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Comparative methane emissions from cattle, red deer and sheep

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ABSTRACT

Methane (CH_4) production (g CH_4/d) and yields (g CH_4/kg dry matter intake (DMI)) from groups of 11 non-lactating dairy cattle, sheep and red deer were compared in January and June of 2007. During each period, methane emissions measured using the SF_6 tracer technique, were measured over four days following 10 days of acclimatisation. All animals were individually housed in metabolism cages and fed ensiled lucerne chaff at a rate of 1.2 times estimated energy requirements according to Australian feeding standards. Total daily methane production from cattle (140.4 g CH_4/day) was greater than deer (31.5 g CH_4/day) which was greater than sheep (18.3 g CH_4/day) ($P < 0.001$) and methane yield from cattle (20.6 g CH_4/kg DMI) was greater than sheep (18.4 g CH_4/kg DMI) which was greater than deer (16.5 g CH_4/kg DMI) ($P < 0.001$). A significant interaction of species by season was driven by the higher methane production and yield of cattle in winter compared with summer ($P < 0.001$). The findings of this experiment show that methane emissions can differ between ruminant species at the same time on the same diet. Reasons for these differences are yet to be elucidated.

Keywords: methane production; methane yield; sheep; cattle; red deer.

INTRODUCTION

Ruminants produce methane, an important greenhouse gas (GHG), as an end product of the microbial fermentation of ingested feed (McAllister *et al.,* 1996). Methane (CH_4) production, measured as total g CH_4 emitted per day, hereafter referred to as methane production, differs between ruminants and is positively related to animal size and dry matter intake (DMI) (Blaxter & Clapperton, 1965). Typically a sheep emits only 12% of the total daily methane emission of a cattle beast (Ulyatt *et al*., 2002). When methane is expressed per unit of DMI as g CH_4/kg DMI, hereafter referred to as methane yield, differences between species are unclear. There has been limited research comparing the methane yield of different ruminant species. Blaxter and Wainman (1961) found no difference in methane yields between sheep and cattle. However, Galbraith *et al.,* (1998) found that bison yielded greater amounts of methane than either Wapiti or white-tailed deer, and methane yields from Wapiti were greater than white-tailed deer. Possible reasons for potential differences in methane yields between ruminant species could be species differences in apparent digestibility, passage rate, rumen fermentation (Milne *et al.,* 1977; Fennessy *et al.,* 1980; Aertus *et al.,* 1984/85; Domingue *et al.,* 1991; Pearson *et al.,* 2006) and possibly differences in microbial populations and site of digestion.

Currently, methane yields in New Zealand's National GHG Inventory for cattle, deer and sheep, primarily measured using the sulphur hexafluoride (SF_6) tracer technique, appear similar. However, deer methane yields of 21.3 g CH_4/kg DMI in this inventory are an average of values used for cattle of 21.6 g CH_4/kg DMI and sheep of 20.9 g CH_4/kg DMI (Anon, 2005), which were obtained from a variety of measurements at different times on different diets. These averages may be misleading as no two experiments with sheep, cattle and deer have been conducted at the same time, under the same conditions when animals have been fed the same diet. Therefore the aim of this experiment was to compare methane emissions from adult cattle, red deer and sheep, housed under the same conditions and fed the same diet, in summer and winter.

MATERIALS AND METHODS

An experiment to measure methane production and yields from 11 mature non-lactating dairy cows (9 fistulated) and 11 wether sheep (4 fistulated) was conducted at AgResearch Grasslands and from 11 castrated red deer (4 fistulated) was conducted at Massey University Palmerston North in January and June 2007. Each measurement period consisted of 10 days to adapt to the diet and housing, followed by 4 days of methane and DMI measurements. All animals were individually housed in metabolism cages suited to each species, to allow for daily individual DMI to be measured directly. The cattle were let out on to a feed-pad for 4 hours each day, to allow for movement to reduce the possibility of lameness.

TABLE 1: Dry matter intake (DMI) (kg and per kg metabolic live weight), methane production (CH_4/d), methane yield per unit of DMI (CH_4 g/kg DMI)and methane yield as a percentage of gross energy intake (GEI) from cattle, sheep and red deer. SEM = Standard error of mean; Spp = Species.

Measurement	Animal species									Probability values		
	Cattle			Sheep			Red deer					
	Summer	Winter	SEM	Summer	Winter	SEM	Summer	Winter	SEM	Spp	Season	Spp x Season
DMI/kg	7.0	6.0	0.05	0.98	1.0	0.05	2.04	1.85	0.06	0.0001	0.0113	0.0824
DMI/kg LW $^{0.75}$	0.060	0.061	0.0012	0.045	0.050	0.0012	0.046	0.046	0.0011	0.0001	0.0601	0.0709
CH_4 g/d	126.3^{a}	154.8^{b}	5.19	18.6^{c}	18.3^{c}	4.57	34.7^{d}	28.3^{dc}	4.75	0.0001	0.0746	0.0016
CH_4 g/kg DMI	18.1^{a}	23.0^{b}	0.99	19.0^{a}	18.2^{a}	0.88	17.1^{a}	15.8^{a}	0.91	0.0002	0.2240	0.0024
CH_4 % GEI	5.1^{a}	6.5^{b}	0.28	5.4^{a}	5.2^{a}	0.25	4.9^{a}	4.5^{a}	0.26	0.0002	0.2254	0.0024

Different superscripts within a row indicate values significantly different (P <0.05).

