Artículo Invitado

Methane emissions from pastoral systems: the situation in New Zealand*

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ABSTRACT: Methane is the major greenhouse gas of concern to countries like New Zealand and Uruguay, which have large ruminant and small human populations. The paper reviews the major factors affecting methane emission from ruminants. The relationship between DM intake and methane emission (g/d) is positive, but not strong. However, there is a stronger, but negative correlation when methane emission per unit of feed intake (kJ/100kJ) is plotted against DM intake, suggesting that as intake increases the percentage of dietary energy lost as methane decreases. Starch and lipid are negatively correlated and fibre positively correlated with methane emission. The relationship between digestibility and methane is confounded with the effects of feed intake level: at low intakes methane increases as digestibility increases, but at high intakes methane decreases as digestibility increases. The SF_6 tracer technique for estimating the methane emission of individual grazing animals is described and evaluated. Provided care is taken with SF_6 permeation tube calibration it is considered that the technique gives reliable and repeatable estimates. Possible methane mitigation strategies are discussed including: reducing livestock numbers, increasing the efficiency of livestock production, exploiting natural between-animal variation in methane emission, dietary chemical additives that reduce methane, immunisation and manipulation of the rumen microbial ecosystem. While there are many interesting possibilities, more research is required before any of them is likely to be economically feasible. Methane mitigation strategies being developed in New Zealand to meet its obligations to the Kyoto Protocol are discussed. Research is focussed on developing accurate inventory methodology based on field measurements of various livestock classes and pasture types, and on possible mitigation technologies such as evaluating the cause of between-animal differences, plant inhibitors, and manipulation of the rumen microbial ecosystem.

Key words: methane emission, feed intake, rumen microbial ecosystem.

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Emisiones del metano de sistemas pastorales: la situación en Nueva Zelandia

RESUMEN: El metano es el principal gas de invernadero que preocupa a países como Nueva Zelandia y Uruguay, que tienen grandes poblaciones de rumiantes y pequeñas poblaciones humanas. Este artículo revisa los factores principales que afectan la emisión del metano en rumiantes. La relación entre el consumo de materia seca (MS) y la emisión del metano (g/d) es positiva, pero no fuerte. Sin embargo, hay una correlación más fuerte, pero negativa cuando se grafica la emisión de metano por unidad de consumo de MS (kJ/100kJ), sugiriendo que como el consumo aumenta el porcentaje de energía dietética perdido como metano, disminuye. El almidón y los lípidos están correlacionados negativamente, y la fibra se correlaciona positivamente, con la emisión del metano. La relación entre digestibilidad y metano se confunde con los efectos del nivel de consumo de los alimentos: a consumos bajos el metano aumenta mientras que la digestibilidad aumenta, pero a consumos altos el metano disminuye mientras que la digestibilidad aumenta. La técnica de trazar líneas SF_6 para estimar la emisión del metano de animales que pastan individualmente se describe y se evalúa. Con tal que se tome el cuidado con la calibración del tubo de impregnación SF_6 se considera que la técnica da estimaciones confiables y repetibles. Se discuten las posibles estrategias para disminuir metano incluyendo: reducción del número de cabezas de ganado, aumentar la eficiencia de la producción animal, explotar la variación natural del entre animales en la emisión del metano, aditivos químicos dietéticos que reducen la emisión de metano, la inmunización y la manipulación del ecosistema microbiano ruminal. Mientras que hay muchas

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posibilidades interesantes, se requiere más investigación antes de que cualesquiera de ellos sean económicamente factibles. Se discuten las estrategias para la reducción de metano que están siendo desarrolladas en Nueva Zelandia para resolver sus obligaciones al protocolo de Kyoto. La investigación se ha centrado en desarrollar una metodología exacta del inventario basada en medidas en el terreno de las varias clases del ganado y tipos de pasto, y en tecnologías posibles para la reducción, tales como, evaluación de la causa de las diferencias del entre animales, de los inhibidores en la planta, y de la manipulación del ecosistema microbiano ruminal.

Palabras clave: emisión del metano, consumo de alimentos, ecosistema microbiano ruminal.

Introduction

Countries that ratified the Framework Convention on Climate Change (FCCC), in 1992, are obliged to provide regular inventories to the United Nations and to introduce policies and measures to limit emissions of greenhouse gases. Under the subsequent Kyoto Protocol (1997) the developed countries negotiated various scenarios to reduce their emissions of green house gases to on average 5% of 1990 levels over the period 2008-2012. If the Kyoto Protocol is ratified its requirements will become legally binding. Of the greenhouse gases, methane is of particular concern to countries like New Zealand and Uruguay because our *per capita* emissions of methane are very high by global standards (Table 1).

