HOW MUCH METHANE DO COWS EMIT?

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Global warming concerns and air quality regulations have focused attention on animal agriculture as one source contributing to these problems. There are a number of approaches and methods that have been used to quantify emissions from various sources. Currently, there is not one universally accepted methodology that exists to make these calculations. However, animal agriculture still needs to examine its contribution to these problems and consider mitigation opportunities.

One concern is the contribution of greenhouse gases to the trend for slightly higher environmental temperatures and rising levels of gases in the atmosphere. The primary greenhouse gases are carbon dioxide, methane, nitrous oxide, ozone and water vapor. These gases trap infrared energy that contributes to higher atmospheric temperatures. It is important to remember that carbon dioxide, methane and nitrous oxide are continuously emitted and removed from the atmosphere by natural processes. In addition to these natural processes, anthropogenic activities also cause emissions of some of these gases. There are also a number of halogenated substances (such as chlorofluorocarbons) that can contribute to the problem but these are products of industrial activities. It is important to remember that the greenhouse gases comprise only about 1% of the total gases in the earth's atmosphere. The predominant gases are oxygen (21% of the total) and nitrogen (78% of the total).

Table 1 contains the changes in global atmospheric concentrations of greenhouse gases since the pre-industrial age. The total greenhouse gas emissions in the US in 2004 were estimated to be 7,047 Tg (1 Tg = 1 million metric tons) of CO_2 equivalents. Carbon dioxide was the primary gas at 5,988 Tg. Total methane missions were 556.7 Tg and nitrous oxide was 386.7 Tg (US EPA, 2006).

Table 1. Global Greenhouse Gas Concentrations [a]

Variable	Carbon dioxide	Methane	Nitrous oxide
Pre-industrial concentration, ppt	280	0.72	0.27
2004 concentration, ppt	376.7	1.756	0.319
Rate of change, ppt/year	1.6	0.005	0.007
Atmospheric lifetime, years	50 – 200	12	114

[a] Adapted from US EPA (2006)

METHANE

Methane is the greenhouse gas related to animal emissions. The primary source of methane is the anaerobic breakdown of organic matter in a variety of biological systems. Agricultural systems are only one of many systems that produce methane. Table 2 contains a breakdown of the sources of methane in the US in 1990 and 2004. Dairy cattle account for about 17% of the total agricultural methane emissions or about 4.8% of the total US methane emissions. About 75% of the total methane emissions from beef cattle are from cow-calf operations. An estimate by EPA indicates that livestock enteric emissions of methane are projected to increase by 6.7% from 1997 to 2010 (US EPA 1999). It is interesting that total methane emissions in the US have already decreased by 9.9% since 1990. Methane emissions related to livestock enteric fermentations have decreased by 4.5% during this same time period.

Table 2. US Methane Emissions (Tg CO_2 equivalents) [a]

Source	1990	2004
Total	618.1	556.7
Landfills	172.3	140.9
Natural gas systems	126.7	118.8
Agriculture (total)	156.8	160.4
- Manure management	31.2	39.4
-Enteric fermentation	117.9	112.6
- Beef cattle	83.2	80.4
- Dairy cattle	28.9	27.0

[a] Adapted from US EPA (2006)

Globally, it has been estimated that total yearly methane emission are 500 – 600 million metric tons. Ruminant animals are suggested to contribute 14 – 20% of this total. Cattle in the U.S. have been calculated to emit 5.5 million metric tons of methane per year. Beef cattle account for about 75% of these emissions. Dairy cattle in the US account for about 23% of this total or 1.26 million metric tons. On a global basis, the dairy cattle population in the US emits about 1.6% of the total emissions from ruminants. This represents only about 0.2 - 0.25% of the total global methane emissions. Any additional decreases in methane emissions from dairy cattle will have a very small impact on total methane emissions from all sources.

What about the methane emissions from dairy cattle in New York? A model was used to predict methane emissions (Livestock Analysis Model). Methane emissions from New York dairy cattle have decreased by 19.5% since 1925 even though total milk production has increased by 73%. The methane emitted per unit of milk produced has decreased by 53% during this same time. The dairy industry should be recognized for this reduction in methane emissions that has already taken place.

