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Methane emissions from cattle production – Issues in meeting the Kyoto targets.

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Abstract.

Methane is a greenhouse gas that is emitted mainly by livestock, and accounts for about 14% of national greenhouse gas emissions. If Australia is to meet the Kyoto targets, then greater attention is likely to be focused on ways that methane emissions can be reduced. The three main options to reduce methane emissions are to reduce livestock numbers (particularly in rangelands areas), reduce emissions per kilogram of beef produced (by improving feed efficiency and other factors), or to manipulate microbial activity in the rumen by biological, chemical or immunological control agents.

Keywords: Greenhouse gas, beef production, mitigation.

1. INTRODUCTION

The issue of greenhouse gas emissions is emerging to be a significant one for grazing enterprises in Central Queensland. There are several reasons for this, but the principal one is that many enterprises are significant emitters of greenhouse gases. The emissions come from three main sources. Methane is emitted from cattle and sheep as a natural by-product of the animals digesting grass in the rumen. Fossil fuels such as petrol and diesel are burnt as a normal part of business operations, releasing carbon dioxide and other greenhouse gases into the atmosphere. Carbon dioxide is released from the breakdown of timber when vegetation is cleared, and from soils under certain farming or grazing practices¹. In total across Australia, these operations mean that agriculture is responsible for about one-third of greenhouse gas emissions.

Australia has taken some steps towards accounting for greenhouse gas emissions and reducing the growth in these emissions. A National Greenhouse Gas Inventory (NGGI) has been established to provide estimates of emission levels over time, and there is a great deal of scientific work being carried out to refine those estimates. The Australian Greenhouse Office has been established, and through the Greenhouse Challenge program, partnership agreements with industry have been sought to reduce emission levels. These voluntary agreements have been effective in reducing the growth in projected emissions in the next decade.

However, Australia is a signatory to the Kyoto Protocol, which is an international agreement that limits growth in emissions to the 2008 – 12 period for Australia to 108% of the 1990 levels. While the Kyoto Protocol still has to be ratified to be binding, and there are some uncertainties about whether this step will be formalised, it remains likely that some emission reduction targets will still apply. Significant reductions in emissions would now be necessary to meet the Kyoto target, as emissions in Australia passed that target level in 1996. This means that the search for opportunities to reduce emissions are likely to continue. Agriculture, as a major contributing sector, is likely to become involved in this process.

To date, the focus of the Commonwealth Government, through the Greenhouse Challenge program, has been to search for win-win situations where emission reductions go hand in hand with improved profitability. This can occur in a large manufacturing plant, for example, where improved plant efficiency can cut power usage, therefore saving on costs and greenhouse gas emissions at the same time. Many of the participants in the Greenhouse Challenge program are larger companies that are involved in power generation, transport and manufacturing sectors, where there have been opportunities to find greater efficiencies.

There has been little involvement with agricultural enterprises in the Greenhouse Challenge program. There are a number of good reasons for this. Agriculture is comprised of large numbers of small and medium sized enterprises, in contrast to the small numbers involved in the industrial sectors. This will add substantially to negotiation and transaction costs. As well, many of the emission processes in agriculture are poorly understood, difficult to measure, and highly variable at a property level scale. This raises problems about the identification and verification of possible emission reductions on property. In contrast, reductions are much easier to measure and verify for industries, as it is relatively straightforward to estimate falls in the consumption of items like electricity and fuel.

¹ Carbon is also sequestered on most properties through pasture and vegetation growth, and vegetation thickening. Sequestration and release often occur simultaneously on the same property.

The emphasis on major industrial companies has also occurred because highest rates of growth in emissions are taking place in areas such as power generation and transport. In contrast, emissions from agriculture are only growing slowly. Although the difficulties in involving agriculture have meant that little burden has been placed on enterprises to find emission reductions, this is unlikely to continue. Low returns in some agricultural sectors means that it may be cheaper to reduce emissions in this sector than in others. If Australia has to search harder to find ways of reducing emissions, more attention may be focused on the agricultural sector.

There are three main reasons why agricultural enterprises need to become more involved in the debate. The first is that the industries have some vested interest in seeing Australia meet the Kyoto target. Australian agriculture may be one of the net losers from any future climate changes, and export industries may suffer if there were any international repercussions about Australia not meeting its targets.

The second reason why agriculture should be involved in searching for potential reduction measures is that it may help to avoid the potential use of government penalties or regulations to achieve emission reductions. Because the costs of individual negotiations are going to be high with the agricultural sector, there will always be some argument for direct controls to be used as a way of achieving emission reductions. To counter this, agricultural industries will need demonstrate where some improvements are automatically occurring, and where there are potential for other reductions to be made.

The third reason why agriculture should be involved is that there may some potential for incentives to be paid to reduce emissions or to provide offsets. Under these scenarios, forms of emissions trading or carbon offset trading schemes could mean that industries purchase sequestration benefits from landholders who are able to provide them. Some of the ways that landholders might provide these benefits might be through establishing plantations or reducing the numbers of livestock that are run. While many of the potential ways of reducing emissions may not be cost-effective or easily verifiable, there may be some opportunities for flexible trading mechanisms to be developed.

One of the major components of emissions from agriculture is methane emissions from beef cattle. The beef industry is a major export industry for Australia, and a mainstay of many regional communities across the country. This means that the debate over greenhouse gas emissions may have particular relevance for that industry. However, little work has been done to estimate emissions at the property level, and identify opportunities for beef producers to reduce emissions.