New Zealand's *per capita* methane emission is 9.7 and Uruguay's 4.5 times greater than the global average. This is because our methane emissions come predominantly from enteric fermentation by ruminant livestock and we have relatively high livestock and low human populations. Further, on a global warming potential basis (effectiveness of a gas in trapping heat in the atmosphere relative to carbon dioxide), methane in New Zealand and Uruguay has a higher percentage than carbon dioxide which is unusual internationally (Table 2).

Implicit in the FCCC reporting requirement is the need to be able to report an accurate inventory for methane outputs and to devise strategies for mitigating methane emission. The Intergovernmental Panel on Climate Change (IPCC 1995) provides a default methodology for calculating national methane inventories which has serious limitations with respect to individual countries. There is a real need for countries that have a lot at stake to produce a methodology that is accurate, has application in the long term and has the confidence of the policy makers both internally and internationally. Some of the policies promoted to reduce methane emissions can be seen as a threat to the viability of the livestock industries. Most measurements of methane production have in the past been conducted indoors in respiration chambers, however, the basic requirement for countries like and New Zealand and Uruguay is to be able to make accurate measurements from grazing livestock under field conditions.

This paper will review some of the major factors affecting methane emission, describe the sulphur hexafluoride (SF_6) tracer technique for estimating methane emission from livestock, outline possible methodologies for reducing methane emission from grazing livestock and discuss the mitigation strategies being adopted by New Zealand.

Factors affecting methane emission

In ruminant animals methane is produced predominantly by fermentation of the diet in the reticulo-rumen, however a significant amount (10-20%) is also produced in the caecum and large intestine. The primary factor affecting methane emission from the gastro-intestinal tract is the diet, because the diet provides the substrate, directly or indirectly, for the methanogenic bacteria. It is likely that certain physiological attributes of the animal interact with the diet and the methanogenic bacteria in a complex way to cause variation in methane emission. The methanogenic bacteria themselves also interact in a complex way with other rumen bacteria and protozoa in a competition to utilise hydrogen to produce methane and other end products of enteric fermentation. The type of fermentation that ensues can vary from a high methane emission, characterised by high ratio of acetate/propionate, to a low methane emission, characterised by a low ratio of acetate/propionate (Johnson and Johnson 1995). Management of hydrogen in the rumen is the key to controlling ruminant methane emissions (Joblin

Table 1. Comparative annual methane emissions 1993/94.

	World	OECD	NZ	Uruguay
Emissions (Tg)	261	67.8	1.6	0.7
Per Capita (kg/head)	47	71	455	212

Table 2. Relative importance of annual green house gas emissions in New Zealand and Uruguay in Tg carbon dioxide equivalents (Global warming potential weighted).

	100 year GWP	New Zealand		Uruguay	
		Emission (Gg)	%	Emission (Gg)	%
CO_2	1	30 489	40	3 344	11
CH_4	21	33 453	44	15 477	54
N_2O	310	11 625	16	10 129	35

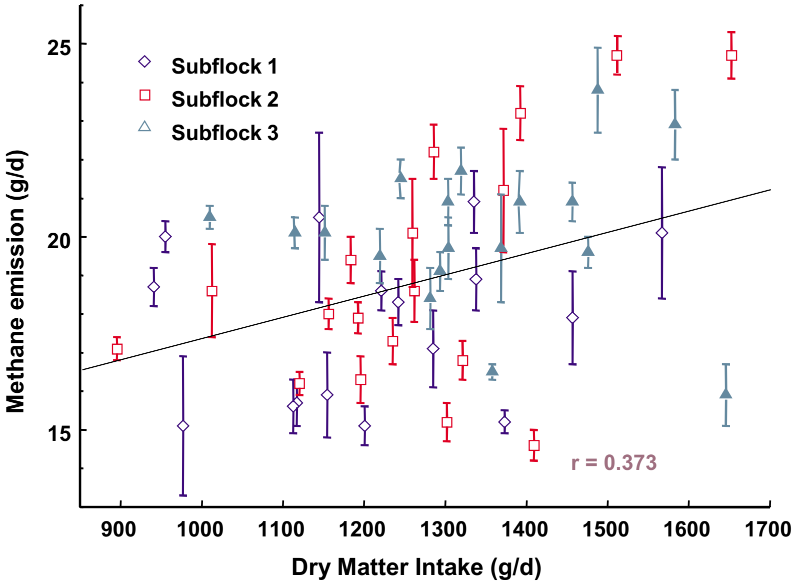

Figure 1. Methane emission versus DM intake in a group of sheep grazed on pasture (n=5), Lassey *et al* (1997).

