Towards greener grazing

Emissions from cattle and sheep are significant contributors to planetary warming. But how close are we to creating low-emitting livestock? **Kevin Morrison** reports.

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Scientists are exploring a host of options for reducing greenhouse gases emitted by cows and sheep.

A herd of cattle grazing lazily in the pasture is a common portrayal of the countryside, but underlying this seemingly innocent scene is a more sinister story of belching bovines adding greenhouse gases to the atmosphere.

Globally, agriculture accounts for about ten per cent of human greenhouse gas emissions — mostly released as methane, though also as nitrous oxide. Livestock are the source of roughly 50 per cent of these emissions[1,2], with cattle and sheep emitting methane directly and nitrous oxide being released as a side-effect of using nitrogen fertilizer and animal manure.

Although short-lived, both gases are potent heat trappers that outstrip carbon dioxide in their warming potential. Yet despite their known contribution to climate change, methane and nitrous oxide emissions are set to soar by more than 50 per cent in the coming two decades, as the human population continues to grow and to consume ever more protein[3]. "This is one particular sector that's really not received any kind of attention — at least, not the level of attention that's justified," says Rajendra Pachauri, chair of the Intergovernmental Panel on Climate Change.

Lowering the carbon footprint of livestock has thus become an important focus for scientists. And because methane makes up the lion's share of agricultural emissions, finding ways to reduce or eliminate its production, without throwing the rest of the system out of balance, is the main challenge and focus of research efforts. It's a goal scientists have been working on for decades, driven not by emissions concerns but by the bottom line. Aside from its climatic effects, methane production reduces the efficiency with which an animal converts food into energy, sapping the potential for profit[4].

BREAK DOWN

With the ultimate goal of eliminating methane from both ends of the animals' digestive tracts, scientists have been keen to understand how the gas is generated at points in between. Regardless of the escape route, emissions released through flatulence or belching are produced in much the same way, as a consequence of how cows and sheep — members of a group called ruminants — process their food. Commonly known as cud-chewers, ruminants have a digestive tract comprising four stomachs, the main chamber being the rumen.

Like humans, ruminants can't break down the tough cellulose in plant material on their own. But unlike us, they host a specialized microbial community that can do the job for them by fermenting the material. An offshoot of this, however, is the production of hydrogen that slows fermentation if not eliminated. Microbes known as methanogens, which are similar in some ways to bacteria but part of their own distinct kingdom, handle this important task, using hydrogen as their energy source and producing methane in the process.

Eliminating methane from this crucial process remains a complex challenge, with driving down atmospheric emissions now a key goal. Stephen Moore from the University of Alberta and his colleagues, for example, are interested in the potential to breed animals with a lower residual feed intake (RFI), which is a measure of how much food an animal takes in beyond what it needs to live and grow. Any extra feed is converted to emissions. In laboratory studies, Moore's team identified the most naturally efficient individuals — those that eat less — and measured their output in isolated chambers. They found that breeding beef cattle with a lower RFI could reduce methane emissions by as much as 25 per cent[5]. In addition, it would cut costs substantially for farmers in areas such as North America where animals are kept in feedlots at least part of the year. "It's a double whammy in the feedlot," says Moore. "You get lower greenhouse gases plus reduced feed costs." The cost of identifying efficient animals currently prevents this approach from being widely used commercially, but the group has already helped develop more economic and farmer-friendly ways to apply their findings.

GOING GENOMIC

Moore and other researchers are also looking at how more technologically advanced methods could inform their efforts. He believes that a cow's genetic make-up influences its gut fauna, and his group is looking for bovine genes that control or affect which methanogens and other microbes thrive in the rumen. "There is a genetic interaction between the two, and we're trying to get a handle on that," says Moore.

In April of this year, researchers finished sequencing the genome of a female Hereford cow[6]. Though this mapping effort wasn't targeted exclusively at addressing livestock emissions, researchers such as Moore are mining the information to identify genes associated with lower emissions and increased efficiency. Using the genetic markers that Moore's group has identified, two companies already offer screening for farmers to identify more efficient animals for breeding. The group is now looking for additional genes that could control the microbial community of the rumen and open up possibilities for other beneficial manipulations. "It may lead to all sorts of other approaches you could take. I couldn't even manage a guess at this point," says Moore.

