other cattle on the farm over the 26 months of the trial. During the methane measurements the steers continued grazing large hill country paddocks and the grazing rotation was arranged so they stayed in the same paddock for the five days of the methane measurements. Hand-pluck samples of pastures on offer were taken each morning of the five days of methane measurements and chemical composition was estimated by Near Infrared Spectrophotometry (NIRS). Values reported for each period are the mean values of the five samples. Methane measurements were made on each animal when they were approximately 6, 11, 13, 15, 23, and 26 months of age. The steers were fistulated in February 2004 at 18 months of age in order to retrieve the intra-ruminal sulphur hexafluoride (SF_6) permeation tubes, which have a limited lifespan. The original permeation tubes were replaced with new tubes in July 2004 before the fifth CH_4 measurement was carried out. Liveweight was measured weekly from 5 to 16 months of age, monthly between 16 and 22 months, and weekly again from 22 months onwards. Average daily liveweight change was estimated by the difference between liveweights recorded two weeks prior and two weeks after the methane measurement. Forage availability was not measured during the methane measurements because of the variable terrain of the large paddocks being grazed. The pastures were predominantly rye grass (*Lolium perenne*) / white clover (*Trifolium repens*) and the amount on offer varied seasonally in line with similarly grazed cattle on surrounding hill country farms.

Dry matter intake (DMI) per animal at each measurement occasion was estimated using the energy requirements for Australian Livestock

(SCA, 1990) with animal age, liveweight, liveweight change, and forage dry matter digestibility estimated by NIRS used as factors in the calculations.

Measurement of methane emissions

Methane was measured using the sulphur hexafluoride (SF_6) tracer technique (Johnson & Johnson, 1995). Brass permeation tubes (12.5 mm in diameter x 40 mm long) with known SF_6 release rates (range 1.6 to 4.8 mg SF_6 per day) were given to each animal 7 days prior to the start of the first methane measurement. All permeation tubes were stored at 39°C for a period of 8 weeks prior to insertion into the rumen, and the release rate of SF_6 for each tube was determined from weekly weighings over this period. A sample of the gases exhaled by each animal was collected in a pre-evacuated PVC yoke with an average volume of 1.8 l. The gas was collected through a nylon tube of 3.2 mm internal diameter placed adjacent to the nose and held in place by a halter. The flow of gas to the collection yoke was regulated by a capillary attached to the halter so that the gas sample collected filled approximately 65% of the yoke volume over a 24-hour period. Yokes were changed every 24 hours between 9.00 and 10.00 am for five consecutive days. Background air samples were collected each day so that gas concentrations in the samples from the collection yokes could be adjusted for ambient concentrations. The concentrations of CH_4 and SF_6 collected in the evacuated yokes over 24 hours was measured in duplicate by gas chromatography as described by Boadi &Wittenberg (2002) and daily methane emissions were calculated according to Johnson & Johnson (1995).

Statistical analysis

Regressions between CH_4/head/day and DMI and intakes of individual constituents of the diet, and between g CH_4/kg DMI and the proportions of the forage components in the DM were analysed using Genstat (2005).

RESULTS

Feed quality

Feed composition estimated by NIRS across the 6 methane measurements was variable (Table 1); predicted metabolisable energy (ME) content ranges from 9.1 to 12.4 MJ/kg DM, digestible dry matter (DMD) from 64.3 to 84.3 g/100 g DM and neutral detergent fibre (NDF) from 42.8 to 48.6 g/100g DM.

TABLE 1: Chemical composition predicted by NIRS of forage offered to the HxF steers during each period of methane measurements. Values reported for each period are the mean of 20 hand plucked samples per paddock collected on 5 consecutive days.

	ME	DMD	CP	NDF	ADF	Ash	LIP	SSS
Feb-03	9.1	64.3	16.3	47.5	28.5	9.3	3.8	7.9
Jul-03	10.0	72.0	23.5	48.6	24.8	10.1	4.4	9.0
Sep-03	9.6	69.4	22.1	43.1	24.9	11.1	3.9	8.1
Nov-03	11.4	81.3	24.2	42.9	22.3	9.7	4.6	10.6
Jul-04	11.5	79.6	27.5	42.9	22.3	10.0	4.1	9.0
Oct-04	12.4	83.7	29.6	42.8	21.7	10.3	4.9	8.5

Crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), lipids (LIP), soluble sugars and starch (SSS) and dry matter digestibility (DMD) as g/100g DM, and metabolisable energy (ME) as MJME/kg DM.

Liveweight and liveweight change

Table 2 shows the liveweight and liveweight change used for predicting DMI for each of the six methane measurements. The maximum liveweight gain was at the age of 15 months in November 2003, reflecting also a high estimated DMI in proportion to liveweight of 3.3 %.

TABLE 2: Mean liveweight and daily liveweight change (± s.d) of 12 HxF steers between 6 and 26 months of age. See text for weighing protocol.

	Age (months)	Liveweight (kg)	Liveweight change (kg/d)
Feb-03	6	158 (± 10.4)	0.09 (± 0.21)
Jul-03	11	204 (± 9.2)	0.56 (± 0.30)
Sep-03	13	238 (± 10.0)	0.55 (± 0.10)
Nov-03	15	323 (± 9.8)	1.75 (± 0.37)
Jul-04	23	437 (± 28.9)	1.31 (± 0.51)
Oct-04	26	497 (± 26.5)	1.54 (± 0.34)

The higher liveweight gains estimated during the last three methane measurements coincided with the availability of better quality forage (Table 1).