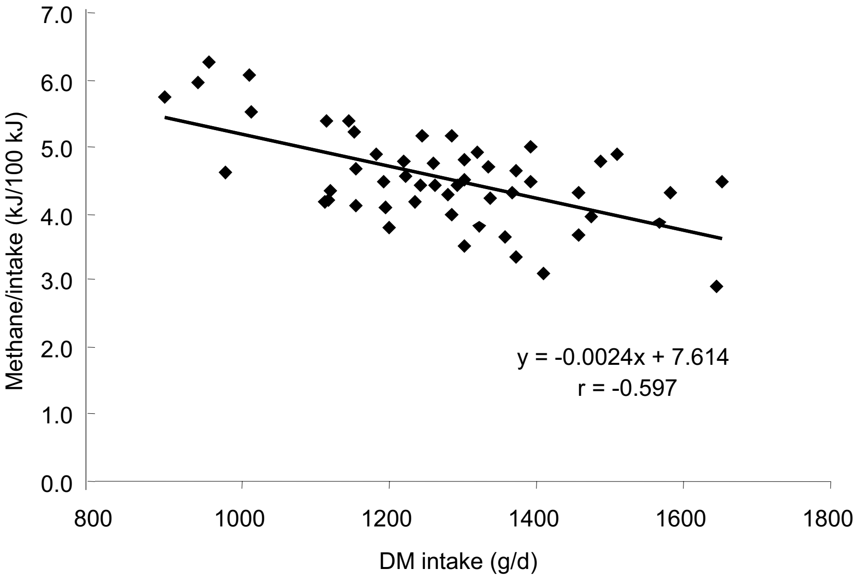

Figure 2. Methane emission per unit of feed intake in sheep grazing pasture.

1999). For normal digestion to proceed the partial pressure of hydrogen in the rumen needs to be kept low.

Feed intake. The relationship between methane emission (g/d) and DM intake is characterised by high variability (Blaxter and Clapperton 1965; Kirchgessner *et al.* 1995; Lassey *et al.* 1997). An example of this relationship is plotted in Figure 1, using data from sheep grazing fresh pasture in New Zealand, showing that the absolute amount of methane emitted increases as intake increases ($r = 0.373$; $P<0.05$) (Lassey *et al.* 1997). The notable thing about this relationship is that approximately 87% of the variation in methane emission is between-animals, suggesting that DM intake *per se* is not a major determinant of the variation in methane emission. However, when methane emission per unit of feed intake (usually expressed as kJ methane per 100 kJ gross energy intake) is plotted against DM intake for the same data (Figure 2), a stronger negative relationship is found ($r = -0.597$; $P<0.01$), indicating that as intake increases the percentage of dietary energy lost as methane decreases. This is a well established relationship for sets of data where animals are feed the same diet at both restricted and *ad libitum* intakes (Armstrong 1964; Blaxter and Clapperton 1965; Johnson and Johnson 1995), suggesting that for efficient animal production and reduced methane emission it is advantageous to feed animals at as high an intake as possible.

Diet composition. The major constituents of the diet, sugars and starch, fibre, protein and lipid, appear to have varying impacts on methane emission. The data of Blaxter and Wainman (1964), where sheep and cattle were fed variable portions of hay and maize at about maintenance and twice maintenance levels of intake, provides a good illustration of the effects of type of carbohydrate on methane emission. As the proportion of maize (and thus starch) increased in the diet from 0 to 100% there was a small reduction in methane at maintenance, and a decrease from about 7.0 to 3.5 kJ/100 kJ intake at twice maintenance. Conversely Blaxter and Wainman (1964) showed that as the proportion of hay increased from 0 to 100%, crude fibre in the diet increased from 2.2 to 33.8 % and methane (kJ/100kJ) showed a small decrease at maintenance, but increased from about 3.5 to 7.0 at twice maintenance. Moe and Tyrell (1979) also found little difference between carbohydrate sources at maintenance but at higher intakes soluble carbohydrates were found to be less methanogenic than cell wall carbohydates.

The effect of protein concentration in the diet is less clear. Pelchen and Peters (1998) analysed 1137 data sets from the literature and developed regression equations to predict methane emission. When crude protein was included as an independent variable it had a negative sign, indicating that increasing protein in a diet would be expected to decrease methane emission.

