Enteric Fermentation Mitigation

Quick Facts

- Ruminant animals have a unique digestive system, which enables them to eat plant materials, but also produces methane, a potent greenhouse gas that contributes to global climate change. Methane is released into the atmosphere from animal effluences.
- Globally, ruminant livestock emit about 80 million metric tons of methane annually, accounting for 28% of global methane emissions from human-related activities. Cattle in the U.S. produce about 5.5 metric tons of methane per year – about 20% of U.S. methane emissions.[1]

Background

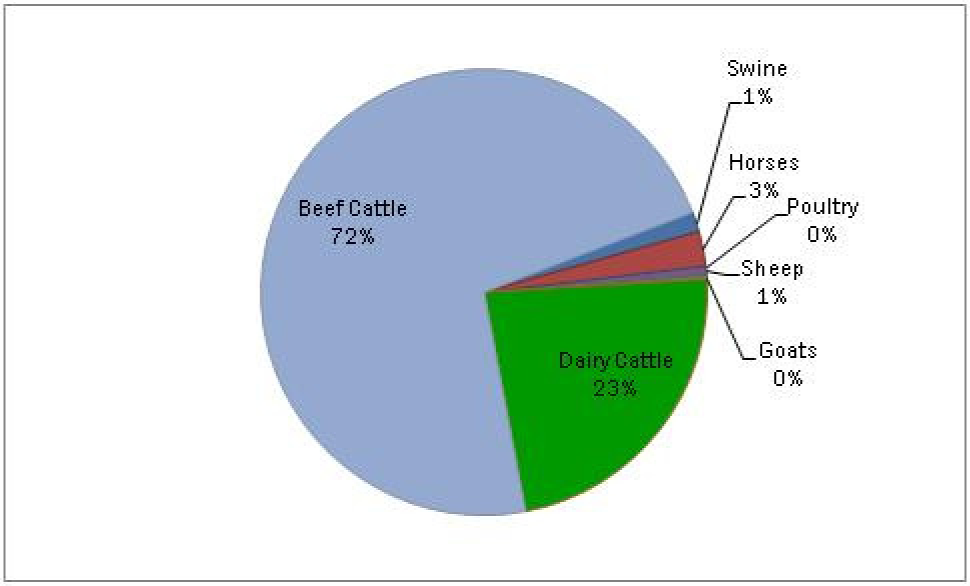
Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal. A resulting byproduct of this process is methane (CH_4), which has a global warming potential (GWP) 25 times that of carbon dioxide (CO_2). Because the digestion process is not 100 percent efficient, some of the food energy is lost in the form of methane. It is estimated that 7-10 percent of a ruminant's energy intake is lost to enteric fermentation (though it can be closer to 4 percent for feedlot cattle in some instances).[2] Measures to mitigate enteric fermentation would not only reduce emissions, they may also raise animal productivity by increasing digestive efficiency.

Description

Enteric fermentation and its corresponding methane emissions take place in many wild and domestic ruminant species,—such as deer, elk, moose, cattle, goats, sheep, and bison. Ruminant animals are different from other animals in that they have a "rumen" – a large fore-stomach with a complex microbial environment.[3] The rumen allows these animals to digest complex carbohydrates that nonruminant animals cannot digest; a natural component of this process also creates methane that is emitted by the animal. Ruminants produce much more methane per head than non-ruminant animals, with the rumen being responsible for 90 percent of the methane from enteric fermentation in a ruminant. Larger ruminants like bison, moose and cattle produce greater amounts of methane than smaller ruminants because of their greater feed intake.[4]

In aggregate, the large number of domestic ruminants, particularly beef cattle and dairy cattle—combined with the high level of methane emissions per head and the high GWP of methane—make enteric fermentation a significant contributor to domestic greenhouse gases from agriculture, with around 28 percent of GHGs in the agriculture sector coming from enteric fermentation in 2007 (the agriculture sector accounts for over 6 percent of U.S. GHG emissions). Enteric fermentation also accounts for nearly a quarter of domestic anthropogenic methane emissions. Beef and dairy cattle are the greatest methane emitters from enteric fermentation that are attributed to anthropogenic activities. Collectively, their effluences accounted for 95 percent of methane emissions from enteric fermentation in the year 2007. Smaller ruminants, like sheep and goats, emitted less than or the same as non-ruminants, like horses and swine, because of their domestic population size. Overall, enteric fermentation from all major domestic livestock groups was responsible for 139 Tg CO_2e (1.9 percent of total greenhouse gas emissions domestically) in the year 2007.[5] Figure 1 below shows the relative contributions to global warming from enteric fermentation in major domestic livestock groups.

