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Feeding strategies for reducing methane

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By changing feeding techniques and boosting efficiency, methane emissions can be curbed.

International organizations are stepping up pressure on dairies and other ruminant sectors to cut methane emissions with the goal of a further reduction in greenhouse gas emissions.

One example is a statement drafted by the FAO Food and Agriculture Organization (FAO) of the United Nations after an intergovernmental meeting on meat and dairy products held in Paraguay in early May. The meeting was accompanied by a symposium called 'Mitigation of greenhouse gas emissions from animal production: A policy agenda'.

FAO documents state that the global production of meat is projected to more than double between 1999/2001 and 2050, from 229 million metric tons/year to 465 tons, with milk output rising in the same period from 580 million tons to 1.043 billion tons. Given the projected expansion of the livestock sector, say these documents, major corrective measures need to be taken to address the environmental impact of livestock production that will otherwise worsen dramatically.

Although the precise figure is hotly debated, FAO estimates that livestock production is estimated to contribute about 18% of all greenhouse gas emissions. Its contribution for carbon dioxide emissions is only 9%, but in terms of methane it contributes 37% and it is responsible for about 65% of the nitrous oxide emitted.

Governments and other representative bodies therefore are being offered guidelines on mitigating those emissions, including changes in feeding of animals so less methane is released into the atmosphere. The issue is most certainly to be debated at this fall's climate change meeting in Copenhagen, Denmark, when nations meet to try and forge a new climate change treaty.

Studies conducted worldwide show that while there is no single sliver bullet to cut methane, a variety of changes can have a significant impact on reducing emissions. There are six key ways to reducing methane output from dairy cows, according to a study by Wageningen University/Wageningen UR, in the Netherlands:

- Improved forage quality
- Larger proportion of concentrates in the diet
- More rumen-resistant starch
- Adding fats and oils
- Secondary plant metabolites
- Feed additives that boost efficiency and reduce pollutants in manure

The study says that while higher energy intake is beneficial for early lactation dairy cows, dietary measures may cause overfeeding in low producing animals.

Therefore, the study says, "they should be applied with great care and, for example, go together with regular monitoring of the body conditions score to avoid fat cows. It is also recommended to keep cows in separate feeding groups according to the level of production (and nutritional needs)."

The study says that from all emissions sources of methane, agriculture is by far the most important source in the Netherlands. Enteric fermentation in ruminants accounts for 75% of the emission and manure management for 25%. The maximum range of methane losses from dairy cows appears to be 4.5% to 8.5% of the Gross Energy Intake (GEI).

Best tool: improving efficiency
By far, the most important method to reduce methane, all studies say, is to simply do what dairy producers have already been doing: boosting efficiency by increasing milk yield per unit of feed.

"Such an increased milk yield can be achieved by a combination of genetic selection and an optimal use of management in the field of growing and conserving forage, housing of dairy cows and milking technique, such as robotic milking."

Milk production in the Netherlands increased from about 6,000 kg/year in 1990 to 7,500/year in 2003. The study further said that by increasing milk production by 10% from 2003 to 2010 would reduce methane emission per kg of fat corrected milk by more than 5%.

Reducing the proportion to young stock to total dairy cows also helps. In the last decade, the number of young stock has declined and is expected to continue to.

"When we assume that for each 10 dairy cows, four young animals are kept, producing 25 and 65 kg of methane per year, respectively, the methane production of the young sock would approach 24% that of mature animals. Reducing this number by 8% in 2010 would result in a reduce reduction of methane losses by 2%."

Feeding more maize helps

Diets for lactating cows in the Netherlands contain on average 55% forage and 45% concentrates, and methane production tends to decrease with the quality of forages fed. Because of its high starch content, maize silage is expected to result in lower methane losses than grass silage, despite its low cell wall digestibility. Replacing half of the 60% of grass silage in the dry matter of a control ration with maize silage fed to mid-lactation dairy cattle reduced methane production from 6% to 5.8% of gross energy intake. Research from New Zealand also suggests that feeding forage legumes like lucerne or red clover tends to decrease methane losses.

