REDUCING NEW ZEALAND'S
AGRICULTURAL GREENHOUSE GASES:

LOW GREENHOUSE GAS FEEDS

NEW ZEALAND AGRICULTURAL GREENHOUSE GAS Research Centre

PGgRc PASTORAL GREENHOUSE GAS RESEARCH CONSORTIUM

WORKING TOGETHER

BACKGROUND

Agriculture is a major component of New Zealand's economy, with exports from agricultural products such as meat and milk comprising more than 60% of the total value of the country's merchandise exports (source: Statistics New Zealand, 2017).

However, agriculture was responsible for almost half (49.2%; 38.7Mt) of the estimated 78.7 million tonnes of carbon dioxide equivalent (CO_2-e) greenhouse gas emitted by New Zealand in 2016. Agricultural emissions are divided evenly between the dairy and sheep / beef sectors. Between 1990 and 2016, emissions from the agriculture sector increased by 12% while the overall increase for New Zealand as a whole was 19.6%. Methane (CH_4) from enteric fermentation makes up 71.7% of the agricultural contribution, while nitrous oxide (N_2O) emissions and methane emissions from manure management make up the remaining 28.3% (source: Ministry for the Environment National Inventory Report, April 2018).

With New Zealand striving to meet the internationally committed targets of reducing its greenhouse gas emissions to 5% below 1990 levels by 2020, and to 30% below 2005 levels by 2030, the New Zealand Government and agricultural sector have been exploring multiple avenues to achieve these targets.

HOW CAN DIFFERENT FEEDS AFFECT GREENHOUSE GAS EMISSIONS?

Enteric methane emissions arising from an individual animal are driven primarily by the quantity of feed eaten: emissions increase as the quantity of feed eaten increases. However, the chemical makeup of feeds can also influence emissions. For example, diets comprising high proportions of cereals (high in readily fermentable carbohydrates) produce less emissions than forage based diets.

Although New Zealand livestock farming is primarily based on the use of high quality fresh temperate forages in managed grazing systems, a wide variety of other food sources are used. These include:

- grass silage
- brassicas
- cereal and root crops
- maize silage
- palm kernel extract (PKE)
- a small amount of concentrate feed, such as maize and barley grain

Nitrous oxide emissions arise mainly from urine patches and are influenced mainly by the quantity of nitrogen (N) deposited in the urine and, to a lesser extent, by the chemical makeup of the urine itself. Different feeds can change both the quantity of nitrogen deposited in urine and the chemical makeup of the urine.

Taken together, the above indicates that any programme of research focussed on reducing methane and nitrous oxide emissions must consider dietary manipulation in its portfolio of approaches.

WHAT RESEARCH HAS BEEN DONE SO FAR?

Since 2003, scientists researching low greenhouse gas forages have received funding from the Pastoral Greenhouse Gas Research Consortium (PGgRc), the New Zealand Agricultural Greenhouse Gas Research Centre (NZAGRC) and the Ministry for Primary Industries' (MPI) Sustainable Land Management and Climate Change (SLMACC) fund. The aim is to establish whether dietary manipulation can provide a practical and cost effective route for reducing emissions of methane and nitrous oxide.

Pasture is the dominant feed for New Zealand ruminants and hence the largest focus in New Zealand has been on measuring emissions from pasture-fed animals. The primary focus of this work has been to establish baseline emissions from pasture-fed animals and to test whether manipulating quality (e.g. digestibility, fibre content) can reduce emissions. The researchers have also examined the effects on methane and nitrous oxide emissions of forages that differ from conventional pasture in a specific chemical constituent (e.g. elevated sugar content).

Work has also been undertaken to examine alternative forages and non-pasture feed options and test whether their incorporation into pasture diets results in a reduction in emissions below those of pasture-only diets.

The majority of work has been carried out using sheep – a consequence of cost, practicality and availability of equipment – although some work with cattle has been undertaken.

Prior to 2009, methane emissions were mostly measured using the sulphur hexafluoride (SF_6) tracer technique. This technique measures emissions from free-ranging animals by sampling exhaled breath in containers placed around the neck of the animal. Since 2009, emissions have been measured almost exclusively in respiration chambers. In these chambers animals are enclosed for 48 hours and exhausted air enriched with methane from exhaled breath is sampled and compared with non-methane enriched ambient air to determine the quantity of methane produced. This is considered to be the standard method for estimating methane emissions from animals as the environment can be controlled, feed intake monitored accurately and measurements made in a stable and reliable manner.

