CARBON FOOTPRINT AND THE DAIRY INDUSTRY

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There continues to be increased pressure and interest by all segments of society to determine their carbon footprint and examine approaches to reduce it. The carbon footprint is basically the total quantity of greenhouse gases produced and related to various activities. The common unit of expression is the total quantity of carbon dioxide (CO_2) equivalents. The dairy industry is also being asked to continue to decrease its carbon foot print. Bauman and Capper (2010) reported comparisons for the U.S. dairy industry between 1944 and 2007. Milk per cow increased by 443% while the carbon footprint decreased by 63%. The U.S. dairy industry has made a commitment to decrease the total industry carbon footprint by 25% by 2020 (Tricarico, 2014). This includes the total industry from growing crops for feed to consumption of milk by consumers. The current total industry carbon foot print is estimated at 17.6 lbs. of total CO_2 equivalent emissions per gallon of milk. Table 1 provides a breakdown of how the various sectors of the industry contribute to the total emissions per gallon of milk. Milk production is listed as being 51.5% of the total emission per gallon while feed production accounts for 20.3%. The other sectors are listed as contributing 3.5 to 7.7% of the total.

Table 1. U.S. Fluid Milk Carbon Footprint [a]

Sector	% of Total Carbon Footprint
Consumer	4.9
Retail	6.5
Transportation/Distribution	7.7
Packaging	3.5
Processing	5.7
Milk production	51.5
Feed production	20.3

[a] Hristov, 2014

GREENHOUSE GAS EMISSIONS

The U.S. EPA considers carbon dioxide, methane (CH_4) and nitrous oxide (N_2O) as the primary greenhouse gases (GHG). Methane is the GHG of concern from ruminant animals. Agricultural soil management is the primary source of nitrous oxide emissions. Agriculture was responsible for 8.1% of the total GHG emissions in the U.S. in 2012 (US EPA, 2014). Total methane emissions were 8.7% of the total GHG emissions. Ruminant animals contributed 24.9% of the total methane emissions or 2.2 % of the total U.S. GHG. Dairy cattle were listed as providing 24.8% of the enteric emissions which is 0.54% of the total U.S. GHG emissions. Beef cattle contributed 71.3% of the total enteric methane emissions. Even though the methane emissions from dairy cattle are relatively small, there is still good rationale for working to decrease methane emissions. One is to assist agriculture in improving environmental stewardship by lowering emissions. A more important reason is to improve the efficiency of nutrient use in dairy cattle which will help in lowering methane emissions while potentially improving profitability.

HISTORICAL PERSPECTIVES

The production of methane from enteric (rumen) fermentation has been measured and reported for over 100 years. An early paper by Armsby and Fries (1915) reported an average methane production of 4.8 parts per 100 grams of rumen digested carbohydrates. In this paper, they referenced earlier work by Kellner that reported an average of 4.2 parts per 100 grams of digested carbohydrates. Moe and Tyrrell (1979a) compared rations containing 40% of the total ration dry matter as corn grain fed to lactating and nonlacting dairy cows. The primary focus of this work was to examine energy metabolism. However, methane emissions were also measured. Two types of corn grain were fed. One was a soft endosperm type while the other had a hard endosperm. There was significantly less methane energy produced in the lactating cows fed the soft endosperm corn ration. The difference between the corn endosperm types was not significant in the nonlactating cows. The energy in the methane produced was about twice as high for the lactating cows. This is largely due to the higher level of dry matter intake of the lactating cows. Coppock et.al. (1964) reported work using rations containing 100% hay, 75% hay plus 25% grain or 50% each of hay and grain fed to lactating dairy cows. The liters of methane produced per day tended to decrease as the level of grain in the ration increased. Moe and Tyrrell (1979b) reported a summary of data from 404 energy balance studies using the Beltsville chambers. These trials used a wide variety of feeds and rations. They concluded that the prediction of methane emissions for lactating cows needs to include the amounts of soluble residue, hemicellulose and cellulose digested. An interesting paper was published by Hristov (2012). This paper estimated the methane emissions from bison in the U.S.in the period before the 15th century. In this paper, the author assumed a bison herd of 50 million animals. Using this assumption, total methane emissions from bison were 86% of current emissions from ruminants on farms in the U.S.

