Australian Government

Department of Agriculture, Fisheries and Forestry

Research Project Summaries

Climate Change Research Program

Reducing Emissions from Livestock Research Program

Internet

Research Project Summaries is available at: daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research

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Overview

The *Climate Change Research Program* (CCRP), which ended on 30 June 2012, funded research projects and on-farm demonstrations to help prepare Australia's primary industries for climate change. Research focused on reducing greenhouse gas emissions, improving soil management and climate change adaptation, and involved projects that will lead to practical management solutions for farmers and industries.

Over four years the Australian Government invested $46.2 million in over 50 large scale collaborative research, development and demonstration projects. Total investment under the program was over $130 million and included contributions from research providers, industry groups, universities and state governments. A breakdown of the allocated government funding is below:

- Reducing Emissions from Livestock Research Program—$11.3 million
- Nitrous Oxide Research Program—$4.7 million
- Soil Carbon Research Program—$9.6 million
- National Biochar Initiative—$1.4 million
- Adaptation Research Program—$11.5 million
- Demonstration on-farm or by food processors—$7.7 million.

Research through the CCRP has increased our understanding of the sources of agricultural emissions and the potential for emission reduction and carbon sequestration. This information has underpinned the development of the first approved methodology under the *Carbon Farming Initiative* and has contributed valuable data for a number of methodologies currently under consideration. This will enable farmers to generate additional on-farm income through selling carbon offsets into domestic and international carbon markets.

Filling the Research Gap, part of the $429 million *Carbon Farming Futures Program* under the $1.7 billion Land Sector Package, is building on research undertaken through the CCRP. Research projects are targeting current gaps around abatement technologies and practices identified through the CCRP, and will continue to support the development of offset methodologies that land managers can use to participate in the *Carbon Farming Initiative*.

The following summaries highlight the key findings from livestock methane research undertaken through the CCRP as well as related projects being funded through Round 1 of *Filling the Research Gap*. This information should be used by potential applicants to guide applications in climate change research for agriculture under Round 2 of *Filling the Research Gap*.

Potential applicants are advised to contact the lead organisations for each project for further information and are encouraged to refer to the *Filling the Research Gap* Research Strategy (July 2012-June 2017).

Climate Change Research Program

Reducing Emissions from Livestock Research Program

National strategies and coordination (Reducing Emissions from Livestock Research Program (RELRP))

Lead organisation
Meat and Livestock Australia

Consortium member organisations
South Australian Research and Development Institute
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
NSW Department of Primary Industries
University of New England
University of Queensland
Department of Primary Industries, Victoria
The University of Melbourne
The University of Western Australia
Cooperative Research Centre for Sheep Industry Innovation
Dairy Australia
Australian Wool Innovation

Objectives
To ensure through active coordination that the RELRP develop practical on-farm options to reduce methane emissions from livestock and inform government and industry of the potential contribution of agriculture to national emissions reduction goals.

Location
The coordination of the RELRP that was comprised of nationally distributed research and demonstration projects was delivered from Sydney, New South Wales.

Key activities
- management of research contracts
- financial management
- budget reporting
- program and project monitoring and evaluation
- program communication
- coordination of projects under six research themes of:
    1. project coordination
    2. quantifying methane emissions, measurement techniques
    3. genetic approaches in sheep and cattle to reduce emissions
    4. manipulation of rumen function for lower emissions
    5. improved management of waste
    6. farming systems for lower methane emissions, demonstration and information delivery.

Findings/Conclusions
Outcomes from projects under the RELRP include:

- development (and patent) of an intra-ruminal wireless sensor unit for measuring concentrations of methane, carbon dioxide and hydrogen in the rumen of individual animals
- researchers in the RELRP have proved that low methane potential in cattle and sheep has a genetic base and is heritable
- researchers in the RELRP have investigated the role of plant derived fats, tannins and plant essential oils in controlling microbial methane production. A methane abatement potential *in vivo* of five to eighteen per cent was identified
- researchers identified a range of tropical legumes, alternative and novel forages, and plant extracts capable of reducing methane in the rumen. Plant extracts of *Eremophila glabra* were found to have the most potent anti-methanogenic properties, with effects persisting over several weeks in cattle
- a successful dissemination of RELRP research outcomes facilitated through four national demonstration sites.

Related projects funded under Round 1 of Filling the Research Gap

All National Livestock Methane Program projects

Publications

Fact sheets produced on the RELRP projects are available on the Meat and Livestock Australia website at www.mla.com.au/Publications-tools-and-events/Publication-details?pubid=5943

Further publications detailing the results of this program are in preparation and will be available.

Novel individual enteric methane measuring system for multiple ruminants

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations

N/A

Objectives

- complete a knowledge and opportunity audit of novel methane measurement
- provide data demonstrating the value and requirements of integrated rumen gas measures and profiles for predicting greenhouse gas (GHG) production by individual animals
- develop a practical, reliable, repeatable individual ruminant methane measurement and data collection system suitable for use with large numbers of grazing animals.

Location

St Lucia, Queensland and Armidale, New South Wales

Key activities

- Evaluate information and identify novel methane measuring technologies from across diverse science and industrial sectors.

- Development of the most promising methane measurement technology to apply to individual animals to produce high quality data on methane emissions from grazing ruminants.

Findings/Conclusions

Gas production in the rumen of livestock provides an important indication of metabolic function, as well as being a significant contributor to greenhouse gas emissions. The livestock industries thus require technology to measure enteric gas emissions from large numbers of individual animals simply, quickly, accurately and reliably. An intra-ruminal wireless sensor unit has been developed for measuring concentrations of methane, carbon dioxide and hydrogen in the rumen. The device is integrated with CSIRO's wireless sensor network platform to provide telemetric capability. The complete unit includes miniaturized infra-red sensors, 'Nano' circuit board, memory storage and battery supply, all of which are inserted into a diffusion cell that protects the device from the corrosive environment of the rumen. Once inside the diffusion cell, the sensors collect and transmit data from the equilibrated rumen gases to the outside world via radio transceiver. This will enable researchers and producers to develop, monitor and validate methane mitigation strategies to reduce emissions from grazing ruminants.

Related projects funded under Round 1 of Filling the Research Gap

- Measuring methane in the rumen under different production systems as a predictor of methane emissions—CSIRO—Chris McSweeney. Funding of $353 265 ex GST
- Development of gas selective membranes (for intra-ruminal capsules)—RMIT University—Simon Liddle. Funding of $840 000 ex GST

Publications

Publications detailing the results of this research are in preparation.

Metagenomic analyses of feed utilisation and hydrogen balance in Australian livestock for lower methane emissions

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations

N/A

Objectives

- construct the metagenomic blueprint of the rumen microbiome in northern Australian cattle
- identify the enzymatic and/or ecological step(s) central to hydrogen transactions within the microbiome
- establish how supplementation strategies in northern Australian cattle impact ruminal microbiology, hydrogen transactions and methane producing microbes
- formulate agonistic and antagonistic approaches to alter ruminal microbiology and redirect ruminal fermentation, which can include the isolation and evaluation of novel microorganisms with potential to reduce enteric methane emissions.

Location
St Lucia, Queensland

Key activities
Working with samples collected from previous and current experiments in northern Australia the researchers:

- began the metagenomic 'genotyping' of the rumen microbiomes of beef cattle maintained on tropical pastures with different levels of methane emissions (per unit of feed intake)
- completed a first round of sampling and enrichment experiments designed to recover the uncultured bacteria relevant to hydrogen transactions and methane emissions
- developed a method for the subtractive enrichment of rumen bacteria that provides access to the metagenome (and proteome) of these populations in northern beef cattle. The samples were also used to construct the metagenomic libraries needed for the functional screens.

Findings/Conclusions
Rumen microbes govern rumen digestion and methane production processes, but the vast majority of them are 'unknown'; so our ability to productively manipulate these processes has been limited. This project developed and used new approaches in microbiology, referred to as 'metagenomics', to better understand how feed utilisation and hydrogen balance might be affected to reduce methane emissions.

The outcomes of the project include:

- producing the genetic "blueprint" of rumen microbiology in northern beef cattle
- identifying "new" bacteria in these cattle relevant to feed digestion and/or hydrogen utilisation without methane formation
- new resources that can be used to track and/or quantify the abundance of these bacteria
- the isolation of some of these bacteria for the first time.

The project has developed some of the resources needed to monitor how the rumen microbiota might be changed via diet and supplementation to reduce methane emissions and ideally, improve feed utilisation.

Related projects funded under Round 1 of Filling the Research Gap
- Culture-independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock—CSIRO—Mark Morrison. Funding of $507 494 ex GST
- Comparative analyses of rumen microbiomes to mitigate ruminant methane and improve feed utilisation—CSIRO—Mark Morrison. Funding of $508 878 ex GST

Publications
1. Rosewarne, C, Pope, P, Denman, S, McSweeney, C, O'Cuiv, P & Morrison, M 2010, 'High-Yield and Phylogenitcally Robust Methods of DNA Recovery for Analysis of Microbial Biofilms Adherent to Plant Biomass in the Herbivore Gut', *Microbial* Ecology, vol. 61, pp. 448-454.

Further publications detailing the results of this research are in preparation and will be available.

Phylogenetic identification of rumen microbial organisms linked with significant differences in methane emissions

Lead organisation
South Australian Research and Development Institute

Consortium member organisations
Department of Agriculture, Western Australia

Objectives
To identify key organisms that drive differences in communities which significantly differ between high and low methane producing cows under specific genetic and dietary treatments.

Location
Urrbrae, South Australia

Key activities
Characterising the rumen bacterial, archaeal and fungal communities by pyrosequencing technology and identifying micro-organisms linked with high feed efficiency cows producing less enteric methane. Pyrosequencing is a deep sequencing technology which can be used to identify microbial genome sequences and assign phylogenetic information to the population.

Findings/Conclusions
Feed efficiency in cattle has been linked to the degree of enteric methane production. Cows which are more efficient in utilising feed produce less methane, although this response is diet related. The micro-organisms present within the rumen are responsible for the digestion of feed and production of methane. These microorganisms have been shown to be influenced by both the animal's genotype and diet, with the latter having a greater effect. The aim of this study was to characterise the rumen bacterial, archaeal and fungal communities by deep sequencing technology and to identify micro-organisms linked with high feed efficiency cows producing less enteric methane. It was found that cows producing less enteric methane contained a more diverse bacterial community at the level of phyla. The rumen methanogenic archaeal communities from high feed efficient cows were more abundant in methanogenic archaeon related species and less abundant in *Methanosphaera stadtmanae*. Rumen fungal communities also differed significantly between high and low feed efficient cows. Although many organisms identified have not yet been grown in the laboratory, the genome sequences generated will enable the development of diagnostic tools to investigate relationships of rumen microorganisms with methane production, which will be of use in evaluating methane mitigation methodologies.

Related projects funded under Round 1 of Filling the Research Gap

- Culture-independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock—CSIRO—Mark Morrison. Funding of $507 494 ex GST
- Comparative analyses of rumen microbiomes to mitigate ruminant methane and improve feed utilisation—CSIRO—Mark Morrison. Funding of $508 878 ex GST

Publications

Publications detailing the results of this research are in preparation.

Blood methane concentration as a marker for bovine greenhouse gas emissions

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO) Livestock Industries

Consortium member organisations

Department of Primary Industries, Victoria

Objectives

- to standardise the blood analysis technique
- to determine the relationship between blood methane concentration and methane emissions measured by calorimetry at Lansdown Research Station using tropical beef breeds and at Ellinbank Research Station using dairy cattle.

Location

Lansdown Research Station, Queensland and Ellinbank Research Station, Victoria

Key activities

Methane blood concentration and Ostwald solubility coefficients were measured at 39°C on dissolved gas samples stored into Exetainer tubes at 40°C for 20 days.