One possibility for increasing efficiency and lowering emissions would be to remove methanogens from the rumen completely. A team in New Zealand has already sequenced the genome of one key ruminant methanogen[7] and is working on others. By identifying enzymes or other potential targets that are both critical and unique to ruminant methanogens, the scientists hope to use direct biological attacks to eliminate them. "Methanogens have been ignored and little understood," says Peter Janssen, a rumen microbiologist involved in the research who works with New Zealand's AgResearch, a government research organization based in Hamilton. "The idea of reducing methane from ruminant animals was current in the 1960s. Here we are working on the same problem 40 years later," he says. But now researchers such as Janssen have a wider variety of tools, such as bioinformatics, to bring to the task. "We're using as much knowledge from as many fields as possible," says Janssen. The team is now working with its first vaccine candidates and conducting drug searches in conjunction with a commercial partner.

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If methanogens can be knocked out, something will still have to process the hydrogen. For this job researchers are looking to acetogens, which are microbes capable of substituting for methanogens as fermenters in the rumen. Because acetogens extract much less energy from the hydrogen, under normal circumstances methanogens out-compete them, preventing their proliferation. But scientists think that if the methanogens are actively removed, then the acetogens already present in small quantities could take over or additional populations could be directly introduced in some way Another option, says Janssen, would be to identify some completely different microbial array that accomplishes the necessary fermentation without producing the unwanted emissions.

Though the impacts of eliminating methanogens are not yet fully understood, Janssen says crude initial experiments suggest that animals can survive without them. The ideal approach, he says, would be an effective vaccination, which would induce a ruminant to begin producing antibodies that attack whatever critical methanogen target might be identified. "If you can stimulate a natural antibody response, then you have continuous, automatic production of antibodies, which would be absolutely fantastic," says Janssen.

LOW-CARBON DIETS

But from a technical perspective, by far the simplest option for significantly reducing emissions from livestock is altering their diet. One possibility involves fortifying livestock feed with tannins, bitter compounds found in many plants — including some that could be used as feed, such as acacias. Tannins appear to inhibit some methanogenic activity and possibly some of the hydrogen production that drives it. Conveniently, tannins also bind with proteins, preventing the nitrogen in the proteins from converting to compounds that are transformed into nitrous oxide after excretion. In situations where animals take in excess protein, nitrous oxide emissions could also be reduced in this way.

Another additive with emission-limiting potential is oil, which is more easily digested than most feed components. Increasing dietary oil by just one per cent can reduce methane emissions by as much as six per cent. Richard Eckard at the University of Melbourne in Australia, who is working on the problem, cautions that increases of more than a few per cent can cause problems for the animals. Nevertheless, "the evidence is there that [oils are] a viable strategy when you have an option for bringing it into the forage", says Eckard.

But even if the ideal low-emissions diet can be identified or created, application would in many cases be challenging if not impossible. In some regions such as parts of the United States, cattle are heavily managed throughout the year, allowing multiple opportunities for

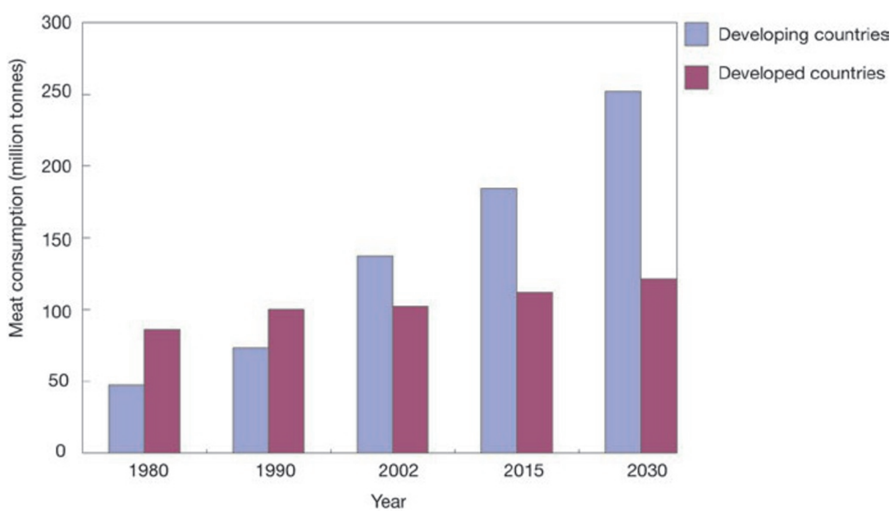

Figure 1 Growing appetite. Meat consumption in the developing world is projected to boom in the coming decades (ref. 8).

