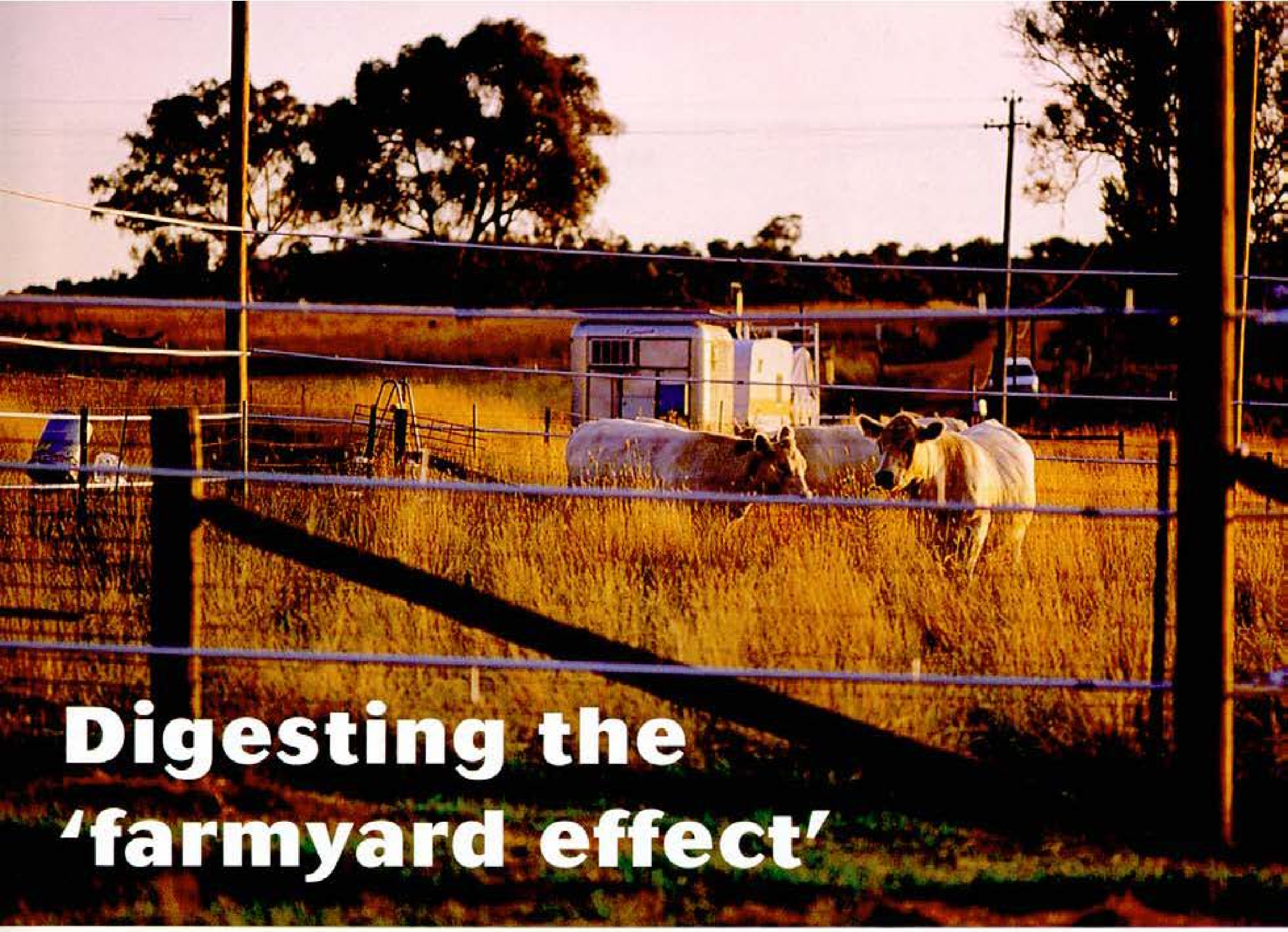


Digesting the 'farmyard effect'

Roger Beckmann explains that microbes and vaccines can be used to lift feed-conversion rates in ruminants, while at the same time clearing the air they exhale.

For many people, the term 'greenhouse effect' conjures up images of blackened, belching smoke stacks. A significant proportion of Australia's contribution to the world's greenhouse gases, however, comes in a different form and from a different source.

Of course, Australia does release plenty of CO_2 (more per capita than many other developed nations) and fossil-fuel-burning is the major cause of this. But while CO_2 contributes most to the global greenhouse effect, methane is actually a far more powerful greenhouse gas on a molecule-for-molecule basis. Fortunately, it exists in air at a concentration about 200 times lower than that of CO_2.