Figure 1: Domestic Enteric Fermentation Emissions by Livestock Animal in 2007



Source: U.S. Environmental Protection Agency (EPA), 2009 U.S. Greenhouse Gas Inventory Report: Agriculture, 2007.

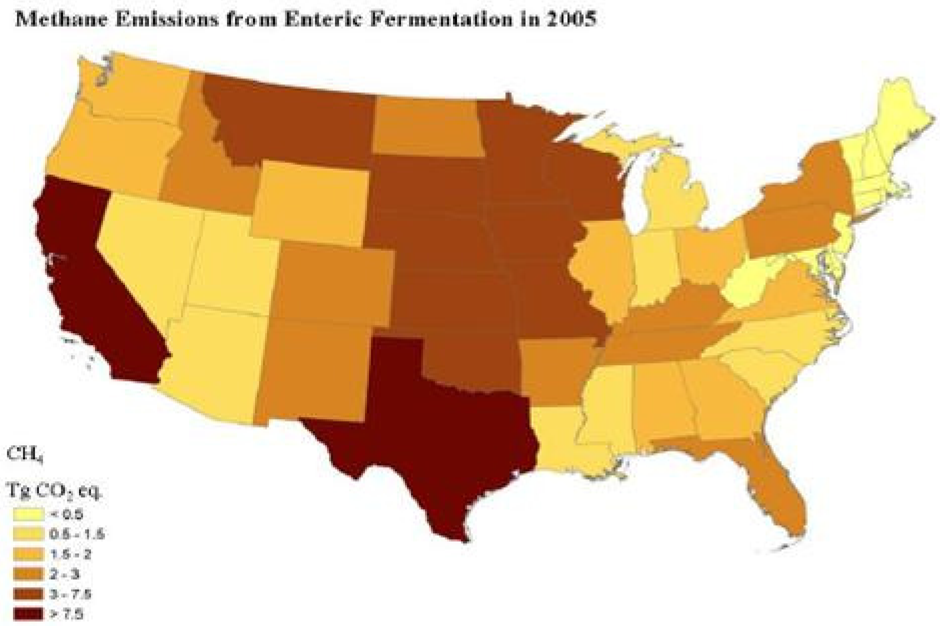
Annual methane emissions from enteric fermentation increased by 4.3 percent between 1990 and 2007, though there were fluctuations in annual emissions levels over this period (emissions trended downwards between 1995 and 2004). This increase can be largely attributed to the growth in domestic beef cattle population, with some of the increase coming from growth in the domestic and wild horse population.[6]

The greatest contributors to GHG emissions from enteric fermentation are states that have large ruminant populations. Texas and California, with their immense dairy and beef cattle operations, are the greatest contributors—each emitting over 7.5 Tg CO_2e annually. Not surprisingly, many agricultural states in the Midwest are also a significant source of enteric fermentation emissions. Figure 2 below illustrates GHG emissions from enteric fermentation by state.[7]

It is estimated that enteric fermentation is responsible for 20-25 percent of anthropogenic methane emissions on a global level.[8] Nations that have agrarian economies with large ruminant populations have much higher emission levels. For example, in New Zealand enteric fermentation is the greatest source of

GHG emissions, accounting for 31 percent of total emissions.[9] In addition, cattle populations have increased dramatically in many developing nations over the past two decades because of rising standards of living and agricultural policy changes in developed nations that have shifted production overseas. As a result, it is estimated that enteric fermentation emissions from the developing world had increased by around 33 percent between 1984 and 2004.[10]

Figure 2: Methane Emission from Enteric Fermentation by State



Source: United States Department of Agriculture (USDA), U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005 Chapter 2: Livestock and Grazed Land Emissions, 2005.

