

Methane Emissions from Dairy Cattle

L. Chase
Cornell University

Species: Dairy
Use Area: Animal Housing
Technology Category: Diet Modification
Air Mitigated Pollutants: Methane

Description:

Global warming and air quality concerns have focused attention on animal agriculture as one source contributing to these problems. Methane is the greenhouse gas that has received the most attention relative to emissions from animals. In 2005, the total greenhouse gas emissions in the U.S. were 7,260 Tg CO₂ equivalents (EPA, 2007). This value has increased by 16.3% from 1990 to 2005. Methane emissions were 539 Tg on a CO₂ equivalents basis. This value has decreased 11.4% since 1990. Methane emissions from enteric fermentation were 112.1 Tg on a CO₂ equivalent basis in 2005 versus 115.7 in 1990. This is a decrease of 3.1%. Thus, there has already been some decrease in both total and enteric fermentation methane emissions in the U.S. since 1990.

Enteric methane emissions are produced in ruminant animals as a result of microbial degradation of carbohydrates in the rumen. Enteric methane accounted for about 21% of the total U.S. CH₄ emissions in 2005. Methane emissions from dairy cattle represented about 25% of total enteric CH₄ emissions while beef cattle accounted for 71%. Methane emissions from all cattle in the U.S. account for about 11% of the world methane emissions from cattle (Westberg et.al. 2001).

Table 1 contains data on methane emissions from dairy cattle in the U.S. for 1944 and 2007. The highest number of dairy cattle in the U.S. was in 1944. Methane production was calculated using the Cornell Net Carbohydrate and Protein System (CNCPS, 2007) model. It is important to note that total U.S. milk production increased by 159% from 1944 to 2007 even though the number of dairy cows decreased by 64.5% during this time period. This was accomplished by a 443% increase in milk production per cow during this time. Methane emissions per pound of milk produced decreased 60% during this same time period. Thus, the dairy industry has already made significant reductions in methane emissions since 1944. This decrease in total methane emissions from dairy cattle is the result of many factors including animal genetics, feed quality, ration formulation, feeding management and changes in herd management.

Table 1. U.S. Dairy Cow Statistics and Methane Emissions

Item	1944	2007	2007, % of 1944
Cows, millions	25.6	9.1	35.5
Milk, lbs/cow/year	4,572	20,267	443
Total U.S. milk production, million lbs.	117,023	185,602	159
Milk, lbs/cow/day	15	66	440
Methane, Mcal/day/cow	3.05	5.3	174
Methane, l/cow/day	332	580	175
Total Methane, l/day, millions	8,499	5,278	62
Methane, l/lb of milk	22	8.8	40

Mitigation Mechanism:

There are a large number of potential approaches that can be used to decrease total methane emissions from dairy cattle or to lower the methane produced per unit of milk produced. The basic objective is to improve the efficiency of both animal productivity and ruminal fermentation. A number of papers have addressed methane mitigation options for ruminant animals (Benchaar et.al., 2001; Boadi et.al., 2004; Chase, 2006 and Johnson et. al. 1996). The primary approaches that can be used include:

1. Continue to improve animal productivity – The information in Table 2 contains the relationship between daily milk production and methane emissions in dairy cattle fed the same ration. Note that as milk production increases the methane produced per cow per day increases. This is logical since the animal is consuming and processing larger quantities of feed as milk production increases. However, the quantity of methane produced per unit of milk produced

decreases as milk production increases. The net effect is that fewer animals would be needed to produce a specific quantity of milk resulting in less total methane being produced. Factors such as genetics, feed quality, ration formulation and daily nutrition management can all assist in increasing animal productivity. The use of rBST has been calculated to lower methane emissions in dairy cattle by up to 9% (Johnson et. al., 1996).