The animals were fed ensiled lucerne (*Medicago sativa*) chaff (Chaffhage, The Great Hage Company) of the same batch to ensure consistency of diet between species and across seasons. They were fed twice daily, at 08:00 hours and 16:00 hours at a rate of 1.2 times their estimated energy requirements for maintenance, based on individual metabolic live weight and adjusted for age according to the Australian feeding standards for ruminants (Anon, 2007; Nicol & Brookes, 2007). All animals had unlimited access to water at all times.

Feed offered and feed refused were collected daily, sub-sampled and the dry matter (DM) content determined in triplicate by oven drying at 100˚C for 24 hours. Two hundred gram samples of the offered feed were taken daily, pooled per a period, stored at -20˚C, then freeze dried and ground to pass a 1 mm sieve (Willey Mill, USA). Sub samples were analysed according to methods described by McWilliam *et al.* (2004) for gross energy (GE), organic matter (OM), crude protein (CP), acid and neutral detergent fibre (ADF and NDF), lignin, hot water-soluble carbohydrates (HWSC) and pectin.

Methane measurements were made using the SF_6 technique (Ulyatt *et al.,* 1999). The collection equipment was modified to fit each species. Permeation tubes manufactured for cattle were used for the cattle (2.937 ± 0.1298 (standard deviation) mg SF_6/day) and deer (3.107 ± 0.2336 mg SF_6/day), and sheep permeation tubes were used for the sheep (1.153 ± 0.6541 mg SF_6/day). Deer that had received permeation tubes in previous experiments had background measurements made before the new tubes were inserted. Any background levels above ambient were then added to the ambient background levels measured during the measurement periods to correct the SF_6 release rate. The permeation tubes of the fistulated animals were retrieved and release rates re-determined between the summer and winter measurements.

Statistical analyses of the data were under taken using the SAS PROC MIXED model with repeated measures. Main effects of species and season and their interactions were compared. Significance was declared when P <0.05 and a trend declared if P was between 0.05 and 0.1.

RESULTS

There was found to be no significant difference in the chemical composition of the ensiled lucerne chaff from summer to winter; (Mean ± (Standard error of mean) % DM) OM 90.0 ± 0.04; ADF 33.9 ± 0.13; NDF 45.2 ± 0.26; CP 21.1 ± 0.19; HWSC 4.0 ± 0.09; pectin 4.8 ± 0.07; lignin 8.3 ± 0.08 and GE (MJ/kg DM) 19.6 ± 0.04.

The DMI intake (Table 1), when expressed per kg of metabolic live weight, was found to be up to 23% greater for cattle than sheep or deer (P <0.001), which were similar (P <0.144).

Table 1 shows that total methane production, for both seasons combined, for cattle of 140.4 g CH_4/day was greater than for deer at 31.5 g CH_4/day which was greater than for sheep at 18.3 g CH_4/day (P <0.001), with no significant difference between seasons (P = 0.074). Methane yields, for both seasons combined, for cattle of 20.6 g CH_4/kg DMI were greater than for sheep at 18.4 g CH_4/kg DMI which were greater than for deer at 16.5 g CH_4/kg DMI (P <0.001), with no significant difference between seasons (P >0.22). When expressed as a percentage of GE intake (GEI), methane emissions differed between species with cattle being 5.8% which was greater than sheep at 5.3 which was greater than deer at 4.7 (P <0.001), with no difference between seasons (P >0.22). However, a significant interaction of species by season was found for both methane yield and methane production as a percentage of GEI (P <0.01). This was driven by the higher methane production and yields of up to 27% for of cattle (P <0.002), but not for sheep or deer (P >0.05), in winter compared with summer.

DISCUSSION

In this study, which is the first time that methane emissions from cattle, deer and sheep have been compared when fed the same diet contemporaneously, methane yield and methane as a percentage of GEI was found to differ between species. However, caution must be taken when extrapolating these findings beyond this initial comparative experiment, as the high between-animal variability in methane production and yields of cattle in winter could mean the species differences observed here may not be real. The mechanisms which may be contributing to the differences in methane emissions between ruminant species in this study and others are not clear.

Galbraith *et al*. (1998) found that following feeding lucerne pellets, bison emitted 6.6% CH_4 as a % of GEI, which was more than the 5.2 % CH_4 as a % of GEI emitted by Wapiti (*Cervus elaphus*), which was more than the 3.3% CH_4 as a % of GEI emitted by white-tailed deer (*Odocoileus virginianus*). In contrast, Blaxter and Wainman (1961) conducted a serial experiment feeding the same cattle and sheep a low quality dried grass diet and rolled oats at different feeding levels and found no difference in methane yields between sheep (8.0 % as a CH_4 % GEI) and cattle (7.6 % CH_4 as a % GEI). The studies of Blaxter and Wainman (1961) and Galbraith *et al.* (1998) both measured methane emissions using calorimeters. A possible weakness of the SF_6 tracer technique, and hence the current study, is that it measures methane from the breath only. Thus, if changes in either the chemical composition or digestibility of the diet occurred, or if there are differences between species in hind gut fermentation changing the proportion of methane expelled in the breath or as flatus, methane in the flatus would not be detected.