The Netherlands study also says that compared to forages, concentrates are usually lower in cell wall components. Due to the presence of non-structural carbohydrates (starch and sugars), concentrates normally ferment faster than forage, giving rise to elevated levels of propionic acid. As a result, one study found, methane production can be lowered by almost 40% when a forage rich diet is replaced by a concentrate rich diet.

In addition, the study says, "attention should be paid to fish oils," because there are indications that they might reduce methane emission without showing a negative effect on cell wall digestibility in the rumen.

There is little question but that cows produce a fair amount of methane. According to a Pennsylvania State University, USA, report, "Methane production and the dairy cow," approximately 132 to 264 gallons of ruminal gas produced by fermentation are belched each day.

"The eructation of gases via belching is important in bloat prevention, but is also the way the way methane is emitted into the atmosphere."

But dairy is not the largest methane producer. According to a U.S. Environmental Protection Agency report, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004," beef cattle remain the largest contributor of methane emissions, accounting for 71% in 2004. Dairy cattle accounted for 24%, and the remaining emissions were from horses sheep, swine, and goats. Generally, emissions have been decreasing mainly due to decreasing populations of both beef and dairy cattle and improved feed quality.

The Penn State study notes that there has been a lot of research conducted in Canada, Australia, Europe and the U.S. on strategies to reduce methane emissions for dairy and beef operations. The main focus has been on nutritional strategies, especially cows grazing on pasture.

Some dietary practices that have been shown to reduce methane include the addition of ionophores, fats, the use of high quality forages and increased use of grains. These nutritional strategies reduce methane through the manipulation of ruminal fermentation, direct inhabitation of methanogens and protozoa or by a redirection of hydrogen ions away from methanogens.

Probiotics, organic acids and other new mitigation options

Relatively new mitigation options have been investigated and include the addition of such additives such as probiotics, acetogens, bacteriocins, organic acids, and plant extracts (i.e., condensed tannins). For the long term approach, genetic selection of cows that have improved feed efficiency have a possibility, the report says.

It continues that rumen modifiers such as ionophores improve dry matter intake efficiency and suppress acetate production, which results in reducing the amount of hydrogen released. In some of the published research, methane has been reduced by 10%, however, the affect of the ionophores has been short-lived in respect to methane reduction. "More research on the continued use of ionophores for this purpose is needed." Ionophores are banned in some countries.

The Penn State report also says that the grinding and pelleting of forages can reduce emissions by 40%, however, the costs associated with this practice may be prohibitive.

Dietary fats have the potential to reduce methane by up to 37%. This occurs through biohydration of unsaturated fatty acids, enchanced propionic production and protozoal inhibition. The effects are variable, however, and lipid toxicity to the rumen can be a problem, the study says. In addition, this strategy can affect milk components negatively and result in reduced income for the producer.

Possibilities of vaccines

The Pennsylvania report says that several novel approaches to reducing methane are not very practical at this point. An example would be defaunation of the rumen. Removing protozoa has been has been demonstrated to reduce methane emissions by 20%. There may be opportunities to develop strategies that encourage acetogenic bacteria to grow so they can perform the function of removing hydrogen instead of methanogens.

Acetogens convert carbon dioxide and hydrogen to acetate, which the animal can use as an energy source. There is also research being conducted to develop a vaccine, which stimulates antibodies in the animal that are active in the rumen against methanogens.

"The problems with some of these mitigation strategies to reduce methane are potential toxicity to the rumen microbes and the animal, short-lived effects due to microbial adaption, volatility, expense, and a delivery system of these additives to cows on pasture."

Greenhouse gas emissions are highest under organic feeding and lowest when maize is fed.

Even though feeding more concentrates may increase daily methane emissions, emissions per kilogram of feed intake and per kilogram of product are almost invariably produced, according to the U.K. report, Philosophical Transactions of The Royal Society Biological Sciences.

Other methods include adding oils to the diet, and improving pasture quality. The report also says that animal manures can release significant amounts of methane. Methane emissions from manure stored in lagoons or tanks can be reduced by cooling or covering the sources, or by capturing the methane emitted. The manures can also be digested anaerobically to maximize retrieval of methane as an energy source. To some extent, the study states, manure emissions might be curtailed by altering feeding practices.