Australia is a relatively high per capita methane emitter because of the nature of its agriculture. Methane is produced when organic (carbon-containing) compounds are combined with hydrogen, usually because oxygen is not present in sufficient quantity. These conditions are met in compost heaps, waste dumps, marshes, the bottom of stagnant lakes, rice paddy fields, and in the gut of many animals.

How much methane goes up?

Finding out roughly how much methane the country produces, and its source, is not easy. Two of the specialists in this area are Dr Tom Denmead and Dr Ray Leuning of the CSIRO Division of Environmental Mechanics in Canberra. They have devised various ingenious techniques for measuring the quantity of methane, carbon dioxide and nitrous oxide emitted from landfills.

For two weeks in August 1994, at a landfill site in Canberra, they calculated a trace gas budget, measuring the gases in air and then using mathematical techniques to scale up the measurements for the area covered (see story on page 34). Of course, they had to take continual account of the speed and direction of the wind, and the gas concentration in air upwind and downwind of the area studied. They found that in the second year after burial, 10 kilograms of methane was emitted to the atmosphere for each tonne of garbage dumped at the landfill.

The scientists also found that the methane concentration in the air at the landfill was some 10 to 100 times its usual value of 1.7 parts per million. But these high concentrations are still not likely to pose any danger to health.

Then, in a two-week period in October 1994, they studied the fluxes of gases at an agricultural site in the region of Wagga Wagga in southern New South Wales. Methane was taken up and destroyed by micro-organisms in the soil at a slow rate, but overall there was a net input of methane to the atmosphere over the region, and the source was undoubtedly the livestock.

Curbing methane

The Centre for Environmental Mechanics was one many CSIRO divisions involved in a series of working parties that put together the National Greenhouse Gas Inventory for Australia. This involved developing methods for estimating how much greenhouse gas is emitted by Australia's various human activities.

It was estimated that agriculture contributes 54% of Australia's total anthropogenic (human-caused) methane gas emissions, with 85% of this total coming from animals (landfills account for about 22%). In absolute terms, cattle and sheep in Australia are thought to produce about 2.2 million tonnes of methane a year (10% of total greenhouse gas emissions).

The Federal government has agreed to an international proposal to stabilise Australia's ever-rising greenhouse gas emissions at 1988 levels by the year 2000, and to reduce them by 20% by 2005. No-one is sure how, or if, this can be achieved, but at one stage a tax on methane-producing livestock was a possibility.

Reducing the amount of methane produced by cattle and sheep would no doubt benefit the atmosphere, and would lessen the burden on farmers were they faced with a methane tax. But is there a way of stopping animals producing methane without inhibiting their growth or damaging their health?

The good news from two CSIRO labs is yes! Two groups at opposite ends of the country are working on curbing methane production in livestock in two completely different ways, and initial trials suggest that both are successful. The aim of this research was to improve the efficiency with which livestock convert food into meat, milk and wool by reducing the amount of feedstuff that ends up as unwanted methane gas. Although it was not designed with the atmosphere in mind, the greenhouse effect is certainly an important extra consideration.

The forestomach in animals such as cattle and sheep is a huge fermentation vat (known as the rumen) where many different types of microbe munch their way through a mush of plant material, much of which is indigestible to the enzymes that mammals can produce.

For some time now, scientists have suggested various ways of modifying the workings of the rumen. For example, antibiotics can be used. By killing or inactivating certain microbes both in the rumen and in the intestine, they can improve the growth rate of animals. Of course, the disadvantages of antibiotic residues in the meat and the creation of antibiotic-resistance in the microbes makes this approach to improving efficiency a two-edged sword.

But the new approaches don't rely on antibiotics. The particular target of both groups of CSIRO researchers has been a group of microbes (which are not actually bacteria, see box story) called methanogens. These obtain their chemical energy by the chemical reduction of simple carbon compounds such as carbon dioxide (CO_2) and formic acid (CH_2COOH), derived from plant starch and cellulose.

In chemical terms, reduction means adding hydrogen and/or removing oxygen, and the result in this case is the formation

Microbes that aren't bacteria any more

Methanogens used to be called bacteria. But recent changes in the classification of all microbes have given the group a new status.

It turns out that methanogens and various other 'unusual' bacteria-like microbes (such as those that are highly salt-tolerant or can exist at very high temperatures) are so different in their biochemistry and appearance that they should no longer be classed with 'real' bacteria. Instead they have been given their own group, known as the Archaea.