Findings/Conclusions

The blood of grazing steers had a mean value of 15.6 ± 9.84 ng/mL and 2.4 ± 2.25 ng/mL for methane blood concentration and Ostwald solubility coefficient, respectively. When measured across breeds, methane blood concentration was similar between Brahman (18.1 ± 5.20) and Belmont red composite (14.6 ± 3.66) steers, while no differences were detected among low (17.3 ± 4.12), medium (19.7 ± 4.62) or high (12.0 ± 4.41) digestibility profile groups. There were no digestibility treatment affects upon methane Ostwald solubility coefficients, but higher ($P < 0.05$) values were found in Belmont red composite than in Brahman cattle. Irrespective of breed and digestive profile, there was a significant ($P < 0.05$) negative relationship between methane blood concentration and platelet (- 0.55) or total protein contents (- 0.52) in the body fluid. It was concluded that although no consistent differences existed in methane blood concentration among experimental groups, multiple measurements on samples of identical origin will contribute to a better standardisation of the blood technique. This will also help to understand the physiological variability of methane concentration and solubility coefficients in blood of northern beef production systems. The use of the

methane blood technique is recommended to assess the association between those blood variables and short and total methane emissions measured currently by open circuit calorimetry at Lansdown Research Station.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. McGinn, S, Turner, D, Tomkins, N, Charmley, E & Chen, D 2011, 'Methane emissions from grazing cattle using point-source dispersion', *Journal of Environmental Quality*, no. 40, pp. 22-27.
2. Tomkins, N, Colegate, S & Hunter, RA 2009, 'A bromochloromethane formulation reduces enteric methanogenesis in cattle fed grain-based diets', *Animal Production Science,* vol. 49, pp. 1053-1058.
3. Tomkins, N, McGinn, S, Turner, D & Charmley, E 2011, 'Comparison of open-circuit respiration chambers with a micrometeorological method for determining methane emissions from beef cattle grazing a tropical pasture', *Animal Feed and Science Technology*, vol. 166-167, pp. 240-247.

Further publications detailing the results of this research are in preparation and will be available.

Effect of starch based concentrates with different degradation characteristics on methane emissions

Lead organisation

Department of Primary Industries, Victoria

Consortium member organisations

N/A

Objectives

- quantify methane (CH_4) emissions and methane intensity in response to feeding dairy cows starch based supplements of different degradation characteristics
- share biological samples with other Australian researchers working in the field of CH_4 mitigation from ruminants.

Location

Ellinbank, Victoria

Key activities

The main activity of this research was the feeding experiment that included measurement of CH_4 emissions.

The three aims of this experiment were to:

- determine if starch (cracked corn grain, which slowly ferments in the rumen) is a suitable dietary supplement to feed to dairy cows in order to reduce total enteric CH_4 emissions and intensity of CH_4 emissions (g CH_4/L milk), without adversely affecting milk production

- determine if the sulphur hexafluoride (SF_6) tracer technique can be used in rumen cannulated cows to accurately measure CH_4 emissions
- elucidate nutritional and biological mechanisms influencing enteric CH_4 emissions and the influence of CH_4 mitigating diets on quality attributes of milk by providing biological samples to collaborating scientists.

Findings/Conclusions

Emissions from cows offered a diet containing 10 kg dry matter (DM) of crushed wheat averaged 219 g CH_4/cow per day or 11.1 g CH_4/kg dry matter intake (DMI), whereas when cows were offered a diet containing 10 kg DM of cracked corn, emissions averaged 424 g CH_4/cow per day or 19.5 g CH_4/kg dry matter intake. The unexpectedly very low CH_4 emissions from the wheat based diet are approximately 50 per cent of what would be expected based on the current Australian inventory for CH_4 emissions from dairy cows. Milk volumes of cows on the wheat (27.8 L /cow per day) and corn (27.9 L /cow per day) based diets were similar; yields of milk protein were also similar (0.94 kg/cow per day for wheat and 0.91 kg/cow per day for the corn based diet, but milk protein percentage was significantly higher on the wheat based diet (3.38 vs 3.25 per cent). Yields of milk fat were substantially decreased on the wheat diet compared to the corn based diet (0.77 vs. 1.18 kg/cow per day) because milk fat per cent was substantially decreased on the wheat based diet (2.75 vs. 4.23 per cent milk fat). Methane emissions measured in the respiration chambers from rumen fistulated and non-fistulated cows were similar, even though the rumen cannulae allowed the ingress of air into the rumen headspace. This is an important experimental finding because it shows for the first time that rumen fistulated cows are valid subjects for research into enteric CH_4 abatement.

Related projects funded under Round 1 of Filling the Research Gap

- Enteric methane mitigation strategies through manipulation of feeding systems for ruminant production in southern Australia—Department of Primary Industries, Victoria—Joe Jacobs. Funding of $1 970 000 ex GST

Publications

Publications detailing the results of this research are in preparation.

Archeaphage therapy to control rumen methanogens

Lead organisation

University of Queensland and Queensland Department of Primary Industries and Fisheries

Consortium member organisations

N/A

Objectives

This project aimed to assemble a collection of phages to be employed in phage therapy.

Location

Brisbane, Queensland

Key activities

- determine the host range of the viruses against a range of methanogens, using the soft-agar overlay technique
- evaluate the efficacy of these phages in a series of 'proof of concept' experiments using an *in vitro* fermentation system that can mimic the rumen conditions of cattle and sheep across a range of feeding systems where different species of methanogens are known to be dominant
- use molecular biological methods for enumeration and community profiling of methanogens, concentrating on real-time polymerase chain reaction (PCR) assays and Denaturing Gradient Gel Electrophoresis (DGGE) methodologies
- collaborate with other projects in the program which are focusing on developing molecular techniques for identifying and quantifying key rumen organisms and functions associated with reduced enteric methane generation.

Findings/Conclusions

A range of animal-derived and environmental source samples were tested using culture-based methodology, however no lytic phages of methanogens were isolated. Given the dearth of knowledge regarding phages of rumen methanogens, this project established that these naturally-occurring phages may be present in very low concentrations within the rumen and this will need to be considered in future methanogen-phage isolation investigations. The project has begun the process of developing and adapting new methodologies for detecting and examining these phages.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Gilbert, R, Ouwerkerk, D & Klieve, A 2010, 'Isolation of viruses for bio-control of methanogenic archaea from the rumen', *Animal Production in Australia*, vol. 28, p. 68.
2. Gilbert, R, Ouwerkerk, D & Klieve, A 2010, 'Mitomycin C induction of methanogenic archaea to detect lysogenic archaeaphage', *13th International Symposium on Microbial Ecology,* USA.

Further publications detailing the results of this research are in preparation and will be available.

Rumen microbial profiling—a tool to investigate methane mitigation strategies

Lead organisation

South Australian Research and Development Institute

Consortium member organisations

Department of Primary Industries, Victoria
NSW Department of Primary Industries
The University of Western Australia
Cooperative Research Centre for Sheep Industry Innovation

Future Farm Industries Cooperative Research Centre

Objectives

The purpose of this project was to develop and provide molecular techniques for use in collaborative research projects to evaluate feeding, breeding and management strategies to reduce methane production in ruminant systems.

The project had the following objectives:

- develop and provide high-throughput DNA profiling assays for rumen and faecal microbiota associated with methane emissions
- use the profiling assays to characterise the influence of feeding and selected methane abatement strategies on rumen microbiota activity
- evaluate surrogate assays for rumen function associated with enteric methane emissions suitable for application to large numbers of animals.

Location

Urrbrae, South Australia

Key activities

- evaluate and refine DNA extraction methodology for rumen and faecal samples
- identify and evaluate universal primers for detection of archaea, protozoa and fungi
- evaluate universal bacterial primers for use in ruminant studies
- characterise rumen microbiota in high/low methane producing cattle and other ruminant species
- investigate influence of feeding and methane mitigation strategies on rumen microbiota
- compare microbial populations in rumen and faeces with the aim of developing a surrogate assay for rumen function
- provide relevant DNA material to collaborators for metagenomic analysis.

Findings/Conclusions

Reducing ruminant methane emissions is an important part of reducing livestock emissions. Development of methane mitigation strategies in ruminants needs to consider the influence of diet, animal genetics and rumen microbiology, and the degree to which these can be manipulated while maintaining animal performance. Molecular microbial profiling tools have been developed to investigate the overall rumen microbiota. These screening tools have been used in collaborative animal studies investigating dietary and genetic methane mitigation strategies in dairy cows, beef cattle and sheep. Diet was shown to significantly alter rumen microbiota. In some cases dietary manipulation resulted in successful methane mitigation, which correlated well with changes in rumen microbiota. In the absence of methane mitigation, diet related changes in rumen microbiota could be linked to animal performance traits such as milk fat composition and feed efficiency. Animal genetics was also found to alter rumen microbiota, however successful methane mitigation was dependant on diet. This project has developed rapid high throughput screening technologies which enable researchers to measure the effects of diverse methane mitigation strategies on rumen microbiota. These technologies can be further developed to provide information to producers on the effectiveness of on-farm methane mitigation strategies.

Related projects funded under Round 1 of Filling the Research Gap

- Culture-independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock—CSIRO—Mark Morrison. Funding of $507 494 ex GST
- Comparative analyses of rumen microbiomes to mitigate ruminant methane and improve feed utilisation—CSIRO—Mark Morrison. Funding of $508 878 ex GST

Publications

Publications detailing the results of this research are in preparation.

Genetic improvement of beef cattle for greenhouse gas outcomes

Lead organisation

NSW Department of Primary Industries

Consortium member organisations

University of New England

Objectives

To define genetic parameters and physiological indicators of methane phenotype by establishing low and high methane cattle selection lines to provide new understanding and technologies to enable the Australian beef industry to select cattle for low methane production.

Location

NSW Department of Primary Industries Grafton research centre and the University of New England, Armidale, New South Wales.

Key activities

This project measured methane yield (MY) on young Angus bulls and heifers in two pedigree performance-recording research herds. Animals were recorded for MY over a minimum of two days on a controlled intake of a high roughage-content diet. Results for 339 animals were obtained.

Findings/Conclusions

Results from 339 animals were obtained in this research. Usually a minimum of one thousand records are required to calculate the heritability of a production trait with reasonable precisions which suggests more records for animals with MY are required to validate and further this research. Results from this research showed that there are cattle that naturally produce less methane relative to their feed intake, that is, cattle that have a naturally lower MY. Differences between sires in MY by their progeny were observed and were statistically significant.

Preliminary results show that phenotypic associations are low, probably negotiable, for MY with weight gained on pasture, body composition and meat quality taken near the time of methane measurement. While the magnitude of genetic correlations cannot be determined until more records for MY are collected, it does appear that phenotypic variation in MY does not appear to be associated with genetic variation in weight traits,

important body composition and carcass traits, and fertility traits (as indicated by lack of associations with Estimated Breeding Values (EBV)).

The implications from these preliminary results are that it is unlikely to be possible to predict MY for individual cattle based on simple phenotypic measurements such as weight or scanned body composition information. Further, selection using current BREEDPLAN®. EBV to change methane production, particularly MY, in the next generation of cattle will not lead to a predictable change in MY. Therefore, to be able to use animal breeding to predictably reduce methane yield will require a new breeding value for a methane-related trait to become available to cattle breeders.