UK: emissions down by 52%

Total UK methane emissions have declined by 52% since 1990, through a combination of reduced livestock numbers and more efficient feeding, states "A scientific review of the impact of UK ruminant livestock on greenhouse gas emissions," by the University of Exeter. This has been accomplished through a combination of improved forage genetic resources and knowledge and technologies for silage making and feeding, as well as improved knowledge of grazing management. This combination has contributed to improved nutritional value of grazed and conserved forage enabling higher milk yields per cow and lower methane emissions per litre of milk.

The report says that although agriculture globally and ruminant livestock production in particular is a net contributor of greenhouse gas emissions, generalizations about the impacts of climate change often fail to distinguish between different systems of production, advances in technology, and the role of extensive grazing lands in contributing to ecological services and food production in situations where other forms of farming are impractical.

The report continues that given the UK government's ambitious targets to reduce all greenhouse gas emissions, further improvements in agricultural management are likely to be necessary. Importantly, these reductions will take place against a background of rising world population, and an anticipated doubling in world food demands by 2050, together with the need to address energy security. Methane is the second most significant greenhouse gas in the UK (carbon dioxide being the first).

It has a Global Warming Potential of 21 times that of carbon dioxide and with around one-third of UK emissions derived from agriculture, represents a greater challenge for ruminant management. The study says that the methane lost from ruminants can be up to 15% of the gross feed energy intake, and understanding dietary manipulation to reduce methane emissions has long been recognized as having economic implications for the livestock industry.

Illustrating the importance of improved efficiency in reducing methane production, the report notes that even though the number of dairy cows in the UK has fallen by about 20% since the mid-late 1990s, milk yield per cow has increased substantially, from 5,000 litres per cow in the late 1980s to 6,900 at present. So despite major structural changes, total UK milk output has remained relatively stable.

Another way to reduce methane production, the study says, is to extend the number of lactations per cow and reducing the period from birth to first calving, which should be considered as objectives for improving net greenhouse has emissions from the herd.

Importance of supplemental feeding

The report says that the UK dairy herds now derive a higher proportion of their intake from high quality forage. However, as the proportion of high genetic-merit cows has increased so has the reliance on the supplementary feeding with concentrates to enable the total feed intake to match the milk yield potential. The net effect has been a gradual reduction in 'roughage' feed supplies to dairy cows (i.e. hay, poor quality silage and pasture grazed at a mature state of growth or containing roughage of low digestibility) and this has had positive implications for methane production.

The continuing improvement in genetic merit of dairy cows has been associated with improvement in diet quality so that methane yields per litre of milk and nitrogen excretions per litre of milk continued to decline. Results show a 16% reduction in methane and a 9% reduction in manure nitrogen excretion from the national UK dairy herd between 1995/96 and 2005/06.

The study also says that comparisons of greenhouse gas emissions from UK livestock farming relative to other countries remain inexact. "There is a need to the international community to develop common guidelines to take account of allocation between sectors and there is also a lack of some key data." For example, the UK study says a New Zealand report claims that overall greenhouse gas emissions per kg of milk were 30% greater in the UK than in New Zealand

"Our analysis suggests that the basis for accounting for these differences does not stand up to scrutiny," say Alan Hopkins and Matt Lobley, authors of the UK Exeter study.

"While some of the differences in nitrous oxide are related to the higher use of fertilizer N on UK dairy farms, it is less clear whether the indirect emissions in New Zealand fully take account of dietary excretal N derived from biologically fixed N from clovers."

Methane output highest from organic dairying

There is variance in greenhouse gas emissions and type of feeding system and intensity. For example, the study notes, greenhouse gas emissions are highest under organic feeding and lowest when maize is used in feeding. Changing from 80% to 20% autumn calving herds (i.e. more summer milk) reduces energy changing needs and GWP by about 5%, but there are pollution swapping implications: nitrate leaching and hence eutrophication potential are increased by 8% and 3%, respectively.