Environmental Benefit/Emission Reduction Potential

Methods to mitigate enteric fermentation emissions are still in development and need further research, but early studies looking at potential mitigation options have yielded some promising results. Most research has focused on manipulating animal diet in an effort to inhibit a rumen environment favorable to methanogens. Diet manipulation can abate methane by decreasing the fermentation of organic matter in the rumen, allowing for greater digestion in the intestines—where less enteric fermentation takes place. This inhibits methanogens and limits the amount of hydrogen (H) available for methane (CH_4) production.[11] Alternatively, changing the type of fermentation taking place – by switching ruminants from a cellulosic to a starch-based diet, for example – can increase the amount of fermentation while still decreasing levels of methane production.

Early research demonstrates that increasing animal intake of dietary oils helps to curb enteric fermentation and increase yields by limiting energy loss due to fermentation. These oils appear to be a viable option because they can be easily substituted into animal diets. A study by Grainger et al. (2008) found that increasing dietary oils could mitigate emissions from enteric fermentation, with a 1 percent increase in dietary oils decreasing methane emissions by 6 percent. As part of this study, whole cottonseed was introduced into the diet of dairy cattle and observed to reduce methane emissions by around 12 percent and increase milk yield by about 15 percent.[12] Another study conducted by Beauchemin et al. found that the introduction of sunflower oil abated methane emissions by 22 percent.[13] Similar studies have demonstrated promising results using other oils, such as coconut and palm. Further research will be needed to examine the long-term viability of dietary oils, as it may be possible that the rumen could adapt to new feed environments and return to previous levels of methane emissions.[14]

There remain other options to combat enteric fermentation—like genetic engineering and the use of additives, but further research and development is needed before such options can be employed. The use of the antibiotic monensin was examined by Beuachemin et al but its use did not significantly reduce methane emissions, and questions remain about the permanence of these reductions.[15] Studies have also been conducted examining the potential for genetic engineering aimed at increasing the efficiency of feed conversion to biomass—which would also reduce enteric fermentation— within animals. One recent study laid the groundwork for breeding cattle that would have 25 percent less methane emissions and require less feed.[16]

One remaining option is to reduce the consumption of ruminant animals and ruminant animal products,[17] but this would involve changes in consumer behavior and preferences that are unlikely to take place in the near future.

Cost

As several potential options exist for mitigating enteric fermentation, it is difficult to enumerate the costs of abatement. For example, diet manipulation options have costs that are subject to feed market volatility. Furthermore, the availability of certain feed or oil types will vary by region and season in some cases, so it would be difficult to assign costs on a national level for diet manipulation. Rather, farmers and ranchers will likely choose to source the lowest-cost dietary supplements available to them at any given time. Increases in yield may also be observed when utilizing supplements to mitigate enteric fermentation, and these would act to ameliorate any costs associated with their purchase.

Genetic engineering will have R&D costs associated with it, but whether or not animals that are genetically engineered to produce more efficiently cost more over their lifetime than current livestock populations remains to be seen. One must take into account both the upfront costs of genetic engineering vs. the potential lifetime benefits of increased production and lower feed usage.

Current Status of Enteric Fermentation Mitigation

Business and research groups have made some early efforts to address enteric fermentation emissions, but a national-level effort has not yet materialized. The USDA and the EPA have both acknowledged enteric fermentation as a source of emissions and included these emissions in greenhouse gas inventory reports, but the EPA's recently proposed national greenhouse gas reporting rule does not include enteric fermentation emissions.

New Zealand has decided to include emissions from enteric fermentation in its GHG emissions trading scheme. In January of 2013, emissions from agriculture in that country—including enteric fermentation emissions—will be capped. Owners of livestock operations out of compliance with their cap will be required to buy permits from those in compliance in order to emit, or they will have to pay a fine. The Australian Government is currently in the process of deciding whether or not to include agricultural emissions—including those from enteric fermentation— in its Carbon Pollution Reduction Scheme. If included, owners of livestock operations in Australia will also have their emissions capped and will be required to buy permits if they exceed their allowance. The Australian Government is set to issue a decision on whether or not to include agriculture by 2013.

