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BRIEF COMMUNICATION

Effect of age on methane emissions of red deer stags from weaning until one year of age grazing perennial ryegrass-based pasture

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INTRODUCTION

The emission of greenhouse gases is a current global issue as global warming and climate change appear a reality. The Kyoto Protocol is an international agreement, which New Zealand (NZ) has signed and under obligations of the agreement, New Zealand must reduce its greenhouse gases (GHG) to the emission levels of the baseline year (1990), by the first ratification of the Protocol in 2008. Methane emissions from ruminant livestock in NZ represent 31.3% of New Zealand's total greenhouse gas emissions; therefore accurate inventories of methane production for all farmed livestock classes are required. As of 2003 (Anon 2005), it has been calculated that sheep (37.3%) contribute the largest amount of methane to New Zealand's total methane from ruminant sources closely followed by dairy cattle (34.1%), then non-dairy cattle (22.7%) and lastly deer (3.3%). However, in relation to the Kyoto Protocol, the change in methane emissions from 1990 are important. Emissions from all livestock sectors, with the exception of sheep, have increased, particularly for the dairy cattle and deer sectors.

Inventories for methane emission from ruminant livestock are based on the methane yield (methane (grams) per unit of dry matter intake (DMI)), and are based on research conducted in NZ using the sulphur hexafluoride technique. The NZ methane inventory for ruminants shows that the methane yield for sheep (20.9 g CH_4/kg DMI) (Anon, 2005), deer (22.5 g CH_4/kg DMI) (Swainson, 2004), and dairy cattle (21.2 g CH_4/kg DMI) (Anon, 2005) appear similar. However, young sheep, less than one year of age, consistently produce 20% less methane (16.8 g CH_4/kg DMI), compared with older adult sheep (Lassey *et al.,* 1997; Anon, 2005; Ulyatt *et al.,* 2005). Similarly, Cavanagh *et al.* (2004) found that methane yields from beef cattle, aged from 6 months to approximately 14 months, (17.8 g CH_4/kg DMI) appear to be lower than that of mature cattle. However, no studies have been conducted to measure methane emissions from immature deer, especially whilst grazing fresh forage.

As at June 2005, up to 38% of the New Zealand deer herd was less than one year of age (Anon, 2006). Consequently, if immature deer produce less methane than adult deer, then total methane emissions in the New Zealand GHG inventory for deer may be over-estimated. Therefore, the primary aim of this study was to measure methane emissions from growing red deer stags from four months to one year of age, whilst grazing conventional perennial-ryegrass-based pasture, to test the hypothesis that methane emissions from young deer increase with age.

MATERIALS AND METHODS

Methane emissions of 20 red deer stags grazing permanent perennial ryegrass-based pasture were measured four times post-weaning, at 4.5, 6.5, 9 and 11.5 months of age, using the sulphur hexafluoride technique, as described by Ulyatt *et al.* (1999). Methane equipment was modified to fit young deer and from weaning until the first methane measurement deer underwent a four week training period to become accustomed to normal handling procedures in the yards and to methane collection equipment, *i.e.* halters, harness and yoke.

During the experiment, deer rotationally grazed on a pasture containing ryegrass (*Lolium perenne* cv Nui) (approximately 87% of the DM) and white clover (*Trifolium repens* cv Huia) (approximately 2% of the DM) and were offered pasture *ad libitum*. Daily pasture allowance to achieve *ad libitum* intake was set at 7 kg DM of "edible" pasture per day per deer. The proportion of edible pasture was defined as total pasture mass per paddock less the percentage of dead and weed material, as determined by botanical composition according to the technique described by Adu *et al.* (1998). For one week prior to, and during each methane measurement, deer grazed on the same three paddocks (average area per paddock of 0.44 hectares). Animals grazed pasture throughout the entire experiment, except in winter (June to August) when pasture supply was limited, and animals received ensiled pasture baleage as a supplement, at a rate of approximately 0.6 kg DM per deer per day, to maintain *ad libitum* intake. During this time, for ten days leading up to, and during, the methane-measurement period (in August), animals were fed *ad-libitum* pasture only.