Addition of lipids to the diet reduces methane emission. Both the quantity and the degree of unsaturation of the lipid have an effect (Czerkawski *et al.* 1966a, 1966b). It appears that the effect of degree of unsaturation is relatively small and that the effect of lipid is mainly in depressing digestion (Johnson and Johnson 1995; Mathison *et al.*1998).

Digestibility. Compilations of data comparing methane emission at various digestibilities exhibit a high degree of variation (Johnson and Johnson 1995; Figure 3). The main reason for this is that the results are confounded by the wide range of diets and intakes used in such comparisons. It has already been shown above that methane is dependent on both diet composition and intake level. Blaxter and Clapperton (1965) calculated that the relationship between methane emission and digestibility is very dependent on intake level. When feed is given at low levels of intake methane emission (kJ/100kJ) increases as digestibility increases, whereas with high intakes methane emission falls as digestibility increases.

Measurement of methane emission under grazing conditions

A method for measuring methane emission in the field known as the sulphur hexafluoride (SF_6) tracer technique, has been developed at Washington State University by Johnson *et al.* (1994a). A calibrated source of SF_6 is placed in the rumen *per os* prior to an experiment, the animal's expired breath is sampled and the ratio of methane to SF_6 determined. The source of SF_6 is a permeation tube, and its rate of release of SF_6 is controlled by a permeable Teflon^{TM} membrane held in place by a porous stainless steel frit and a locking nut. Each tube is calibrated at 39°C by regular weighing for a period prior to insertion into the rumen. The tubes, typically 35 mm length by 11 mm in external diameter, are made from brass rod and weigh about 32g. Each test animal is fitted with a halter, which supports an inlet tube that is placed so that its opening is close to the nose. The inlet tube leads via a capillary tube and shut-off valve to a PVC collection yoke which is fitted over the neck and strapped to the halter. The collection yoke is evacuated

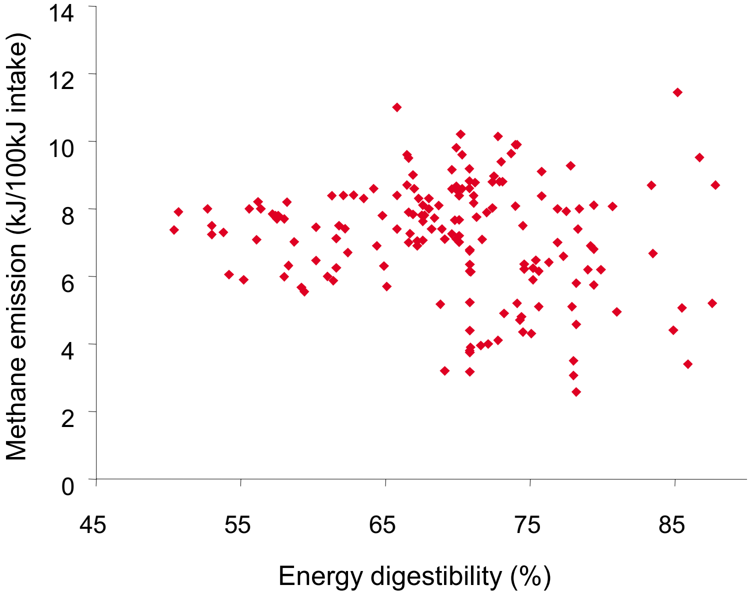

Figure 3. Effect of digestibility on methane emission: world beef cattle data (DE Johnson, pers.comm).

prior to use and the rate at which air is sampled from near the animal's nose is determined by the length and internal diameter of the capillary tube. The yoke is easily isolated for daily changing by means of a shut-off valve and quick connect fittings. Yoke volumes are typically 1.7 and 2.5 litres for sheep and cattle respectively and the capillary system is designed to deliver half this volume during the collection period, usually 24 hours. An identical apparatus is placed upwind each day to collect an integrated background air sample. The methane emission rate (Q_{CH4}) is calculated as:

$$Q_{CH4} \quad \frac{Q_{SF6} \quad [CH_4\ \text{sample}] \quad [CH_4\ \text{ambient}]}{[SF_6\ \text{sample}] \quad [SF_6\ \text{ambient}]}$$

where Q_{SF6} is the calibrated rate of permeation from the SF_6 tube and $[CH_4]$ and $[SF_6]$ are concentrations in the collection yokes and background concentrations.

Permeation tube calibration. The reliability of permeation tubes in releasing SF_6 at a steady and predictable rate is a critical factor in the success of the tracer technique. Several factors have been shown to influence permeation tube behaviour and are discussed in detail by Ulyatt *et al.* (1999).

