Reducing Methane in Dairy and Beef Cattle Operations: What is Feasible?

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SUMMARY

About 3 to 12% of the energy consumed by ruminants (cattle and sheep) is converted to methane in the rumen (referred to as enteric methane) and released into the atmosphere. Adopting feeding strategies that will minimize the amount of energy, lost as methane, can improve feed conversion efficiency, improve animal productivity, and is good for the environment. Producers can reduce their herd's methane production between 5 - 25% by making changes in their management practices and diet but these changes in management and diet add to the cost of producing meat and milk. Farmers will not likely adopt these measures unless there are economic benefits.

Background

Methane is a potent greenhouse gas that contributes to global warming. Over the past three centuries, the amount of atmospheric CH_4 has grown by 2.5-fold[2]. The world's estimated 1.3 billion cattle, 75% of which are found in developing countries, account for one-fourth of the total CH_4 that arises from human activity[2].

Most methane (CH_4) that is emitted from livestock originates in the forestomach, also called the rumen, of ruminants (cattle and sheep). This source of methane is called enteric CH_4. Only about 10% of the total CH_4 from ruminants in Canada is from manure. While the digestion process enables ruminants to convert forages into usable energy, a portion of the feed energy (3 to 12%) is used to produce enteric CH_4, and is released into the atmosphere as the animal breathes[1]. Minimizing the production of CH_4 can improve efficiency of livestock production and is an environmentally sound practice.

About 25% of the enteric CH_4, produced by the 16.25 million cattle in Canada, is generated by the dairy industry. Most of the remaining 75% is produced by beef cattle, which comprise about 84% of the country's total cattle population.

How Enteric Methane is Produced by Cattle

Ruminants are unique in their ability to use forages as an energy source for maintenance, growth and milk production. Plant carbohydrates are broken down by the bacteria in the rumen, producing volatile fatty acids (VFA), the major energy source for the animal. The main VFAs are acetate, propionate, and butyrate. The proportions of each depend on the type of feed. Ruminal digestion generates hydrogen (H_2) as an end product; the amount of H_2 depends on the abundance and type of VFA produced. For example, the formation of acetate generates twice the amount of H_2 compared to the formation of butyrate, whereas the formation of propionate uses up H_2. The accumulation of H_2 in the rumen inhibits feed digestion.

The majority of the methane emitted from cattle occurs during breathing. While much research is being conducted to reduce methane emissions from cattle, the inclusion of ruminant animals into prairie farming systems allows for more efficient land use and better risk management.
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Micro organisms in the rumen, also referred to as methanogens, convert H_2 and carbon dioxide into CH_4 and water. This process lowers the amount of H_2 in the rumen. Methane production is the main way that H_2 is used in the rumen. Strategies to lower enteric CH_4 production involve reducing the production of H_2 in the rumen, inhibiting the formation of CH_4, or redirecting H_2 into products such as propionate.

Benefits of Reducing Enteric Methane Emissions

Reducing enteric CH_4 emissions decreases greenhouse gases in the atmosphere and improves the efficiency of converting plant material into milk and meat. A 20% reduction in enteric CH_4 in Canada would decrease greenhouse gas emissions from agriculture by 6% and Canada's total greenhouse gas emissions by 0.5%.

At the same time, this reduction may improve the competitiveness of Canada's livestock sector. Reducing CH_4 emissions can increase animal performance by conserving energy - energy that could be redirected to milk production or weight gain. A 20% reduction in CH_4 could allow growing cattle to gain an additional 75 g/d of weight or dairy cows to produce 1 L/day more milk. Revenue generated from this increased productivity would help offset the cost of the dietary mitigant. These calculations are theoretical and more research is needed to document the economics.

While feeding diets that lower CH_4 emissions is environmentally responsible, cattle producers are unlikely to adopt these measures unless there are also positive economic benefits for them. In the future, cattle producers may also be able to generate revenue from carbon exchange programs. The price of carbon is expected to increase in the future, which may make it financially more rewarding for Canadian livestock producers to participate in these programs.

Methods of Reducing Enteric Methane and their Potential Effectiveness

Numerous ways of lowering enteric CH_4 emissions from ruminants are proposed or are under investigation (Table 1). Some of these technologies are experimental and require development, but the Canadian beef and dairy sectors could implement a few immediately. There is an increasing body of research that demonstrates it's possible to reduce CH_4 by changing the diet or the management.

Lowering the amount of CH_4 formed in the rumen per kilogram of feed

Feeding higher grain diets

Feeding high grain diets to cattle unequivocally lowers the formation of CH_4 in the rumen. With grain diets, the percentage of the energy consumed that is converted to CH_4 in the rumen is typically reduced to about 3%, from the 6.5% or more that is common for animals fed primarily forages[3]. However, for a drop in CH_4 production to occur, grain must comprise more than 90% of the diet, as is common practice in many western Canadian feedlots. For the feedlot sector, decreasing the duration of the backgrounding phase, in which high forage diets are fed, would decrease the industry's contribution to greenhouse gas emissions.

