Nutritional management options to reduce enteric methane emissions from NSW beef and dairy herds

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Abstract: *There are considerable opportunities to reduce the methane emissions per unit animal product by individual and herd management changes that reduce the proportion of energy expended in maintenance. Maximised fecundity, health and maximising daily product output by provision of ad-libitum high digestibility feed or supplementation of less digestible feeds are appropriate technologies. Reducing total emissions (kg/d) rather than simply emission intensity (methane/product) from the herd or flock will require constraining animal number or implementing mitigation strategies such as the inclusion of fats or oils in the diet. Potential exists to reduce emission without restricting animal performance by grazing pastures of moderate tannin levels or chicory, by supplementing with oils or white cottonseed and by some tannin and saponin supplements. Genetic improvement of animals for feed use efficiency and methane yield may also enable emission reduction without compromising productivity.*

Introduction

Two thirds of greenhouse gas emissions from Australia's agricultural sector are emitted as enteric methane, and this constitutes approximately 11% of Australia's total anthropogenic GHG emissions (DCC 2008). Methane is an end-product of fermentation in all ruminants and approximately 6% of dietary gross energy is lost as methane. Enteric emissions may be calculated as the product of animal population, the quantity of food consumed per animal and the methane yield (methane/kg DMI) of each animal. Methane yield has been observed to range between 16 and 26 g CH_4/kg DMI) in global studies (Grainger; Munger & Kreuzer 2005; Molano & Clark 2008). Reducing methane yield and feed intake by ruminants using means which will not reduce animal production is a major research emphasis in Australia and New Zealand. Effects of nutrition on methane production have been reviewed (Blaxter & Clappeton 1965, Pelchen & Peters 1998) and summaries of practical information are starting to be released to producers (Beauchemin et al., 2009; Hegarty 2009). This paper explores and explains current knowledge on how nutritional management, both of the farm system and of the individual ruminants, can be utilised to achieve the goal of reducing enteric methane emissions without reducing animal production.

The digestibility – intake – methane relationship

The ruminant industries strive for improved conversion of pasture DM into animal product. This conversion efficiency incorporates both harvesting efficiency (DM grown to DM consumed) and efficiency of conversion of consumed DM into animal product. The effect of variation in feed digestibility on daily methane production (DMP) is confounded with concomitant changes in DMI in animals consuming feed *ad-libitum*.

Simulation of the daily DMP and daily live weight gain (LWG; g/d) of a 350 kg Angus steer offered unlimited feed of 55%, 65%, 75% or 85% digestible DM with adequate nitrogen to fully meet requirements of the rumen microbes and the animal are summarised in Figure 1. Scenarios were modelled using Grazfeed (Freer et al., 1997).

The principles demonstrated graphically in Figure 1 are:

Increased DMI leads to near linear increases in liveweight gain (LWG) but the rates of LWG are