The permeation rate of the SF_6 tubes is established by weighing in the laboratory prior to the experiment for a period (ideally two months) at 39°C. A typical permeation record for a tube kept under such controlled conditions for 500 days is shown in Figure 4. While a linear regression usually gives a good fit to this data (R^2 typically > 0.998), close inspection shows that the plot is slightly curvilinear, with permeation rate being slower at the end than at the beginning of the measurement period. If tubes are recovered after a period in the rumen and permeation rate again monitored under controlled laboratory conditions, the post-experimental rate is usually lower than the pre-experimental rate. In the example shown in Figure 4 the pre-experiment permeation rate was 1.0 mg/d and the post-experimental rate after 235 days in the rumen 0.8 mg/d, a difference of 20%. Lassey (pers. comm.) found that the data is best fitted with quadratic expression which allows accurate interpolation between the pre- and post-experimental periods to obtain a permeation rate for the actual time of any experiment.

The validity of the SF_6 technique has been checked in comparisons with respiration chamber measurements. Johnson *et al*. (1994) compared 55 measurements using the SF_6 technique with 25 chamber measurements of cattle and showed that while the SF_6 estimates were 0.93 of those in the chamber, the difference was not significant. Similarly, Pinares-Patillo (unpublished) in New Zealand found in one experiment with 10 sheep fed chaffed lucerne hay that methane production estimated from SF_6 was 0.95 chamber emission. This is what might be expected, given that Murray *et al.* (1976) estimated that greater than 98% of combined rumen and hind gut methane production is excreted via the mouth. However, a number of workers (C. Pinares *pers comm*; D. E. Beever *pers comm*; McCrabb and Baker *pers comm*), have obtained results that did not provide ac-

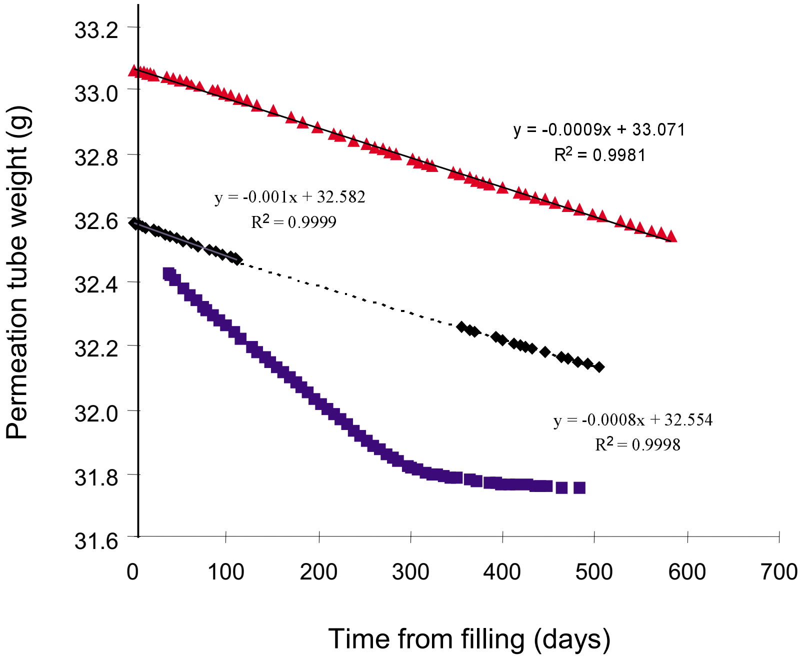

Figure 4. SF_6 permeation tube behaviour over time. ▲, control tube 482, monitored in the laboratory at 39°C, showing long term behaviour and bset-fit linear regression; ■, control tube 341, monitored in the laboratory at 39°C, showing the decline in permeation rate when the tube became depleted of SF_6; ◆, tube 379 monitored before and after a period of 235 days in the rumen, with the separate regression fits.

ceptable agreement between chamber and SF_6 measurements. Clearly there is a need to confirm that SF_6 reliably reflects respiration chamber estimates of methane production.

The SF_6 technique must be the preferred method for measuring methane emission under grazing conditions because data can be obtained from individual animals and it allows the imposition of experimental treatments (McCaughey *et al.* 1997).

Methane mitigation possibilities and strategies

A wide range of possibilities for reducing livestock methane emission have been suggested: reducing livestock numbers; increasing the efficiency of animal production, exploiting between-animal variation; anti-methanogenic feed additives; immunisation; and, manipulation of the rumen microbial ecosystem.