Obstacles to Further Development or Deployment of Enteric Fermentation Mitigation

There are several obstacles that could prevent action on enteric fermentation for the foreseeable future. These include:

- **Difficulty of measurement**

  Emissions from enteric fermentation are diffuse and this makes them difficult to measure. Emissions can be measured *in vitro,* by trying to simulate the rumen in a lab, or *in vivo,* by measuring emissions directly from an animal.[18] Preference is given to *in vivo* methods when possible. Current *in vivo* methods include placing livestock in emissions measurement chambers or using portable sulfur hexafluoride (SF_6) tracers to measure methane emissions from the rumen in the field. Both techniques have disadvantages; the SF_6 tracer does not measure emissions from the anterior of the animal and the chamber can be costly and place animals under stress, which could increase emissions. Neither method provides instantaneous data on emissions from the animal. A study by McGinn et al. (2004) found that, on average, methane emission measurements from the SF_6 tracer method were 4 percent lower than those of the chamber, while a study by Grainger et al. (2008) found the SF_6 tracer method results were 8 percent lower.[19,20] While the SF_6 tracer method and the chamber method are both accurate, a mobile measuring apparatus that provides instantaneous data will improve both the ability to make management decisions and research capabilities.

- **Heterogeneity in management practices**

  Studies examining abatement through enteric fermentation mitigation must assume baseline diets and management practices from which reductions are taking place. In reality, farms have many different diets they feed animals that vary with season, price, and availability. Thus, it becomes difficult for farmers to accurately estimate emissions reductions from new management practices because their baselines may be dramatically different than those assumed in studies.

- **Inherent price volatility of mitigation**

  Enteric fermentation mitigation options dependent on diet manipulation are subject to volatility in feed markets. A mitigative diet that is affordable one year may not be the following year, and this will make long term mitigation dynamic in nature as farmers will have to periodically adjust the composition of the diets they are giving animals because of the costs and availability of certain feeds. This will have an impact on both the costs of mitigation and the level of emissions abated at any given period.

Policy Options to Help Promote Enteric Fermentation Mitigation

- **Inclusion in EPA greenhouse gas reporting rule**

  Requiring livestock operations to report enteric fermentation emissions will improve the understanding of emissions sources and catalyze the development of cost-effective technologies to measure and report emissions from enteric fermentation at the farm level. Quantifying these emissions will allow farmers to make better decisions and allow for their inclusion in various abatement mechanisms. This reporting may have costs to the livestock producer.

- **Incentivization of management practices**

  Previous farm bills have established environmental performance programs, such as the Conservation Reserve Program, designed to incentivize practices that protect the environment. The inclusion of enteric fermentation mitigation in an existing program, or the establishment of a program dealing with enteric fermentation, would incite many farmers to take action.

- **Cap and trade with functioning offsets markets**

  A price on carbon alone would not stimulate enteric fermentation mitigation because it is unlikely that enteric fermentation emissions would be included in any regulatory regime, be it cap-and-trade or a tax. Rather, the establishment of a cap on carbon emissions, along with offsets markets where polluters can buy emissions reductions not included in the cap, would create a market for enteric fermentation reductions. If farmers could verify their emissions reductions from enteric fermentation mitigation, they could sell them to polluters covered under the cap who could then use them for compliance.

Related Pew Center Resources

- Agriculture's Role in Greenhouse Gas Mitigation, 2006

Further Reading / Additional Resources

U.S. Environmental Protection Agency Resources:

- Ruminant Livestock: http://www.epa.gov/rlep/faq.html
- 2009 US Greenhouse Gas Inventory Report: Agriculture

U.S. Department of Agriculture Resources:

- U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005 Chapter 2: Livestock and Grazed Land Emissions

Wood, Christina, et al. *Global Climate Change and Environmental Stewardship by Ruminant Livestock Producers.* s.l. : National Council for Agricultural Education, 1998.