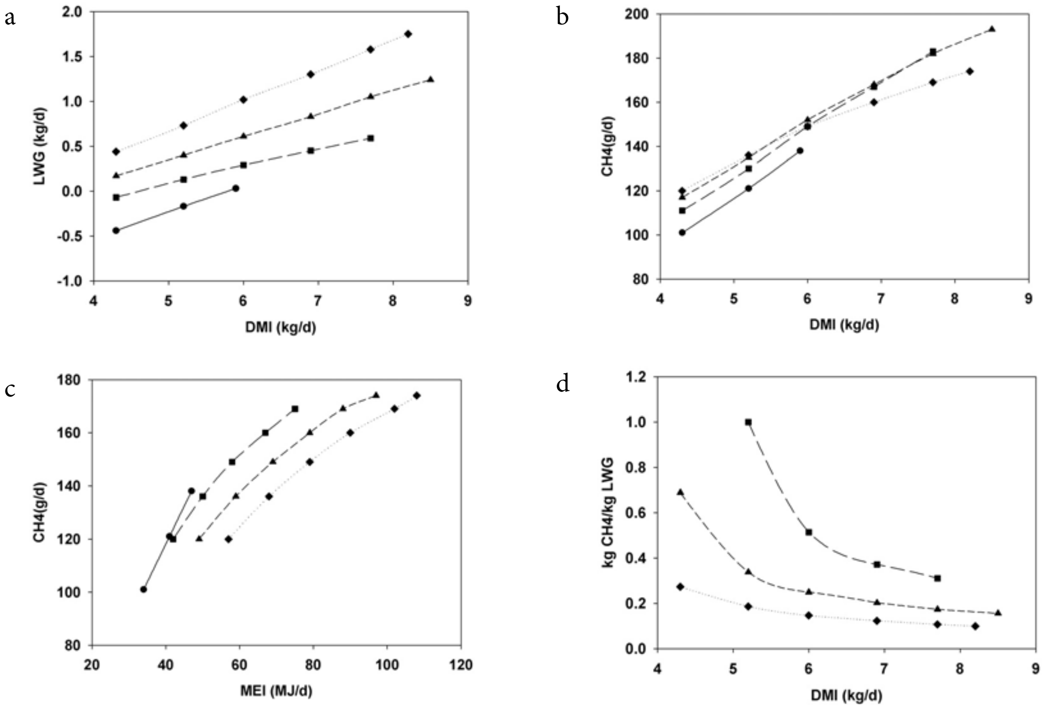

Figure 1. Changes in live weight gain (LWG) and daily methane production (DMP) associated with changes in dry matter intake (DMI) by 350 kg Angus steers, as modelled by Grazfeed, where DMP is predicted by the equation of Blaxter and Clapperton 1965. Rations are ● 55%, ■65%, ▲75% or ◆85% DM digestible

greater for feeds of greater metabolisable energy content (ME; MJ/kg DM, Fig. 1a).

Increased DMI increases daily methane production for diets of low to moderate digestibility as typically found in Australian extensive grazing. Only at very high intakes of high digestibility diets (◆), does daily methane production decline with additional feed intake (Fig.1b).

When the energy density of the feed is allowed for (Fig. 1c), it is apparent that daily methane production arising from consuming a fixed ME intake is lowest when the energy is provided by the diet of highest ME density (MJ ME/kg DM).

While increased intake of any feed reduces the emissions intensity of growth (kg CH_4/kg LWG), emissions intensity at any DMI is always lower for feeds of higher digestibility (Fig. 1d).

Small changes in energy intake will cause small changes in methane output but large changes in animal performance. For example; allowing the 350 kg example animal to consume 7 kg of 75% rather than 65% digestibility forage would increase LWG from 290 g/d to 610 g/d while causing only a marginal increase in methane output (149 g to 152 g/d).

Nutritional management

Pasture species

Reviews of the association between methane production and the nutritional characteristics of feeds (e.g. Blaxter & Clapperton 1965; Pelchen & Peters 1998) have not noted any feeds for which the methane output was not consistent with the fibre, protein and oil content of the feed. As a generic statement therefore, the chemical composition and intake of forages adequately describes the DMP that will arise from their consumption. On account of their lower fibre content, legumes typically have a lower methane yield than do grasses (Waghorn et al., 2002; Beauchemin et al., 2009) but lower fibre also enables a higher daily DMI of legume than of grass (Freer & Jones 1984). As a consequence of higher intake daily methane emission may at times be higher on legume than grass diets when consumed *ad libitum* (McCaughey et al., 1999). Recent studies have identified species where low methane yield is evident and is not explained by fibre or nitrogen content of the feed. Ulyatt et al., (2002) observed low methane yield on kikuyu pastures in one year but not subsequently. Pastures rich in condensed tannins (Sulla, *Hedysarum coronarium* and Birdsfoot trefoil, *Lotus corniculatus*) have been shown to have low methane yield (Waghorn et al., 2002; Woodward et al., 2002) in keeping with condensed tannins reducing methane output. Chicory (*Chicorium intybus*) which has no condensed tannins also has also shown a low methane yield in initial studies (Swainson et al., 2008)

Pasture maturity

Plant maturation is associated with increased fibre content and reduced digestibility, so higher methane yields can be expected from more mature pastures. This has been observed as grazing seasons progress on some occasions (Waghorn & Clark 2006) but not others (Pinares Patino et al., 2003). High methane yields have been noted in animals consuming mature tropical forages in Australia (McCrabb & Hunter 1999) and New Zealand (Ulyatt et al., 2002). These may reflect a consequence of C4 photosynthetic metabolism in tropical grasses and the higher methane yield is consistent with the higher fibre content in C4 forages.