Table 2. Milk Production and Methane Emissions in Dairy Cattle

Milk, lbs/day	Dry matter intake, lbs/day	Methane, Mcal/day	Methane, l/day	Mcal of Methane/lb. of milk	Liters of Methane/lb. of milk
44	37	4.75	518	0.11	11.8
66	43	5.31	580	0.08	8.8
88	52	5.97	652	0.068	7.4
110	62	6.64	725	0.06	6.6
132	73	7.26	793	0.055	6.0

2. Feed high quality forages – Higher quality forages help to decrease methane emissions due their higher efficiency of use in the animal. A trial was conducted with lactating beef cows to evaluate methane production on two types of pasture (McCaughey et. al., 1999). An alfalfa-grass pasture (13% CP, 53% NDF) and a grass pasture (9% CP, 73% NDF) were used. Methane production was about 9% higher for cows on the grass pasture which is a lower quality forage.

3. Feed high grain or soluble carbohydrate rations – Feeding grain or soluble carbohydrates tends to increase ruminal propionate while lowering rumen acetate levels from the microbial fermentation. Previous work has indicated that methane emissions are increased as rumen acetate levels increase. Using a modeling approach, it was reported that replacing beet pulp with barley decreased methane emissions by 22% (Benchaar et. al., 2001). Using this same approach, a 17.5% reduction in methane emissions was reported when corn grain replaced barley in the ration. This is the reason that finishing beef steers in feedlot situations have low methane emissions compared with dairy cattle. An in vitro study also indicated that methane production decreased as rumen pH decreased (Russell, 1998). However, there are a number of rumen and animal health concerns that limit the quantity of grain that can be fed to dairy cattle. This limits the potential decreases in methane emissions that can be attained in dairy cattle by feeding higher grain diets.

4. Processing of forages – Lower methane losses per unit of feed intake have been reported when smaller particle size forages are fed (Johnson et. al., 1996). Forage particle size reduction has practical limitations for dairy cattle since there is a need to maintain chewing and rumination activity and rumen health. Most forages fed to dairy cattle in the U.S. are fed in the form of silage. The particle size of these forages is reduced during harvest but there is little opportunity for further decreases in forage particle size on most dairy farms.

5. Dietary fat sources – The addition of medium chain length fatty acids has been reported to lower methane production (Dohme et. al., 2000). Methane production has also been decreased by adding fish oil to rations (Fievez et. al., 2003). These fats were added as free oils. A trial with lactating dairy cows used whole cottonseed or canola seeds as fat sources to increase total ration fat levels from 2.3 to 5.6% (Johnson et. al., 2002). In this trial, the added fats did not reduce methane emission rates. This may be related to the fact that the fats in these products were part of a feed and may have had a slower release rate in the rumen and had less impact on ruminal fermentation. A review paper concluded that adding unsaturated fats may help to decrease methane production but may also have negative effects on feed intake or animal performance (Giber-Reverdin et. al., 2003).

6. Additives to alter rumen fermentation – A logical approach would be to add compounds to the ration that could alter rumen fermentation and decrease methane production. A large number of compounds have been screened for methane emissions using in vitro techniques. Many of these look promising but have not been used in animal trials. Methane production was decreased by 49 to 75% in growing lambs when an encapsulated fumaric acid product was used (Wallace et. al., 2006). The addition of sarsaponin to an in vitro rumen system decreased methane production up to 60% (Lila et al., 2003). Methane production has been decreased by up to 42% in an in vitro continuous culture system when an extract of *Yucca schidigera* or *Quillaja saponaria* was added (Pen et. al., 2006). The ionophore, monensin, has decreased methane production in ruminant rations (Guan et. al., 2006; McGinn et. al., 2004 and Tedeschi et.al, 2003). The proposed mechanism is a shift in the rumen microbial population that results in a higher propionic to acetic acid ratio. A recent paper examined the effect of including monensin in dairy rations over a 6-month period of time (Odongo et. al., 2007). Methane production was decreased by 7-9% when monensin was added. Dry matter intake and milk production were not affected when monensin was added but decreases in both milk fat % and milk protein % were reported. The addition of monensin to dairy rations in the U.S. has been approved by FDA (Food and Drug Administration). The approved use level is between 11 to 22 g/ton of total ration dry matter.