TABLE 1:

The quantum of work undertaken is substantial as can be seen from the summary presented in the table.

The table below contains details of published and unpublished experiments where methane yield (grams per kilogram [g/kg] dry matter intake [DMI]) has been measured using respiration chambers, and feed intake has been accurately measured.

Feed		Number of treatments		Methane yield (g CH4/kg DMI)		References
		Sheep	Cattle	Mean	Variability (standard deviation)	
Pasture		107	29	22.4	2.35	2-8, 10-14, 16-27
Pasture chaff			8	23.7	1.38	15
Brassicas	Kale	1		19.8	-	18
	Radish	1		11.4	-	23
	Rape	9	1	14.9	3.62	18-22
	Rape: pasture	3		16.6	3.10	25
	Swede	1		16.9	-	18
	Turnips	5		18.7	3.84	18, 21, 23
Others	Chicory	3		22.3	0.76	16-17
	Fodder beet	2		13.2	7.71	27
	Lucerne silage	1		18.3	-	9
	Lucerne silage: Maize silage	3		22.0	1.35	8-9
	Lucerne silage: Maize grain	3		21.8	2.21	8-9
	Maize silage	1	1	22.4	1.98	8-9
	Pasture: Maize silage		1	25.9	-	8, 14
	Pasture: Palm kernel extract		1	23.4	-	8, 14
	White clover	5		23.1	2.6	3-5
	Total mixed ration		1	21.3	-	28, 29

WHAT HAVE WE FOUND?

BROAD CONCLUSIONS

There are a number of broad conclusions that can be drawn from the work already completed in addition to specific conclusions from research streams (see pages 6-7):

1. Enteric methane emissions are generally stable when expressed on a unit of intake basis.
2. It takes large changes in diet to bring about changes in enteric methane emissions.
3. Predicting emissions based on chemical analysis is highly problematic. For example, chicory and forage rape are similar in quality but chicory appears to have no influence on methane emissions while forage rape does.
4. Even where emissions are shown to be reduced (e.g. forage rape), the overall impact at the national scale will be small because the alternative feed makes up a minor component of the overall diet.
5. Although there is no direct link between feed quality and lower emissions at a plant level, continuing to use high quality feed can lower a farm system's emissions intensity (emissions per unit of product). More specific findings are on the following pages.

WHAT NEXT?

CURRENT AND FUTURE RESEARCH

Many different crops have been analysed and, while showing promise in some areas, there are no definitive, easy or dramatic ways to reduce emissions of pasture based livestock by diet alone.

More work is needed to assess the overall emissions impact of feed options. Individual gases can not be considered in isolation.
While reducing nitrogen losses is an immediate priority for many farmers, lower nitrogen intake may in turn lead to higher methane emissions.
For example, maize silage has lower nitrogen content but can be of lower quality than other feed options so an animal needs to eat more to achieve optimal performance. Thus, reductions in nitrous oxide are likely to be partially offset by increases in methane emissions.

Current research priorities include undertaking a comprehensive evaluation of the nitrous oxide emissions associated with grazing forage rape and other work to fill in knowledge gaps, and undertaking thorough assessments of promising options such as plantain. Work with plantain is being extended to comprehensively study its impacts on nitrogen partitioning, methane and nitrous oxide emissions, and soil carbon stocks.



SPECIFIC FINDINGS

PASTURE QUALITY

Pasture quality has been extensively researched in many different studies, from field trials to animals fed pasture in respiratory chambers.

The most striking finding from these studies is that broad pasture quality parameters, such as digestibility and fibre content, have very little influence on methane emissions. Only in young sheep has there been any indication that diet quality can influence emissions. This finding implies that management manipulations to change forage quality will not reduce emissions per unit of dry matter intake. The positive side of this finding is that predicting methane emissions from pasture dominated diets is relatively straightforward once intake is known since emissions per unit of intake can be highly predictable. The findings from these pasture trials underpin the national New Zealand enteric fermentation inventory.

MANIPULATING SPECIFIC COMPONENTS OF PASTURE

Sugars

Work instigated in the UK suggested that grasses bred to have high fructan levels (commonly called high sugar grasses [HSG]) could reduce methane and nitrous oxide emissions. Reductions of methane were found through a direct effect on the fermentation process, and nitrous oxide through an indirect effect of reducing the quantity of nitrogen excreted in urine. As HSG are available in New Zealand, a comprehensive testing programme was undertaken.