How much methane does an individual cow emit? There are 3 primary methods used to report this information. These are:

A. Liters/cow/day – Literature values for lactating dairy cows range from 420 to 763 liters/cow/day (Holter and Young, 1992; Wilkerson et.al., 1995). A recent paper indicated that using an in vitro gas technique to measure methane production from commercial dairy rations might be an alternative method of determining methane emissions (Getachew et. al., 2005). The results from this technique gave a calculated daily methane production similar to literature values from whole animal studies.
B. Yearly methane per cow (kg/cow/year) – The EPA lists annual emission factors for dairy cattle from 111.8 to 139.4 kg/cow/year (EPA, 1999). This same source indicates that replacement heifers emit 57.4 to 61.2 kg of methane per year for heifers. Johnson and Johnson (1995) listed a range of 109 to 126 kg/cow/year.
C. Methane production as a percent of gross energy intake – Johnson et.al. (1996) indicated that a methane loss equal to 6% of gross energy (GE) intake was typical of most of the sheep and cattle in the world. Other reports have values ranging from 1.7 to 14.9% of GE intake for lactating dairy cattle (Holter and Young, 1992; Wilkerson et.al., 1995). Dry cows have been reported to have methane emissions representing 3.1 to 10% of GE intake (Holter & Yiung, 1992; Wilkerson et.al., 1995). Beef steers fed high grain rations may have <3% of GE intake as methane emissions (Johnson et. al., 1996). Harper et. al. (1999) compared methane emissions from grazing and feedlot cattle. The grazing cattle had methane emissions representing 7.7 to 8.4% of GE intake. The value for cattle fed a high grain diet was 1.9 to 2.2% of GE intake.

Table 3. New York - Number of Cows, Milk Production and Methane Production [a]

Item	1925	1950	1975	2000	2005
Number of Cows	1,347,000	1,300,000	917,000	686,000	648,000
Milk/cow/year, lbs	5,200	6,810	10,866	17,378	18,639
Total milk, million lbs.	7,004	8,853	9,964	11,921	12,078
Methane emissions, tons/year	135,278	141,612	118,761	110,807	108,837
Methane emissions, lbs/100 lbs. milk	3.86	3.2	2.38	1.86	1.8

[a] Calculated using the Livestock Analysis Model Version 1.01

What nutritional adjustments can be made to further reduce methane emissions from dairy cattle? This topic was addressed in recent papers (Benchaar et.al., 2001; Boadi et. al., 2004; and Johnson et. al.1996). There are a large number of approaches to nutritional adjustments that can be made to decrease methane production from ruminants. These include:

1. Feed high grain or soluble carbohydrate rations – The types of volatile fatty acids produced in the rumen directly affect methane emissions (Van Soest, 1994). Methane emissions are greater when acetate is produced and less in propionate based fermentations. High grain diets tend to produce more propionate while forage based diets produce more acetate. As indicated above, methane emissions are lower in steers fed high grain diets than in dairy cattle fed typical diets. Moe and Tyrrell (1979) reported that soluble residue (ND solubles – CP – EE), hemicellulose and cellulose were the best predictors of total methane production. Added sugars in dairy rations may result in increased methane production since sugars tend to promote a butyrate fermentation while starches favor propionate fermentation. Methane production was reduced by 22% when barley replaced beet pulp using a modeling approach (Benchaar et. al., 2001). Using the same approach, these workers reported a 17.5% decrease in methane production when corn replaced barley.

2. Feed high quality forages – Forage quality also has an impact on methane production. Lactating beef cattle grazing alfalfa-grass pastures lost 7.1% of GE intake as methane while those grazing a grass only pasture lost 9.5% of GE intake (McCaughey et. al., 1999). Methane production tends to increase as more mature forages are fed (Boadi et. al., 2004).

3. Obtain high levels of dry matter intake – It has been reported by Johnson and Johnson (1995) that methane losses expressed as a percent of GE intake decreased by 1.6 units for each multiple increase in feed intake. This may be primarily a rate of passage effect since feed would be subjected to less ruminal fermentation at higher intake levels.

4. Processing of forages – Smaller particle size forages have been reported lower methane losses per unit of feed intake (Johnson et. al., 1996). This effect is probably related to a combination of a faster rate of passage, a decrease in acetic acid and an increase in propionic acid (LeLiboux and Peyraud, 1999).

