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Does feeding sulla (*Hedysarum coronarium*) reduce methane emissions from dairy cows?

S.L. WOODWARD¹, G.C. WAGHORN², K.R. LASSEY³ AND P.G. LABOYRIE¹

¹Dexcel, Private Bag 3221, Hamilton, New Zealand.

ABSTRACT

Most of New Zealand's methane is generated as a by-product of feed fermentation in the rumen of livestock and is released through the mouth and nose. An experiment conducted in late summer using Friesian and Jersey dairy cows investigated whether feeding sulla (*Hedysarum coronarium*), a condensed tannin (CT)-containing legume, reduced methane emissions without compromising milksolids production. Cows grazing sulla had higher intake (DMI; 13.1 vs. 10.7 kg DM/cow/d, $P < 0.001$) and milksolids production (1.07 vs. 0.81 kg MS/cow/d, $P < 0.001$) than cows grazing perennial ryegrass pasture. Total daily methane emissions were similar (253.9 vs. 260.0 g CH₄/cow/d, ns). However, cows fed sulla produced less methane production per unit DMI (19.5 vs. 24.6 g CH₄/kg DM, $P < 0.05$) and per unit milksolids yield (243.3 vs. 327.8 g CH₄/kg MS, $P < 0.01$) than those fed ryegrass due to the higher nutritive value of sulla compared with the ryegrass, and possibly the presence of CT. Further research will determine whether feeding alternative, high quality forages is a viable methane mitigation option for New Zealand dairy farm systems, but results of this study clearly indicate that CT-containing legumes, such as sulla, do effectively reduce methane emissions from dairy cows without compromising milksolids production.

Keywords: methane emissions; condensed tannin; legume; pasture; grazing; milk production; milksolids.

INTRODUCTION

Release of greenhouse gases, such as carbon dioxide, nitrous oxide and methane (CH₄), into the atmosphere is believed to be a major cause of global warming. Methane is New Zealand's most potent greenhouse gas (45% of total CO₂-equivalent emissions in 1998) followed by carbon dioxide (39%) and nitrous oxide (16%) (MfE, 2000). Almost all of New Zealand's methane is produced by ruminant livestock (enteric methane) accounting for 87% of total annual methane emissions (Clark, 2001). Dairying produces around 23% of total agricultural methane compared with 53% from sheep and 18% from beef farming (Clark, 2001). However, on a per hectare basis, dairy cattle produce about 265 kg CH₄/ha, more than twice that of sheep and beef cattle (114 kg CH₄/ha). When methane emissions are expressed per head of human population, values for New Zealand are very high (455 kg CH₄/cap/y) compared with the global average (47 kg CH₄/cap/y), due mainly to our small human population relative to our ruminant livestock population (Taylor & Smith, 1997). While policy options to ensure New Zealand's compliance with its target under the Kyoto Protocol cannot ignore pastoral agriculture, they must recognise the pivotal role of that sector to the national economy. This highlights important research needs, including the accurate definition of methane production from forage-fed ruminants, and the identification of strategies for reducing methane emission.

Enteric methane is generated as a by-product of the fermentation of feed, particularly fibre digestion, in the rumen (90%) and the large intestine (10%). Hydrogen, one of the main products of fibre digestion, is captured and converted to methane by methanogenic bacteria. The majority of this methane (98%), whether it is produced in the rumen or the large intestine, is released through the mouth and nostrils (Murray *et al.*, 1976). Methane production also represents a substantial loss of potentially useful energy to the animal (Blaxter & Clapperton, 1965).