The paper is structured as follows. In the next section of the report some background to the greenhouse gas debate and methane emissions from livestock in Australia is provided. Section four contains an overview of beef cattle enterprises in Central Queensland, and section five outlines the methodology for estimating methane emissions. Section six contains a number of case study examples appropriate for the region, and section seven concludes the report.

2.0 INTRODUCTION

Methane is a natural gas occurring in the earth's atmosphere. It is naturally produced by anaerobic bacterial decomposition of vegetation in soils, lake sediments and marshes as well as by anaerobic bacterial fermentation of cellulose in the digestive system of termites and herbivores (Chang, 1991). Methane is also released from biomass burning through pyrolysis.

Methane (CH₄) is a basic organic compound (hydrocarbon) consisting of the two elements hydrogen (H) and carbon (C). The concentration of methane in the atmosphere, just like other greenhouse gases, has increased considerably over the last century. Atmospheric concentrations of methane are currently increasing by about 1% per year (BRS et al, 1994). An imbalance has been developing between the rate of input of gases into the atmosphere from various sources and the rate at which it is removed into sinks. This is thought to be contributing to the greenhouse effect.

Greenhouse gases vary considerably regarding their warming potential. Methane and nitrous oxide are emitted in smaller amounts than carbon dioxide, but have much higher warming potential.

Table 1. Global warming potential of major greenhouse gases using CO₂ as a base.

Greenhouse Gases	Warming Potential
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	21
Nitrous oxide (N ₂ O)	310

Source: Hassall and Associates (1999)

Australian livestock industries emit various greenhouse gases through land clearing, transport, processing activities and legume pasture establishment (Table 2). They also provide sinks through tree and shrub establishment and pasture improvement (NGGIC, 1996). The agricultural sector is responsible for the emission of carbon, methane and nitrous oxide as well as carbon dioxide.

The agricultural sector produces about 20.2 % of the total net national emissions (Figure 1). These consist mainly of methane from enteric fermentation from livestock, and nitrous oxide from agricultural soils. In 1998 livestock generated 68.2% of the agricultural sector's emissions representing 13.8% of the total national emissions (NGGIC, 1998). For comparative purposes, emissions are normally reported in terms of their global warming impact using CO₂ as a base (CO₂-equivalents).

When comparing livestock emissions to other agricultural activities, modelling has shown that emissions from livestock are much greater than emissions from cropping. This is shown in Table 2, where **Enteric Fermentation** accounts for about two-thirds of emissions from the Agriculture

sector. Lenzen (1998)² has found that meat production results in 6.5 kg CO₂-equivalent per A\$ of production compared to emissions from grain crops at 3.5 kg of CO₂-equivalents per A\$ of production.

Figure 1. National Emissions by Sector in 1998.

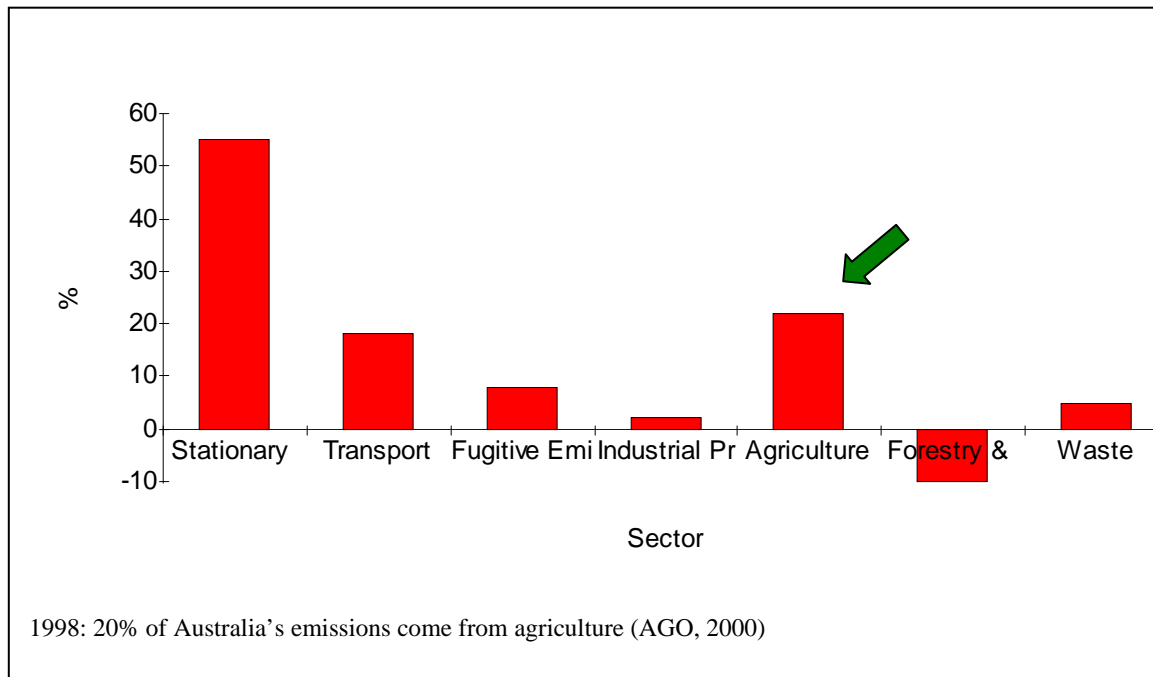


Table 2. Total National Agricultural Emissions

Total national agricultural emissions in CO₂-equivalents in 1998					
CO ₂ -equivalent emissions (Gg)					
Greenhouse Gas Source and Sink Categories	CO ₂	CH ₄	N ₂ O	Total	% Total Net National Emissions
Total Net National Emissions	312100	114908	27472	455899	100.0
AGRICULTURE		70273	21927	92200	20.2
Enteric Fermentation		60623	NA	60623	13.3
Manure Management		1748	525	2274	0.5
Rice Cultivation		721	NE	721	0.2
Agricultural Soils		NA	16054	16054	3.5
Burning of Savannas		6966	5263	12229	2.7
Burning of Ag.-Residue		214	84	298	0.1

Source: NGGIC (1998).