REVIEW PAPERS

There have been a number of in-depth review papers published recently that provide excellent resource information that the dairy industry can use to examine mitigation options. A series of 3 papers examined enteric fermentation, manure management and animal management options mitigation options (Hristov et.al., 2013a; Montes et. al., 2013 and Hristov et. al. 2013b). Another review paper looked at enteric methane mitigation options for dairy cattle (Knapp et. al, 2014). These authors provided some initial quantification of the potential impact of a number of options. The estimated potential reduction methane emission per unit of energy corrected milk was about 18% for genetic selection and 15% for feeding and nutrition. The potential reduction for rumen modifiers was 5% while other management approaches were about an 18%

reduction. The potential reduction was about 30% when all of these approaches were combined.

HERD MANAGEMENT OPTIONS

Garnsworthy (2004) indicated that replacement heifers could account for up to 27% of the total methane emissions in a dairy herd. He also indicated that improving herd fertility to levels commonly found in 1995 could lower methane emissions by 10-11%. Another paper looked at the effect of improving cow productivity, longevity and fertility (Bell et. al., 2011). A one standard deviation in feed use efficiency would lower CO_2 equivalent emissions by 6.5%. Bauman and Capper (2010) reported that the use of rbST could lower methane emissions about 8.3% compared to not using rbST. This decrease is a combination of more milk per cow and fewer cows needed to produce the same quantity of milk. The importance of improving fertility and improving animal health are discussed in a couple of papers (Hristov et. al., 2013b; Place and Mitloehner, 2010). The negative impacts of mastitis and lameness on emissions are also described (Place and Mitloehner, 2010).

NUTRITION AND FEEDING FACTORS

Altering nutrition and feeding management practices that improve feed efficiency are probably the primary short-term approach to lowering enteric methane emissions (Knapp et. al., 2014). Hristov (2014) indicated improving feed efficiency and forage digestibility may be the most practical short-term approaches for U.S. dairy farms to mitigate methane emissions. One of the review papers provided some estimates of the impact of potential nutritional shifts on methane emissions (Knapp et. al., 2014). Table 2 contains a summary of these estimates. In looking at this list, it is important to consider cow productivity and potential health issues. If cows consistently have a rumen pH <5.5, there can be some negative effects on DMI, milk production, fiber digestibility and health. High levels of fat feeding (especially plant based fats) can impact DMI, milk production and milk components. However, this list does provide an index of which areas have the most opportunity to assist the industry in decreasing emissions.

Hristov et. al., 2013a looked at some of these options in a different way. They classified the potential methane mitigation of various strategies in response categories. Some of their results are:

- Dietary fat – low to medium potential (low =<10% mitigating effects, medium = 10 to 30% mitigating effect).
- Adding grain – low to medium
- Improving forage quality – low to medium
- Grazing management – low
- Feed processing – low
- Using TMR’s - ?
- Precision feeding and feed analysis - low to medium

Table 2. Nutrition and Feeding Management Impacts on Methane Emissions [a]

Change	Methane/Energy Corrected Milk
Increase dry matter intake	Decrease 2 to 6% for each 2.2 lb. increase
Decreased forage particle size	Neutral
Processing of grain	Decrease about 1 – 2.5% for a 5% increase in total tract starch digestibility
Rumen pH < 5.5	Decrease of 15-20%
Feeding higher grain levels	Decreases about 2% for a 1% increase in ration NFC (maximum credit about 15%)
Increased forage quality	Decreases about 5% with a 5 unit increase in total tract NDF digestibility
Forage type and selection	Decreased by 0 to 4%
Fat feeding	Decreased buy about 5% for each unit of fat in the ration

a Adapted from Knapp et.al. 2014

Forage type and genetics are additional factors related to enteric methane emissions. The energy loss as methane was 6.1, 6.7 and 5.4% of gross energy intake for early cut grass, late cut grass and corn silages (Brask et. al., 2013). A report by Archimedes et. al. (2011) was the result of a meta-analysis using 22 in vivo studies with 112 observations. The conclusions were that animals fed C4 grasses had 17% more methane per unit of organic matter intake than animals fed C3 grasses. A number of other reports indicate lower methane emissions when corn silage is fed compared with grass silages. It appears that the lower fiber and higher passage rates for legumes may decrease methane emissions compared with grasses. However, it is difficult to partition these differences between forage type, forage quality and management practices. At the farm level, the forage(s) grown will depend primarily on soil types and environmental conditions. The key is to manage each forage to improve quality and digestibility. Selecting forages based on yield potential, quality, fiber digestibility and starch digestibility may be the most practical approach at the farm level to minimize methane emissions from forages.