Although options are available for mitigating ruminant

methane, many are long term, requiring extensive research (e.g., modification of methanogenic bacteria populations in the rumen) or untenable (e.g., reducing livestock numbers), but dietary modification has good promise in the short term. The lower methane production from ruminants fed concentrate diets is well known (Blaxter & Clapperton, 1965) and use of low-fibre diets, such as legumes, has also been shown to reduce methane production relative to high-fibre forages (Woodward *et al.*, 2001). Furthermore, high feed intake enables a high level of productivity, and, when legumes or concentrates comprise a large proportion of the diet, a high proportion of energy is used for production rather than maintenance requirements. Hence, methane emissions from livestock (dairy cows and sheep) fed legumes are lower per unit production than emissions from livestock fed grass-based forages (Woodward *et al.*, 2001). Measurement of methane emissions from dairy cows (fed ensiled forages) and sheep (fed fresh forages) have shown that animals fed condensed tannin (CT)-containing legumes, such as birdsfoot trefoil (*Lotus corniculatus*) and Lotus major (*Lotus pedunculatus*), produced substantially less methane per unit dry matter intake than those fed either perennial ryegrass (*Lolium perenne*) or lucerne (*Medicago sativa*).

This paper describes the measurement of methane emissions and milk production from dairy cows fed sulla (*Hedysarum coronarium*), a biennial legume species that contains CT, and has low concentrations of fibre and high concentrations of soluble carbohydrate. Sulla originated in the Mediterranean region (Waghorn *et al.*, 1998) and, although it is not commonly used on New Zealand dairy farms, this work was designed to investigate whether sulla could be fed to lactating dairy cows to decrease methane production without compromising milksolids production.

MATERIALS AND METHODS

Trial design

The trial was conducted over 12 days in March 2001 at Dexcel's No 5 Dairy, Hamilton, New Zealand using 16

²AgResearch Limited, Grasslands Research Centre, Private Bag 11008, Palmerston North, New Zealand.

³NIWA, PO Box 14901, Kilbirnie, Wellington, New Zealand.

late lactation (211 ± 15 days), mixed-age dairy cows (eight Friesian and eight Jersey breed). Cows were allocated to one of two treatment herds which were balanced for breed, daily milksolids yield (milkfat plus milk protein yield; MS), and live weight when all cows were grazing the same ryegrass/white clover-based pasture prior to the trial. During the trial one herd grazed ryegrass-dominant pasture (termed 'ryegrass' in this paper for brevity) and the other herd grazed sulla. Forage nutritive value, intake, milk production and composition, methane emission over the final three days (the 'measurement period') of the trial.

Grazing management and forage measurements

Pre-grazing herbage mass in the ryegrass and sulla paddocks was determined by calibrated visual assessment of herbage mass, and measurement of forage dry matter (DM) content. The size of the respective 24-hour grazing breaks was then calculated to ensure cows on both treatments had a daily herbage allowance of 40 kg DM/cow. This allowance ensured that cows were not grazing large amounts of dead material or vegetative stem in the base of the swards. From day eight of the trial the breaks were fenced to prevent back-grazing.

Pre-grazing samples (cut to grazing height) of ryegrass and sulla were collected daily during the measurement period, split into two and analysed for dry matter content (oven dried 95°C for 30 hours), and chemical composition (after oven drying 65°C) using near infrared reflectance spectrophotometry (NIRS systems 6500). Samples of sulla (cut to grazing height) were also collected daily during the measurement period and bulked before freeze drying, and the concentration of CT measured using the butanol-HCL colorimetric procedure (Terrill *et al.*, 1992).

Cows were given 345 mg C32 alkane marker twice daily for five days prior to the measurement period and during the three-day faecal sampling period to estimate individual cow dry matter intake (DMI) (Dove & Mayes, 1991).

Milk measurements

Daily milk yield (p.m. plus a.m. milking) was measured over two days pre-trial and during the measurement period. Daily milk samples were also collected from each cow and analysed for milkfat, milk protein and lactose concentration using an infrared milk analyser (Milkoscan 133B, Foss Electric, Hillerød, Denmark).