² from Hassall and Associates, 1999

To be able to calculate and estimate emissions on a national level a National Greenhouse Gas Inventory (NGGI) has been developed. These workbooks were first published in 1994 and 1995. Each workbook covers emissions from a particular sector and revisions of the workbooks are published every two years. The NGGI is the key monitoring and reporting tool for Australia's domestic emissions (NGGI, 1996). The inventory follows the broad guidelines established by the FCCC and includes six groups of greenhouse gases. CO₂ is the most important greenhouse gas and all emissions are generally measured in tonnes of CO₂ –equivalents.

The main atmospheric sink for methane is its reaction with hydroxyl radicals (OH) to produce CO₂ and water. Oxidation processes in soil, vegetation thickening, establishment of timber plantations and forage shrubs are also providing important sinks, in which methane is absorbed.

The increase of atmospheric methane concentrations is due to human activities such as agriculture, mining and transport. In agriculture the main methane emitters are livestock, emissions from rice paddies and biomass burning. Methane emissions from livestock alone account for about 61.2% of Australia's total methane emissions (NGGIC, 1998). Methane is a significant contributor to the greenhouse effect, because it has 21 times the greenhouse warming potential of carbon dioxide (Hassall and Associates, 1999).

Methane is produced in ruminants as a waste product from the digestion processes in the rumen and the intestine. Plant material is fermented under anaerobic conditions in the rumen resulting in fatty acids, which are absorbed, and waste gases, which are mainly vented by belching (eructation). Unfermented feed passes on to the intestines where they are dealt with in secondary fermentation. Most methane is produced in the rumen. Most of the methane emitted by livestock is by belching. Some methane is also emitted from ponded manure in dairies and feedlots. Nitrous oxide is another greenhouse gas that may also be emitted from manure.

3.0 METHANE EMISSIONS FROM LIVESTOCK

Methane emissions from livestock are a significant contributor to greenhouse gas emissions in Australia. Methane emissions account for about 14 % of national greenhouse gas emissions. The main emitters are cattle and sheep (ruminants) from open grazing systems. Although dairy cattle are higher emitters at approximately 115 kg of methane per annum³ compared to beef cattle (74 kg per annum), the large numbers of beef cattle mean this industry is the major emitter of methane. In comparison, sheep emit approximately 6.6 kg per annum and pigs 19.1 kg per annum, (after emissions from manure have been included) (AGO 2000a).

Methane (CH₄) is purely a waste product for ruminants and is produced when beef cattle digest their food. CH₄ represents a loss of about 4-12% of the energy from food digested by the animal (Hegarty, 1999). The amount of CH₄ produced depends on the amount of food eaten as well as the type and quality of the food. The NGGI assesses methane emissions by accounting for the number and type of animals present, animal class and size, for the seasonal and geographic effects on the animal and for the pasture and feed type, quality and quantity.

³ This includes emissions from manure, which are about 7% of methane emissions from the dairy sector.

3.1 Measurement of Methane Emissions and Associated Problems

There are different ways to measure and estimate livestock methane emissions. Emissions can be measured directly in respiration chambers or can be measured in the atmosphere as atmospheric concentrations. As well, ice core measurements document atmospheric concentrations of gases as far back as 1000 years. Measurements of atmospheric concentrations of greenhouse gases are used to verify emissions calculated by the National Greenhouse Gas Inventory (NGGI). The CSIRO division for Atmospheric Research for example has mapped estimates of greenhouse gas emissions including the ones for methane from livestock on an annual basis⁴.

For livestock, measurements of methane can be derived from field experiments and respiration chambers. Most predictions of emissions are based on respiration chamber data due to insufficient data from direct field measurements.

Blaxter and Clapperton (1965)⁵ measured the methane yield from ruminants on temperate forage diet. Closed circuit respiration chambers were used to measure methane yield from cattle in grams per day. They developed a predictive equation from their data, which is still used for many inventories. However, such estimates are not fully accurate for cattle feeding on tropical forage or for feeding conditions in an open grazing system where consumption of forage occurs *ad libitum*. Experiments conducted by CSIRO use different respiratory chambers where methane output is measured continuously and cattle have access to forage *ad libitum* (McCrabb and Hunter, 1999).

To calculate emissions the NGGIC estimates the gross energy intake of a beast and then calculates the proportion of this energy that is converted into methane. This proportion is based on the digestibility at maintenance rations of feed energy and the level of feed intake relative to that required for maintenance. The amount of methane is then calculated using a conversion factor (55.27 MJ/kg CH₄) (NGGI, 1996).