7. Additional Approaches – A number of possible ways to reduce methane emissions have been tried in laboratory environments. These include immunization, vaccines, use of probiotics, adding essential oils and protozoal defaunation. All of these have some potential to decrease methane production in short-term in vitro trials. Long term animal trials are needed to determine if they have potential for practical use on dairy farms.

Applicability:

Reducing methane emissions on dairy farms is a practical and realistic goal. However, there must be some economic return to dairy producers if we expect them to adopt practices to decrease methane production. The practices used must also be practical and fit within the dairy herd management system. Practices that improve animal production and efficiency usually provide a positive economic return to the dairy producer. The practices listed above such as using higher quality forages and using various carbohydrate energy sources in the ration can be done on most dairy farms. Forage quality and ration formulation practices continue to improve on dairy farms and have both economic and environmental benefits to the producer. Feed efficiency has been shown to improve when monensin is fed to dairy cattle. This increases the quantity of milk produced per unit of feed consumed and improves the income over feed cost for the dairy producer.

Limitations:

There is no direct economic incentive for a dairy producer to develop a program to lower methane emissions. The incentive is rather an improvement in efficiency of feed use or an increase in farm profitability by fine tuning the forage and feed program on the farm. A large number of the possible approaches outlined above have only been tried experimentally and need additional animal research to verify or quantify their potential to alter methane emissions. There is also a question of balance. We could design rations for dairy cows to dramatically lower methane emissions. However, these rations may not be practical since they could lower animal productivity or impair animal health.

Cost:

It is very difficult to put cost or benefit values on the above practices as they will vary widely between farms. Cost and return analysis should be done on animal efficiency or productivity terms. In most cases, a practice that improves animal efficiency or productivity will also decrease methane emissions. One author has suggested that a 5:1 return can be attained by using monensin in dairy cattle rations (Hutjens, 2007).

Implementation:

The practices described above offer opportunities to dairy producers to alter nutritional practices to decrease methane emissions from dairy cattle. The type and extent of practices adopted will be farm specific and will need to be reviewed and discussed by the dairy producer and his outside consultants.

Technology Summary:

The U.S. dairy industry was responsible for about 21% of the total enteric methane emissions in 2005. The total methane emissions from dairy cattle have already decreased by 38% compared to 1944 while milk production per cow has increased by 443% during this same time. The liters of methane produced per pound of milk have gone from 22 in 1944 to 8.8 in 2005. There are still opportunities for the dairy industry to further decrease methane emissions. Since there is no direct benefit to a dairy producer to lower methane emissions, the primary changes will be to improve animal efficiency and productivity. By doing this, the methane produced per unit of product will be reduced. The primary areas to concentrate on to lower methane emissions are improving forage quality, better balancing rations to improve the efficiency of rumen fermentation and nutritional management practices to increase feed efficiency. A number of feed additives look promising for reducing methane emissions based on laboratory and in vitro results. However, most of these have not been tested in long-term experiments with dairy cattle. Until this is done, the potential reduction in methane emissions and the cost to benefit ratio cannot be determined. Monensin is one additive that has been shown to lower methane emissions and is approved for use in dairy cattle rations by FDA. One estimate is that the benefit to cost ratio for this product is 5:1.

Additional Resources:

EPA website: www.epa.gov/climatechange

References:

- Benchaar, C., C. Pomar and J. Chiquette. 2001. Evaluation of dietary strategies to reduce methane production in ruminants: A modeling approach. *Can. J. Anim. Sci.* 81:563-574.
- Boadi, D., C. Benchaar, J. Chiquette and D. Masse. 2004. Mitigation strategies to reduce enteric methane emissions from dairy cows: Update review. *Can. J. Anim. Sci.* 84:319-335.
- Chase, L.E. 2006. How much methane do cows emit? *Proc. Cornell Nutr. Conf.*, Syracuse, NY. Pp: 219-226.
- CNCPS. 2007. Cornell Net Carbohydrate and Protein System model. Available at: www.cncps.cornell.edu.
- EPA. 2007. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2005. Available at: www.epa.gov/climatechange/index.html.
- Giger-Reverdin, S., P. Morand-Fehr and G. Tran. 2003. Literature survey of dietary fat composition on methane production in dairy cattle. *Livestock Prod. Sci.* 82:73-79.
- Johnson, K.A., R.L. Kincaid, H.H. Westberg, C.T. Gaskins, B.K. Lamb and J.D. Cronrath. 2003. The effect of oilseeds in diets of lactating dairy cows on milk production and methane emissions. *J. Dairy Sci.* 85:1509-1515.
- Johnson, D.E., G.M. Ward and J.J. Ramsey. 1996. Livestock methane: Current emissions and mitigation potential. In: *Nutrient management of food animals to enhance and protect the environment*. E.T. Kornegay, ed. Lewis Publishers, New York, NY. Pp: 219-234.
- Hutjens, M. 2007. Use of ruminants in dairy diets. Available at: http://www.extension.org/pages/Use_of_Rumensin_in_Dairy_Diets. Accessed: March 20, 2007.
- Lila, Z.A., N. Mohammed, S. Ksanda, T. Kamada and H. Itabashi. 2003. Effect of sarsaponin on ruminal fermentation with particular reference to methane production in vitro. *J. Dairy Sci.* 86:3330-3336.
- McCaughey, W.P., K. Wittenberg and D. Corrigan. 1999. Impact of pasture type on methane production by lactating beef cows. *Can. J. Anim. Sci.* 79:221-226.
- Odongo, N.E., R. Bagg, G. Vessie, P. Dick, M.M. Or-Rashid, S.E. Hook, J.T. Gray, E. Kebreab, J. France and B.W. McBride. 2007. Long-term effects of feeding monensin on methane production in lactating dairy cows. *J. Dairy Sci.* 90:1781-1788.
- Pen, B., C. Sar, B. Mwenya, K. Kuwaki, R. Morikawa and J. Takahashi. 2006. *Anim. Feed Sci. Tech.* 129:175-186.
- Russell, J.B. 1998. The importance of pH in the regulation of ruminal acetate to propionate ratio and methane production in vitro. *J. Dairy Sci.* 81:3222-3230.
- Sauer, F.D., V. Fellner, R. Kinsman, J.K.G. Kramer, H.A. Jackson, A.J. Lee and S. Chen. 1998. Methane output and lactation response in Holstein cattle with Monensin or unsaturated fat added to the diet. *J. Anim. Sci.* 76:906-914.
- Tedeschi, L.O., D.G. Fox and T.P. Tylutki. Potential environmental benefits of ionophores in ruminant diets. *J. Environ. Qual.* 32:1591-1602.
- Wallace, R.J., T.A. Wood, A. Rowe, J. Price, D.R. Yanez, S.P. Williams and C.J. Newbold. 2006. Encapsulated fumaric acid as a means of decreasing ruminal methane emissions. *International Congress Series.* 1293:148-151.
- Westberg, H., B. Lamb, K.A. Johnson and M. Huyler. 2001. Inventory of methane emissions from U.S. cattle. *J. Geophysical Res.* 106:12633 – 12642.

Point of Contact:

Dr. L. E. Chase
Cornell University
272 Morrison Hall
Ithaca, NY 14853
USA
607-255-2196

As published in the proceedings of:
**MITIGATING AIR EMISSIONS FROM ANIMAL FEEDING
OPERATIONS CONFERENCE**
Iowa State University Extension
Iowa State University College of Agriculture and Life Sciences
Conference Proceedings
Sponsored by:
NRI Air Quality Extension & Education
U.S. Pork Center of Excellence
Iowa Farm Bureau Federation
Iowa Egg Council
Iowa Pork Industry Center
Iowa Pork Producers Association