Methane measurements

Enteric methane production was measured using the sulphur hexafluoride (SF_6) tracer technique (Johnson *et al.*, 1994). The SF_6 intraruminal marker was released at a known rate (3.0 mg/day) from brass permeation tubes inserted into the rumen of each animal before the start of the trial. Respired air from each cow was subsampled (continuously over 24-hour periods) during the three-day measurement period via a fine bore capillary tube above the nose, and the sample collected in an evacuated yoke fitted around the neck of each cow. Background concentrations of atmospheric methane and SF_6 were collected from paddocks adjacent to those grazed by cows

on each treatment. Methane and SF_6 concentrations were measured by gas chromatography, and the methane emission rate was then calculated as:

$$Q_{\text{CH}_4} = Q_{\text{SF}_6} \times ([\text{CH}_4 \text{ yoke}] - [\text{CH}_4 \text{ background}]) / ([\text{SF}_6 \text{ yoke}] - [\text{SF}_6 \text{ background}])$$

where Q_{SF_6} is the calibrated rate of permeation from the SF_6 capsule.

Statistical analysis

Milk yield and milk composition data collected during the trial were analysed using analysis of variance (Genstat Release 4.1) including forage treatment, breed, and data collected during the pre-treatment uniformity period as a covariate. Methane emission and DMI data, together with the herbage data, were also analysed but no covariate data were collected for these parameters. Treatment (ryegrass vs sulla) means and the standard error of the difference (SED) are given for all parameters. Breed (Friesian vs Jersey) means and SEDs were also calculated for some of the cow measurements.

RESULTS AND DISCUSSION

The sulla pastures were $98 \pm 1\%$ pure sulla (% of total DM), whereas the ryegrass pastures were variable and comprised $73 \pm 7\%$ ryegrass, $14 \pm 5\%$ summer grasses, and $13 \pm 3\%$ weed species. The sulla was higher quality than the ryegrass pasture ($P < 0.001$) as indicated by the metabolisable energy (ME), crude protein and soluble carbohydrate contents relative to the high fibre content in the ryegrass (Table 1). Previous trials have also demonstrated that legumes, such as white clover and *Lotus corniculatus* (Harris *et al.*, 1998) maintain high nutrient quality throughout the year, while ryegrass is of lower quality over summer-autumn compared with spring, mainly due to reproductive stem development.

Although the sulla was mature and contained only 35% leaf in the DM, the low fibre content and high soluble carbohydrates in the grazed material indicate a high nutritive value for ruminants (Table 1). The presence of CT in the sulla (Table 1) also increased the nutritive value through protection of plant protein from degradation in the rumen (Waghorn *et al.*, 1998). This contrasted with the high concentration of structural fibre in the ryegrass pasture (Table 1).

Cows grazing sulla had higher DMI than those grazing ryegrass (Table 2; $P < 0.001$). This was probably due partly

TABLE 1: Chemical composition (g/100g dry matter, unless otherwise stated) of the perennial ryegrass (*Lolium perenne*) and sulla (*Hedysarum coronarium*) grazed by lactating dairy cows. Values are the mean of five samples per treatment, and standard error of the difference (SED).

	Ryegrass	Sulla	SED
Dry matter (%)	18.5	13.0	0.42
Crude protein	21.2	26.6	0.66
Lipid	3.9	3.4	0.06
Acid detergent fibre (ADF)	27.6	14.5	0.55
Neutral detergent fibre (NDF)	48.3	14.7	0.95
Soluble carbohydrates	5.7	19.2	0.39
Metabolisable energy (MJ/kg DM)	9.8	12.6	0.12
Total condensed tannin (CT)	0	2.72	N.A.

to the higher nutritive value of the sulla and especially the lower fibre concentration compared with the ryegrass pasture (Table 1; $P < 0.001$). Although previous studies have demonstrated that CT in *Lotus pedunculatus* (CT concentration ranged from 5.0 to 9.0 g/100g DM) can reduce feed intake in sheep due to their ability to slow the rate of digestion in the rumen (Waghorn *et al.*, 1997; Waghorn *et al.*, 1998), the low concentration of CT in the sulla in this study (Table 1) is unlikely to have reduced feed intake. A similar low concentration of CT in *Lotus corniculatus* had no effect on feed intake in lactating dairy cows (Woodward *et al.*, 2000).

TABLE 2: Dry matter intake (DMI), milk yield, milk composition and milksolids production of mixed-age Friesian and Jersey dairy cows grazing either perennial ryegrass or sulla in late lactation. Values are the mean of eight cows on each treatment and the standard error of the difference (SED).