The name reflects the fact that these 'bacteria-like' creatures were probably some of the earliest life-forms on the planet, evolving in conditions very different from those that exist over most of the planet today. Thus the habitats in which these microbes can live nowadays are unusual to say the least: hot oil deep beneath the ground, super-saline lakes, and oxygen-free places such as bottom of marshes or the guts of more recently evolved organisms. You won't find many of the exotic Archaea in the usual abode of bacteria.

A study of gas emissions at Wagga Wagga in New South Wales found that livestock contributed to the net input of methane to the atmosphere over the region.

of the gas methane (CH_4). This is then vented from the animals when they exhale. The methane represents carbon that, rather than going to the atmosphere, could be incorporated into the animal if it were in the right chemical form. It's been calculated that about 2-12% of the plant energy that the animal takes in is then lost through methane production.

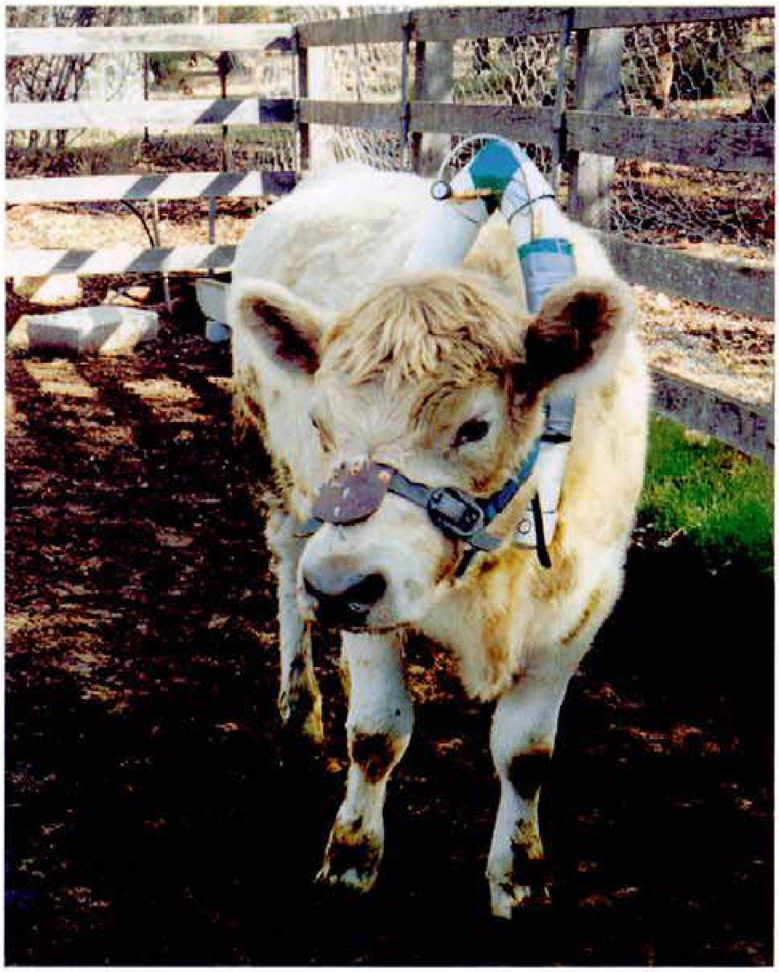
Dr John Edgar and Dr Chris May, at the CSIRO Division of Animal Health in Melbourne, have come up with a new form of a chemical compound that blocks the biochemical pathway that leads to the formation of methane. The compound, which they have produced as a simple white powder, is not an antibiotic, and does not interfere with the other rumen microbes. It simply prevents the formation of methane by the microbes, and in so doing, leads to a more efficient use of the starch and cellulose in the animal's diet.

The work has led to discussions with companies with a view to commercial production of the compound, and CSIRO has filed a patent. It's expected that the product will be on the market within about two years.

Trials on animals are revealing that the compound does not lose its effect quickly, as some antibiotics do. Scientists have noted that methane production remains inhibited for some time after the dose wears off. And so far no side-effects have been found. The compound is naturally metabolised by the animal and the breakdown products are excreted without any harmful residues remaining. The trials are supported by wool and meat producers through the IWS and the MRC.

Vaccinating for greenhouse

The other approach to solving the problem involves relying on the immune systems of the animals themselves. In work partly funded by the Meat Research Corporation, Dr Sue Baker and her colleagues at the Division of Animal Production at Floreat Park in Western Australia have found



Researchers at CSIRO's Division of Animal Production in Western Australia have fitted 100 cattle with high-tech 'sniffer collars' which measure the amount of methane exhaled.