In discussing measures to reduce methane emissions, the authors say that mitigations aimed at enteric fermentation may be addressed at three different levels: dietary changes, direct rumen manipulation, and systematic changes. The dietary changes involve measures which enhance the efficiency of feed energy use, an area which has potential implications for forage use in the future. Even assuming a constant percentage method loss, this strategy will decrease methane loss per unit of product and probably decrease methane emissions in the long term. However, lack of understanding and potential concerns about the economic implications and uncertainties about side effects are likely to limit uptake in the short term.

The Exeter study says that a relatively natural way to depress methane production is to manipulate the diet to give high rates of fermentation and/or passage through the rumen, affecting rumen volatile fatty acids (VFAs). These changes in VFA proportions have been associated with a decrease in the fiber content of the diet (e.g., by including maize silage). Ingestion of organic acids (aspartate, malate and fumarate) and yeast culture have been associated with reduced emissions in total methane per cow and also with beneficial increases in animal product.

Research has demonstrated the potential of medium-chain fatty acids used either in esterified form (coconut oil, palm kernel oil of GM rape) or as non-esterified form to substantially reduce ruminant methanogenesis.

"Even at less than 3% in the diet, a 50% reduction in methane is possible," the authors say.

They add, however, that organic acids are not yet commonly used, and they may also trigger some pH problems in the rumen. The authors continue that yeast culture "is a promising successful mitigation option as it is already in common use."

The authors state that direct rumen manipulation offers an alternative to dietary change, for instance, defaunation of protozoa decreases the number of methanogenic bacteria as an important proportion of rumen are parasitic to protozoa. However, there are many drawbacks including risks of metabolic disorders.

The ingestion of ionophores acts as propionate enhancers and hence increases the ratio of propionate: acetate. Their use is very limited as they are antibiotics. Some changes in the dietary fat contents of the ration have been described to reduce methane emissions from ruminants as some fats alter the ruminal microbial ecosystem.

"Clearly," the authors say, "many research challenges exist before these approaches can be implemented."

Systematic changes involve identifying animal breeds which result in a reduction of methane output per cow, but the study says that so far, no clear evidence has been found. Increasing productivity per head (i.e., milk yield per cow) or increasing the number of lactations for which the average cow remains economically productive (optimizing the lifetime efficiency of the milking cow) would reduce methane production per unit of milk. The most greenhouse gas efficient option would be to reduce the replacement rate to 30% and sell the surplus heifers for slaughter, giving a mitigation reduction potential of -11.2%. However, the authors say, this has farm-scale economic cost implications.

In addition, the authors note, "although more intensive forms of animal production tend to decrease total methane output, they might not be compatible with other policy targets, including animal welfare considerations, both nationally and at particular farm-scale levels."

An alternative approach that can enable dairying to deliver "improved animal welfare" together with reduced methane per unit of milk output, and meet economic requirements is the use of extended lactation as a production system whereby dairy cows are managed with increased lactation persistency and rebred to calve at around 18 months rather than 122; the emphasis is on modest daily yield sustained over a long period, rather than on peak yield, enabled by simple management interventions.

The authors cited a 2008 study that modelled the potential impact of methane mitigation methods at the UK scale and concluded that on the method with a per-cow milk yield increase (of 30% more than the baseline) would result in a sizeable reduction in methane emissions (-24%). The next most effective mitigation strategy was a high fat diet, which provides a 14% savings, followed by improved heat detection rates of cows at oestrus (-7%) and a high starch diet (-5%). Conversely, a reduction in the milk yield per cow by 30% coupled with an increase in the number of cows to maintain national milk production would result in a 15% increase in methane emissions.

In addition, the UK study says, livestock manure is a significant source of atmospheric methane, especially during liquid storage. One method to reduce it is through the use of anaerobic digesters to produce methane in a controlled environment and hence use it as a source of energy.

"This technique could represent a sustainable option, and if the issues of high capital cost can be overcome, this may become an important feature of future forage-based systems with low methane emissions with adversely affecting ammonia emissions."

A 2009 report by the U.S. Department of Agriculture, called "Switching on Cow Power," said that co-ops could play a pivotal role in assisting producer-members make use of methane digesters, both in terms of providing services related to the adoption of anaerobic digester technology as part of its members services, or a group of similarly situated dairy farmers could form a separate entity to address their specific digester needs.