Related projects funded under Round 1 of Filling the Research Gap

- Genetic technologies to reduce methane emissions from Australian beef cattle—NSW Department of Primary Industries—Graham Denney. Funding of $3 000 000 ex GST

Publications

1. Arthur, P, Herd, R & Basarab, J 2010, 'The role of cattle genetically efficient in feed utilisation in an Australian carbon trading environment', *AFBM Journal,* vol. 7, pp. 5-13.
2. Herd, R, Bird, S, Donoghue, K, Hegarty, R & Arthur, P, 2011, 'Breeding cattle for lower greenhouse gas emissions', *In Fourth Annual World Congress of Industrial Biotechnology*, Dalain, China*,* 25-30 April, p. 219.

Further publications detailing the results of this research are in preparation and will be available.

Methanotrophs in natural ecosystems and their role in ruminant methane mitigation

Lead organisation

University of Queensland

Consortium member organisations

N/A

Objectives

To evaluate the potential for methanotrophs to reduce ruminant methane emissions in a novel approach to rumen methane abatement.

Location

St. Lucia, Queensland

Samples collected from: Nudgee landfill in Brisbane, Grantham Piggery effluent pond, the Elanora Wastewater Management Centre (Department of Primary Industries, Victoria) and Highchester Abattoir (Gleneagle).

Key activities

- review literature and current research on methanotrophs and methane reduction, including in soils and oceans

- investigate the abundance of both bacterial and archaeal methanotrophs in natural ecosystems including in soils, lake sediments, marine sediments, the gastrointestinal tracts of mammals and birds, sewage treatment plants and settling ponds
- obtain a range of cultivable methanotrophs, determine how well these represent the total diversity and if necessary undertake further targeted isolations
- using a fermentation apparatus, determine whether the available methanotrophs are effective at reducing methane emissions in a rumen-like environment and monitor the population dynamics of both methanotrophs and methanogens using specifically designed real-time polymerase chain reaction (PCR) assays
- make available methanotrophs that successfully reduce methane emissions for evaluation in future work with cattle and for the development of economically viable delivery vehicles.

Findings/Conclusions

This study is the first to characterise rumen methanotrophs using a molecular methodology. Using a combination of denaturing gradient gel electrophoresis and phylogenetic analysis, it was found that simple communities of proteobacterial methanotrophs can be native residents of the rumen microbial community in grain-fed *Bos indicus* steers. A putative methanotrophic Gamma-proteobacterial *Methylobacter* species was also enriched from grain-fed whole rumen contents using novel techniques. However, the activity of these organisms *in situ* remains to be fully understood. There is also the possibility that a grain-based dietary affect influences the diversity and activity of methanotrophs *in situ*.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Finn, D, Ouwerkerk, D & Klieve, A 2012, 'Investigating the biodiversity of Proteobacterial methanotroph communities in the rumen of Australian cattle', *Australian Society for Microbiology.*
2. Finn, D, Ouwerkerk, D & Klieve, A 2012, 'Molecular characterisation of aerobic methanotroph communities present in the rumen of Australian cattle', *FEMS Microbiology Letters*.

Further publications detailing the results of this research are in preparation and will be available.

Mitigation of methane emissions from the northern Australian beef herd

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations

The University of Melbourne

Objectives

- to develop and validate the open path laser technique for use in extensive northern landscapes to measure methane emissions from cattle and to develop proof of concept for indirect assessments using sensor networks
- to measure methane emissions under up to six northern production scenarios (e.g. stocking rate, bio-region, biomass, season) and potential abatement properties of tropical legume species to assess the impact of management practices on methane productions in northern grazing systems.

Location

Queensland and Northern Territory farms

Key activities

- validation and application of a methodology for estimating methane emissions at the herd scale using open-path lasers with micrometeorlogical data and a dispersion model
- collection of data sets from production systems in Queensland and the Northern Territory.

Findings/Conclusions

A micrometeorological methodology for estimating herd scale emissions using an indirect open-path spectroscopic technique and an atmospheric dispersion model is described. Livestock emissions have been measured for properties in Queensland and the Northern Territory. In addition, 22 diets, combining tropical grass and legume species, have been fed to cattle under animal house conditions and methane (CH_4) emissions measured using open-circuit respiration chambers. Daily mean (± sem*) CH_4 emissions from the study sites ranged from 136 ± 21.5 g/hd/d to 281 ± 22.3 g/hd/d. Low emissions were associated with young steers grazing irrigated and fertilised Rhodes grass. High emissions were associated with mature Brahman cows and heavier steers grazing Buffel/Sabi grass pasture. Animal house studies indicated that CH_4 production could be predicted as 19.6 g/kg forage dry matter intake. Mean CH_4 emission rates across all diets were approximately 5.2 - 7.2 per cent of gross energy intake which compare favourably with Tier 1 emission factors from the Intergovernmental Panel on Climate Change (IPCC, 2006) for large ruminants fed low-quality crop residues and by-products.

Methane emission values for mixed diets have been characterised and can be benchmarked in grazing systems across northern Australia using the dispersion methodology.

**standard error mean*

Related projects funded under Round 1 of Filling the Research Gap

- Genetic technologies to reduce methane emissions from Australian beef cattle—NSW Department of Primary Industries—Graham Denney. Funding of $3 000 000 ex GST
- Impacts of *Leucaena* spp. plantations on greenhouse gas emissions and carbon sequestration in northern Australian cattle production systems—CSIRO—Chris McSweeney. Funding of $750 000 ex GST

Publications

1. Kennedy, P & Charmley, E 2012, 'Methane yields from Brahman cattle fed tropical grasses and legumes', *Animal Production Sci*ence (In press).

2. Mcginn, S, Turner, D, Tomkins N, Charmley, E & Chen, D 2011, 'Methane emissions from grazing cattle using point-source dispersion', *Journal of Environmental Quality,* vol. 40, pp. 22-27.
3. Tomkins, N, McGinn, S, Turner, D & Charmley, E 2011, 'Comparison of open-circuit respiration chambers with a micrometeorological method for determining methane emissions from beef cattle grazing a tropical pasture', *Animal Feed and Science Technology*, vol. 166-167, pp. 240-247.

Further publications detailing the results of this research are in preparation and will be available.

Manure management to reduce greenhouse gas emissions from cattle feedlots

Lead organisation
The University of Melbourne

Consortium member organisations
N/A

Objectives
To examine manure management strategies for reducing greenhouse gas emissions from a beef cattle feedlot. The focus of the work was on the effectiveness of operational application of urease inhibitor (UI) to cattle pens and manure stockpiles, in reducing ammonia (NH_3) and nitrous oxide (N_2O) emissions.

Location
Charlton, Victoria

Key activities
The project assessed the feasibility of application of UI to cattle pens and manure stockpiles, as a strategy for reducing NH_3 and N_2O emissions. The study included a combination of atmospheric dispersion modelling, mineral nitrogen analysis and laboratory incubations.

Findings/Conclusions
UI application to cattle pens was found to have a significant effect on urea content in manure but, even after treatment, retained urea was rapidly depleted within the first days after pen clearing and manure stockpiling, and UI-treatment could not be reliably linked to reduced NH_3 emissions from manure stockpiles. Sustained retention of urea in the manure as it is removed, stockpiled and ultimately incorporated into agricultural soils remains an operational challenge, because of the transient effect of the UI, and pen-access difficulties in wetter months. Moreover, even if practicable, the additional cost of implementing UI application at the label rate was estimated at $38 per turned-out-steer, or $459 per tonne of mitigated CO_2-e. Cost effectiveness of UI application for mitigation of ammonia and greenhouse gas emissions seems doubtful however recommendations to progress this work include more resilient additives, cheaper and more reliable application methods, and improved emissions measurement within the pens.

Related projects funded under Round 1 of Filling the Research Gap

- Mitigating the greenhouse gas potential of Australian soils amended with livestock manure—The University of Western Australia—Sasha Jenkins. Funding of $655 563 ex GST

Publications

Publications detailing the results of this research are in preparation.

Antimethanogenic bioactivity of Australian plants for grazing systems

Lead organisation

The University of Western Australia

Consortium member organisations

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Sheep Cooperative Research Centre
Future Farm Industries Cooperative Research Centre
Department of Primary Industries, Victoria

Objectives

To assess the potential for Australian forage plants to contribute to feedbase management strategies to reduce methane from grazing livestock by identifying the bioactive compounds responsible for the anti-methanogenic effects, investigating the mechanism(s) behind their observed action at the molecular microbial ecology level, and testing the most promising and most consistently antimethanogenic plants under *in vivo* conditions.

Location

Perth, Western Australia

Key activities

- investigate the 'antimethanogenic' bioactivity of a range of fodder plants, plant extracts and selected feed additives
- investigate the variability, persistency and mechanisms behind identified bioactivity, using a laboratory based system.

Findings/Conclusions

The project identified a range of tropical legumes (e.g. *Leucaena leucocephala, Desmanthus virgatus*), novel forages (e.g. turnip and chicory), plant extracts (e.g. *Eremophila glabra, Santalum spicatum*) and feed additives (e.g. grape marc or marine products—docosahexaenoic acid (DHA) and *Nannochloropsis oculata*), that have the potential to reduce methane in the rumen. Significant reduction in methane was observed with 21 samples, including eight feed additives (up to 40 per cent reduction), all eight essential oils (up to 75 per cent reduction), two plant extracts (14 per cent reduction) and three industry by-products (up to 37 per cent reduction).

One plant (*E. glabra*) was shown to reduce methane by directly affecting the methanogens in the rumen. This effect persisted over several weeks and is now being studied to confirm if it works in sheep. The specific plant fractions that are responsible

for these effects were purified, as it is anticipated that this will lead the research to the specific compounds that are antimethanogenic and the mechanism behind their action. Most variability in antimethanogenic bioactivity was observed when plants were grown at different locations and between different plant accessions within a species. Season, phenology and grazing had less influence on the variability. The results will assist in developing new grazing and management systems for reducing methane emissions from grazing ruminants.

Related projects funded under round 1 of Filling the Research Gap

- Supplementation with tea saponins and statins to reduce methane emissions from ruminants—CSIRO—Chris McSweeney. Funding of $250 000 ex GST
- Best choice shrub and inter-row species for reducing emissions and emissions intensity—The University of Western Australia—Phillip Vercoe. Funding of $500 000 ex GST
- The mechanism of antimethanogenic effects of bioactive plants and products on methane production in the rumen—The University of Western Australia—Phillip Vercoe. Funding of $250 000 ex GST
- Efficient Livestock and Low Emissions (ELLE) from southern grazing systems—The University of Western Australia—Phillip Vercoe. Funding of $1 500 000 ex GST

Publications

1. Durmic, Z, Hutton, P, Revell, DK, Emms, J, Hughes, S & Vercoe, PE 2010, '*In vitro* fermentative traits of Australian woody perennial plant species that may be considered as potential sources of feed for grazing ruminants', *Animal Feed Science and Technology*, no. 160, pp. 98-109.
2. Durmic, Z, Vercoe, P & Revell, D 2009, 'Bioactive plants for livestock production', *Evergreen Farming December*, pp. 12-13.
3. Li, XX, Durmic, Z, Liu, SM & Vercoe, PE 2010, 'Eremophila glabra and Kennedia prorepens Reduces Methane Emission from Medicago sativa In Vitro', *Proceedings of the Australian Society of Animal Production*, no. 28, p. 67.
4. Martin, GB, Durmic, Z, Kenyon, PR & Vercoe, PE 2010, 'Clean, green and ethical animal reproduction: extension to sheep and dairy systems in New Zealand'. *Proceedings of the New Zealand Society of Animal Production,* no. 69, pp. 140-147.

Further publications detailing the results of this research are in preparation and will be available.