Supplements

Effects of providing supplementary dietary energy can be predicted as a direct consequence of changing the ME content of the diet as per Figure 1. In practice, grain supplementation leads to some reduction in forage intake (i.e. substitution) and so the expected increase in DMP may not be discernable (Boadi et al., 2002). Provision of low digestibility supplements (e.g. hay during drought) can also be expected to increase daily emissions but reduce emissions per unit product.

White cottonseed has become increasingly important as a supplement and in dairy systems will reduce daily methane output (Grainger et al., 2008a) and may increase milk output. Reductions in methane yield in tropical beef cattle consuming low digestibility feeds have also been observed when cottonseed is fed (Klieve et al., 2009). The effect of cottonseed is believed to result from its oil content and Beauchemin et al., (2008) found a general suppression of oils on methane production (Fig. 2). Reduced digestibility from high oil inclusion may explain why production responses are not always achieved (Beauchemin et al., 2009) and may contribute to lower methane output. At present, oil supplements are the most practical means of direct methane mitigation with lowest costs oils being preferred rather than paying high prices for coconut oil which has the highest efficacy (Machmüller & Kreuzer 1999). Other supplements targeted to suppress methane, such as tannins, have not always been effective (e.g. Beauchemin et al., 2007, 2009) and sources and tannin inclusion levels must be carefully selected to ensure animal production is not compromised.

Monensin is one additive that has been extensively researched for ruminal activity. While there have been numerous short-term studies showing efficacy, in field situations with fresh forage, major studies in Australia (Grainger et al., 2008b) and New Zealand (Waghorn et al., 2008) have shown no suppression of methane emission from dairy cows treated with the commercially available intra-ruminal control release device. In contrast, sustained effect has been observed in dairy cattle on total mixed rations (Odongo

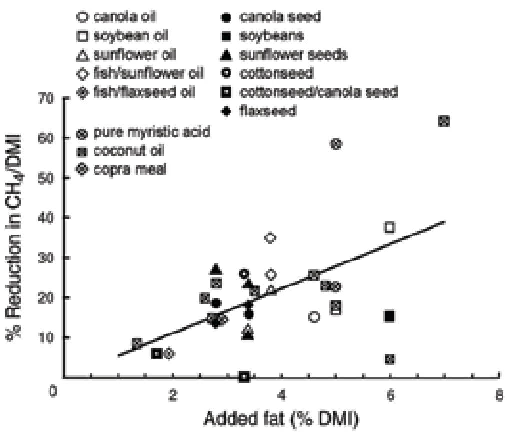

Figure 2. Reduction in methane yield (g methane/kg DMI) resulting from inclusion of exogenous fats in the ration of ruminants (after Beauchemin et al., 2008)

et al., 2007). There are a large number of other compounds currently being tested for their methane inhibiting effect, with some successful compounds (e.g. medium chain fatty acids) being too expensive for commercial use.

Exploiting between-animal differences in feed use

Two nutrition related traits are being considered for selective breeding (genetic improvement) of animals which may reduce enteric methane emissions. Firstly a program to breed beef cattle for lower net (residual) feed intake (NFI) has been in progress for over 15 years (Arthur 2004). Selection for this moderately heritable trait could lead to reduction in enteric emissions in Australia exceeding 600 kt over the next 25 years (Alford et al., 2006) as well as reducing nitrogen excretion and potentially nitrous oxide loss (Herd et al., 2002).

More recently studies have begun to determine whether methane yield is a genetically determined trait, and if so, what production traits it correlates with. Studies for genetic improvement of methane yield in sheep and in beef cattle have recently commenced in Australia.