Reducing global methane emissions

Methane levels in the earth's atmosphere are low but the gas makes a sizeable contribution to global warming, second only to that of carbon dioxide. More than 70% of methane emissions are associated with human activities, a major contributor being coal-based activities.

CSIRO's Division of Coal and Energy Technology is contributing to an International Energy Authority research and development program on global methane emissions. The program will establish the most effective control technologies or practices for reducing, eliminating or utilising methane emissions from coal. A first stage in the study will assess:

- worldwide emission levels in relation to factors such as coal type, rank, porosity and depth;
- differences in global practices and technologies for trapping or utilising the gas; and
- the environmental consequences of using methane.

The study will seek to identify appropriate technologies for monitoring, controlling or utilising methane emissions from coalbeds, mining ventilation systems, coal preparation, stockpiling, handling and transport. In some instances this will include identifying the potential for additional research and development.

A 1995 International Panel for Climate Control estimate suggests 22-36 million tonnes per year of methane are emitted from the coal-based activities of 10 major coal-producing nations. Only a small fraction of this methane is utilised.

As demand for coal forces companies to mine deeper seams, methane levels will increase. Removal and utilisation of the methane will make sense both in terms of economics and safety. The study will provide forward projections of both methane levels and likely improvements to usage.

And, while the less-concentrated methane in ventilation gas is less easy to access, the study will also identify technologies for extracting this methane as a possible fuel.

Further downstream, in coal preparation, it is estimated that up to 40% of the methane may still reside within the micropores of the coal: right up to the cleaning stage. The study will validate this figure, and again identify any technologies or processes being used to collect methane during coal preparation.

The study will be one of the most comprehensive available in this area and will provide a global picture of the potential for improvement in management of methane emissions including increased use of a valuable energy resource.

that it's possible to vaccinate livestock against the microbes, thereby causing the animals' antibodies to reduce methane production by the methanogens. The animal is made resistant to the methanogens as it would be to disease-causing micro-organisms. Dr Baker's team has filed a patent.

The team has been monitoring cattle and sheep fitted with specially-developed collars that act as methane measurers for any of the air exhaled. About 100 privileged Western Australian animals are having their breath carefully analysed for methane with these 'sniffer' collars. The animals wear the collars for about a day at a time, with no discomfort. Of course, measuring the breath is difficult. You can't easily collect all of it. The collars only measure gas concentrations near the mouth and nostrils. How can this be accurate?

The technique relies on putting a small tube containing an inert gas (sulfur hexafluoride) into the animal's rumen. The gas is released at a known rate and measured by the collar near the mouth and nostrils of the animal. The actual amount measured, when compared with the amount known to be released in a given time, tells the scientists the extent to which the gas is diluted before it hits the detector around the animal's face. Methane is also measured in the same place. The 'dilution factor' calculated from the SF_6 gas is then used to multiply up the methane measured and thereby deduce how much actual methane must have been produced.

With the 'sniffer collars', Dr Baker's team is also working on improving techniques for estimating greenhouse gas emissions from livestock. Baker says existing estimation methods are based on studies of penned sheep and cattle.

Methane production by grazing animals, however, is affected by the nature and composition of their diet, and by the amount of food consumed. To account for these variables, Baker's team is measuring emissions from grazing sheep and cattle under a range of pasture conditions in Australia. The results of this work will allow estimation methods used for the National Greenhouse Gas Inventory for Livestock to be evaluated.

Both vaccination and the antimethanogen compound are showing that with ingenious science it's possible to curb methane emissions from livestock without any damage to the animals concerned. In fact, there's a considerable benefit to the farmer, the atmosphere and, who knows, maybe to the animals themselves. After all, imagine what it would feel like to be producing all that gas!

More about methane

Denmead (1994) Measuring fluxes of CH_4 and N_2O between agricultural systems and the atmosphere. CH_4 and N_2O Global Emissions and Controls from Rice Fields and Other Agricultural Industries, Proceedings of an International Workshop: *Methane and Nitrous Oxide Emission from Natural and Anthropogenic Sources and their Reduction Research Plan*, Tsukaba, Japan (eds K Minami A Mosier and R Sass) March 25-26, 1992.

Johnson K Huyler M Westberg H Lamb B and Zimmerman P (1994) Measurement of methane emissions from ruminant livestock using SF_6 tracer technique. *Environmental Science and Technology*. Vol 26 No 2.

Department of Environment, Sport and Territories, Commonwealth of Australia (1994) *National Greenhouse Gas Inventory*. Canberra.