3.2 Problems with measuring and estimating methane production

Some problems with measuring methane production are due to large variations between individual animals and difficulties with estimation from culture techniques of microbial populations in rumen digesta. There also may be more diverse microbial populations and methanogen species present than are currently known (Baker, 1999). Another problem is that other microbes may interfere with hydrogen utilisation by methanogens in the rumen. One theory is that whenever fermentation rate in the rumen is high (eg on a high grain diet) other microbial populations may out-compete methanogens for hydrogen (Baker, 1999). Thus for an individual animal there may be large variations between actual and predicted levels of methane emissions.

Problems with estimating emissions from livestock for the NGGI and IPCC include lack of data to estimate emissions from livestock in tropical grazing systems. McCrabb and Hunter, (1999) show that these emissions are substantially different to those from temperate pastures, but more work is needed to identify emissions across different types of tropical pastures. Another problem is the lack of accurate data about livestock numbers, live weights and live weight gains (Reyenga and Howden, 1999). Much of the available data for livestock numbers in Australia is not collected for the same categories that are used in the National Greenhouse Gas Inventory, and there is little data available on annual live weights or live weight gains. Thus at the regional or

⁴ see www.csiro.au for a map

⁵ from McCrabb and Hunter, 1999

national level there may be considerable uncertainties about total methane emissions for beef cattle.

Calculations of emissions per animal in a year are not always informative because of the different groups and stages involved in a beef herd. For this reason, it is sometimes more useful to estimate emissions in terms of the kilograms of beef produced. This effectively calculates emissions over the life cycle of a beast, and helps to identify where producers are most efficient in producing beef. Factors such as reproduction rate, heifer replacement, culling of breeding stock, growth rates and the mortality of calves are all factors to consider in exploring the dynamics of a beef herd (McCrabb and Hunter, 1999).

Substantial differences can be identified between southern and northern Australia when methane emissions per kilogram of beef produced are estimated. McCrabb and Hunter (1999) estimate that cattle in northern Australia on tropical pastures have about four times the methane emissions per kilogram of saleable beef than do cattle on grain, and about three times the level of cattle on tropical pastures. Their work indicates that finishing cattle on grain or other supplements may help to lower average emissions per kilogram of saleable beef.

4.0 LIVESTOCK CONTRIBUTION TO EMISSIONS

A linear relationship for methane production can be established between methane emissions and feed intake: being about **27g CH₄/kg** feed dry matter for animals on high grain diets (as in feedlots) and about **34g CH₄/kg** feed dry matter for animals on tropical forage (as in open grazing systems)(Kurihara, 1998).

The National Greenhouse Gas Inventory approach is quite simply to apply at a property level, as liveweights and liveweight gains are the only data needed to calculate emissions. The first step is to estimate the feed intake of animals, while the second is to convert that to methane emissions.

An equation presented by Minson and McDonald (1987) calculates feed intake (**I** kg dry matter/head/day) from liveweight and liveweight gain:

$$I = (1.185 + 0.00454W - 0.0000026W^2 + 0.315LWG)^2$$

Where:

$$\begin{aligned} W &= \text{liveweight in kg} \\ LWG &= \text{liveweight gain in kg/head/day} \end{aligned}$$

For animals on tropical pastures total daily production of methane (**M** kg CH₄/head/day) is given by Kurihara et al. (1999) as:

$$M = (41.5 \times I - 36.2) / 1000$$

At the individual property level, estimates of emissions at a property or paddock level can be made by using liveweight and liveweight gains for the stock on hand. Two simple examples are shown in the tables below.

Table 3. First case scenario:

300 breeders with calves on foot with a 85% calving rate on native pasture. The liveweights and live weight gains are based on annual average figures estimated from the seasonal data provided by the National Greenhouse Gas Inventory for Queensland.

<i>1000 cows on native pasture and 850 calves</i>	<i>LW (kg)</i>	<i>LWG (kg/day)</i>	<i>CH4 (kg/head/day)</i>	<i>Annual Emissions/beast</i>	<i>Total CH4 per annum across herd (kg)</i>
1000 Cow >2	450	0.15	0.277	101.11	101,105
425 Steer <1	135	0.35	0.107	39.10	16,598
425 heifer <1	135	0.35	0.107	39.10	16,598
Total for herd					134,301

Table 4. Second case scenario:

1200 steers on improved pasture (buffel) gaining 0.5 kg per day.

<i>1200 steers</i>	<i>LW (kg)</i>	<i>LWG (kg/day)</i>	<i>CH4 (kg/head/day)</i>	<i>Annual Emissions/beas t</i>	<i>Total CH4 per annum across herd (kg)</i>
600 Steer 1-2	305	0.5	0.220	80.30	48,180
600 Steer 2-3	485	0.5	0.321	117.17	70,229
Total for herd					118,409

In CO₂ equivalents, the property in case study A would be emitting 2,820 tonnes of greenhouse gases per year from methane, while the property in case study B would be emitting 2,486 tonnes of greenhouse gases each year. To put this into perspective, the property in case study A would be emitting approximately as many CO₂ equivalents as a business with:

- An electricity bill of at least \$250,000 per year, or
- A natural gas bill of at least \$225,000 per year, or
- A diesel bill of at least \$980,000 per year.

This helps to demonstrate the scale of emissions from grazing cattle properties.

4.1. Methane Emissions from Beef Cattle in Tropical Grazing Systems

Beef cattle in tropical grazing systems tend to differ from beef on temperate pastures and beef cattle in feedlot situations regarding relationships between methane production, energy utilisation and live-weight change. This may be due to the higher content of fibre and dry matter in tropical pastures as compared to temperate or grain based diets (Kurihara et al, 1999) and due to the continuous feeding situation (Hegarty, 1999). It is thought that tropical grasses are about 13% less digestible than temperate grasses due to their higher levels of fibre and lignin and their low non-fibre carbohydrate concentrations (Kurihara et al, 1999).