	Ryegrass	Sulla	SED
DMI (kg DM/cow/d)	10.7	13.1	0.6
Milk yield (kg/cow/d)	8.35	11.24	0.35
Milkfat concentration (%)	5.80	5.51	0.14
Milk protein concentration (%)	3.76	4.05	0.06
Fat yield (kg/cow/d)	0.49	0.62	0.03
Protein yield (kg/cow/d)	0.32	0.45	0.02
Milksolids yield (kg MS/cow/d)	0.81	1.07	0.04

Sulla allowed cows to achieve high intakes of good quality roughage compared with ryegrass, and this higher nutrient intake was reflected in higher milk production ($P < 0.001$) and milksolids yield ($P < 0.001$) (Table 2). Cows grazing sulla also had higher milk protein concentration ($P < 0.001$), and slightly lower milkfat concentration ($P < 0.10$) than those grazing ryegrass (Table 2). Woodward *et al.* (2000) showed CT were responsible for the increased milk protein concentration in cows fed *Lotus corniculatus*. In the current trial, the higher crude protein concentration of the sulla compared with the ryegrass may also have contributed to the higher milk protein concentration of the sulla-fed cows.

Total methane production from cows in this trial was similar to that reported by Lassey *et al.* (1997) who measured an average methane emission rate of 263 g CH₄/cow/d from Friesian cows grazing fresh ryegrass-white clover pasture in late summer (late March). The cows in the Lassey *et al.* (1997) study had higher DMI (12.9 kg DM/cow/d) and milk production (14.0 kg milk/cow/d) with lower methane production per unit DMI (20.6 g CH₄/kg DM) than cows grazing ryegrass pasture in this study (Table 3). Methane production per unit DMI from the sulla-fed cows (Table 3) was comparable to the ryegrass-white clover-fed cows in the Lassey *et al.* (1997) study. Differences between studies may be attributable to forage quality, especially the presence of white clover in the diet available to cows in the Lassey *et al.* (1997) experiment. Lassey & Ulyatt (2000) also reported clear seasonality in methane emission from dairy cows that correlated well with milk production. Methane production by cows in early lactation was double that of cows in late lactation, while methane emission per unit milk production was slightly higher in late lactation (16.9 g CH₄/kg milk) than in early lactation (14.0 g CH₄/kg milk).

While measurement of total methane production is

TABLE 3: Methane emission rates and methane energy as a percentage of gross energy intake (GEI) and metabolisable energy intake (MEI) of mixed-age Friesian and Jersey dairy cows grazing either perennial ryegrass or sulla in late lactation. Values are the mean of eight cows on each treatment and the standard error of the difference (SED).

	Ryegrass	Sulla	SED
Methane production (g CH ₄ /cow/d)	260.0	253.9	24.7
Methane per unit intake (g CH ₄ /kg DMI)	24.6	19.5	1.6
Methane per unit production (g CH ₄ /kg MS)	327.8	243.3	24.7
Methane energy as % of GEI	7.2	6.1	0.4
Methane energy as % of MEI	14.0	9.5	0.8

important for inventory purposes and for evaluating the implications of greenhouse gas production, measurement of enteric methane production per unit DMI or per unit production is more appropriate for evaluating mitigation options. Expressing methane emission per unit DMI, or per unit digestible DMI, is an accepted protocol enabling fairer comparison of methane production by different animal species, and from animals fed a range of different feeds. In this trial, the higher DMI of cows grazing sulla resulted in significantly lower methane emissions per kg DMI ($P < 0.05$) despite similar total methane production from the two forages (Table 3). Blaxter & Clapperton (1965) have demonstrated a small reduction in methane emission per unit DMI as intake increased. Hence, the lower methane per unit DMI from cows grazing sulla is likely to be a function of feed type rather than intake level when compared with ryegrass.

The importance of considering possible economic implications of methane production from the perspective of the whole farm system means that expressing methane emission per unit production (e.g., milksolids) is also important. Cows grazing sulla had higher milksolids production than those grazing ryegrass and, as a result, methane production per unit milksolids yield was lower on the sulla than on the ryegrass (Table 3; $P < 0.01$).