However, for this drop in CH_4 production to occur, the finishing diet needs to contain starch-based grain rather than high-fiber byproduct feeds (e.g., screenings, millrun). Starch containing grains lower CH_4 formation in the rumen by forming more propionate and less acetate. Feeding high grain diets also causes the rumen environment to become more acidic, which inhibits the growth of rumen methanogens.

While increased use of grains in ruminant diets reduces enteric CH_4 emissions, there is concern that increased grain production may increase the use of fossil fuels for fertilizer, machinery, and transport,

Ruminants Are Important to Sustainable Agriculture

Cattle and sheep are integral components of prairie agriculture. Reducing their numbers would have profound implications for the agricultural industry, the economy and the environment.

From an environmental perspective, the ability of these species and other livestock species to graze forages is very important. Forage grasses and legumes are ideally suited to marginal soil conditions - those soils which can be too dry, too wet, too saline, or too sandy to support annual crop production.

Grazing animals are able to convert forages, not suitable for human consumption, into valuable products like milk and meat which are consumable by humans. The inclusion of grazing into prairie farming systems allows for more efficient land use.

Methane emissions from prairie agriculture come almost entirely from ruminant digestion with a small amount from manure. Although methane reductions are possible with changes in diet i.e. higher grain rations, this is not always feasible or desirable because ruminants are very valuable at converting forages grown on more marginal soils.

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resulting in more greenhouse gas emissions. Grain feeding ignores the importance of ruminants in converting fibrous feeds, unsuitable for human consumption, to high-quality protein sources (i.e. milk and meat). Furthermore, high grain diets can negatively affect cow health due to acidosis. With escalating grain prices, the scope of further increasing the grain content of ruminant diets in Canada is limited.

Grain type

The extent to which high grain diets lower CH_4 emissions depends on the source of grain. For example, greater reductions are achieved with corn than with barley. Our studies[3] show beef cattle, fed diets containing mainly corn grain, produce about 30% less CH_4 than diets containing mainly barley grain. Thus, higher CH_4 emissions are expected from western Canadian feedlots, which rely on feeding barley, than from U.S. feedlots using primarily corn.

Fats and oilseeds

Supplementing diets with fats and oils (excluding sources that are protected from digestion in the rumen) lowers enteric CH_4 emissions. Reductions greater than 40% have been achieved, but reductions of 10 to 25% are more commonly reported[4]. Incorporating fat in the diet as an energy source lowers the carbohydrate content, which is the substrate for CH_4 formation. Fats also lower the number of protozoa in the rumen, many of which are physically associated with the methanogens. Some fats may depress CH_4 emissions because they are toxic to the rumen methanogens. Fats rich in unsaturated fatty acids, such as found in prairie oilseed crops, also reduce CH_4 formation in the rumen because they compete with methanogens for H_2.

With each 1% fat that is added to the diet, CH_4 production is reduced by about 5.6%[4]. The response also depends on the fat source, the form in which the fat is administered (i.e., either as refined oil or as full-fat oilseeds), and the type of diet. Of the fat sources available to cattle producers in Canada, oilseeds and animal fats are usually less expensive than refined oils. Most oilseeds require mechanical processing prior to feeding to ensure the fat interacts with the rumen microbial populations. Another potential fat source is corn distiller's dried grains, which contains 10 to 15% fat. Incorporating 20% corn distiller's grains into the ration is expected to lower CH_4 production by about 10 to 15%.

Cost is the major limitation of using fat feeding to lower CH_4 emissions. In addition, added fat can negatively affect animal performance by decreasing fibre digestion and feed intake. Making sure that total dietary fat is kept below 6% of the diet helps avoid this negative effect.

Use of legumes

Methane emissions are lower from animals fed legume forages (i.e. alfalfa, clover) compared with those fed grasses[5,6], but this relationship is also influenced by the maturity of the forage at the time of consumption[7]. The lower CH_4 observed with legumes is attributed to lower fiber content and faster rate of passage of feed through the rumen. While this strategy has promise, farmers are often reluctant to replace grass with legumes because of pasture management issues and bloat risk.

Use of corn silage and small grain silages

Use of corn silage and small grain silages, rather than grass silage, and hay, can also lower CH_4 production. The high starch content of grain-based silages favours the production of propionate rather than acetate in the rumen. These forages also promote high dry matter intake and have a faster rate of passage through the rumen. Furthermore, replacing grass silage or hay with grain silage often improves animal performance, thereby lowering CH_4 emissions per unit of animal product[8].