A co-op, the report says, could engage experts to negotiate rates and terms of trade with utilities, digester suppliers, firms that wish to dispose their organic waste into the digester, and so forth. A group of dairy producers would have more market power to command favorable terms, or gain higher quality expertise at lower cost to address their specific needs, than they would if acting as individuals. Under certain circumstances, the report says, under certain circumstances, a group of closely located small- and medium-sized dairy producers may be able to more effectively operate a common digester by member-farmers manure than if each member installs a digester on their own operation.

Ag in UK responsible for 7%

The FAO findings notwithstanding, the British scientists say that in the UK, the total net greenhouse gas emissions attributed to all of agriculture account for a relatively low proportion (about 7%) of the country's total greenhouse gas emissions. Even so, agriculture will continue to be under pressure to reduce emissions.

The authors say their study found a number of research and policy implications. Those included the fact that many research challenges and knowledge gaps remain, and should give given a high priority at both the national and international levels; research is needed to determine the importance of regional or management-related differences in greenhouse gas emissions and differences in relation to farming system, such as organic versus conventional farming; support for 'carbon sensitive farming'; English agri-environmental schemes do not specifically reward or compensate actions; and consideration should be given to the development of a 'low-GHG-emission' standard for market UK meat and dairy products. However, the UK livestock industry needs to understand that although there is scope to gain market share, there is also potential for other countries to improve their GHG emissions.

How diet shifts can impact methane

A new Canadian study published in the Journal of Dairy Science found that dietary changes cut methane production by an average of 13%. The study, "Crushed sunflower, flax, or canola seeds in lactating dairy cow diets: Effects on methane production, rumen fermentation and milk production," tested cows on three diets: a commercial source of calcium salts of long-chain fatty acids (CTL); crushed sunflower seeds (SS), crushed flaxseed (FS) and crushed canola seed (CS).

The oilseeds added 3.1% to 4.2% fat to the diet (dry matter basis). When corrected for differences in dry matter intake, compared with CTL, methane production (g/kg of DM intake) was decreased by feeding FS (-18%) or CS (16%) and was only numerically decreased (-10% by feeding SS). However, compared with the CTL, feeding SS or FS lowered digestible DMI by 16% and 9%, respectively because of lowered digestibility.

Thus, only CS lowered methane per unit of DM intake. Feeding SS and CS decreased rumen protozoal counts, but there were no treatment effects of mean ruminal pH or total volatile fatty acid concentration. Milk efficiency (3.5% fat corrected milk/DMI), milk yield component yield and concentrations were not affected by oilseed treatments.

The study shows that adding sources of long-chain fatty acids to the diet in the form of processed oilseeds can be an effective means of reducing methane emissions. However, for some oilseeds, such as SS or FS, the reduction in methane can be at the expense of diet digestibility. The use of crushed CS offers a means of mitigating methane without affecting diet digestibility, and hence, milk production.

Efficiency is the key to reducing methane

Which produced less methane: the pasture-based low input dairy system of the 1940s or todays more intensively managed modern system.

It's no contest, according to a study by Cornell University scientists published earlier this year in the Journal of Animal Science. Today's dairy system in the United States has a much lower carbon footprint. Modern dairy practices require considerably fewer resources than dairy in 1944, with 21% of animals, 23% of feedstuffs, 35% of the water, and only 10% of the land required to produce the same 1 billion kg of milk. Waste outputs were similarly reduced, with modern dairy systems producing 24% of the manure, 43% of the methane, and 56% of the nitrous oxide per billing kg of milk compared to equivalent milk from historical dairying.

The carbon footprint per billion kg of milk produced in 2007 was 37% of equivalent milk production in 1944.

"To fulfil the increasing U.S. population's requirement for dairy products it is essential to adopt management practices and technologies that improve productive efficiency allowing milk production to be increased while reducing resource use and mitigating environmental impact."

A common misperception, the study's authors say, is that "pasture-based, low-input dairy systems characteristic of the 1940s were more conducive to environmental stewardship than modern milk production systems."

New Zealand releases new greenhouse gas study

New Zealand-based Fonterra, one of the world's largest dairy companies, released the results of an 18-month study on 29 May, which measured the carbon footprint of its products from the cows to the company's consumers.