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[1] United States Environmental Protection Agency (EPA). Ruminant Livestock. *EPA. 2007.* Accessed October 13th, 2009. http://www.epa.gov/rlep/faq.html.

[2] Moss, A.R. and D.R. Givens. *Effect of supplement type and grass silage:concentrate ratio.* Vol. Proc. Br. Soc. Anim. Prod. Paper No. 52. 1993,

[3] Thorpe, Andy. *Enteric fermentation and ruminant eructation: the role (and control?) of methane in the climate change debate.* Numbers 3-4, Berlin : Springer Netherlands, 2009, Vol. 93.

[4] Johnson, DE, et al. *Ruminants and other animals. In:Kahlil (ed) Atmospheric methane: its role in the global environment.* Berlin: Springer, 2000.

[5] U.S. EPA. 2009 US Greenhouse Gas Inventory Report. *United States Enviromental Protection Agency.* April 2009. Accessed June 23, 2009. http://epa.gov/climatechange/emissions/usinventoryreport.html.

[6] Ibid.

[7] United States Department of Agriculture (USDA)**.** U.S. Agriculture and Forestry Greenhouse Gas Inventory-Livestock and Grazing. *USDA.* 2005. Accessed June 25, 2009. http://www.usda.gov/oce/global_change/AFGG_Inventory/2_LivestockandGrazing.pdf.

[8] Thorpe 2009.

[9] New Zealand's Greenhouse Gas Inventory 1990-2007: Agriculture. *New Zealand Ministry for the Environment.* Accessed July 6, 2009. http://www.mfe.govt.nz/publications/climate/greenhouse-gas-inventory-overview-2009/html/page5.html

[10] Thorpe 2009.

[11] S. M. McGinn, K. A. Beauchemin, T. Coates and D. Colombatto. Methane emissions from beef cattle: Effects of monensin, sunflower oil, enzymes, yeast, and fumaric acid. *Journal of Animal Science.* American Society of Animal Science, 2004. http://jas.fass.org/cgi/content/full/82/11/3346.

[12] Grainger, C., T. Clarke, K.A. Beauchemin, S.M. McGinn, & R.J. Eckard. Effect of whole cottonseed supplementation on energy and nitrogen partitioning and rumen function in dairy cattle on a forage and cereal grain diet. *Australian Journal of Experimental Agriculture*, 48, 860-865. 2008. DOI: 10.1071/EA07400

[13] McGinn et al. 2004.

[14] Ibid.

[15] Ibid

[16] Britten, Nick. Cows that burp less methane to be bred . *UK Telegraph.* June 24, 2009. Accessed June 28, 2009. http://www.telegraph.co.uk/scienceandtechnology/science/sciencenews/5612957/Cows-that-burp-less-methane-to-be-bred.html.

[17] Thorpe 2009.

[18] Hess, H.D. and C.R. Soliva. Measuring Methane Emission of Ruminants by In Vitro and In Vivo Techniques . [book auth.] Harinder P.S. Makkar and Philip E. Vercoe. *Measuring Methane Production From Ruminants.* Dordrecht : Springer Netherlands, 2007.

[19] S. M. McGinn, K. A. Beauchemina, A. D. Iwaasab and T. A. McAllistera. Assessment of the Sulfur Hexafluoride (SF_6) Tracer Technique for Measuring Enteric Methane Emissions from Cattle. *JEQ.* 2006. Accessed June 28, 2009. http://jeq.scijournals.org/cgi/content/full/35/5/1686.

[20] C. Grainger, T. Clarke, S. M. McGinn, M. J. Auldist, K. A. Beauchemin, M. C. Hannah, G. C. Waghorn, H. Clark and R. J. Eckard**.** Methane Emissions from Dairy Cows Measured Using the Sulfur Hexafluoride (SF6) Tracer and Chamber Techniques. *Journal of Dairy Science.* 2007. Accessed June 28, 2009. http://jds.fass.org/cgi/content/full/90/6/2755.