Ionophores

Ionophores such as monensin are antimicrobials that are used in commercial beef and dairy cattle diets in Canada to modulate feed intake, control bloat, and improve feed efficiency. Monensin causes a change in the bacterial species in the rumen resulting in an increased proportion of propionate. At times, monensin may also cause a decrease in the numbers of rumen protozoa in the rumen, which provide a habitat for the rumen methanogens.

Decreases in CH_4 production of up to 10%[4] are possible with monensin, depending upon the dose but the reduction in CH_4 is not always sustained over time. This limits the usefulness of monensin as a long-term solution to CH_4 abatement[9].

Reducing CH_4 by Increasing Feed Conversion Efficiency

A second approach to lowering enteric CH_4 emissions is to improve the efficiency of converting feed to meat and milk. By reducing the amount of feed it takes to produce animal products, less enteric CH_4 is generated, because CH_4 emissions are related to feed intake. This increased efficiency of production can be achieved through animal breeding and improved nutrition.

Reducing CH_4 by Increasing Animal Productivity

A third approach is to increase the productivity of individual animals so that fewer animals are required to produce the same amount of product. In this case, the total amount of CH_4 produced per kilogram of milk or meat declines, but CH_4 emissions per animal increase. Overall, however, a reduction in CH_4 occurs because animal numbers decrease. For the beef industry, improved feeding, and animal genetics, can reduce the time cattle are on feed. This has a major impact on lifetime CH_4 emissions. In addition, improving reproductive performance of cattle can reduce total CH_4 emissions from the herd by reducing the number of replacement heifers required. This approach is particularly attractive as there are economic incentives to improve reproductive efficiency even without consideration for potential reductions in CH_4 emissions.

In general, the approach of reducing CH_4 emissions by increasing animal productivity works best when a supply management system limits the total amount of product produced, as in the case of milk production within the Canadian dairy sector. It is estimated that since 1990, CH_4 emissions from the Canadian dairy industry have decreased by 24%, simply due to improved efficiency of milk production and a concomitant decrease in cow numbers[10]. However, beef cattle numbers have increased over that time and so have the total greenhouse gas emissions.

Canadian dairy and beef producers could potentially lower enteric CH_4 emissions by up to 25% by implementing some of the currently available solutions. Further reductions may be possible in the future as new technologies are developed. Some of the more promising novel methods of lowering CH_4 formation in the rumen currently under investigation include immunization with a methanogen vaccine[11,12], biotechnology solutions[13] (e.g., bacteriophages and bacteriocins), and new feed additive development[13,4,14] (e.g., tannin extracts, saponin extracts, bacterial probiotics, yeast, enzymes). However, these options are not expected to be commercially available for another 3 to 10 years.

Lowering CH_4 emissions requires a change in management, or diet that adds to the cost of producing meat and milk. Farmers will not likely adopt these measures unless there are financial benefits, yet in many cases, the profitability of these measures has yet to be determined. In the future, cattle producers may also be able to generate revenue from carbon exchange programs.

One limitation of the research on enteric CH_4 mitigation is that few studies have examined the greenhouse gases arising from the whole farming system. Methane mitigation strategies can affect other greenhouse gases emissions at some other point in the production system, thus the effects of these enteric CH_4 mitigation strategies need to be assessed using a lifecycle analysis. To date, there are few such assessments for enteric CH_4 mitigation strategies.

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Table 1. Some possible mitigation practices for methane reduction and their estimated efficacy

Mitigation Method	**Percentage Reduction in Methane**			**Comments**
	Gross energy intake basis	Per kg of dry matter intake	Per kg of meat or milk	
Reduction in CH_4 by lowering formation in the rumen				
Higher grain diets	10-100			High certainty
Grain type	5-30			High certainty
Fats and oilseeds	5-25			High certainty
Forage and pasture quality	0-10	5-25		Moderate certainty
Forage species	5-25			Moderate certainty
Ionophores	0-10			Dose dependant, possible transient response
Plant secondary compounds (condensed tannins, saponins, essential oils)	0-25			Depends on source and level, experimental
Organic acids	0-40			Dose dependant, cost prohibitive
Yeast	0-5			Depends on strain, experimental
Reduction in CH_4 by improving feed conversion efficiency				
Animal breeding for Residual Feed Intake		5-30		Experimental
Feeding to improve feed conversion efficiency		5-20		Moderate certainty
Reduction in CH_4 by increasing animal Productivity				
Diet formulation to improve rate of gain or milk production			10	High certainty
Reducing numbers of replacement heifers			10	Experimental
Lifetime management of beef cattle			10-20	High certainty
Better reproductive performance			Unknown	Experimental
Breeding for increased productivity	10-20			High certainty