5. Alteration of rumen fermentation – A number of products and additives have been tested to alter ruminal fermentation and lower methane production. These include malic acid, fumaric acid and ionophores. A recent paper indicated that adding either fumaric acid or encapsulated fumaric acid to lamb diets lowered daily methane production by 49 to 75% (Wallace et. al., 2006). It would be interesting to have similar data for dairy cattle. Adding sarsaponin to an invitro rumen system decreased methane production up to 60% depending on dose level and length of the fermentation period (Lila et. al.,

2003). An extract of *Yucca schidigera* decreased methane production up to 42% in an in vitro continuous incubation system (Pen et. al., 2006). Ionophores have also been shown to reduce methane production. (Guan et. al., 2006: McGinn et. al., 2004 and Tedeschi et. al., 2003). The ionophore effect may be related to a shift that occurs in the rumen microbial population that results in a higher propionic to acetic acid ratio. One report indicated that methane production could be reduced by an average of 25% when monensin was added (Van Nevel and Demeyer, 1995). There have been mixed results when monensin is incorporated in rations on a long-term basis in terms of methane production and potential microbial adaptation. Additional work is needed to clarify these relationships.

6. Rumen pH – Methane production decreased as rumen pH changed from 6.5 to 5.7 (Lana et. al., 1998). The shift in rumen pH was made by using rumen fluid from steers fed a high grain diet instead of using rumen fluid from steers on a high forage diet.

7. Dietary fat sources – The addition of fats with a medium chain length (C_8 – C_{16}) have been reported to decrease methane production (Dohme et. al., 2000). Studies have used fat sources such as coconut oil or canola oil. Fish oils have also been shown to lower methane production (Fievez et. al., 2003). One paper used whole cottonseed or canola oilseeds added to dairy cattle rations (Johnson et. al., 2002). Total ration fat levels were increased from 2.3 (control) to 4 or 5.6% fat. In this study, there was no effect of the added oilseed fat on methane production. These added fats have depressed fiber digestion in some studies.

8. Improved animal productivity – The data on methane production in Table 2 is an example of the influence of the level of animal production on methane emissions. Higher producing animals do produce more total methane per day than lower producing animals. However, they produce less methane per unit of product produced. The net effect is that fewer animals are required to produce a specific quantity of product resulting in less total methane produced. The use of bST has been calculated to lower methane emissions in dairy cattle by up to 9% (Johnson et. al., 1996).

9. Other approaches – There are a number of other approaches that have been tried in laboratory situations. These include protozoal defaunation, bacteriocins, immunization, essential oils, probiotics and specific chemicals that inhibit methane production. All of these have shown some potential to reduce methane emissions in short-term trials. Additional work needs to be done with these in both longer-term trials and in vivo trials to better assess their true potential. One concern that needs addressed in longer-term trials is the possibility that the ruminal microorganisms may adapt to some of these over time and the actual change in methane emissions may be lower than the initial response.

SUMMARY

Enteric fermentations account for about 20% of the total US methane emissions. Dairy cattle in the US contribute about 24% of the total enteric fermentation methane production. On a global basis, US dairy cattle account for about 0.25% of the total methane emissions. Methane emissions from New York dairy cattle have decreased by about 19.5% since 1925 even though total milk production has increased by 73%. There may be additional opportunities to lower methane emissions from dairy cattle and increase the efficiency of feed use. However, reducing methane emissions in US dairy cattle will have minimal effects on altering global methane emissions.

The above information could be used to develop a diet for dairy cattle to decrease methane emissions. This would be a low forage-high grain diet with high levels of starch and added rumen active fats. A fine-chopped high quality forage would be used in this diet. Some of the feed additives could be included to alter rumen fermentation and lower methane production. The goal would be high levels of both dry matter intake and milk production. Methane production should be decreased by >40 – 50% on this type of diet. However, there may be practical palatability, rumen function and animal health considerations that would prevent implementation of this type of diet. Practically, basing dairy rations on high quality forage, balancing ration protein and carbohydrate fractions and stimulating high levels of dry matter intake and milk production is the best approach to lower methane emissions while maintaining animal health and profitability.

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