Breeding low methane emitting sheep and elucidating the underlying biology

Lead organisation

Cooperative Research Centre for Sheep Industry Innovation

Consortium member organisations

The University of Western Australia
NSW Department of Primary Industries
Department of Agriculture, Western Australia

Objectives

- identify useful predictors of daily methane production that can be applied to large populations of sheep to enable the generation of genetic parameters for a methane trait
- apply that method to genetic resource flocks in Australia to establish preliminary estimates of phenotypic and genetic correlations between methane emissions and production traits
- identify high and low methane-emitting individuals using in-field screening and chambers and use them to compare rumen physiology, rumen microbial ecology and net feed intake (NFI) to improve understanding of the underlying biological basis for differences in methane production.

Location

Kattaning, Western Australia
Cowra, Kirby and Trangie, New South Wales
Rutherglen, Victoria

Key activities

The project developed a short-term method for measuring methane in the field using portable accumulation chambers. In excess of 3000 animals were screened to estimate genetic parameters and identify high and low methane-emitting individuals. These individuals were selected for investigations of rumen physiology, rumen microbial ecology and net feed intake.

Findings/Conclusions

Genetic improvement is one method to reduce enteric methane production by grazing sheep. It is suited to extensive grazing systems where other forms of intervention are impractical. Measurements are required on large numbers of individual animals to estimate the impact of genes on methane production and establish correlations with other commercially important traits. Methane yield (production/kg dry matter intake) is related to the time feed particles spend in the rumen. The preliminary work has not identified any clear differences in the microbial ecology between high and low emitting animals. Sire variation was noted in a number of traits linked to feed but there is little evidence that feed efficiency explained variation in daily methane production. Current estimates of heritability of methane output are low but there is enough evidence to suggest there is scope for industry to benefit through genetic selection and developing a methane index.

Related projects funded under Round 1 of Filling the Research Gap

- Genetic technologies to reduce methane emissions from Australian beef cattle—NSW Department of Primary Industries—Graham Denney. Funding of $3 000 000 ex GST

Publications

1. Bickell, S, Robinson, D, Toovey, A, Goopy, J, Hegarty, R, Revell, D & Vercoe, P 2011, 'Four-week repeatability of daily and one hour methane production of mature merino wethers fed *ad libitum*', *Association for the Advancement of Animal Breeding and Genetics, Australia*, no. 19, pp. 415-418.
2. Goopy, J, Robinson, D, Woodgate, R & Hegarty, R 2009, 'Repeatability of VFA concentration in sheep under field conditions', *Recent Advances in Animal Nutrition Australia,* no. 17, p. 176.

3. Goopy, J, Woodgate, R, Donaldson, A, Robinson, D & Hegarty, RS 2011, 'Validation of a short-term methane measurement using portable static chambers to estimate daily methane production in sheep', *Animal Feed Science and Technology,* no. 166, pp. 219-226.
4. Hegarty, R, Alcock, D, Robinson, D, Goopy, J & Vercoe, P 2010, 'Nutritional and flock management options to reduce methane output and methane per unit product from sheep enterprises', *Animal Production Science,* no. 50, pp. 1026-1033.
5. Robinson, D 2009, 'Improving the accuracy of selecting animals from reduced methane emissions', *Association for the Advancement of Animal Breeding and Genetics, Australia,* no. 18, pp. 64-647.
6. Robinson, D, Bickell, S, Toovey, A, Revell, D & Vercoe, P 2011, 'Factors affecting variability in feed intake of sheep with *ad libitum* access to feed and the relationship with daily methane production', *Association for the Advancement of Animal Breeding and Genetics, Australia*, no. 19, pp. 159-162.
7. Robinson, D, Goopy, J & Hegarty, R 2010, 'Can Rumen Methane Production be Predicted from Volatile Fatty Acid Concentration?' *Animal Production Science*, no. 50, pp. 630-636.
8. Robinson, D, Goopy, J, Hegarty, R & Vercoe, P 2010, 'Repeatability, Animal and Sire Variation in 1-hr Methane Emissions & Relationships with Rumen Volatile Fatty Acid (VFA) Concentration', *Proceedings of the Ninth World Congress on Genetics Applied to Livestock Production,* Leipzig, Germany, 1-6 August, <http://www.kongressband.de/wcgalp2010/assets/pdf/0712.pdf>

Further publications detailing the results of this research are in preparation and will be available.

Use of peptide-phage display libraries to discover peptides that are bioactive against rumen methanogens

Lead organisation
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations
N/A

Objectives
Demonstrate that peptide-phage display technology can be used to reduce rumen methanogenesis, and develop peptides which could be used as supplements or in a vaccine strategy, hence providing improved understanding of the feasibility and practicality of reducing rumen methane emissions from livestock.

Location
St Lucia, Queensland

Key activities
The primary goal of this project was to use bioactive peptides, discovered by screening peptide phage display libraries, to redirect fermentation end products away from methane formation, thereby reducing greenhouse gas emissions from livestock production systems.

Findings/Conclusions

By using a specifically designed screening method, three bacteriophage-peptides were identified with inhibitory activity towards a model methanogen *Methanobrevibacter ruminantium*, as well as less dominant strains in the rumen, *Methanosarcina barkeri* and *Methanobrevibacter gottschalkii*. It is expected some modification of the peptide sequences may be required to further enhance their activity and to protect them from degradation in the rumen environment. This technology could be delivered as inhibitory peptides for use as ruminant supplements, or through a vaccination based approach where the peptides are used to identify cell surface proteins that are crucial to survival of methanogens in the rumen.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. Hartman, B, Bishop-Hurley, S & McSweeney, C 2010, 'Discovery and characterisation of peptide antimicrobials directed towards rumen methanogens: A potential greenhouse gas mitigation strategy', *Fifth International Peptide Symposium,* Kyoto, Japan.

Further publications detailing the results of this research are in preparation and will be available.

Increasing productivity and reducing methane emissions by supplementing feed with dietary lipids

Lead organisation

Queensland Department of Primary Industries and Fisheries, and the University of Queensland

Consortium member organisations

N/A

Objectives

To investigate the impact of lipids containing feed additives on the suppression of methane emissions and improvements in the growth rate of steers fed a basal diet of tropical pastures.

Location

Gatton, Queensland

Key activities

This project studied a range of potential lipid containing supplements that could be used with subtropical/tropical grazing systems. The project initially focussed on the effect of lipid containing additives on methane production using *in vitro* techniques. Lipid containing supplements that showed potential by reducing methane production were then studied *in vivo* by means of a pen trial.

Supplements studied using *in vitro,* rumen based, fermentation experiments included Algamac 3050 (a marine algal meal (three, five and seven per cent oil inclusion in the diet)), spirulina (three per cent inclusion), safflower oil (three, five and seven per cent oil inclusion in the diet) and canola oil (five and seven per cent inclusion).

Supplements studied to confirm and quantify their impact on rumen methanogenesis and determine performance benefits in cattle when fed with a production ration (*in vivo* study) where algamac, sunflower oil and whole cotton seed.

Findings/Conclusions

In vitro research using Algamac 3050 at all levels of inclusion reduced methane generation whilst appearing not to affect rumen microbial population dynamics, including the methanogen population. There were no differences in dry-matter digestion or the numbers of methanogens or methanogen population structure. All levels of Algamac inclusion had similar effects, suggesting that the mechanism that lowers methane with algal oils is different to that of other oils, which directly impacts on the microbial ecosystem at higher levels of inclusion.

In vitro research using the supplement canola oil at seven per cent inclusion appears to only transiently reduce methane generation and would not appear to be a good candidate as a feed supplement for lowering methane emissions. The effectiveness of safflower inclusion is dose related. Safflower at seven per cent inclusion reduces methane generation significantly and at a constant level. The inclusion at five per cent was not effective at reducing methane production.

Spirulina at three per cent inclusion in the diet (it was not possible to get higher concentrations into the diet due to intrinsically low lipid concentrations of this freshwater alga), had no effect on methane concentrations or other fermentation parameters. No further work was therefore undertaken with this alga.

A range of lipid containing supplements were tested *in vivo* in a feeding trial using *Bos indicus* cross steers. The supplements included Algamac, sunflower oil and whole cotton seed. All lipid supplements were included at a rate of 50 g lipid/kg DM. Supplementation increased live-weight gain over an 11 week period. The highest gain was from whole cottonseed supplementation (15.7 kg) followed by Algamac supplementation (12.1 kg). Supplementation of Algamac and sunflower oil reduced methane emissions on a live-weight and dry matter intake basis by around 22 per cent and 19.4 per cent respectively. Using these functions there was no reduction in methane emissions per head with whole cottonseed supplementation, however, when calculating methane emissions as a function of average daily gain (ADG), both whole cottonseed and Algamac supplementation had a four-fold reduction in emissions. Taking this reduction into account plus the fact that increasing live-weight would reduce the number of days to market, the overall reduction in methane emitted would be substantial. It is recommended the use of whole cottonseed and Algamac be considered as a supplement to cattle fed a basal diet of tropical pastures due to its positive impact on live-weight gain, and the reduction in methane per kilogram of average daily gain, however there are supplement uptake issues that need to be overcome.

Related projects funded under Round 1 of Filling the Research Gap

- Development of algae based functional foods for reducing enteric methane emissions from cattle—CSIRO—Nigel Tomkins. Funding of $500 000 ex GST

Publications

1. Klieve, A, McLennan, S, Ouwerkerk, D & Hegarty, R 2009, 'Methane emissions and liveweight gain of cattle fed supplements of cottonseed and coconut oil', *In Proceedings of the 11th International Symposium on Ruminant Physiology* (Clermont-Ferrand, France), Chilliard, Y, Glasser, F, Faulconnier, Y, Bocquier, F, Veissier, I & Doreau, M (ed.) Wageningen Academic Publishers, Wageningen.

Further publications detailing the results of this research are in preparation and will be available.

A genomic strategy to identify archaeal viruses in the rumen

Lead organisation

University of Queensland

Consortium member organisations

Queensland Department of Agriculture, Fisheries and Forestry (formerly Department of Employment, Economic Development and Innovation)

Objectives

To gain a better understanding of ruminal archaeaphage to enhance the ability to recognise and isolate these viruses for use in an archaeaphage therapy strategy.

Location

Brisbane, Queensland

Key activities

The one-year project investigated the viral metagenome (virome) of the rumen. Virus particles were successfully purified and concentrated from relatively small volumes of bovine rumen fluid and sufficient quantities of viral DNA obtained to facilitate high throughput sequencing, without the inclusion of additional amplification steps.

Findings/Conclusions

Results of sequence analysis indicated that the rumen contains a highly diverse virus population, dominated by double-stranded DNA viruses (tailed bacteriophages of the order Caudovirales), with evidence of some changes occurring in the viral population in relation to the time of feeding. Viral marker genes (terminase large subunit) associated with previously sequenced archaeaphage (including the Siphoviruses,

Methanobacterium phage ψM2 and *Methanothermobacter* phage ψM100) were detected within the virome dataset. Characterisation of the corresponding rumen microbial populations using a 16S rRNA gene approach also indicated the types of methanogens which may be infected or associated with these archaeaphage. Utilising a metagenomic approach has provided an ideal platform for identifying archaeaphage present within

the rumen virome and has provided an insight into the advantages of adopting this approach for future studies examining the phage and viral populations of the rumen.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

Publications detailing the results of this research are in preparation.

Enteric methane abatement strategies for ruminant production systems in south eastern Australia

Lead organisation

Department of Primary Industries, Victoria

Consortium member organisations

The University of Western Australia

Objectives

- to evaluate forages and dietary supplements for methane mitigation and production impacts
- to evaluate open-path tracer methods for measurement of methane from grazing ruminants.

Location

Ellinbank and Hamilton, Victoria
Perth, Western Australia

Key activities

This project evaluated a range of dietary oil supplements, tannin, micro algae oils and grape marc for effects on methane emissions, milk yield and milk composition in dairy cows.