Reducing livestock numbers. As methane emissions from livestock are the predominant source of greenhouse gases in countries like New Zealand and Uruguay, reducing livestock numbers would be one way of meeting FCCC commitments. However, such countries are heavily dependent on their livestock industries for generating national income and imposition of regulations aimed at reducing livestock numbers would be politically unacceptable. Reducing livestock numbers through normal market processes can be effective. For example, in New Zealand sheep farming has become less profitable over the past ten years and farmers have reduced sheep numbers and used the land for alternative enterprises, such as forestry. Sheep numbers have reduced from 57.9 million in 1990 to 45.2 million in 2000, while dairy cattle and beef cattle numbers have increased slightly. The net outcome has been a decline in ruminant methane emission from 1.45 to 1.31 Tg/year from 1990 to 2000. This change in stock numbers, predominantly a reflection on the profitability of sheep farming, has meant that New Zealand has been able meet its commitments to the FCCC. This trend is predicted to continue to 2008 and will play a large part in New Zealand's efforts to meet its commitments to the Kyoto Protocol. It will also allow breathing space to develop alternative mitigation techniques. However, livestock numbers will respond positively to improved economic conditions and if sheep farming becomes more profitable an increase in stock numbers and thus CH4 emission is a possibility.

Increasing the efficiency of livestock production. Improving the efficiency of ruminant animal performance will generally lead to a reduction of CH4 emitted per unit of animal product. There are two aspects of this: genetic improvement of the animals themselves to achieve more product per unit of feed intake, as has been achieved with pigs and poultry, and dietary manipulation via increased feed intake and appropriate feed composition. In the grazing ecosystem improvements in intake and feed quality would have to implemented through improved pasture and animal management, including appropriate supplementation strategies.

Table 3. Effect of feed intake on methane emission in cows.

Feed intake (kg DM/d)	10.8	16.0	21.1
Milk production (kg/d)	10	20	30
CH4 emission (g/d) *	269	317	305
g CH4/kg milk	26.9	15.9	10.2

* Blaxter & Clapperton (1965).

a. Increasing feed intake. Increasing feed intake decreases the methane emission per unit of feed intake as shown in Figure 2. A calculation is given in Table 3, where the increased intake of the same diet to a cow increases milk production, but decreases methane emitted per unit of milk. A similar effect was shown by Kirchgessner *et al.* (1995): as milk yield increases methane emitted per unit of milk yield decreases. This relationship is seen in Figure 5, using data from dairy cows grazing New Zealand pasture. By feeding animals *ad libitum* it is possible to both maximise efficiency and reduce methane emission per unit of product. This is because as intake increases the methane emission associated with the essential, but non-productive, requirements for maintenance is diluted.
b. Dietary manipulation. As described above, decreasing dietary fibre and increasing starch and lipid will reduce methane emission. Generally, diets of higher digestibility have these characteristics. This effect can be seen in the calculation in Table 4 where dairy cows were given feeds of increasing digestibility to achieve the same level of milk production. The animals would have eaten less of the higher digestibility diets and thus produced less total methane and reduced methane emitted per unit of milk produced. Improving the nutritive value of the feed given to grazing animals by balancing the diet with concentrates, or by breeding improved pasture plants, should result in reduced methane emission.
c. Metabolic efficiency. Treatment of animals with growth promoting substances can result in increased efficiency of production. An example based on bovine somatotrophin (bST) treatment of milking cows (Bauman *et al.* 1985) is given in Table 5. As bST dose was increased, milk production per unit intake (efficiency) increased and methane emitted per kg milk was calculated to decrease. Growth stimulants such as steroids would be expected to have a similar effect: less feed and methane overall to achieve the same level of production. Such measures must of course meet the required regulatory and consumer acceptance standards.

All these techniques use dilution of maintenance requirements to achieve reduced methane emission. Their maximum effectiveness in terms of reducing methane emis-