RUMEN ENVIRONMENT FACTORS

A large number of inhibitors, electron acceptors, plant bioactive compounds and enzymes have been evaluated or proposed as being able to reduce enteric methane emissions. Most of these were evaluated using short-term in vitro techniques. Some of these were promising with decrease in methane emissions up to 30-70%. However, very few of these were examined in long-term in vivo trials. There is a poor relationship between in vitro and in vivo results for many of the phytogenic compounds (Flachowsky and Lebzien, 2012). One concern is that over a period of time that the rumen microbial population could adapt to the compound and the long-term effect or benefit is unclear. A review paper on the use of direct-fed microbials as a method to lower enteric methane emissions concluded that additional work is needed to better understand the potential for practical application (Jeyanathan et.al. 2013). The role of monensin in reducing methane emissions was reported in a recent meta-analysis (Appuhamy et. al., 2013). This paper used a data set of 22 studies from 13 papers. The average reduction in methane emissions in dairy cattle was 6 ± 3 grams/per day with a monensin feeding rate of 21 m/kg of DMI. This paper did not consider the potential reduction in methane emissions that could be associated with improved feed efficiency of dairy cows fed monensin. The reduction in methane emissions for beef steers was 19 ± 4 grams per day at a feeding rate of 32 g/kg DMI. There has also been interest in the potential of rumen defaunation as a method of lowering enteric methane emissions. However, no long-term trials have been conducted to determine if this effect would persist over time. More in-depth discussions of the effects of rumen modifiers are available in the review papers (Hristov et. al., 2013a: Knapp et.al. 2014).

WHOLE FARM FACTORS

The use of whole farm modeling is another tool that can be used to asses changes in farm management strategies on the carbon footprint (Rotz, 2014). The IFSM (Integrated Farm System Model) was used to simulate the effects of varying levels of milk production or feeding strategies. Feeding strategies used were full confinement, summer grazing and an all grass, low input system. Milk production levels from 16,000 to 30,000 lbs. of milk per cow were used for the full confinement system. This analysis indicated a 1% decrease in the carbon footprint (lb. CO_2 equivalent/lb. milk) for each 2,000 lb. increase in milk per cow. A herd using summer grazing with a milk production level of 20,000 lbs. of milk per cow had a similar carbon footprint to confinement herds producing 26,000 lbs. of milk or more. The all grass herd with a milk production level of 16,000 lbs. of milk had a carbon footprint similar to the summer grazing and confinement herds listed above. This type of approach needs to be more frequently used by the industry to examine alternative approaches.

SUMMARY

The dairy industry has made great strides in lowering the carbon foot print of milk production. The challenge is to continue to lower the total industry carbon footprint. From a nutrition and herd management perspective, the alteration to be made in the future can be divided into 2 basic categories. These are:

Long-Term:

- These will be applicable over the next 5 to 15 years and will need additional data and research information to provide a base for application. Examples include:
  - Genomics and genetic selection to improve feed efficiency.
  - Opportunities to alter the rumen microbial population (including protozoa and defaunation).
  - Added compounds that can alter methane emissions from the rumen. These will need long-term trials to determine efficacy and also whether or not the response is maintained over a period of time in the animal.

Short-Term:

- These are technologies and practices that will continue to improve the efficiency of feed nutrient use and rumen fermentation. Examples include:
    - Continuing to manage animals for higher levels of productivity and efficiency of nutrient use.
    - Balancing rations using the concepts of fiber and starch digestibility.
    - Utilizing feed additives and production technologies that are based on research data.
    - Selecting forages based on a combination of yield, quality and digestibility.
    - Providing feeding and management systems that improve cow comfort.
    - Improving herd health and reproductive performance.
    - Lowering the age at 1st calving in replacement dairy heifers.

The short-term list above reflects what the industry has already done and has helped the industry attain the current carbon footprint level. All of these areas have made significant contributions in reducing the carbon footprint. They will continue to be the key factors that will help in further reductions while research continues on the items on the long-term list so that they can be implemented.

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