Dry matter intake of deer was estimated using the energy requirements for maintenance (0.57 MJ ME/kg^{075}/d), adjusted for season, and growth rate (37 MJ ME/kg liveweight gain) according to the methods of Fennessy *et al.* (1981) and Suttie *et al.* (1987). Animal production was determined from mean daily liveweight gain. Deer were weighed fortnightly throughout the experiment and linear regression of age and live weight was used to determine mean daily liveweight gain within each season. Pasture samples to determine the ME energy content of the pasture were collected by the forage-selected method, which involved the hand plucking of samples in the areas of the paddocks that animals were most often observed to graze, as described by Semiadi *et al.* (1993).

Analyses of data were carried out using SAS (Statistical Analysis System, version 9.1; SAS Institute Inc., Cary, NC, USA). Means and standard error means for chemical composition of the pasture were obtained the GLM procedure with a linear model that considered the fixed effect of period (March, May, Aug and Oct). Repeated measures of dry matter intake and measures of methane production per animal, per kilogram of DM and per kilogram of LW were analysed using the MIXED procedure with a linear model that considered the fixed effect of age and the random effect of animal.

RESULTS

The chemical composition of pasture offered to deer is shown in Table 1. The ash, organic matter digestibility, ME content and crude protein content of the pasture was found to increase (P < 0.05) with time. In contrast, the lignin content of pasture decreased (P < 0.03) over time.

Methane production (g/d), as shown in Table 2, was found to increase with age (P < 0.0001); 4.5 months < 6.5 = 9.5 < 11.5 months of age. Similarly, methane yield (g/kg DM) was also found to increase with deer age (P < 0.0001); 4.5 months < 6.5 = 9 = 11.5 months of age. There was also a trend for methane per kg live weight to decrease with age (P < 0.078); methane per kilogram of live weight was lower at 9 and 11.5 months of age than at 4.5 and 6.5 months of age.

Table 1: Chemical composition of feed selected pasture samples grazed by deer during methane measurements conducted during March, May, August and October.

% DM	March (n = 4)	May (n = 4)	August (n = 4)	October (n = 4)	Average SEM
Ash	9.8^{a}	10.0^{ab}	10.1^{ab}	10.4^{b}	0.13
ADF[1]	21.7	20.1	21.6	21.2	0.53
NDF[2]	41.6	39.0	41.3	40.5	0.95
CP[4]	21.7^{a}	23.5^{ab}	23.1^{ab}	24.6^{b}	0.69
Lipid	3.7	3.8	3.9	4.0	0.11
SSS[3]	11.8	11.7	11.7	11.6	0.64
Lignin	2.1^{a}	1.5^{ab}	1.9^{ab}	1.3^{b}	0.26
OMD[5]	82.0	84.7	82.9	85.0	0.53
ME [6]	11.9	12.5	12.15	12.6	0.10

[1] Acid detergent fibre [4]Crude protein
[2]Neutral detergent fibre [5]Organic matter digestibility
[3]Starch and soluble sugars [6]Metabolisable energy (MJ/kg DM)
^{ab} Denotes a significant difference of the mean between columns within rows.

Table 2: Dry matter intake (DMI) and methane emissions (CH_4), production (CH_4 grams per day) and yield (CH_4 per kilogram DMI) of weaned red deer stags at 4.5 (March), 6.5 (May), 9 (August) and 11.5 (October) months of age (Mean ± SEM).