Reductions in energy loss to methane could also improve feed conversion efficiency. Cows grazing sulla lost 6.05% of gross energy intake (GE) to methane compared with 7.17% of GEI lost by cows grazing ryegrass (Table 3; $P < 0.05$). This additional energy available to the cows grazing sulla may have contributed to the higher milksolids production compared with the cows grazing ryegrass. Overall, the percentages of GEI lost to methane production are similar to previously published data for lactating dairy cows (Lassey *et al.*, 1997).

The reasons for the lower methane production from cows grazing sulla compared with those fed ryegrass were not defined here but contributing factors could include low fibre content, high carbohydrate concentrations, and the presence of CT in sulla. Woodward *et al.* (2000) showed that approximately 50% of the increase in milksolids production when cows were fed *Lotus corniculatus* compared with when cows grazed ryegrass-based pasture, was due to the action of CT. Condensed tannins have major effects on rumen function (Waghorn *et al.*, 1997) and it is possible that there are direct or

indirect effects on methanogens but further work will be required to elucidate mechanisms of action.

The present trial demonstrated considerable variation in total methane production between individual cows grazing the same forage. Variation between cows may result from differences in intake, rumen retention time and rumen fill (Pinares-Patino *et al.*, 2000). These factors may explain some of the the variation in methane production observed between cows in the current trial, even when the cows are separated into the different breeds to allow for differences in live weight, intake and rumen size. For example, daily methane emission of the Friesian cows grazing ryegrass ranged from 255.2 to 348.9 g CH₄/cow/d, and from 238.0 to 307.0 g CH₄/cow/d for those grazing sulla. Likewise, total methane emission from the Jersey cows grazing ryegrass ranged from 201.4 to 228.6 g CH₄/cow/d, and from 209.3 to 250.7 g CH₄/cow/d for those on sulla. The extent of variation in methane production between cows of the same breed on the respective forages was similar to that previously shown by Blaxter & Clapperton (1965) for a range of different diets, and by Lassey *et al.* (1997) for cows grazing ryegrass-white clover pasture. Future investigations are necessary to show whether or not such variation in methane production between cows has a genetic link. If such a genetic link exists, low methane-producing cows may be able to be achieved through a breeding programme.

The trial also allowed a preliminary investigation of differences between dairy cow breeds in terms of methane emission. Caution should be used in the interpretation of the results, however, given the small number of cows representing each breed. On average the Jersey cows produced significantly less total methane than the Friesian cows (227.5 vs. 284.5 g CH₄/cow/d, SED=16.0; P<0.01) most probably because of their lower feed intakes (11.0 vs. 12.9 kg DM/cow/d, SED=0.6; P<0.05). Although the Jersey cows also had considerably lower methane production per kg milk solids than the Friesian cows (246.4 vs. 320.4 g CH₄/kg MS, SED=24.4; P<0.01), there were no differences between the breeds in methane production per unit DMI (20.2 vs. 23.2 g CH₄/cow/d, SED=1.7; n.s.).

CONCLUSION

An obvious mitigation option for farmers would be to reduce the number of cows but this would lower total milk solids production within the farm system and probably also reduce the farm's financial profitability. Methane mitigation options must be developed with the whole-farm system in mind in order to reduce methane emissions without compromising production or profitability. Short-term studies, have demonstrated that feeding alternative forages such as sulla and *Lotus corniculatus* may offer a means for dairy farmers to reduce methane emissions while still maintaining or improving per cow milk solids production. Research is still required to determine how alternative forages can be incorporated into a viable whole-farm system, and whether these forages offer a practical and sustainable option for enteric methane mitigation and whole-farm profitability.

ACKNOWLEDGEMENTS

The authors thank Brett Walter, Liz Grayling (Dexcel) and Simon Woodward (AgResearch Limited) for their assistance to Barbara Dow (Dexcel) for statistical analysis of data. Funding was provided by the New Zealand Dairy Board's On-farm Research and Development Environment Global Programme and by the Foundation for Research, Science and Technology.

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