The key activities included four experiments at Ellinbank measuring methane and productivity responses to feeding different types of dietary supplements to dairy cows, as well as research at Hamilton evaluating an Open Path Tracer technique for measuring methane emissions from grazing sheep.

The four experiments on lactating dairy cows compared the effects on methane emissions, milk yield and milk composition of a basal diet of lucerne hay with the following dietary supplements:

1. crushed wheat, brewers' grains, hominy meal or cold-pressed canola
2. four rates of algae meal containing 20 per cent docosahexaenoic acid (DHA)
3. cottonseed oil, crude tannin, or both the cottonseed oil and the tannin
4. dry grape marc (the skins and seeds after grapes are pressed to make wine) or ensiled grape marc

Research on the Open Path FTIR Tracer technique focused on development of novel methods to enable it to be used to measure methane emissions from flocks of grazing sheep.

Findings/Conclusions

- High fat feed supplements, especially by-products such as brewers' grains, hominy meal and cold-pressed canola can reduce methane emissions. When a high fat feed supplement is added to a diet, methane emissions are reduced by 3.5 per cent for every 1 per cent increase in the total fat concentration in the diet.
- Feeding cows on algae meal containing high concentrations of docosahexaenoic acid (DHA) does not reduce methane emissions but results in milk with lowered milk fat concentration. This finding is contrary to international *in vitro* studies that had reported algae meal high in DHA had potent anti-methanogenic properties with the potential to decrease methane emissions by 75 per cent.
- Dietary supplements of fat and tannin have been shown to inhibit methane emissions from ruminants. This research has shown that when supplements of fat and tannin are fed simultaneously, as extracts, the inhibitory effect was not additional.
- When either dried grape marc or ensiled grape marc were fed to cows, methane emissions were reduced by approximately 20 per cent without decreasing feed intake, or milk yield, or having adverse impacts on milk composition.
- The open path FTIR technique can be used to measure methane emissions from flocks of grazing sheep. The technique could detect differences of less than 10 per cent in the methane emissions from different flocks and from flocks grazing different pasture types. The technique can be used as a tool to demonstrate methane abatement strategies on commercial farms.
- The sulphur hexafloride (SF6) tracer technique can be used to accurately measure methane emissions from dairy cows housed indoors. The research also showed that background concentrations of both SF6 and methane are elevated indoors compared to outdoors, and that concentrations indoors can vary spatially.

Related projects funded under Round 1 of Filling the Research Gap

- Enteric methane mitigation strategies through manipulation of feeding systems for ruminant production in southern Australia—Department of Primary Industries, Victoria—Joe Jacobs. Funding of $1 970 000 ex GST

Publications

1. Browne, N, Eckard, R, Behrendt, R & Kingwell, R 2011, 'A comparative analysis of on-farm greenhouse gas emissions from agricultural enterprises in south eastern Australia', *Animal Feed Science and Technology,* vol. 166-167, pp. 641-652.
2. Cullen, B & Eckard, R 2011, 'Impacts of future climate scenarios on the balance between productivity and total greenhouse gas emissions from pasture based dairy systems in south-eastern Australia', *Animal Feed Science and Technology*, vol. 166-167, pp. 721-735.
3. Eckard, R, Grainger, C & de Klein, C 2010, 'Options for the abatement of methane and nitrous oxide from ruminant production: a review', *Livestock Science*, vol. 130, pp. 47-56.
4. Moate, P, Williams, R & Eckard, R 2010, 'Influence of cold pressed canola, brewers grains and hominy meal as dietary supplements suitable for reducing enteric

methane emissions from lactating dairy cows', *Animal Feed Science and Technology* (In press).
5. Moate, P, Williams, S, Grainger, C, Hannah, M, Ponnampalam, E & Eckard, R 2011, 'Influence of cold-pressed canola, brewers grains and hominy meal as dietary supplements suitable for reducing enteric methane emissions from lactating dairy cows', *Animal Feed Science and Technology*, vol. 166-167, pp. 254-264.
6. Williams, S, Moate, P, Hannah, M, Ribaux, B, Wales, W & Eckard, R 2011, 'Background matters with the SF6 tracer method for estimating enteric methane emissions from dairy cows', *Animal Feed Science and Technology*, vol. 170, pp. 265-276.

Further publications detailing the results of this research are in preparation and will be available.

Using infrared thermography as a proxy for measuring methane emissions

Lead organisation
The University of Melbourne

Consortium member organisations
Department of Primary Industries, Victoria

Objectives
- evaluate the infrared (IR) thermography system to determine if IR thermography methods will provide accurate, repeatable data on methane yield from ruminants
- provide information on the relationship between heat production and residual feed intake (RFI), to improve the ability to rapidly screen animals for differences in these traits.

Location
Ellinbank, Victoria

Key activities
The measurement of methane production and feed efficiency in ruminants is expensive; infrared thermography has been proposed as a proxy in cattle. The difference in temperature between left and right flanks is believed to be indicative of the heat of fermentation in the rumen, and hence methane production.

A thermal imaging camera was used to record flank temperatures on cattle fed either a wheat or corn based diet. The thermal imaging camera was mounted above the animal inside the chamber and images remotely recorded at 5 minute intervals for the whole 48 hour period that the animal was confined to the chamber (total of 576 images per animal per chamber session). A total of 12+ days of chamber images were collected at the conclusion of the Ellinbank experiment in late March 2012.

Findings/Conclusions
The project found a weak correlation between methane emissions and temperature variations. The correlation between methane emissions and flank temperature immediately after feeding ranged between r^2=0.35 to 0.46 post feeding but no correlation across the day. However, the project did find a difference in the average daily temperature between flanks (wheat fed cows 1.43°C vs. corn fed cows 0.71°C).

The use of thermography to estimate methane emissions may be a useful qualitative tool, but further work evaluating the relationship between flank temperature and emissions under different conditions is necessary before a quantitative measure can be determined.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

Publications detailing the results of this research are in preparation.

Mitigation of methane emissions from the northern Australian beef herd demonstrating field laser research

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations

N/A

Objectives

- measure methane emissions from grazing cattle at a commercial scale using open path laser (OPL) techniques
- demonstrate the magnitude and variability of methane emissions from cattle grazing tropical pastures

Location

Douglas Daly Research Farm, and AACo Brunette Downs, Northern Territory

Key activities

- methane measurement using open path lasers
- estimating herd scale emissions using an indirect open path spectroscopic technique and an atmospheric dispersion model.

Findings/Conclusions

Methodologies to measure methane (CH_4) emissions associated with beef production systems are available to measure emissions from individual animals but are yet to be quantified for commercial sized herds in northern Australia. Applying existing methodologies to measure CH_4 emissions from cattle in the extensive grazing environments of northern Australia has proved challenging. The project developed and assessed a method for micrometeorological estimation of herd scale emissions using an indirect open path spectroscopic technique and an atmospheric dispersion model.

Livestock emissions were measured for properties in Queensland and the Northern Territory. Using OPL, CH_4 measurements were obtained from two sites in the Northern Territory; Douglas Daly Research Farm, and AACo Brunette Downs. These additional campaigns have measured CH_4 flux from Brahman cross and composite heifers grazing predominantly unimproved pastures typical of northern Australia. Emissions of CH_4

were measured using OPL for up to five hours per day for at least 12 days and estimated with a bLS dispersion model. Calculated daily CH_4 emissions (g CH_4/day) for 12 valid measurement periods obtained at Kidman Springs for Brahman and Brahman x Senepol cross heifers (mean ± sem* liveweight 316 ± 4.5 kg) ranged from 65 ± 18.4 g/day to 257 ± 25.8 g/day. Data obtained at Brunette Downs on the Barkly Tablelands for composite heifers (mean ± sem liveweight 287 ± 6.2 kg) grazing an *Astrebla sp*. dominated sward has yet to be processed. An additional campaign was completed in 2012 on Hamersley Station, Western Australia which added further emission data for benchmarking heterogeneous grazing systems across northern Australia.

Conclusions from the study include:

- The method provides data that is credible. Validation with other methodologies (e.g. open circuit calorimeters and model estimates) demonstrates that the results are within the expected range. The standard errors consistently declined as the technique was developed over successive deployments.
- Emissions of CH_4 in the paddock appear to be higher (approximately 10 to 20 per cent higher) than would be expected based on intensive chamber studies. This is most probably attributed to higher voluntary intakes under commercial grazing conditions.
- The need for reliable method of estimating intake of grazing cattle in the north is the single most serious knowledge gap that currently exists.
- Variation between sites exists, and while some of this can be attributed to the size and class of animal, it is impossible to determine other contributing factors.

**standard error mean*

Related project funded under Round 1 of Filling the Research Gap

N/A

Publications

Publications detailing the results of this research are in preparation.

Demonstration projects for on-farm practical methane strategies

Lead organisation

Meat and Livestock Australia

Consortium member organisations

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
NSW Department of Primary Industries
University of New England
Department of Primary Industries, Victoria
The University of Western Australia

Objectives

To support the transition of outcomes of the applied research and development activities in the Reducing Emissions from Livestock Research Program (RELRP) through to demonstration of practical commercial abatement applications.

Location

Ridgefield, Western Australia
Lansdown, Queensland
Trevenna, New South Wales
Hamilton and Terang, Victoria

Key activities

Demonstration and extension activities have been conducted at a range of locations including:

- The University of Western Australia Future Farm, Ridgefield, Western Australia
- CSIRO Lansdown Research Station, Burdekin Catchment, Queensland
- NSW Department of Primary Industries and the University of New England, Trevenna demonstration site, New South Wales
- Department of Primary Industries, Victoria, field days and extension activities at Hamilton and Terang, Victoria.

The two most significant field day events held at the University of Western Australia Future Farm Ridgefield were 'Coping with Climate Change' in October 2010, and 'Whole-farm Carbon Emissions' in October 2011. Community engagement was also undertaken at the Dowerin Field Day with a booth containing posters of the RELRP program, displays, videos and information of other work funded through the Climate Change Research Program.

Key activities at the Lansdown Research Station (638 hectares of native and improved pastures) included:

- An inaugural field day attracting about 120 visitors and the CSIRO Agriculture Flagship leadership team
- Primary Industries Adaptation Research Network Master Class one day workshop and tour
- Northern Australian Beef Research Council forum.

At the 'Trevenna' farm demonstration site farmers, scientists, and students have participated in 49 events in the last 2 years, with more than 2000 people hearing about the project and 550 people visiting the site. One of the most significant events was a field day on the 29th March 2011 that showcased the demonstration trial and early results on reducing methane in sheep production systems.

At Hamilton and Terang, six extension activities consisting of two service provider meetings, two field days at the Department of Primary Industries, Victoria site at Hamilton and two at Terang, attended by a total of 312 participants, were conducted during 2010 and 2011. The majority of attendees (45 per cent) were from the agricultural service and agribusiness sectors, 34 per cent from extension and research, and 21 per cent were farmers. Two field campaigns measuring methane emissions from grazing sheep and lactating dairy cows using open-path fourier transform infrared (OP-FTIR) methodology were also conducted with Wollongong University.

Findings/Conclusions

The University of Western Australia Future Farm is helping to ensure commercial application and farmer acceptance, and the CSIRO Lansdown demonstration site is

helping to communicate research activities and results to the northern beef industry. The Lansdown location makes it ideal for further demonstrations that will be required to demonstrate measuring emissions under local conditions for the northern beef herd.

The Trevenna site demonstrated that the fourier transform infrared (FTIR) spectrometer estimate of methane (CH_4) emissions were 19.5 and 17.5 g CH_4/animal/day on high (HPL) and low productivity landscapes (LPL), respectively. Nitrous oxide emissions (N_20) were 4 times higher on the HPL than the LPL 20 v. 5 µg $N_2O/m^2/h$ in autumn, but 13 times higher on HPL in winter when the C_4 plant species was dormant on the LPL.