Age (months)	4.5		6.5		9		11.5		P-value Age
DMI*	1.66^{a}	± 0.030	1.93^{b}	± 0.030	1.85^{b}	± 0.031	2.27^{c}	± 0.031	<0.0001
CH_4 g/d	24.6^{a}	± 1.108	32.8^{b}	± 1.626	32.3^{b}	± 1.790	40.1^{c}	± 1.679	<0.0001
CH_4/kgDMI*	14.9^{a}	± 0.57	17.0^{b}	± 0.72	17.4^{b}	± 0.85	17.7^{b}	± 0.75	<0.0001
CH_4/kg LW	0.513	± 0.0216	0.566	± 0.0259	0.482	± 0.0241	0.483	± 0.0232	0.08

^{abc} Denotes a significant difference of the mean between columns within rows.
*DMI based on calculations of energy requirements for maintenance and growth

DISCUSSION

This study indicates that methane yield and production increases with age in young deer and is less that previously reported for adult deer (Swainson 2004), which agrees with findings in sheep (Lassey *et al.,* 1997; Anon, 2005; Ulyatt *et al.,* 2005) and cattle (Cavanagh *et al.,* 2004), when the SF_6 technique has been employed to measure methane emissions. However, these results conflict with the findings of Graham (1980), which showed that methane production was not affected by age, when measured from sheep 2, 4 and 10 months old and concurrently measured from mature sheep via closed-circuit respiration chambers.

Reasons for reduced methane production and yield in young animals compared with older animals are not clear and may be due to a host of interacting factors. Microbial populations which are responsible for fermentation of ingested feed are established at an early age with cellulolytic bacteria (Anderson *et al.,* 1987; Fonty *et al.,* 1987) and methanogens (Anderson *et al.,* 1987; Skillman *et al.,* 2004) present in the rumen within the first week of life. Within three weeks of birth, flock-reared lambs appear to have cellulolytic and methanogenic bacteria populations that are similar to that found in the mature ruminant (Fonty *et al.,* 1987). Furthermore, Joyce & Rattray (1970) found, when using rumen fluid inocula taken from lambs under three weeks of age, that grass and hay had lower *in vitro* digestibilities compared with rumen inocula taken from adult sheep. However, when rumen fluid was taken from lambs aged three weeks or older the *in vitro* digestibility of the hay and grass was similar to that observed when inocula were taken from adult animals. This suggests that the microbial population is not limiting fermentation within the digestive tract from approximately 3 weeks of age.

Animal factors rather than microbial factors may have a substantial influence on methane production as animals age. Pinares-Patiño *et al.* (2003) and Okine *et al.* (1989) have demonstrated that methane emissions can be influenced by animal factors including fractional outflow rate of the particulate phase of the digesta, pool size of organic matter in the rumen, organic matter intake and rumen fill. However, little research has been conducted to examine these animal factors in young ruminants (post weaning) compared with mature ruminants and whether these factors could be responsible for the reduced methane emissions recorded in young animals in this and other studies (Lassey *et al.,* 1997; Cavanagh *et al.,* 2004; Ulyatt *et al.,* 2005).

By eight weeks of age, the digestive tract of lambs was thought to function similarly to that of a mature ruminant (Wardorp & Coombe, 1961). The rumen function of bovine calves, with unlimited access to roughage, was determined to reach functional maturity by eight weeks of age (Godfrey, 1961a) and VFA concentrations were found to be stable from five weeks of age onwards (Godfrey, 1961b). In contrast, Oh *et al.* (1972) found that the proportion of total VFAs of rumen origin from the digestive tract of lambs increased as the lambs aged. At seven days of age, 31.5% of the VFA were of rumen origin; however, by 75 and 150 days of age, 87.2% and 91.9% of the total VFA originated from the rumen. This indicates that, as lambs age, there was a shift in the site of fermentation from the hindgut to foregut. There is some evidence that methane production in the hindgut is lower per unit of feed fermented than that of the rumen (De Graeve & Demeyer, 1988, in Moss, 1993). Therefore, changes in the site of digestion may explain the lower methane production from young animals compared with older animals. However, no work of this type has been conducted in deer.

In conclusion, methane production and methane yield from deer in the present study increased with age and were less than those previously recorded in adult deer. This implies that there may be an overestimation of methane from deer in the NZ GHG Inventory if a separate value for deer less than one year of age is not used. However, as this study did not simultaneously measure methane from adult and immature animals consuming the same diet at the same time, absolute differences in methane emissions with age could not be determined from this study. Further research is needed to investigate the mechanisms by which methane production and yield may be reduced in adolescent animals.

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