Managing the intensity, efficiency and mix of enterprises to reduce emissions

The basic nutritional principles governing the relationships between forage quality, intake and DMP and demonstrated in Figure 1 were based on meta-analysis of diet:methane relationships of individual animals. Considerable scope exists however to manage emissions by managing herd/flock efficiency, the intensity of nutritional management and the proportion of enterprises on the farm in order to reduce emissions without compromising profitability.

Improving feed use efficiency

Pasture quality, supplementation and selection for NFI were described as means of reducing the emissions intensity and total methane emissions from livestock. Efficiency of the whole herd or flock can also be improved by further increasing productivity of stock and minimising the proportion of consumed energy utilised in maintenance. Removing growth impediments by control of parasites and ensuring maximum reproductive efficiency are examples of how non-nutritional tools can improve herd feed use efficiency. Recent modelling of the consequences of changing from British-breed cattle to composite bred cattle in northern Australia showed changing to the tropically adapted cattle has reduced emissions/kg LW weaned by approximately 25% (Bentley & Hegarty 2008). Synchronising pasture availability and the breeding cycle of the herd/flock can also reduce emission from the system by ensuring maximum efficiency of pasture harvest in times of high pasture production (Howden et al., 1996). Pasture improvement can also enable the same amount of product to be generated from a smaller area and this is evaluated further under enterprise intensity

Enterprise intensity and grazing system

From the relationships between methane, DMI and LWG previously described, one strategy to reduce emissions is to intensify the animal management system to produce the same or more product with lower methane emissions. This could be achieved in many ways including:

Pasture improvement or use of forage crops in association with increased stocking rate and a reduced grazing area (Alcock and Hegarty 2006).

Time control grazing in a manner that leads to animals consuming a higher digestibility diet than they would have otherwise achieved, but having limited DM intake. As shown in Fig 1b, providing higher digestibility feed (as may occur with spelled paddocks at certain times of the year) will only reduce DMP if intake is also constrained below *ad-libitum*. Pinares Patino et al., (2007) found this in cattle in France where high stocking rate improved DMD and cattle performance but did not reduce DMP of grazing cattle. Animals which are given access to fresh (high digestibility) forage every few days (rather than daily or twice daily as with dairy cows) are more likely to show reduced total emission. This is because under high stocking rates, DMP declines over time when animals are held on the same paddock over 4 days (Murray et al., 2001); probably reflecting a decline in intake as feed becomes trampled and soiled. In contrast, when cattle are moved to fresh forage more frequently (every 1-3 d,) DMP is reduced as well as achieving superior LWG relative to continuously grazed cattle (DeRamus et al., 2003). There is no Australian field emission data on continuous versus any form of time controlled grazing.

Lot feeding. Providing cereal grains at over 70% of the diet leads to a lower daily methane emission than does consumption of a forage diet. While this is desirable, a more comprehensive assessment of the total emissions associated with producing lot finished animals is required to establish the ultimate GHG advantage. Simplistic life cycle assessment of providing a high-cereal TMR for dairy cows suggests the embedded carbon cost of the grain may cause the total GHG of animal products to be higher from grain fed animals (Van der Nagel et al., 2003).

Balance of enterprises

While intensification may not be possible in all areas (e.g. marginal grazing lands), one of the advantages is that it enables the same product output from a smaller area of land (Alcock & Hegarty 2006). This creates the opportunity for including new non-livestock farm enterprise on land no longer required for grazing. This provides significant opportunity to diversify into alternate income streams (e.g. cropping, forestry) and so reduce exposure to financial and climatic risk, as well as potentially sequester carbon in forestry projects.

Conclusions

Managing of livestock emissions needs to be considered as part of a whole farm approach to meeting a net farm emissions target. Choices about balancing emission reduction targets with farm productivity targets will ultimately depend on the priority (and probably relative economic value) of these target outcomes. The first step in reducing emission intensity of ruminant production should be to increase animal productivity by means such as removal of production impediments and of breeding stock that fail to conceive or have low fecundity. Increased feeding intensity though pasture improvement, supplementation or feedlotting with cereal grains can be further used to reduce emissions but reductions in total emission will only result if total stock number is not allowed to increase. Specific diet additives such as oils are possible to reduce enteric emissions and at times increase productivity of both beef and dairy cattle in Australia but have little application for the more extensive pastoral industries. Genetic improvement for nutritional traits (NFI and methane yield) may offer slow emission reduction, if the economic value of greenhouse gases justifies their inclusion in breeding indices.