giving them supplements or controlling exactly what they eat. But in places such as the Australian outback, beef cattle range freely and may not ever come in contact with humans until the day they're rounded up for slaughter. "The chances of finding those animals — let alone feeding them something — are very limited," says Eckard.

CULTURAL SHIFT

As options for reducing animal emissions emerge, adoption will doubtless be difficult. "One of the hardest things is to get farmers to change the way they manage their business," says Roger Hegarty, head of the Beef Industry Centre of Excellence at the New South Wales Department of Primary Industries in Armidale, Australia. "They have been doing things the same way for generations, and dealing with climate change requires a cultural shift for many farming families."

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> Richard Eckard

There is not yet an economic driver to force or even encourage the use of any emissions-reduction techniques beyond those that offer separate benefits — but that situation could well be changing. Though agriculture was left out of the Kyoto Protocol, ongoing deliberations on a post-Kyoto agreement are more focused on land-use issues, and New Zealand and Australia both intend to reduce agricultural emissions even if no treaty requires it.

Just how much mitigation the sector can accomplish remains unclear. "Considering the time, in terms of evolution, that has gone into developing these animals with guts that can digest hard grasses and make food, we might be a bit optimistic to think we can knock all that out with a few years of research," says Beverley Henry, an agricultural emissions expert with an industry group called the Meat and Livestock Association, based in Sydney, Australia. Nonetheless, she's optimistic that research is going to lead to options for driving down emissions.

Moore, too, is optimistic about the research, but he suggests that reducing livestock emissions should be thought of in terms of a larger solution to overall agricultural emissions. "I think there's got to be a more global strategy to take into account all these things. If we just push methane out of cows, that's valuable, sure, but let's try to do better than that," says Moore.

The alternative, of course, is for humans to decrease demand for livestock by eating less meat (Fig. 1). "People are so dependent on the whole industry, in terms of food we eat and dietary preferences, that we don't see it as an area where changes are required or even possible," says Pachauri. "It's much more attractive to look at those sectors that don't seem to directly affect your day-to-day biological existence. So I think it's just a case of looking beyond what we have become accustomed to. It's an attitudinal issue, really."

But Eckard points out that changing from pastoral agriculture would be challenging for arid regions that don't support crop growth, for example. "We might be able to reduce emissions per unit of food or milk, but if the world's population increases, we will need more cattle and we will have more emissions. There is no escaping this reality," he says. And in contrast to the broad spectrum of alterative energy technologies that could replace fossil fuel, there is no emission-free type of food production. Emissions are associated with every step of the process, from clearing land to the way animals — including humans — process the food they eat. "You can use policy tools to drive people away from coal-fired power plants," says Eckard, "but there's no alternative to food."

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References

1. Oenema, O. *et al. Nutr. Cycl. Agroecosys.* **72,** 51–65 (2007).
2. eauchemin, K. A. *et al. Aust. J. Exp. Agr.* **48,** 21–27 (2008).
3. *The State of the World's Animal Genetic Resources for Food and Agriculture* (Food and Agriculture Organisation of the United Nations, Rome, 2007); http://tiny.cc/graze3
4. Kurihara, M. *et al. Brit. J. Nutr.* **81,** 227–234 (1999).
5. Ellis, J. L. *et al. J. Anim. Sci.* **87,** 1334–1345 (2009).
6. Elsik, C. G. *et al. Science* **324,** 522–528 (2009).
7. Attwood, G. T., Kelly, W. J., Altermann, E. H. & Leahy, S. C. Aust. J. Exp. Agr. **48,** 83–88 (2008).
8. *Livestock's Long Shadow: Environmental Issues and Options* (Food and Agriculture Organisation of the United Nations, Rome, 2006); http://tiny.cc/graze8

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