The activities conducted at Hamilton and Terang have increased the awareness of research being conducted into these areas by RELRP and other programs. The attendances and the feedback from the extension activities conducted as part of the project indicate that the agricultural service, agribusiness and extension sectors are the most receptive to, and interested in, new information in these areas. The project was moderately successful in attracting farmers to extension activities. Together with other feedback, this indicates that at the present time, the issue of greenhouse gas emissions and their mitigation are not a high priority for farmers and as such, farmers are not attracted to attend such activities dealing with greenhouse activities per se. However the up-skilling of the agricultural service and extension sectors is an important step in progressively extending this information to the broader dairy, sheep and beef industries.

The identification through the Hamilton and Terang work that reducing emissions from livestock is not a high priority for producers is reiterated in the findings from the University of Western Australia. At the 'Coping with Climate Change' field day of the 83 participants most of the participants were from the scientific community with 34 scientists and 7 students, with only 19 grower/producers attending.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

1. McPhee, M, Edwards, C, Meckiff, J, Ballie, N, Schneider, D & Hegarty, R 2011, 'Preliminary results of estimating on-farm methane emissions for sheep production on the Northern Tablelands of Australia', *The National Climate Change Research Strategy for Primary Industries meeting,* Melbourne, 15-17 February.
2. McPhee, M, Edwards, C, Meckiff, J, Ballie, N, Schneider, D, Trotter, M et. al. 2011, 'Preliminary results of estimating methane sheep production on the Trevenna demonstration site at UNE', *Proceedings of Rural Climate Change Solutions Symposium,* 3-4 May, Cowie, A, p. 37.

Further publications detailing the results of this research are in preparation and will be available.

Can multiple short-term measures of methane be used to quantify daily methane emissions in beef cattle?

Lead organisation
University of New England

Consortium member organisations
NSW Department of Primary Industries

Objectives
Testing of the automated methane measurement device

Location
University of New England, Armidale and Tullimba feedlot

Key activities
The GreenFeed Emissions Monitoring (GEM) devices are unique patented tools which use a 'bait station' to attract individual cattle to a small feeding booth in which their carbon dioxide (CO_2) and methane (CH_4) emissions are measured over three to five minutes, five to ten times per day. They can be used to determine total CH_4 production, total CO_2 production, and also differentiate CO_2 arising from mammalian respiration, from that arising from rumen fermentation.

The research conducted two experiments using GEM:
1. An evaluation of short term methane production measures as indicators of daily methane production by cattle.
2. Issues arising in cattle feedlot application of GEM supplement unit.

These experiments investigated some of the attributes of GEM units (one that delivers pellets as an attractant and one that delivers water), together with assessing limits to their use and ways to overcome impediments to use.

Findings/Conclusions
This study evaluated a GEM unit using a supplement and a GEM unit using water as the baits. With appropriate filtering, the estimate of daily emissions from the two units was within one per cent of each other. A comparison of GEM measured emissions and Calorimeter measured emissions from cattle was slightly confounded by reduced intake on days when cattle were in chambers, however the methane yields (g CH_4/kg dry matter intake) were very similar between the two systems. Emissions from individual animals were remarkably stable over time (CV < 6 per cent). Recovery of a carbon dioxide pulse (as a test gas) through the GEM unit was 99 per cent. The results indicate that the GEM units can, with appropriate control, provide an accurate measure of daily methane emissions period, based on Australian and New Zealand data.

There is scope for the units to have automated calibration ability added; to clarify data processing and filtering to ensure transparency of data is maintained; and optimise the construction to better suit remote use (eg. larger feed hopper, heavy duty trailer/frame) and these improvement are currently being made by the manufacturer.

Related projects funded under Round 1 of Filling the Research Gap

- Evaluating and optimisation of GreenFeed Emission Monitoring units for measuring methane emissions from sheep and cattle—University of New England—Belinda Snell. Funding of $465 000 ex GST

Publications

Publications detailing the results of this research are in preparation.

Intra-ruminal measurement of methane validation and verification under different management systems

Lead organisation
Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations
N/A

Objectives
- evaluate the utility of an intra-ruminal device to sense changes in methane production under varying feeding conditions in sheep
- improve the energy efficiency, transmission capability and size of the device for use in both small and large ruminants.

Location
St Lucia, Queensland

Key activities
Development of methane measurement technology to apply to individual animals to produce high quality data on methane emissions from grazing ruminants.

Findings/Conclusions
Currently there are no methods available to accurately and reliably measure methane production from large numbers of grazing animals. Methane emissions data from respiration chambers do not take into account diet selection of grazing ruminants and day to day variation on total feed intake amongst animals.

An intra-ruminal battery powered device incorporating miniaturised infra-red gas sensors, coupled with CSIRO's wireless sensor network platform has been developed to measure rumen methane concentrations. This unit can be dosed orally in cattle and resides in the rumen of the animal. Inside the diffusion cell, the sensors are protected from the corrosive environment of the rumen where they collect and transmit data from the equilibrated rumen gases to the outside world via a 915 MHz radio transceiver.

Validation studies have been undertaken in fistulated sheep. Methane (CH_4) and carbon dioxide (CO_2) concentration data from the rumen was collected with the device over several days. The same animals were simultaneously run through the respiration chambers and CH_4 and CO_2 emissions were recorded. Gas concentration in the rumen consistently demonstrated diurnal variation for a once daily feeding regime.

There was a 1.0°C increase in temperature during fermentation in the rumen for the sheep fed a below maintenance ration (500 g pellets, 100 g chaff) as compared to a 1.5°C rise for the sheep on above maintenance ration (750 g pellets, 100 g chaff). The pressure in the rumen was similar for both diets peaking at 105 kPa after 24 hours in the rumen and then dropping to around 101 and 98 kPa on subsequent days.

Due to differences in the siloxane membrane permeability to different gases (CO_2 permeability 3 times greater than for CH_4) and gas concentration gradients in the rumen, CO_2 readings on the intraruminal device are more dynamic and responsive than that of CH_4. Hence, CH_4 concentrations are lowest as measured by the device when CO_2 concentrations peak. The counter-cyclical results in the gas concentrations observed with this device is in contrast to respiration chamber data that demonstrated that maximum methane emissions are strongly associated and aligned with feed intake. The ratio of CO_2:CH_4 for two sheep estimated by the intra-ruminal device was markedly lower than those calculated from chamber emissions.
However, there are limitations with data precision and repeatability with the infrared gas sensors. Refinement to the original electronics and supporting software that underpins this technology has been continuing concurrently despite having to create a system whereby the sensors can withstand additional non-target gases in the rumen.

Reduction in power consumption of the latest device prototype will assist in expanding the number of measurements obtainable from a designated battery source and extend the working life of the unit.

Field testing of the membrane mounted controlled release device that houses the device's electronics has demonstrated that it can maintain its integrity in terms of providing an effective seal to rumen liquor and digesta for more than three months under grazing conditions. Devices used in fistulated sheep for up to a week have been cleaned and reused for a second and third run without loss of integrity.

Although the technology is still undergoing development, considerable advances have been made with the expectation that reliable data and validation will be achieved.

Related projects funded under Round 1 of Filling the Research Gap

- Measuring methane in the rumen under different production systems as a predictor of methane emissions—CSIRO—Chris McSweeney. Funding of $353 265 ex GST
- Development of gas selective membranes (for intra-ruminal capsules)—RMIT University—Simon Liddle. Funding of $840 000 ex GST

Publications

Publications detailing the results of this research are in preparation.

Microbial ecology of hydrogenotrophic rumen microorganisms in response to methane inhibitors

Lead organisation

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Consortium member organisations

Japan's National Institute for Livestock and Grassland Science

Objectives

- deliver new knowledge on the presence of acetogenic and hydrogenotrophic bacteria in the digestive tract of ruminants and their contribution to hydrogen sequestration
- provide insights into the ecology of organisms involved in alternative pathways to methanogenesis for carbon and hydrogen sequestration
- deliver to industry and government the best scientific advice on the feasibility and practicality of modifying enteric methane emissions from livestock.

Location

National Institute for Livestock and Grassland Science (NILGS), Japan

Key activities

- An animal trial was undertaken using four rumen fistulated goats at the National Institute for Livestock and Grassland Science in Japan. Methane and hydrogen production were measured in these animals using open-circuit respiration chambers while feeding the methane inhibitor bromochloromethane (BCM).
- Measurements of methane production and rumen hydrogen concentration in animals were performed using open-circuit respiration chambers and hydrogen sensors in the chambers while feeding three levels of the methane inhibitor BCM.
- Rumen microbial DNA from the animal trial was used for investigating microbial phylogeny and functional changes.
- Using 'next generation' sequencing rumen microbial DNA from the animal trial was used for metagenomic sequencing and analysis of functional genes from the control and high BCM samples.
- Culture based experiments were undertaken to isolate specific bacteria that were observed to change with respect to the increase in hydrogen within the rumen.

Findings/Conclusions

This research showed a dose-dependent inhibitory effect of BCM on methane production in the goat rumen. Doses of net BCM, 0.04, 0.16, and 0.4 g/100 kg live weight, reduced methane production by 5, 71 and 91 per cent respectively compared to controls, and there was no effect on maintenance feed intake and neutral detergent fibre (NDF) digestibility. This indicates fibre digestion was not compromised on a highly digestible diet even though H_2 concentration increased markedly in the rumen due to inhibition of methanogenesis.

The suppression of methane production by BCM led to a large accumulation of H_2 while rumen fermentation end products were mostly unchanged except for significant increases in propionate and iso-valerate at the mid and high doses. However, even though the flow of 2H into short chain fatty acids (SCFA) increased by >20 per cent at the high BCM dose, it was observed and calculated that the majority of 2H available from reduced methane formation flowed into H_2 gas instead of SCFA. Therefore, there still remains an opportunity to further enhance the metabolic hydrogen production flows into SCFA in order to reduce production of greenhouse gases and to increase feed efficiency in ruminants.

Microbial ecology studies of the BCM affected rumen showed that the major shift in bacterial population abundances can be attributed to *Prevotella, Succiniclastium* and

Selenomonas spp. These microbiota were found in association networks to form a sub-network that possessed the key function of carbohydrate breakdown with the concurrent release of propionate as an end product.

Related projects funded under Round 1 of Filling the Research Gap

- Culture-independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock—CSIRO—Mark Morrison. Funding of $507 494 ex GST
- Comparative analyses of rumen microbiomes to mitigate ruminant methane and improve feed utilisation—CSIRO—Mark Morrison. Funding of $508 878 ex GST

Publications

1. Denman, S, Mitsumori, M, Shinkai, T, Asanuma, N & McSweeney, C 2011, 'Describing microbial population in the rumen using genomic rDNA and rRNA as templates reveals greater diversity', *CGIF, Chicago*, pp. 3-4.
2. Mitsumori, M, Shinkai, T, Keng, P, Denman, S & McSweeney, C 2010, 'What happens in the rumen when methanogenesis is inhibited and hydrogen increases dramatically', *RRI-INRA Gut Microbiology Symposium*, Aberdeen, Scotland.
3. Mitsumori, M, Shinkai, T, Takenaka, A, Enishi, O, Higuchi, H, Kobayashi, et. al. 2012, 'Responses in digestion, rumen fermentation and microbial populations to inhibition of methane formation by a halogenated methane analogue', *British Journal of Nutrition,* vol. 108, no. 3, pp 482-491.

Further publications detailing the results of this research are in preparation and will be available.