References

Alcock, D & Hegarty, RS 2006, Effects of pasture improvement on productivity, gross margin and methane emissions of a grazing sheep enterprise, *International Congress Series* 1293, 103–106.

Alford, AR, Hegarty, RS, Parnell, PF, Cacho, OJ, Herd, RM & Griffith, GR 2006, The impact of breeding to reduce residual feed intake on enteric methane emissions from the Australian beef industry, *Australian Journal of Experimental Agriculture* 46, 813-820.

Arthur, PF, Archer, JA & Herd, RM 2004, Feed intake and efficiency in beef cattle: overview of recent Australian research and challenges for the future, *Australian Journal of Experimental Agriculture* 44, 361-369.

Beauchemin, KA, McGinn, SM, Martinez, TF & McAllister, TA 2007, Use of condensed tannin extract from quebracho trees to reduce methane emissions from cattle, *Journal of Animal Science doi:10.2527/jas.2006-686*

Beauchemin, KA., Kreuzer, M, O'Mara, F & McAllister, TA 2008, Nutritional management for enteric methane abatement: a review, *Australian Journal of Experimental Agriculture* 48, 21–27.

Beauchemin, KA, McGinn, SM & Grainger, C 2009, Reducing methane emission from dairy cows, www.wcds.afns.ualberta/Proceedings/2008/manuscripts/Beauchemin.pdf Cited 11/05/2009.

Boadi, DA, Wittenberg, KM, & McCaughey, WP 2002, Effects of grain supplementation on methane production of grazing steers using the sulphur (SF_6) tracer gas technique, *Canadian Journal of Animal Science* 82, 151-157.

Blaxter, KL & Clapperton, JL 1965, Prediction of the amount of methane produced by ruminants, *British Journal of Nutrition* 19, 511-522.

DCC 2008, National greenhouse inventory 2006 (Department of Climate Change Canberra, Australia) http://www.climatechange.gov.au/inventory/2006/pubs/inventory2006.pdf.

DeRamus, HA, Clement, TC, Giampola, DD & Dickison, PC 2003, Methane emissions of beef cattle on forages: efficiency of grazing management system, *Journal of Environmental Quality* 32, 269-277.

Freer, M, Moore, AD & Donnelly, JR1 1997, GRAZPLAN: Decision support systems for Australian Grazing Enterprises – II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS, *Agricultural Systems* 54, 77-126.

Grainger, C, Clarke, T, McGinn, SM, Auldist, MJ, Beauchemin, KA, Hannah, MC, Waghorn, GC, Clark, H & Eckard, RJ 2007, Methane emissions from dairy cows measured using the sulphur hexafluoride (SF_6) tracer and chamber techniques, *Journal of Dairy Science* 90, 2755-2766.

Grainger, C, Clarke, T, Beauchemin, KA, McGinn, SM & Eckard RJ 2008, Supplementation with white cottonseed reduces methane emissions and can profitably increase milk production of dairy cows offered a forage and cereal grain diet, *Australian Journal of Experimental Agriculture* 48, 73-76.

Grainger, C, Auldist, NJ, Clarke, T, Beauchemin, KA, McGinn, SM, Hannah, MC, Eckard, RJ, & Lowe, LB 2008, Use of monensin controlled release capsules to reduce methane emissions and improve milk production of dairy cows offered pasture supplemented with grain, *Journal of Dairy Science* 91, 1159-1165.

Hegarty, RS 2009, Current and emerging technologies to decrease enteric methane emissions from individual ruminants, *Recent Advances in Animal Nutrition in Australia* (submitted)

Herd, RM, Arthur, PF, Hegarty, RS & Archer, JA 2002, Potential to reduce greenhouse gas emissions from beef production by selection for reduced residual feed intake, *7th World Congress on Genetics Applied to Livestock Production,* August 19-23, Montpellier, France.