At CSIRO Tropical Agriculture in Rockhampton data was collected from cattle fed on two different tropical forage diets reflecting open grazing systems and a high grain diet reflecting feedlot conditions. Methane output was found to be highest for low quality tropical forage, a little

less for better quality tropical forage and lowest for the high grain diet (Kurihara et al, 1999). Finishing cattle for 2-5 months on a grain-based feedlot diet is associated with a 34-54% reduction in lifetime methane production per kg saleable beef yield (McCrabb, 1998). Also cattle with live-weight gains (LWGs) exceeding 1 kg per day have relatively low levels of methane production compared to cattle with LWGs lower than 0.5 kg/day (Kurihara et al, 1999).

McCrabb and Hunter (1999) found that methane yield for tropical forages was higher than actual yield predicted using Blaxter and Clapperton's (1965) equation, which is based on experiments with temperate forage. The NGGI 1996, which based its estimates on Blaxter and Clapperton's equation, has underestimated the methane yield by about 40% compared to these estimates based on experiments with tropical forage. The International Panel for Climate Change (IPCC) 1996 also underestimated the methane yield for cattle on tropical forage (Kurihara et al, 1999).

Howden and Reyenga (1999) make the comment that feeding livestock with high digestibility supplements such as grain in feedlots may reduce the direct methane emissions from livestock. However, at the same time the emissions caused by growing grain, harvesting, processing and transporting it also need to be considered. Howden and Reyenga (1999) estimated that the feedlot cattle gaining 1-1.5 kg/day consume an amount of grain that is responsible for four times the emissions which are directly emitted by the livestock. The total effective emissions per kg LWG would be equivalent to those of an animal gaining only 0.2-0.3 kg per day on pasture. This means that finishing cattle on grain may not achieve overall reductions in greenhouse gas emissions.

There is more opportunity to reduce emissions from cattle on tropical pastures compared to cattle on temperate pastures. This is because cattle on temperate pastures are already achieving high liveweight gains compared to tropical regions. When high liveweight gains are recorded, then cattle are using their feed very efficiently, and not as much is being lost into methane conversion. When low weight gains are recorded, the feed conversion process is not very efficient, and more methane is released. Thus larger gains in methane reduction can be made by improving feed efficiency and liveweight gains in tropical pastures (northern Australia) compared to temperate pastures (southern Australia) (McCrabb and Hunter 1999).

When comparing tropical pastures with each other it has been found that there is not a great difference in digestibility and nutritional qualities of low quality tropical forage compared to medium quality tropical forage. The methane yield is therefore very similar for cattle feeding on these two forage diets (McCrabb and Hunter, 1999).

Table 5. Average Emissions from Cattle on Different Feed Types.

Feed Type	Average CH₄ emissions per head
Low quality tropical pasture	0.754 kg/day
High quality tropical pasture	0.646 kg/day
High grain diet (feedlot)	0.321 kg/day

(adapted from Kurihara et al, 1999)

Some indication of methane emissions and the relationship to rates of weight gain are available from Figure 2. This calculates the average methane emissions from a 340 kilogram steer that might grow at different rates. At higher growth rates, total methane emissions for the beast are higher (because of the higher weights that are achieved). To demonstrate the efficiencies inherent in higher growth rates, the daily weight gain has been compared to a ratio of emissions and the average weight of the beast.

Figure 2. Predicted methane emissions per kilogram of beef x daily weight gain.

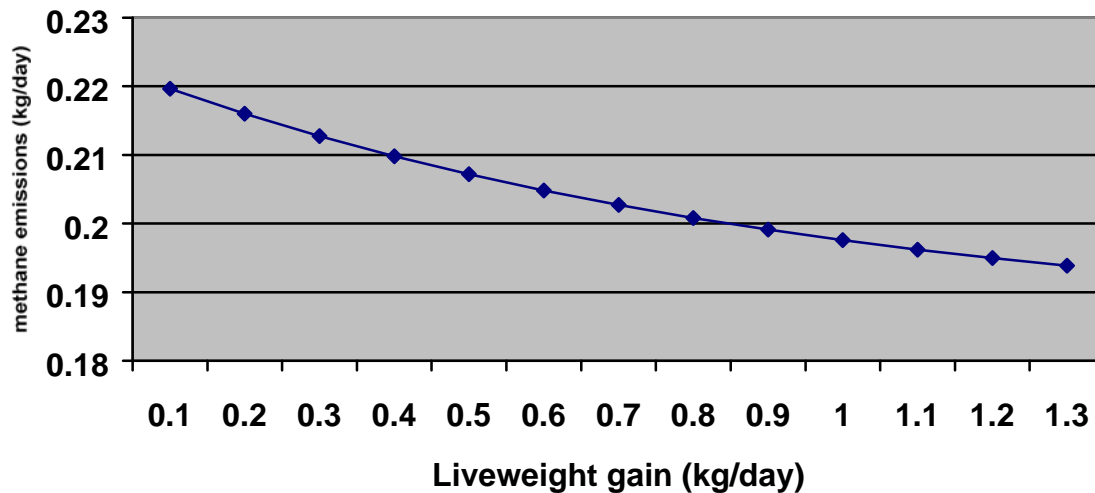


Figure 2 demonstrates that as growth rates increase, feed conversion rates are better and the loss of methane is reduced. The curve is slightly concave, demonstrating that at the lower growth rates, the marginal effects are larger than at higher weight gains. However, the Figure also demonstrates that the proportional decrease in methane emissions is quite small (between 1 and 2 %) for each 0.1 kilogram improvement in liveweight gain. For these reasons, it is more helpful to concentrate on life cycle emissions.