Variability in fermentability and methane production in Lucerne

Lead organisation

South Australian Research and Development Institute

Consortium member organisations

The University of Western Australia

Objectives

To determine the variation in methane production and fermentability of *Medicago sativa subsp*. germplasm and benchmark commercial lucerne cultivars at different stages of development.

Location

Perth, Western Australia and Urrbrae, South Australia

Key activities

Lucerne was assessed to evaluate the anti-methanogenic properties of the forage crop. Thirty accessions of selected Australian cultivars and wild accessions of lucerne were grown in plot trials at the South Australian Research and Development Institute. The material selected represented synthetic hybrids and wild types. The plant material was sampled at two strategic times (reflecting the use of the crop under commercial conditions) followed by the evaluation of:

- methanogenic potential of the plant when screened using *in vitro* batch fermentation technique at the University of Western Australia
- nutritional profiles
- phenotypic characterisation of forage quality traits by the South Australian Research and Development Institute
- the influence of cutting and conservation regime on methanogenic potential.

Findings/Conclusions

Practical tools for graziers to reduce methane emissions from extensive livestock production systems are extremely limited and few practical and cost-effective options for significant and persistent abatement have been developed. Lucerne is widely used to benchmark other forages or diets for their potential to mitigate methane. Evaluation of the amount and distribution of genetic diversity amongst lucerne accessions can enhance the genetic exploitation of lucerne by plant breeders.

The findings from this research suggest there is significant genetic variation in the chemical composition of lucerne. There was significant variation between lucerne accessions for dry matter digestibility (DMD), crude protein, neutral detergent fibre, acid detergent fibre, hemicelluloses and ash, and all plant physical traits recorded. Tannin data is not reported as all samples had less tannin than the no tannin control used in the analysis (effectively zero tannin). The research showed no significant differences for methane production or methane gas per unit of dry matter (DM). Plant physical traits showed very good relationships with dry matter digestibility as expected.

DMD of accessions ranged from 72.5 to 64.2 per cent. Predictions using the ruminant feeding model GrazFeed suggest that a pregnant Merino ewe (day 100 of gestation) fed the highest quality lucerne would eat 1.2 kg of DM per day and grow at a rate of 210 g/week. In contrast the same ewe eating the lowest quality lucerne would eat 0.97 kg of DM per day and lose 112 g/week. For mature, non reproducing sheep, the difference in weight gain would be 3-fold (125 g gain/week on the lowest quality lucerne and 440 g/week for the highest quality lucerne). Estimated metabolisable energy (ME) values ranged from 9.34 to 10.75 MJ ME/kg DM. DMD was not correlated to methane production or total gas production. Crude protein ranged from 18 to 23 per cent, and all would meet the estimated crude protein requirements of reproducing ewes and growing lambs.

Related projects funded under Round 1 of Filling the Research Gap

- Impacts of *Leucaena* spp. plantations on greenhouse gas emissions and carbon sequestration in northern Australian cattle production systems—CSIRO—Chris McSweeney. Funding of $750 000 ex GST
- Best choice shrub and inter-row species for reducing emissions and emissions intensity—The University of Western Australia—Phillip Vercoe. Funding of $500 000 ex GST
- Efficient Livestock and Low Emissions (ELLE) from southern grazing systems—The University of Western Australia—Phillip Vercoe. Funding of $1 500 000 ex GST

Publications

Publications detailing the results of this research are in preparation.

Farming systems for lower methane emissions, demonstration and information delivery

Lead organisation
Meat and Livestock Australia

Consortium member organisations
All partners in the Reducing Emissions from Livestock Program (RELRP)

Objectives
To maximise the value of investment in a coordinated research, development and demonstration program on managing emissions from livestock by ensuring a capacity to share data between projects, publish research results, integrate policy-relevant information for stakeholders in government and industry and effectively communicate progress and outcomes to farmers.

Location
National

Key activities
This project was undertaken as four sub projects to provide:
- further development of the FarmGAS Calculator, delivered by the Australian Farm Institute
- application and extension of the FarmGAS decision support tool, delivered by the Australian Farm Institute
- construction of a publication database and collection from publically available literature reporting the effects of dietary mitigation on methane emissions, delivered by the University of Melbourne
- a scoping study for RELRP database, delivered by CSIRO.

Findings/Conclusions
This project expanded and improved the original FarmGAS Calculator, enabling farmers to incorporate options for livestock emissions abatement based on the outputs of the RELRP. However, with mixed production making up more than 80 per cent of all farm enterprises it is important that the tool is capable of demonstrating the impact of new research on mitigation options across commodity mixes, to increase farmers' awareness of alternative management systems and enable them to consider the economic and emissions implications of these options. The new Scenario Tool developed under this project extends the capabilities of the Calculator through the provision of additional enterprise options, reporting features and the ability to alter relevant emission factors.

The Scenario Tool enables two estimates (two sets of results) to be produced, one set of 'Default' emissions which utilise the production factors assumed in Australia's National Greenhouse Gas Inventory (NGGI) Methodology (2006), and the other producing 'revised' emissions based on choices and inputs from the user.

To increase awareness and capacity of advisor and extension specialists to use the FarmGAS Scenario Tool and encourage adoption amongst clients, train the trainer workshops were held in each Australian state, except Northern Territory during March to May 2012. Following training, users would be sufficiently skilled to use the Scenario

Tool with farmers, in research and policy applications. Approximately 64 advisor and extension specialists were trained in use of FarmGAS with an additional three workshops planned.

A publication database and collection was constructed from publically available literature reporting the effects of dietary mitigation on methane emissions. The data collection contained 782 sources from the international peer reviewed literature. The literature was subdivided into a number of individual collections.

A scoping study of the issues around the development of the framework (including a metadata database) for all the projects within the RELRP has been undertaken. A schema for the storage of the metadata has been designed and implemented in Microsoft Access to facilitate the process of gathering and storing the metadata about the datasets generated and held by the component projects of the RELRP. Two rounds of metadata collection have been conducted to collect information on the experimental designs, the parameters and variables relating to the measurement of greenhouse gas emissions, the data format and structures, and the data storage and management systems used by the research groups. Collation of the metadata information from individual projects identified a range of issues relating to the accuracy of the definition of datasets and experiments, data formats and concerns about intellectual property. Through redefining the system structure and quality editing of metadata information (including applying a controlled vocabulary list developed for this project), a metadata database illustrating the basic framework of a future database and data summary sheets showing the current status of data attributes for each project have been produced.

Related projects funded under Round 1 of Filling the Research Gap

N/A

Publications

Publications detailing the results of this research are in preparation.

Novel strategies for enteric methane abatement

Lead organisation

University of New England

Consortium member organisations

NSW Department of Primary Industries

Objectives

- to determine the impact of defaunation on methane production and productivity of cattle, by evaluating a suite of anti-protozoal chemicals for potential application to reduce methane production from livestock
- to evaluate the dose response of methane production inhibition with dietary nitrate and make recommendations on delivery systems, acclimation, safe feeding levels and expected methane inhibition.

Location

Armidale, New South Wales

Key activities

The project assessed the effectiveness of dietary nitrate inclusion and the effectiveness of elimination of rumen protozoa to achieve reduced enteric methane emissions from ruminants.

Findings/Conclusions

The amount of methane (CH_4) emitted by ruminants per unit production is higher in animals subjected to poor nutrition. Livestock in northern Australia are often restricted to diets of low nutrition consisting of predominantly dry mature roughage. Supplementing animals on low quality forage (eg. standing dry-season grass pastures in tropical and sub tropical Australia) with urea and nitrate (NO_3) has been shown to improve production by increasing rumen ammonia concentration, increasing the rate of fermentation and so increasing pasture intake. However there is a risk from supplementing forages with urea and NO_3 of nitrite toxicity which may result in fatalities. Nitrate salts can potentially replace urea as non protein nitrogen (NPN) with the added benefit that NO_3 will reduce CH_4 emissions.

This research showed that dietary nitrate is a highly effective abatement technology reducing methane emissions in proportion to the dose added for livestock in northern Australia. It can be delivered safely in processed feeds and in lick blocks at levels which deliver quantifiable emissions reduction. Ruminal nitrate reduction is extremely rapid and emission levels return to normal after three hours of nitrate feeding.

Methane yield of cattle without rumen protozoa did not differ from that of untreated cattle, but protozoa-free cattle were 30 kg heavier than untreated counterparts by the completion of the study. Bioactive compounds from a range of chemical families were assessed for anti-protozoal action in the laboratory. The lead compound showed no efficacy in sheep.

Further research is required to investigate the nutritional value and animal safety of supplementing livestock diets with nitrates. Such research is required to warrant the development of nitrate supplementation as a Carbon Farming Initiative methodology for reducing methane emissions of livestock in northern Australia farming systems.

Related projects funded under Round 1 of Filling the Research Gap

- Strategic science to develop dietary nitrate and defaunation as mitigation methodologies for grazing ruminants—University of New England—Belinda Snell. Funding of $400 000 ex GST
- Practical and sustainable considerations for the mitigation of methane emissions in the northern Australian beef herd using nitrate supplements—Ridley AgriProducts Pty Ltd—Louise Edwards. Funding of $200 000 ex GST

Publications

1. Hegarty, R 2009, 'Methane Emissions from Ruminants: How Manageable are they?, *Proceedings of the Industry and Investment, Beef and Sheep Conference,* Orange, 24-26 November.
2. Hegarty, R 2010, 'Factors affecting methane emissions from cattle', *Proceedings of the Feeder Steer School 2010 CRC for Beef genetic technologies conference*.

3. Hegarty, R, Alcock, D, Robinson, D, Goopy, J & Vercoe, P 2010, 'Options for reducing methane output and methane per unit product from sheep enterprises', *Animal Production Science* (In press).
4. Hegarty, R & Clark, H 2009, 'Methane mitigation research in Australia and New Zealand', *Proceedings of the Fourth Non-CO_2 Gases in Agriculture Workshop,* New Zealand, 16-17 November.

Further publications detailing the results of this research are in preparation and will be available.

Round 1 of Filling the Research Gap

Overview

Filling the Research Gap supports research into emerging abatement technologies, strategies and innovative management practices that reduce greenhouse gas emissions from the land sector, store soil carbon and enhance sustainable agricultural practices.

A total of 57 successful projects are being undertaken under Round 1 of the program. These projects share $47 million in Australian Government funding over the years 2011–12 to 30 June 2015 and are grouped into five sub-programs:

- National Livestock Methane Program
- National Agricultural Manure Management Program
- National Agricultural Nitrous Oxide Research Program
- National Soil Carbon Program
- National Agricultural Greenhouse Gas Modelling Program.

The following projects are been funded under Round 1 of *Filling the Research Gap* to participate in the National Livestock Methane Program, the National Agricultural Manure Management Program and the National Agricultural Greenhouse Gas Modelling Program. Descriptions of all successful Round 1 projects are available at http://www.daff.gov.au/climatechange/carbonfarmingfutures/ftrg.

National Livestock Methane Program

Coordination of the National Livestock Methane Program—Meat and Livestock Australia—Tom Davison. Funding of $1 350 000 ex GST

This project will coordinate and manage the *National Livestock Methane Program*. The program will assist livestock producers to reduce methane emissions by conducting research under a nationally agreed collaborative program including nutrition, rumen processes, genetics, modelling focussed on abatement and increased farm productivity that will underpin methodology development for the *Carbon Farming Initiative*.

Measuring methane in the rumen under different production systems as a predictor of methane emissions—CSIRO—Chris McSweeney. Funding of $353 265 ex GST

This project progresses the development of an intra-ruminal capsule developed under the *Reducing Emissions from Livestock Research Program* (2008–2012) to measure rumen methane concentrations. This project will validate the use of an intra-ruminal capsule to determine methane yield by the animal under a range of feeding systems. Measurement of methane yield and concentration will allow emissions intensity, total emissions and efficiency of rumen fermentation and will provide important data for modelling and emerging policies under the *Carbon Farming Initiative*.