Howden, SM, White, DH & Bowman, PJ 1996, Managing sheep grazing systems in southern Australia to minimise greenhouse gas emissions: adaptation of an existing simulation model. *Ecological Modelling* 86, 201-206.

Klieve, AV, McLennan, SR, Ouwerkerk, D & Hegarty, RS 2009, Reduced methane emissions and increased liveweight gain in cattle fed supplements of cottonseed and coconut oil, *Proceedings of theXI International Symposium on Ruminant Physiology*, In press.

Machmüller, A & Kreuzer, M 1999, Methane suppression by coconut oil and associated effects on nutrient and energy balance in sheep, *Canadian Journal of Animal Science* 79, 65-72.

McCaughey, WP, Wittenburg, KM, Corrigan, D 1997, Impact of pasture type on methane production by lactating beef cows, *Canadian Journal of Animal Science* 79, 221-226.

McCrabb, GJ & Hunter, RA 1999, Prediction of methane emissions fom beef cattle in tropical production systems, *Australian Journal of Agricultural Research* 50, 1335-1339.

Molano, G & Clark, H 2006, The effect of level of intake and forage quality on methane production by sheep, *Australian Journal of Experimental Agriculture* 48, 219-222.

Munger, A & Kreuzer, M 2006, Methane emission as determined in contrasting dairy cattle breeds over the reproduction cycle, *International Congress Series* 1293, 119-122.

Murray, PJ, Gill, E, Balsdon, SL & Jarvis, SC 2001, A comparison of methane emission from sheep grazing pastures with differing management intensities, *Nutrient Cycling in Agroecosystems* 60, 93-97.

Odongo, NE, Bagg, R, Vessie, G, Dick, P, Or-Rashis, M, Hook, SE, Gray, JT, Kebreab, E, France, J & McBride, BW 2007, Long term effects of feeding Monensin on methane production in lactating dairy cows, *Journal of Dairy Science* 90, 1781-1788.

Pelchen, A & Peters, KJ 1998, Methane emissions from sheep, *Small Ruminant Research* 27, 37-150.

Pinares-Patino, CS, Baumont, R, & Martin, C 2003, Methane emissions by Charolais cows grazing a monospecific pasture of timothy at four stages of maturity, *Canadian Journal of Animal Science* 83, 769 -777.

Pinares-Patino, CS, Hour, PD, Jouany, JP & Martin, C 2007, Effects of stocking rate and carbon dioxide emissions from grazing cattle, *Agriculture Ecosystem and Environment* 121, 30-46.

Swainson, NM, Hoskin, SO, Clark, H & Brookes, IM 2008, The effect of coconut oil and monensin on methane emission from sheep fed either fresh perennial ryegrass pasture or chicory, *Australian Journal of Experimental Agriculture* 48, lxxviii.

Ulyatt, MJ, Lassey, KR, Shelton, ID & Walker, CF 2002, Methane emission from dairy cows and wether sheep fed subtropical grass-dominant pastures in midsummer in New Zealand, *New Zealand Journal of Agricultural Research* 45, 227-234.

Van der Nagel, LS, Waghorn, GC & Forgie, VE 2003, Methane and carbon emissions from conventional pasture and grain-based total mixed rations for dairying, *Proceedings of the New Zealand Society of Animal Production* 63, 28-132.

Waghorn, GC, Tavendale, MH & Woodfield, DR 2002, Methanogenesis from forages fed to sheep, *Proceedings of the New Zealand Grasslands Association* 64, 159-165.

Woodward, SL, Waghorn, GC, Lassey, KR & Laboyre, P 2002, Does feeding sulla (*Hedysarum coronarium*) reduce methane emissions from dairy cows? *Proceedings of the New Zealand Society of Animal Production* 62, 227-230.

Waghorn, GC & Clark, DA 2006, Greenhouse gas mitigation opportunities with immediate application to pastoral grazing for ruminants, *International Congress Series* 1293, 107-110.

Waghorn, GC, Clark, H, Taufa, V & Cavanagh, A 2008, Monensin controlled-release capsules for methane mitigation in pasture-fed dairy cows, *Australian Journal of Experimental Agriculture* 48, 65-68.