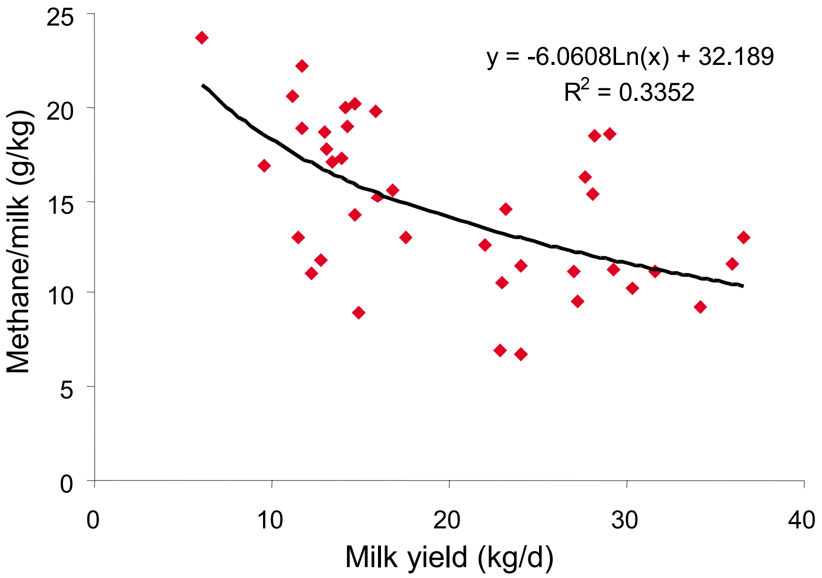

Figure 5. Relationship between milk yield and methane emission in New Zealand dairy cows grazing pasture.

Table 4. Effect of feed quality on methane emission of cows with the same level of milk production.

DM digestibility (%)	55	65	75
Milk production (kg/d)	20	20	20
Feed intake (kg DM/d)	21.6	17.5	14.6
CH_4 emission (g/d) *	499	386	306
g CH_4/kg milk	24.9	19.3	15.3

* Blaxter & Clapperton (1965).

Table 5. Effect of bovine somototrophin (bST) on methane emission by lactating cows. (Source: Bauman *et al.* 1985).

	bST dose (mg/d)		
	0	13.5	27.0
Milk production (kg FCM/d)	27.9	34.4	38.0
NE intake (MJ/d)	143	154	164
Kg milk/MJ NE intake	0.195	0.223	0.232
CH_4 emission (g/d) *	365	361	351
g CH_4/kg milk	13.1	10.5	9.2

* Blaxter & Clapperton (1065).

sion, would be in maintaining present levels of animal production with fewer animals, or in increasing animal production with the same number of animals. This would provide the farmer with options for land use that should improve profitability.

Exploiting between-animal variation in methane emission. A notable feature of methane emission in experiments where large numbers of animals have been fed the same diet is that there are large differences in emission per unit of feed intake between animals. Between-animal differences account for most the variance, 70-80%, with a lesser amount attributed to differences between measurement days. Such differences between animals are real (Blaxter and Clapperton 1965; Lassey *et al.* 1997; Ulyatt *et al.* 1999) and can persist for some time (Lassey *et al.* 1997). We have found that in any group of animals approximately 10% are high and 10% low emitters, with the difference between these two groups approximately 40%. The question of whether these differences remain stable over time remains unresolved at present; in some experiments the differences have been transitory, while in others the difference has persisted for up to four months. Given that methane results from microbial activity, the animal can only have an impact on this variation through interactions with the microbes directly, through the diet selected, or through control of the fermenter (rumen) conditions. Animal effects on fermentation could be via the saliva, feed processing (eg., comminuition), or flow rate through the rumen. It is possible that the animal impact on fermentation is genetically determined and if this is the case it may be possible to obtain markers that can be used to select low methane emitters.

Chemical compounds that reduce methanogenesis. A wide range of chemicals are available that will reduce rumen methanogenesis (Chalupa 1980; Johnson and Johnson 1995; Mathison *et al.* 1997):

a. Alternative hydrogen acceptors, such as fumarate, sulphate/sulphite, nitrate/nitrite and unsaturated fatty acids. Generally the amount required to be effective in reducing methane emission is likely to be either toxic to the animal, cause disruptions to digestion, or be uneconomic.

b. Halogenated methane analogues, such as, chloroform, carbon tetrachloride, chloral hydrate, bromochloromethane and bromoethanesulphonic acid can be very potent methane inhibitors. While some of these compounds are volatile and difficult to administer, McCrabb *et al.* (1997) claimed success in inhibiting methane in cattle with bromochloromethane complexed with -cyclodextrin, which reduced volatility. Mathison *et al.* (1998) concluded that halogenated methane analogues have potential as methane inhibitors, provided that problems such as adaptation by rumen microbes, host toxity and suppression of digestion can be overcome.

c. Ionophores, such as monensin and lasalocid have been shown to reduce methane emission (Johnson and Johnson 1995), though the affect appears to be short-lived as the rumen microbes adapt to the additive within two weeks.

d. Defaunating agents, like manoxol, teric, alkanate 3SL3 and sulphosuccinate can reduce methane emission (Mathison *et al.* 1998). They appear to act by disrupting the close symbiotic relationship between methanogenic bacteria and protozoa. Many of these defaunating agents are toxic to the host animal and this restricts their routine use.