Development of gas selective membranes (for intra-ruminal capsules)—RMIT University—Simon Liddle. Funding of $840 000 ex GST

This project aims to develop polymeric/nanomaterial (gas selective membranes) to improve methane gas measurement. The project will develop membranes to tackle the challenges of sensing systems to: improve the selectivity for specific gases in the methane gas measurement environment, the diffusion rates of specific gases and allow simultaneous sampling for microbial analyses. This project will be undertaken in collaboration with the CSIRO project "Measuring methane in the rumen under different production systems as a predictor of methane emissions".

Evaluating and optimisation of GreenFeed Emission Monitoring units for measuring methane emissions from sheep and cattle—University of New England—Belinda Snell. Funding of $465 000 ex GST

This project will be delivered through international collaboration. It aims to evaluate and optimise the capability of GreenFeed Emission Monitoring (GEM) units to quantify daily methane emissions of grazing sheep and cattle. This capability is required to verify mitigation claims for *Carbon Farming Initiative* methodologies, to facilitate mitigation research and validate national inventories. GEM emission measures will be compared with respiration chamber measures, the hardware modified for remote use and the design adapted for sheep.

Genetic technologies to reduce methane emissions from Australian beef cattle—NSW Department of Primary Industries—Graham Denney. Funding of $3 000 000 ex GST

This project aims to deliver genetic technologies for breeding cattle with a low methane trait. It will provide new knowledge on genetic variation in methane production and genetic associations with other production traits and will record methane production by animals from the major Australian breeds. It will also cost methane emissions into the breeding values and profit indices used to describe the genetic merit of cattle in the national genetic evaluation system BREEDPLAN.

Understanding methane reducing tannins in enteric fermentation using grape marc as a model tannin source—The Australian Wine Institute—Karl Forsyth. Funding of $500 000 ex GST

This project aims to reduce methane emissions by identifying and characterising the active ingredients in grape marc responsible for reducing ruminant emissions. Tannins in the grape marc are believed to be the active ingredient. The project will quantify, through understanding tannin chemistry and mechanisms, the potential of using grape marc and other tannin rich food sources as a supplement for reducing ruminant emissions. This project will be incorporated into the Victorian Department of Primary Industries project “Enteric methane mitigation strategies through manipulation of feeding systems for ruminant production in southern Australia”.

Development of algae based functional foods for reducing enteric methane emissions from cattle—CSIRO—Nigel Tomkins. Funding of $500 000 ex GST

This project is focusing on proof of concept for the development of algae based functional foods for reducing enteric methane emissions from cattle. It will evaluate a range of algae for antimethanogenic activity and identify lines of algae which may be trialled in future research.

Supplementation with tea saponins and statins to reduce methane emissions from ruminants—CSIRO—Chris McSweeney. Funding of $250 000 ex GST

This project aims to research the suitability of feed additives (tea saponins and statins) to reduce methane emissions from ruminants. Problems that may be associated with some methane reducing additives that prevent their use includes toxicity to microbes and animals, short-lived effects due to microbial adaptation, expense and failure to meet consumer acceptance. The project will undertake animal studies with varying levels of supplementation to intensively fed ruminants with the tea saponin extract and the yeast *Monascus ruber*.

Practical and sustainable considerations for the mitigation of methane emissions in the northern Australian beef herd using nitrate supplements—Ridley AgriProducts Pty Ltd—Louise Edwards. Funding of $200 000 ex GST

The project will determine if nitrate salts in supplement blocks can safely replace urea when feeding low quality forages and if the nitrate blocks will effectively reduce methane emissions of cattle consuming forages typical of northern Australia. Research will occur in methane chambers, individual pens and in the paddock, where supplement blocks are self-fed. In both studies cattle will consume low quality tropical forages, typical of those used in conjunction with urea supplement blocks. This project will be funded as part of a collaboration with the University of New England application "Strategic science to develop dietary nitrate and defaunation as mitigation methodologies for grazing ruminants".

Strategic science to develop dietary nitrate and defaunation as mitigation methodologies for grazing ruminants—University of New England—Belinda Snell. Funding of $400 000 ex GST

This project seeks to develop the science underpinning nitrate supplementation of livestock to ensure these become safe, sure and commercially attractive methane mitigation technologies by June 2015. Intensive study of the modes of action of these processes in the rumen will be undertaken to optimise their efficacy and safety for ruminants on pasture. This project is funded as part of a collaboration project with the project "Practical and sustainable considerations for the mitigation of methane emissions in the northern Australian beef herd using nitrate supplements".

Enteric methane mitigation strategies through manipulation of feeding systems for ruminant production in southern Australia—Department of Primary Industries, Victoria—Joe Jacobs. Funding of $1 970 000 ex GST

This project will quantify the mitigation potential of a range of feeds (not currently used as mainstream feeds by the dairy and sheep industry) and feeding strategies both alone and in combination. The project aims to provide new data for national inventories and to form the basis for development of *Carbon Farming Initiative* offset methodologies.

Impacts of *Leucaena spp*. plantations on greenhouse gas emissions and carbon sequestration in northern Australian cattle production systems—CSIRO—Chris McSweeney. Funding of $750 000 ex GST

This project will build on previous work by CSIRO that demonstrates that *Leucaena spp*. supplementation to cattle may result in decreased methane emissions. This project will investigate the potential to reduce greenhouse gas emissions through *Leucaena* cattle-feeding systems in comparison with native pastures by evaluating yearly livestock productivity, herd methane emissions and the sequestration of carbon in the soil. The project will also assess the microbial changes in the rumen that reduce methane to inform research that aims to manipulate the rumen through improved digestive efficiency.

Best choice shrub and inter-row species for reducing emissions and emissions intensity—The University of Western Australia—Phillip Vercoe. Funding of $500 000 ex GST

This project will quantify the effects of grazing systems based on shrub and pasture inter-row species that exhibit low methanogenic potential on livestock production and methane emissions in the field. It will use the data to model the whole-farm profitability.

The mechanism of antimethanogenic effects of bioactive plants and products on methane production in the rumen—The University of Western Australia—Phillip Vercoe. Funding of $250 000 ex GST

This project aims to deliver information for reducing methane in the rumen. It will determine the compounds and mechanisms that reduce methane production by testing plants and plant products in pure and batch cultures and in an artificial rumen to examine their effects at both the microbial ecology and cellular levels.

Efficient Livestock and Low Emissions (ELLE) from southern grazing systems—The University of Western Australia—Phillip Vercoe. Funding of $1 500 000 ex GST

This project will quantify the genetic diversity in methane reducing and productivity properties of temperate pasture species. Some pasture species have the potential for greater adoption because they reduce methane emissions directly and/or emissions intensity through improved efficiency of livestock production. Using both field and

laboratory experimentation the project will generate data required to develop a new *Carbon Farming Initiative* methodology based on the choice of temperate pasture species to reduce methane and emissions intensity.

Culture-independent metagenomic approaches for understanding the functional metabolic potential of methanogen communities in ruminant livestock—CSIRO—Mark Morrison. Funding of $507 494 ex GST

This project aims to use culture-independent approaches developed by CSIRO scientists to characterise the metabolic capabilities of rumen methanogens in livestock. The outcome of this project will be new information that helps define critical control points to reduce livestock methane emissions.

Comparative analyses of rumen microbiomes to mitigate ruminant methane and improve feed utilisation—CSIRO—Mark Morrison. Funding of $508 878 ex GST

This project aims to increase the understanding of the greater rumen microbial populations in livestock using the datasets produced in Australia and abroad. The project will generate the knowledge required to develop low methane animals, either by animal selection and/or by increasing the metabolic capacity of the microbial community.

National Agricultural Manure Management Program

Coordination of the National Agricultural Manure Management Program—Australian Pork Limited—Darryl D'Souza. Funding of $185 196 ex GST

This project will coordinate and manage the *National Agricultural Manure Management Program*. The program will assist the intensive livestock industries to evaluate the agricultural greenhouse gas emissions abatement potential for various manure management systems. Information from the program will underpin the development of *Carbon Farming Initiative* methodologies.

Mitigating the greenhouse gas potential of Australian soils amended with livestock manure—The University of Western Australia—Sasha Jenkins. Funding of $655 563 ex GST

The aim of this project is to evaluate the effectiveness of different mitigation strategies at reducing greenhouse gas emissions following the application of piggery, poultry or feedlot manure to land by measuring carbon dioxide, nitrous oxide and methane fluxes from soils following amendment using laboratory and field studies.

Advancing livestock waste as low emission-high efficiency fertilisers—Queensland Department of Agriculture, Fisheries and Forestry—Matt Redding. Funding of $996 124 ex GST

The project will develop know-how for reducing greenhouse gas emissions from intensive livestock production, increasing emission offsets through innovative managements for land-applied manures from intensive livestock production (egg, chicken meat, pork, beef) and fertiliser formulations.

Pork greenhouse gas mitigation—Feedlot Services Australia Pty Ltd (trading as FSA Consulting)—Eugene McGahan. Funding of $673 625 ex GST

This project will quantify differences in greenhouse gas from each system over a summer and winter period. Data will be made available to update the PIGBAL model. Quantification of mitigation potential from these systems will enable development of two additional *Carbon Farming Initiative* methodologies for the pig industry, enabling far broader participation.

Poultry greenhouse gas mitigation—Feedlot Services Australia Pty Ltd (trading as FSA Consulting)—Stephen Wiedermann. Funding of $464 420 ex GST

This project will address knowledge gaps in greenhouse gas estimation to allow development of two *Carbon Farming Initiative* methodologies based on changed feeding (dietary nitrogen) or manure management in the chicken meat and/or egg industries.

National Agricultural Greenhouse Gas Modelling Program

Potential soil carbon sequestration in Australian grain regions and its impact on soil productivity and greenhouse gas emissions—CSIRO—Enli Wang. Funding of $639 283 ex GST

This project will define soil organic carbon (SOC) sequestration potential and identify management practices that benefit both productivity and SOC stocks. It will use the farming systems model APSIM (Agricultural Production Systems Simulator), together with measurements to identify agricultural practices that increase SOC, quantify SOC sequestration potential across Australian grain regions, assess the vulnerability of sequestered carbon to subsequent changes in management and climate, and investigate the impacts of SOC change on carbon-nitrogen cycling, productivity and greenhouse gas emissions.

Facilitation of improvement in systems modelling capacity for Carbon Farming Futures—CSIRO—Andrew Moore. Funding of $629 816 ex GST

This project aims to eliminate any inconsistencies in modelling activities across *Filling the Research Gap* (FtRG). It will ensure that models are developed and applied

consistently in FtRG, and that they embody the best scientific understanding of methane, nitrous oxide and soil carbon fluxes. A series of workshops and comparative studies will result in more robust and consistent abatement predictions and increased human capacity for modelling.

Whole farm systems analysis of greenhouse gas abatement options for the southern Australian grazing industries—The University of Melbourne—Richard Eckard. Funding of $537 902 ex GST

This project will conduct whole farm systems analysis of a range of nitrogen, carbon and energy efficiency and greenhouse gas abatement strategies for the dairy, sheep and southern beef industries. Each strategy will be analysed in a whole farm systems context, including methane, nitrous oxide, soil carbon, productivity plus the interactions between these. The outcomes from the project will be evaluated options: for reducing emissions intensity, improving farm profitability and/or further development into *Carbon Farming Initiative* offset methods.

The 'Biosphere' Graphic Element
The biosphere is relevant to the work we do and aligns with our mission—we work to sustain the way of life and prosperity for all Australians. We use this shape as a recognisable symbol across our collateral.

For more information please contact:

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