Cattle fed on feedlot diet (grain) have much lower methane emissions per head per day. The lifetime methane production per kg saleable beef yield of cattle finished on grain for 2-5 months can be reduced significantly by about 34-54% compared to cattle finished on pasture. This is due to the lower age at slaughter and the higher daily growth rates. Steers reaching slaughter weight at a younger age consume less dietary energy over their lifetime and produce less methane than steers growing to the same slaughter weight more slowly (McCraab and Hunter, 1999).

Table 6. Lifetime CH₄ Emissions per kg Saleable Beef Yield (SBY) for Cattle from different Finishing Systems.

Slaughter weight (kg)	Finishing system	Slaughter age (months)	Lifetime CH ₄ production	
			kg CH ₄	kg CH ₄ /kg SBY
400	Pasture	20	86	0.60
	Grain	16	50	0.35
520	Pasture	28	148	0.82
	Grain	22	98	0.54
640	Pasture	37	248	1.15
	Grain	24	117	0.53

(adapted from McCraab, Kurihara and Hunter, 1998)

Methane emitted from cattle makes up about 6-12% of dietary energy lost – different energetics in different climate zones also contribute to the variation in methane production (Hunter and McCrabb,). Steers on native pastures in semi-arid tropics may have a low growth rate of about 100 kg/year and use about 80% of their dietary energy intake for maintenance and 20 % for growth. Their lifetime methane production, if sold at 550kg LW, would be 301kg and they are 5.3 years old. Steers on improved tropical pasture may gain 200kg annually, use 68% of dietary energy for maintenance and 32% for growth, sell at 2.5 years old and produce 167kg methane over their life time. Steers on grain gaining 365kg annually reach 550kg in 1.5 years, use 48% of energy for maintenance and 52 % for growth and produce 60kg of methane over their lifetime.

Table 7. Estimated Energy Use and CH₄ Emissions by Steers Slaughtered at 550 kg Liveweight.

Slaughter weight (kg)	Age at slaughter (years)	Annual LWG (kg)	Energy requirements for maintenance (%)	Energy requirements for growth (%)	Lifetime CH ₄ Production (kg)
550	5.3	100	80	20	301
550	2.5	200	68	32	167
550	1.5	365*	48	52	60

*non-roughage diet
(adapted from Hunter and McCrabb, 1998)

5.0 POSSIBLE STRATEGIES TO REDUCE METHANE EMISSIONS FROM CATTLE

There are three main options to reduce emissions from livestock. One is to use management strategies to reduce emissions per kg beef produced, another is to modify the function of the rumen in some way, while the third is to reduce livestock numbers.

One way of achieving the first option is to change management practices on the farm. Additional emission reduction could be achieved by improving health, husbandry and productivity aspects of grazing operations. The modification of rumen function and introduction of biotechnology options may offer other future alternatives for producers to reduce emissions from livestock.

However, there may be a counterbalancing effect in so far as it allows producers to increase their overall productivity per carcass as well as being able to produce more kg of beef per year. Improved efficiencies may simply be offset by increases in cattle numbers. An increase in herd size in some regions would therefore defeat the effort in of reducing methane emissions. To identify where this might be a consideration, some mechanisms for reducing emissions per head are outlined below.

5.1 Options for reducing methane emissions per unit product

Turning cattle off at younger age can lead to reduction of methane emissions. Less mature animals have higher gross efficiencies, because feed intake (as multiple of maintenance)

decreases with age. Smaller visceral organs have a lower rate of energy use compared to the carcass tissue. Therefore younger animals are more efficient (Oddy et al, 1997).

Improving livestock performance through management options also may lead to a reduction in methane emissions. These management options may vary from region to region. Generally there is more scope to reduce CH₄ emissions from tropical grazing systems than from temperate grazing systems where beef production is energetically more efficient (McCrabb and Hunter, 1999). Management options include

- Improving animal health
- Improving animal husbandry (access to water, improved water quality, shade, stress free handling, etc)
- Improved genetics (selection of livestock with lower levels of methane emissions)
- Improved efficiencies in breeding strategies (eg high calving rate, culling of old and infertile breeders) (US EPA, 2000).

When quantity and quality of pasture are low and cattle do not gain weight sufficiently on pasture other feeding systems need to be considered. Feedlotting, supplementation (especially high protein supplements) or crop fattening will give high energy rations, high LWGs and reduce pressure on pasture resources. These feeding systems

- Reduce the age of turn-off
- lower the grazing pressure and improve selection of pasture for the rest of the herd
- allow the producer to aim for specific markets.

Genetics do influence weight gain and different lines of cattle may vary by as much as 100kg in their annual weight gain under the same conditions. Similar variations can be observed between individuals of the same line of cattle. Therefore careful selection of good performers in particular production systems is very important (Dodt and Esdale, 1999). However, when estimating methane emissions from cattle Kurihara et al (1998) did not find any difference in methane emissions between cattle of different breeds (*Bos indicus* and *Bos taurus*) if fed on the same diet.

