Carbon, Methane Emissions and the Dairy Cow

Agriculture contributes approximately 6 to 7% of the total U.S. greenhouse gas emissions. Methane from enteric (microbial) fermentation represents 20% and manure management 7% of the total methane emitted. Some dietary practices that have been shown to reduce methane include addition of ionophores, fats, use of high quality forages, and increased use of grains.

Introduction

The atmosphere has a natural supply of greenhouse gases that capture heat and keep the surface of the Earth warm. Before the industrial revolution took off in the mid 1700s, the greenhouse gases released into the atmosphere were somewhat balanced with what could be stored on Earth. Natural emissions of heat trapping gases matched what could be absorbed in natural sinks such as when plants take in carbon dioxide when they are growing and release it back into the atmosphere when they die. As countries became more industrialized, more gases were being added to the natural levels in the atmosphere. These gases can stay in the atmosphere for at least 50 years and longer. These greenhouse gases are building up beyond the Earth's capacity to remove them and creating what has been termed "global warming." There are two main factors influencing global warming, depletion of the ozone layer and an increase in greenhouse gas emissions.

Naturally occurring greenhouse gases consist of water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Carbon dioxide, CH_4 and N_2O have a direct global warming effect, and their concentrations in the atmosphere are the result of human activities. Gases produced from industrial activities include chlorofluorocarbons and hydrochlorofluorocarbons.

There are several gases that have an indirect effect on global warming by influencing the formation or destruction of greenhouse gases, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x) and non-CH_4 volatile organic compounds. Aerosols, which are small particles or liquid droplets can also affect the absorptive characteristics of the atmosphere.

Sources of Naturally Occurring Greenhouse Gases

In the United States, carbon dioxide makes up 84.6% of all emissions. The major sources of CO_2 emissions are fossil fuel combustion, iron and steel production, cement manufacturing, and municipal solid waste combustion. In the United States in 2004, fuel combustion accounted for 95% of CO_2 emissions.

Methane makes up 7.9% of all emissions. The major sources include landfills, natural gas systems, enteric fermentation (dairy and beef cattle primarily), and coal mining. According to the Intergovernmental Panel on Climate Change (IPCC), methane is more than 20 times as effective as CO_2 at trapping heat in the atmosphere. The concentration of CH_4 in the atmosphere the past two centuries has increased by 143%.

Nitrous oxide makes up 5.5% of all emissions and is produced primarily by biological processes that occur in soil and water. Major contributors to this gas include agricultural soil management, fuel combustion from motor vehicles, manure management, nitric acid production, human sewage, and stationary fuel combustion.

Methane Production and the Dairy Cow

Agriculture contributes approximately 6 to 7% of the total U.S. greenhouse gas emissions. Methane from enteric (microbial) fermentation represents 20% and manure management 7% of the total CH_4 emitted. Ruminants (beef, dairy, goats, and sheep) are the main contributors to CH_4 production.

The ruminant animal is unique because of its four stomach compartments: reticulum, rumen, omasum and abomasum. The rumen is a large, hollow muscular organ where microbial fermentation occurs. It can hold 40 to 60 gallons of material and an estimated 150 billion microorganisms per teaspoon are present in its contents. The function of the rumen as a fermentation vat and the presence of certain bacteria promote the development of gases. These gases are found in the upper part of the rumen with CO_2 and CH_4 making up the largest portion (Table 1). The proportion of these gases is dependent on rumen ecology and fermentation balance. Typically, the proportion of carbon dioxide is two to three times that of CH_4, although a large quantity of CO_2 is reduced to CH_4. 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 CH_4 is emitted into the atmosphere.

Source: Sniffen, C.J. and H. H. Herdt. The Veterinary Clinics of North America: Food Animal Practice, Vol 7, No 2. Philadelphia, PA: W. B. Saunders Company, 1991.	
Component	**Average percent**
Hydrogen	0.2
Oxygen	0.5
Nitrogen	7.0
Methane	26.8
Carbon dioxide	65.5

Table 1. Typical composition of rumen gases.

Based on the EPA report, *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2004*, beef cattle remain the largest contributor of CH_4 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 for feedlot cattle.

Dietary Strategies to Lower Methane Emissions

There has been a lot of research conducted in Canada, Australia, Europe, and the U.S. on strategies to reduce methane emissions from dairy and beef operations. The main focus has been on nutritional strategies, especially cows grazing pasture. Some dietary practices that have been shown to reduce CH_4 include the addition of ionophores, fats, the use of high quality forages, and the increased use of grains. These nutritional strategies reduce CH_4 through the manipulation of ruminal fermentation, direct inhibition of the methanogens and protozoa, or by a redirection of hydrogen ions away from the methanogens.

Relatively new mitigation options have been investigated and include the addition of such additives 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 is a possibility. The following gives more detail about some of the strategies that reduce CH_4:

1. Increasing the efficiency in which animals use nutrients to produce milk or meat can result in reduced CH_4 emissions. This can be accomplished by feeding high quality, highly digestible forages or grains. However, the emissions produced in producing and/or transporting the grain or forage should be considered.

2. 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, CH_4 has been reduced by 10%, however the effect of the ionophores have been short-lived in respect to CH_4 reduction. More research on the continued use of ionophores for this purpose is needed.

3. The grinding and pelleting of forages can reduce emissions by 40%, however the costs associated with this practice may be prohibitive.

4. Dietary fats have the potential to reduce CH_4 up to 37%. This occurs through biohydration of unsaturated fatty acids, enhanced propionic acid production, and protozoal inhibition. The effects are variable and lipid toxicity to the rumen microbes can be a problem. This strategy can affect milk components negatively and result in reduced income for the producer.

There are several novel approaches to reducing CH_4 that are not very practical at this point. An example would be the defaunation of the rumen. Removing protozoa has been demonstrated to reduce CH_4 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 the 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 CH_4 are potential toxicity to the rumen microbes and the animal, short-lived effects due to microbial adaptation, volatility, expense, and a delivery system of these additives to cows on pasture.

Resources

- Inventory of U.S. Greenhouse Gas Emissions and Sinks:1990-2004. April 2006. USEPA #430-R-06-002.
- Fight Global Warming, Environmental Defense.
- Methane emissions from dairy cows measured using the sulfur hexafluoride tracer and chamber techniques. 2007. J. Dairy Sci. 90:2755-2766.
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- Long-term effects of feeding monensin on methane production in lactating dairy cows. 2006. J. Dairy Sci. 90:1781-1788.
- Manipulating enteric methane emissions and animal performance of late lactation dairy cows through concentrate supplementation at pasture. 2005. J. Dairy Sci. 88:2836-2842
- Mitigation strategies to reduce enteric methane emissions from dairy cows: update review. Canadian J. of Animal Sci. 2004. 84:319-335.
- The effect of oilseeds in diets of lactating cows on milk production and methane emissions. J. Dairy Sci. 2001. 85:1509-1515.

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