Methane emissions expressed as a percentage of GEI in this study for cattle of 5.8% is lower than that reported for bison of 6.6% (Galbraith *et al.,* 1998). Additionally, the average methane production and yield of 140.6 CH_4 g/d and 20.6 CH_4 g/kg DMI for cattle in this study were lower than previously reported from other studies in New Zealand when cattle were fed fresh perennial ryegrass based pasture where estimates of 344.4 CH_4 g/d and 35.13 CH_4 g/kg DMI (Woodward *et al,*. 2001) and 260 CH_4 g/d and 24.6 CH_4 g/kg DMI (Woodward *et al.*, 2002) , were reported. However, methane yields in the current experiment were similar to those reported in the New Zealand GHG inventory of 21.6 g CH_4/kg DMI (Anon, 2005). For sheep, methane production of 18.3 CH_4 g/d was similar, but the methane yield of 18.4 CH_4 g/kg DMI was lower in this study than previously reported for sheep fed fresh perennial ryegrass based pasture (16.0 CH_4 g/day and 20.1 CH_4 g/kg DMI, reported by Woodward *et al.* (2001); 22.0 CH_4 g/d and 25.1 CH_4 g/kg DMI, reported by Ulyatt *et al.* (2002); 28.7 CH_4 g/d and 25.7CH_4 g/kg DMI, reported by Waghorn *et al.* (2002); and 20.9 g CH4/kg DMI, reported in the New Zealand GHG inventory (Anon, 2005)). Feed intake was not restricted in most of these studies, in contrast to the current study.

It has been suggested that possible differences in apparent digestibility, site of digestion, microbial populations and the rate of digesta flow between species could influence methane emissions (Blaxter and Clapperton, 1965; Milne *et al.,* 1977; Fennessy *et al.,* 1980; Aertus *et al.,* 1984/85; Domingue *et al.,* 1991; McAllister *et al.,* 1996; Moss *et al.,* 2000; Pinares-Patiño *et al.,* 2003; Pearson *et al.,* 2006).

Previous studies have shown distinct differences in apparent digestibility between sheep and cattle, and between sheep and deer, where cattle typically digest medium to low quality feed better than sheep (Aertus *et al.,* 1984/85; Pearson *et al.,* 2006). Across 82 comparative trials, cows were found to be better able to digest lower quality diets than sheep, while the digestion of high quality diets was similar in the two species (Aertus *et al.,* 1984/85). Similarly, Pearson *et al*. (2006) found that when cattle and sheep were fed lucerne, early cut hay, late-cut hay or barley straw *ad libitum* the mean apparent digestibility of diets by cattle was up to 5% greater than sheep. Comparisons of the ability of deer and sheep to digest conserved forages reveal conflicting results. Fennessy *et al.* (1980) found that deer digested pelleted hay and mature meadow hay better than sheep by up to 10% and 6%, respectively. Similarly, Domingue *et al.,* (1991) found the apparent digestion of DM, OM, and fibre of chaffed lucerne hay by deer to be up to 4% greater than by sheep. However, Milne *et al.* (1977) found that deer were up to 4% less efficient at digesting dried grass pellets than sheep. Animals in these various studies were fed at *ad libitum.* No such comparisons have been made of cattle, sheep and deer at the same time.

The rate of passage of digesta through the digestive tract, either measured as mean retention time (MRT) or fractional outflow rate (FOR), particularly through the rumen has also been linked to methane emissions within, but not between species, (Pinares-Patiño *et al.,* (2003) in sheep and Okine *et al.,* (1989) in cattle). Pearson *et al.* (2006) found the mean MRT of cattle was up to 5 hours longer than in sheep across a range of diets. Milne *et al.,* (1977) found that sheep appeared to have a longer mean MRT than deer, which did not appear to change with season. Domingue *et al.,* (1991) found that the FOR of particulate matter was slower in sheep compared with deer in winter, but in contrast to Milne *et al.,* (1977), in summer Domingue *et al.,* (1991) found deer had longer particulate FOR compared with sheep. However, MRT/FOR and apparent digestibility in the above studies appeared to be influenced by level of feed intake and dietary composition.

Results from the present study imply that results from the widespread use of sheep as the experimental ruminant model animal for methane experimentation should not be blithely extrapolated to other species. Further research is required to confirm differences between ruminant species in methane yield and elucidate the reasons for these differences, with further investigations of rumen microbial populations, digesta passage rate, apparent digestibility and site of digestion required, preferably with the use of calorimeters to measure methane emissions. Understanding these parameters may lead to new mitigation strategies or mean that different ruminant species may respond differently to the implementation of methane mitigation technologies, particularly if it involves dietary changes and/or supplements.

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