Efficiencies in breeding herds need to be high to keep the methane emissions as low as possible. This involves controlled mating, strategic weaning and pregnancy testing to ascertain high calving rates per year. Appropriate nutrition and high health standards are also important for an efficient breeding herd. The producer should keep records on production indicators such as pregnancy percentages, calves weaned per cow and weaning weights of the calves. Monitoring of the herd will then allow adjustments to management where they are necessary on an annual basis. The trade-off associated with these strategies is that such improvements usually allow the producer to run larger numbers of livestock and therefore cause more emissions. Increasing livestock performance may also result in increased food intake by cattle and higher emissions per head (Howden and Reyenga, 1999). The other difficulties are that improvements in these factors are often incremental, highly dependent on seasonal conditions, and difficult to verify.

It can be concluded that these management strategies mentioned above would only be effective mitigation strategies if cattle numbers were adjusted to sustainable stocking rates at the same time (AGO, 2000b). While there would appear to be opportunities for win-win outcomes to be developed, the incremental nature of management improvements and the verification difficulties mean that the opportunity costs will vary widely. More work is needed to explore accounting and

verification issues, and to determine if emission reduction strategies can be incorporated into quality assurance programs and other industry management tools.

However, there are ongoing productivity gains in beef production in northern Australia that will automatically help to reduce emissions per beast. The development of the live cattle export market means that average ages of cattle are falling, and herds are being run more efficiently. There is increased interest in supplementation, and ongoing development to improve productivity. The industry has opportunities to flag the beneficial spillover effects of such improvements, and to search for ways to research and flag better management practices.

5.2 Possible manipulations of rumen microbial populations to reduce methane output from ruminants

There are three main options to reduce methane output by rumen manipulation. These include the inhibition of H₂ production, the diversion of H₂ to other microbial populations for uptake and the inhibition of rumen methanogens and protozoans. Inhibiting methanogenesis needs to go hand in hand with finding an alternative reaction to remove H₂ and thereby prevent the inhibition of rumen fermentation (Klieve and Hegarty, 1999).

The three options listed above can be achieved in several ways: either by use of chemical control, by use of biological control mechanisms and/or by immunological control. Biological or immunological control are becoming the preferable options, due to the possibility of residues in meat after treatment of animals destined for human consumption with chemicals. Consumer resistance to chemical usage in food production is generally increasing (Reyenga and Howden, 1999).

Rumen control options are attractive for a number of reasons. In most cases they enhance production as well as suppressing methane, and hence offer a win-win situation. They are much more easy to verify than the management options, and are should be more substantial in their impact. The difficulty is that the most promising options for control agents (biological and immunological) controls have not yet been developed.

Biological Control Agents

The biological control agents reducing methane emissions from the rumen will either act directly by affecting methanogens or will act indirectly by affecting rumen protozoan populations.

The direct control method includes the use of viruses and bacteriocins, which attack methanogens specifically. Viruses are pathogens that infect and destroy bacterial cells. They can rapidly reduce population densities of the bacterial cells they attack. There are high densities and large variety of viruses present in the rumen, however not much is known about specific viruses attacking only methanogens. The host specificity may limit the suitability of using viruses to control methane emissions effectively. However present research involves the isolation of viruses and phages from methanogens to be used in genetic manipulation of methanogens and acetogens. There is no research into the direct control of methanogens (Klieve and Hegarty, 1999).

Bacteriocins are peptides or proteins produced by bacteria. They could also be used to manipulate the rumen microbial fauna, either by attacking methanogens directly and reducing their population density or by attacking other bacteria, which supply methanogens with substrate (H₂). Bacteriocins have a wider host range than viruses. One successful bacteriocin used in this manner

is nisin, a commonly used food preservative. It is produced by *Lactococcus lactis*. A long history of safe use of bacteriocins in food products and its successful reduction of methane emissions by up to 36% make it an attractive option for commercialisation. There is some research being done in this area (Klieve and Hegarty, 1999).

The indirect biological control of methane emissions can be achieved by eliminating rumen protozoans (defaunation of the rumen). Some protozoans symbiotically support certain methanogens. Methanogens may either live within or attached to the outside of protozoans. The symbiotic protozoans provide habitat to about 20% of the methanogens present in the rumen. Generally, the higher the population density of protozoans in the rumen, the more methanogens are present and the higher the methane emissions from that host animal. There are fungal pathogens eg chytrid fungi which specifically infect methanogens, there are viruses that attack protozoans and there are rickettsia like organisms which can infect protozoans. It is not clear which method is effective in successfully reducing protozoan populations of the rumen though (Klieve and Hegarty, 1999).

Another control method would be to introduce acetogens to rumen fauna. These acetogens would need to be highly competitive to out-compete methanogens for substrate (H_2). Forage control and/or nutrient manipulation could achieve the increase in numbers of acetogens that are naturally present in the rumen. This would be beneficial for the environment as well as for productivity, because acetogens convert H_2 and CO_2 into nutrients for the host animal instead of producing the waste product methane. More research is needed into natural occurring acetogen populations in the rumen of grazing ruminants, particularly for those of tropical grazing systems (Joblin, 1999).