This programme included both artificially elevating the levels of specific sugars in sheep diets and also a multi year experiment of ryegrass cultivars with naturally differing sugar concentrations. The net result of this series of trials was that sugar concentrations in general do not influence methane emissions and that differences in sugar concentrations in the cultivars tested do not result in lower nitrogen concentrations in the urine.

Lipids (fat)

International work manipulating the lipid content of cattle diets suggests that higher dietary lipid concentrations can result in lower methane emissions: a reduction of ~5% for each 1% increase in the lipid content. Pasture diets typically contain 3-4% lipid and the maximum recommended lipid content is ~7-8%. Pasture grasses with elevated lipid levels are not currently available for trials, so initial work was carried out by supplementing pasture diets directly with lipids (sunflower, linseed and fish oils have all been tested). The results of these trials were inconsistent and methane reductions small and variable. The variable results and cost of the oils did not make direct application worth pursuing. However the effects demonstrated in the grazing trial suggest the potential of current efforts to increase the lipid content of forages using genetic engineering.

Other New Zealand work has developed a ryegrass cultivar which has elevated levels of lipid and correspondingly lower levels of nitrogen. Greenhouse gas emissions reductions from using this cultivar as an animal feed have not been tested in New Zealand as this is a genetically modified pasture. However, a small non-New Zealand based trial will take place in 2018/19 to better understand its reduction potential.



BRASSICA CROPS

Several different brassica crops have been tested. These include kale, turnip, radish, swede and forage rape.

As a group, these crops show promise in reducing enteric methane emissions. Rape has been the crop most rigorously tested. Compared to ryegrass/white clover diets, 100% rape diets consistently reduce emissions by an average of 30%. Furthermore, the reduction in emissions is proportional to the proportion in the diet, i.e. a 50% rape diet will have emissions reduction of 15%; 20% rape, 6% reduction, etc. Although enough evidence exists to clearly demonstrate that feeding rape will reduce emissions, more data is needed before any definitive claims can be made about other brassica crops. A potential issue with brassica crops is that, in some circumstances, they may be fed when conditions are conducive to increased nitrous oxide emissions (high nitrogen load under wet and disturbed soil conditions). The quantity of data available does not allow conclusions to be drawn on whether decreases in methane emissions from feeding rape will be offset by increases in nitrous oxide emissions.

Work is underway to quantify nitrous oxide emissions from the urine of rape-fed livestock managed under a range of soil types and conditions.

FODDER BEET

Fodder beet is an increasingly popular crop, particularly in the South Island dairy industry.

It is a high sugar, low fibre and low nitrogen content crop and therefore has the potential to influence both enteric methane and nitrous oxide emissions. Results from the trials undertaken so far indicate that fodder beet can reduce methane emissions by around 20% but only at very high levels of inclusion in the diet (greater than 70%). The results are also somewhat variable and, in some circumstances, could be the result of short-term digestive disruptions rather than genuine long-term emissions reductions.

Fodder beet has less than half the nitrogen content of pasture, which results in lower quantities of nitrogen excreted in urine and dung. This should reduce nitrous oxide emissions. However, similar to forage rape, the conditions under which it is fed could lead to elevated nitrous oxide emissions. There is very little direct nitrous oxide measurement data available for fodder beet. Maintaining high levels of fodder beet in the diet requires careful management and may not be achievable in many farm systems.

NON-PASTURE FEEDS

A range of other feeds have been tested. Published results include information on white clover, chicory, various silages, PKE and maize grain.

The published studies set out in Table 1 do not do justice to the quantum of work undertaken. Testing began on a range of alternative pasture species in 2003 using the SF_6 tracer technique. Many more species were tested than have been reported in the scientific literature. Caucasian clover, sulla, and lotus species were amongst the other species tested. Some of these did show initial promise but differences disappeared when tested more rigorously in respiration chambers. None of the alternative feeds tested have shown sustained reductions in enteric methane emissions when compared with pasture.

With regards to nitrous oxide emissions much less work has been done looking at the direct effect of plant species. Reduced nitrogen content in the diet will reduce emissions due to lowered nitrogen excretion rates. Small-scale field trials suggest that plant species can also influence emissions independently of the amount of nitrogen added to them but this work is still in an early stage.

The most promising plant is plantain, which appears to reduce both nitrogen excretion and emissions per unit of nitrogen applied. However, more work is needed to fully understand these reductions.

WORKING TOGETHER

Experimental reference list. For links to these data, go to: www.nzagrc.org.nz/feeds

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