The main problems with chemical additives are that many are toxic to the animal, toxic to rumen microflora and therefore reduce digestion and food intake, have short lived effects because the rumen microbes adapt, are volatile and thus difficult to administer, are expensive, or would fail to meet consumer product acceptance. With grazing animals, especially under extensive conditions, slow release devices would be required to ensure regular delivery into the rumen.

There are naturally occurring compounds in some forages that appear to have antimethanogenic properties. Gupta *et al.*(1993) claimed that the leaves of the tropical plant *Enterolobium timbouva* defaunated the rumen of buffalo, while G. C Waghorn (unpublished) has found depression of methane emission by feeding sheep the condensed tannin-containing legume *Lotus corniculatus*. Such plants offer the prospect of methane reduction in the grazing environment.

Immunisation. Scientists in Australia have registered patents for immunisation procedures that are claimed to reduce methane emission. They have developed a vaccine containing an antigen derived from methanogenic bacteria (Baker 1998) and an immunogenic preparation which reduces the activity of rumen protozoa (Baker *et al.* 1997). The antimethanogenic vaccine is claimed to reduce methane in *in vitro* incubations, and significantly increase DM intake and wool growth. Such vaccines have the potential to provide a cost-effective treatment to reduce methane emission and enhance animal production.

Manipulation of the rumen microbial ecosystem. The methanogenic bacteria, which are highly efficient scavengers of hydrogen, are the main, but not the only, agents for converting hydrogen to methane in the rumen (Joblin 1999). There is also evidence that the rumen can function satisfactorily the absence of methanogens (Joblin 1999). There are many potential opportunities for mitigating methane through microbial intervention in the rumen such as: targeting methanogens with antibiotics, bacteriocins, or phage; removing protozoa from the rumen; development of alternative sinks for hydrogen such as reductive acetogenesis. All these opportunities are possible through microbial intervention, however it is very early days in the realisation of these possibilities

While production of methane in the rumen is carried out by the methanogenic bacteria utilising carbon dioxide and hydrogen, there is another class of bacteria present in the rumen, the acetogens, that utilise carbon dioxide and hydrogen to produce acetic acid, a major nutrient of the ruminant. Acetogens do not compete well in the rumen compared to methanogens, so experiments are in progress to see if the microbial ecosystem can be manipulated to enhance acetogen activity (Joblin 1999). One strategy is to genetically modify acetogens so that they can compete more effectively in the rumen.

Mitigation strategies adopted by New Zealand

Under the terms of the Kyoto Protocol New Zealand, as an Annex 1 country, has a target of zero change in total greenhouse gas emissions between 1990 and 2008-2012. This does not seem to be ambitious, however carbon dioxide levels are predicted to be 39% above 1990 levels by 2008-2012. This will be offset to some degree by a predicted 15% reduction over the period in ruminant methane emissions, largely because sheep numbers are falling in response to a decline in the profitability of sheep farming. An unknown is the emission of nitrous oxide from agricultural land, especially as this gas has a very high global warming potential. However, there is unlikely to be much change in nitrogenous fertilizer use and therefore in nitrous oxide emission between 1990 and the commitment period. New Zealand also has been involved in extensive planting of exotic forests and if the current planting rate of about 60,000 ha per year is maintained, 130 million tonnes of carbon sink could be available for trading to offset the predicted unfavourable balance in greenhouse gas emissions.

The New Zealand Government has made a serious commitment to international initiatives on greenhouse gases and global warming, but it wants to meet its emission reduction targets in ways that impose least cost to the economy. At present it is considering alternative methods that distribute the cost fairly across all appropriate sectors of the economy, such as: a domestic carbon emissions trading regime that interfaces with an international system; a low level carbon tax for the energy sector; policies that would lead to increased efficiency of energy use; and, project level trading, where an investor could obtain credit for emission reductions that were derived from projects external its core business (eg., a power company investing in a project that would bring efficiencies leading to substantial reductions in power use).

At present agriculture is not being considered in an emissions trading system, mainly because widely dispersed sources of greenhouse gases (eg., a cow or sheep) are very difficult to measure accurately. However, this does not mean that agriculture will be exempt in the future. The New Zealand Government is supporting research aimed at improving inventory measurements and in developing mitigation technologies. The inventory research is using the SF_6 tracer technique to develop emission factors (g methane per head per year) that truly reflect agricultural practice in New Zealand. Default emission factors published by IPCC do not adequately represent the New Zealand situation. A model will be developed that will be responsive to changes in agricultural practice and meet our requirements for policy development and international reporting. Research is also concentrating on evaluating the cause of the variation between animals in methane emission, plant factors that might inhibit methane and manipulation of the rumen microbial ecosystem.

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