Some feed additives, perceived as natural control agents, include fungal probiotics and feed supplements, such as urea, fats and oils and oilseeds. Fungal probiotics are products based on specific yeasts or filamentous fungi, which act to stimulate bacteria in the rumen to improve fibre break down and increased production of protein (BRS et al, 1994). Feed supplements such as urea and urea combined with protein meal improve the nutrient balance for ruminants by stimulating the digestibility of high fibrous diets (BRS et al, 1994). Fats and oils as feed additives could also be successful in reducing methanogen populations in the rumen. They are toxic to these bacteria and at the same time unsaturated fatty acids react with H_2 and therefore reduce substrate concentrations available for methanogens. Fats and oils may be added to feed at concentrations below 7% - higher concentrations inhibit rumen fermentation altogether. More research is needed on supplementation of cattle with oilseeds (eg cottonseed, soybeans) and the effect on methane production (Hegarty, 1999).

Chemical Control Agents

Chemical control agents for reduction of methane emissions from ruminants involve ionophores, antibiotics and chemical additives. Reduction of methane output can be achieved by chemical manipulation, slow release implants into rumen (CRD-controlled release devices- such as commercially available monensin) and hormonal growth promotants.

Ionophores are chemical agents, which improve feed conversion efficiency by selective effects on rumen microorganisms. Monensin for example is an ionophore antibiotic that increases food conversion efficiency by 5-8% for cattle on high concentrate diet as well as for cattle on high roughage diet. At the same time it can reduce methane emissions by 20-30%. It acts by attacking microbes responsible for producing substrate (H_2) for methanogens. Monensin is commercially available (BRS et al, 1994).

Hormonal growth promotants are chemical agents, which improve the efficiency of cattle and therefore effectively reduce methane emissions (McCrabb and Hunter, 1999). They act by improving feed conversion efficiencies in cattle. The problem with using them in grazing systems is the rising consumer resistance to use of hormones in meat products.

Immunological Control Agents

Methane emissions can be reduced by vaccinating livestock with antibodies against bacteria that are naturally present in rumen and serum (these antibodies develop shortly after birth) (Baker, 1999). After vaccination of ruminants the concentration of antibodies against methanogens increases considerably. This may offer an opportunity to reduce CH₄ in free-ranging ruminants (Baker, 1999). As with the other rumen agents, a side advantage would be that productivity gains in the animal would also increase.

CSIRO Livestock Industries are exploring the development of a vaccine for both sheep and cattle, and field trials of a prototype vaccine are occurring. The vaccine for sheep is more advanced than that for cattle. If one for cattle can be developed, it is likely that there would be an international market as well as an Australian one for the product.

5.3 Options for reducing methane by reducing cattle numbers

The third option may be to reduce livestock production in regions of low productivity such as the rangelands of Australia (Howden and Reyenga, 1999). Hassall and Associates (1999) suggest that the removal of herbivores have double benefits regarding greenhouse impacts and land management: removal of the source of methane as well as removing ruminants. Reducing animal numbers as well as emissions will also help to reduce soil and vegetation degradation. This will improve the general sustainability of operations. Fewer animals may also mean better feed conversion efficiencies from higher quality forage through selective grazing (AGO 2000b). This would allow major reductions in carbon dioxide and methane emissions and this reduction could be made a tradeable item in a carbon trading system. Discussion groups of experts on National Emission Trading have also discussed issues regarding the removal of ruminants and/or the modification of ruminants (Rossiter and Lambert, 1998).

The removal of ruminants would increase biomass accumulation in pasture areas reducing carbon dioxide emissions. This would allow greater carbon sequestration⁶ in grazing regions. Because there are over 400 million hectares of rangelands in Australia, even small improvements in per hectare carbon sequestration will be a large contribution to overall carbon uptake (Hassall and Associates, 1999). Modelling has shown that if 5% of rangelands areas would be restored by better management practices over the next 20 years, sequestration of about 14.3 tonnes of CO₂ equivalents per annum would be possible (Hassall and Associates, 1999). Hassall and Associates (1999) estimated that a 20% reduction in stocking numbers on rangeland areas could lead to a sequestration of 14 million tonnes of CO₂-equivalents over 20 years (in comparison 57 million tonnes of CO₂ equivalent were emitted by Australia in 1999).

⁶ Sequestration is the process of increasing the carbon content of a carbon pool other than the atmosphere (IPPC, 2000)

7.0 CONCLUSION

There are three broad conclusions that can be drawn about methane emissions and the Australian beef industry. The first is that issues of emission reduction may be a substantial one for the industry to address because livestock industries are such a large contributor. Even if the industry has only slow or negative growth in emissions, the question about where reductions can be made most cost-effectively in Australia means that greater attention is likely to be focused on agricultural enterprises at some point.

The second broad conclusion is that there are no major solutions presently available to reduce methane emissions in the beef industry. Improvements in feed utilisation should reduce emissions per head, but most of the profitable opportunities have probably already been found, and the levels of reduction are slight. Feedlotting and supplements reduce methane emissions per kilogram of beef produced, but there are other carbon emissions to consider. Rumen agents offer the most promise but more research and development is needed to bring these to fruition. De-stocking marginal areas will reduce methane emissions and allow carbon to be sequestered, but is a tradeoff with livestock production and profitability.

The third broad conclusion is that the current levels of knowledge and awareness about methane emissions is generally poor. There are continuing deficiencies in data about livestock and research into tropical pastures in northern Australia. There is little involvement in greenhouse issues by the agricultural sector, and little debate about how to position the sector in a favourable light.

Some of these problems arise because much of the debate and estimates about emissions have remained abstract for many producers. Many of the larger grazing properties in northern Australia are large emitters of greenhouse gases through the beef herds, yet there is little knowledge or awareness of these issues. Finding ways to bring the debate to producers and to search for low-cost opportunities to reduce methane emissions are important goals to pursue.

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