Methane emission and dry matter intake

Table 3 shows the mean and standard deviation (± s.d.) of predicted DMI, CH_4 emissions per head per day, and CH_4 emissions per unit of intake for the 12 steers for the six periods. Methane emissions per head per day and DMI increased with age and liveweight, whereas CH_4 emissions per DMI were high at the first measurement but remained relatively constant thereafter.

TABLE 3: Mean daily (± s.d.) CH_4 emissions, predicted DMI, and calculated CH_4/kg DMI of 12 HxF steers between 6 and 26 months of age.

Month	Age (months)	CH_4/d (g)	DMI (kg)	CH_4/DMI (g/kg)
Feb-03	6	89.1 (± 9.9)	3.6 (± 0.73)	26.1 (± 7.0)
Jul-03	11	95.9 (± 9.5)	5.4 (± 1.09)	18.3 (±3.3)
Sept-03	13	112.5 (± 12.1)	6.2 (± 0.53)	18.3 (± 2.3)
Nov-03	15	189.0 (± 16.2)	10.7 (± 1.55)	17.9 (± 2.4)
Jul-04	23	169.9 (± 28.0)	10.2 (± 2.44)	17.3 (± 3.7)
Oct-04	26	221.8 (± 45.7)	12.0 (± 1.66)	19.0 (± 5.6)

The proportions of the variation in CH_4 emissions per head per day accounted for by DMI ($R^2 = 0.69$; $p < 0.001$) was similar to that accounted for by the intake of individual components of the feed (R^2 = 0.67, 0.72, 0.73, and 0.71 for NDF, CP, digestible DM and ME intake, respectively; $p < 0.001$). A small amount of the variation in CH_4/kg DMI could be accounted for by changes in the proportion of the components of the forage DM (R^2 = 0.08, 0.19, 0.14, and 0.10 for proportions of NDF, CP, digestible DM, and ME, respectively; $p < 0.01$ to $p < 0.001$)

DISCUSSION

Methane emissions per day clearly increased with increasing age of the HxF steers and this increase was a reflection of their increasing liveweight and associated DMI. When the methane emissions were corrected for DMI there were relatively constant emissions of CH_4/DMI at all ages except for the higher emissions of 26.1 (7.0) gCH_4/ kg DMI found for the cattle at 6 months of age. There was no apparent reason for this higher value in the younger calves, and this contrasts with sheep studies in where young animals have lower emissions than old animals (Clark *et al.,* 2003)

The mean value of CH_4/DMI in this study across 6 measurements of animals between 6 and 26 months of age was 19.5 g CH_4/kg DMI, slightly lower (9.7%) than the current value used in the national inventory for beef cattle of 21.6 g CH_4/kg DMI (Clark *et al*., 2003). This result is also lower compared with values reported in New Zealand for dairy cattle fed indoors; 20.4 g CH_4/kg DMI (Robertson & Waghorn, 2002), and 21.0 g CH_4/kg DMI (Pinares-Patino *et al.,* 2005), and with reports of dairy cattle under grazing conditions; 22.4 g CH_4/kg DMI (Wahgorn *et al*., 2003). This difference could arise as an outcome of the methodologies for measuring or estimating DMI. The DMI was measured directly in the indoor trials but in the present trial was estimated from the energy requirements according to the Australian Livestock Feeding Standards (SCA, 1990). It is not known how appropriate these estimates are for cattle grazing New Zealand hill country.

Methane is produced in the rumen by methanogenic archaea as a metabolic end product. These emissions are a result of a complex interaction between rumen micro flora, feed quality and DMI plus other environmental or dietary factors (McAllister *et al.,* 1996). Methane emission per unit of intake has been related to feed quality and level of feed intake by a number of authors (Blaxter & Clapperton, 1965; Boadi & Wittenberg, 2002), but the results from experiments with fresh forages have been less clear in this regard (McCaughy *et al.,* 1999; Molano *et al.,* 2003; Pinares-Patino *et al.,* 2003).

McAllister *et al.* (1996) in a review suggested that methane production in ruminants tends to increase with the maturity of forage due to the increased fibre component of the diet. However, in this experiment, which used forages differing in chemical composition, DMI was as good a predictor of CH_4 emissions as the intake of specific dietary components as shown by the very similar R^2 values. Despite the fact that DMI was estimated rather than measured, CH_4 emissions per unit of intake were relatively constant across a range of feed qualities These data therefore suggest that for inventory purposes in ruminants fed fresh forages, CH_4 can be adequately predicted from DMI.

CONCLUSION

These were the first measurements of methane emissions from growing beef animals grazing hill country in New Zealand and the results show that the methane emissions per unit of DMI are slightly lower than the current values used in the Green House Gas inventory (19.5 vs 21.6 g CH_4/kg DMI). In order to obtain better estimates of emissions from beef cattle, measurements under control conditions where DMI can be accurately measured would be required. These data, which were obtained from animals grazing fresh forages differing in chemical composition, appear to support the use of a constant value for CH_4 emissions per unit of intake in the national CH_4 inventory.

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