Key findings of the research are:

- **The carbon footprint was 940g of CO2 equivalent per litre of liquid milk**
- **Around 85% of the greenhouse gases are emitted on the farm (59% of those are methane; 17% are carbon dioxide, and 24% are nitrous oxide**
- **Processing/manufacturing accounts for 10% of total emissions**
- **Distribution accounts for 5% of total emissions**
- **Products requiring larger quantities of milk have a larger carbon footprint**

"It's well known that Zealand's greenhouse gas profile is heavily influenced by agricultural emissions and this research confirms that," says Barry Harris, the chairman of Fonterra's sustainability team. "It also confirms that our best opportunities to reduce greenhouse gas emissions and our carbon footprint lie in continued efforts to develop practical tools and techniques for farmers to adopt. That's important because farmers are fast adopters and if we put the right tools in their hands (they use them)—a good example being nutrient budgets which are now being used by 98% of farmers whereas six years ago only one if five farmers used them."

The livestock sector has already managed to achieve reductions in GHG emissions by farming animals more efficiently, the study says. Incremental improvements in the quality of New Zealand herds have already reduced on-farm emissions per kg of milk solids produced by about 1%/year since 1990. Possible solutions to further reducing methane production range from changing the mix of microbes in the rumen of cattle, to altering diets and selective livestock breeding.

Fonterra is also working with key international dairy organizations, such as the Sustainable Agricultural Initiative and the International Dairy Federation on the development of a global carbon footprinting standard for dairy.

"We hope our work will speed efforts to agree to a milk product carbon measurement standard that can be used by farmers and dairy companies everywhere to establish baselines for improvement," Harris says.

"An agreed standard methodology also means that if people want to make comparisons with other milk products or benchmark their performance, there is a fair and scientifically robust basis for doing so."

rBST cuts methane output

The treatment of U.S. cows with recombinant bovine somatotropin (rBST) reduces methane output by 7.3%, and manure output by 6.8%, according to a 2008 study conducted by Cornell University and Monsanto Co. scientists. Furthermore, nitrogen and potassium, two major environmental pollutants arising from animal agriculture, were reduced by 9.1% and 11.8%, respectively.

The reason why: milk yield per unit of feed was increased. rBST use reduces the maintenance energy and protein requirements per unit of milk by 11.8% and 7.5% respectively, and total feed requirements by 8.1%, the study found.

"Gains in productive efficiency offer the producer an opportunity to improve milk production and main market supply of milk and dairy products from a smaller dairy population," the researchers say. They add that ruminants contribute 15% to 20% of global anthropogenic methane emissions from enteric fermentation and manure. "Although this may be altered by dietary manipulation, the magnitude of such a decrease is unlikely to reach that achieved by rBST use."

The researchers continue that supplementing 1 million dairy cows with rBST is the equivalent of removing 400,000 family cars from the road or planting 300 million trees. They say that fossil fuel consumption raises two major environmental concerns: atmospheric pollution and resource sustainability. As a consequence of the reduced herd population and total feed requirement from rBST supplementation of 1 million cows, the energy required from fossil fuels (cropping only) and electricity for milk production is decreased.

"To put these figures into context, the savings in gasoline alone would be sufficient to power 1,550 passenger cars, each travelling an average of 12,500 miles per year. Furthermore, the total fossil fuel British thermal units (BTU) and electricity savings would be sufficient annual heat and electricity for 16,000 and 15,000 houses, respectively."

The study says that increased milk requirements from a growing population to 2040 necessitate a great U.S. cow population but, relative to conventional systems, 8% fewer cows are needed in an rBST-supplemented population, whereas organic production systems require a 25% increase to meet production targets. The greater number of animals needed to produce a comparable quantity of milk in the organic system results from lower milk yields per cow.

“This characteristic reduction in yield conferred by pasture-based systems can be attributed to a lack of adequate supply of nutrients, especially metabolizable energy, and the greater maintenance energy expenditure associated with grazing behaviour.”

Current U.S. organic dairy production standards stipulate that ruminants must “have access to graze pasture” and that “grazed feed must provide a significant proportion of total feed intake."

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