Strategies to Reduce Greenhouse Gas Emissions through Feeding and Grazing Management

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Introduction

At this time, the current Canadian government still remains committed to the Kyoto Agreement, especially in the areas of international collaboration and obligations. However, the government is working towards the development and implementation of a Made-in-Canada plan for reducing greenhouse gases (GHG) and ensuring clean air, water, land and energy for Canadians. Greenhouse gases are atmospheric gases that absorb and re-emit long-wave radiation released by the earth back to the surface and as a consequence average global temperatures are predicted to rise (0.5 to 2.5 0C by 2030) (IPCC 2001). In the Canadian Prairies, temperatures are predicted to increase significantly over the coming century, while predictions for precipitation are much more uncertain and variable (McGinn et al. 2001). These climate changes will greatly impact arable agriculture, especially forage and grazing livestock production, which are directly dependent upon weather and climate. The primary GHG in the earth's atmosphere are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and these gases have risen dramatically during the past century. Of these three gases, CO_2 is the most abundant in the atmosphere and has the greatest effect on global warming. Nitrous oxide is a highly stable gas occurring at lower concentrations than CO_2, but has a stronger effect on warming (about 310 times that of CO_2 - a value referred to as *Global Warming Potential* [GWP]) (CAST 2004). The major agricultural sources of N_2O are from manure handling and storage and commercial fertilizer. Methane is also present in the atmosphere at low concentration and has a GWP of 20 times that of CO_2. Since the mid – 1700s, CH_4 in the atmosphere has increased by 145% and currently is increasing at a rate of about 0.3% per year. One of the largest biogenic (i.e., produced by a living organism) source of CH_4 is digestive fermentation from ruminant animals and it is estimated that about 90% of CH_4 emissions from Canadian agriculture (17.1 Mt CO_2 equivalent, 2.6% of total GHG emissions) comes from ruminants (Environment Canada 2005). Therefore, feeding and grazing strategies to mitigate CH_4 emissions can contribute to reducing overall GHG emissions, as well as, improve Canadian cattle performance. This paper will present some feeding/forage and grazing management strategies that can be utilized by cattle producers to potentially reduce methane emissions.

Enteric Fermentation and Methane Cycle

The major feed component of beef cattle is forages which can constitute more than 80% of the diet of a beef cow. The microbial breakdown of forages and other feedstuffs in the rumen is know as enteric fermentation and results in the production of CH_4. Methane production in the rumen (first of four stomach compartments of a ruminant animal) occurs as a result of the presence of a group of micro-organisms called methanogens that convert organic matter into CH_4. These organisms reside in the reticulo-rumen and large intestine of ruminant animals (e.g., cattle, sheep, goats etc.). About 87% of enteric methane occurs in the reticulo-rumen, while the remainder is produced in the hindgut. A significant portion of the CH_4, about 89-98%, is absorbed and expired through the lungs, with a small amount being excreted through the anus

(Murry et al. 1976; Ominski and Wittenberg 2006). On average the amount of CH_4 produced by a sheep is about 30 litres each day and a dairy cow up to almost 200 litres per day, however, composition of the feed consumed will greatly affect CH_4 production. Losses in gross energy intake (GEI) associated with CH_4 production ranges from 2 to 3% of GEI when animals are fed high-grain diets to 11 to 12% of GEI when consuming low-quality forages (CAST 2004; Ominski and Wittenberg 2006). Therefore, CH_4 production represents a loss of energy to the animal and thus considerable interests by animal scientists have already been focus on decreasing this loss in domestic livestock. Implementation of certain animal feeding and grazing management practices could reduce CH_4 emissions and increase feed efficiency and cattle performance, as well as, mitigate CH_4, a potential Win Win Situation.

About 70% of CH_4 production arises from anthropogenic (caused by human activity) sources and approximately 30% from natural sources (e.g., wetlands, permafrost, oceans, lakes and wildfires). Agriculture is considered responsible for about two-thirds of the anthropogenic sources globally and of this domestically raised ruminants (e.g., cattle, deer, buffalo, sheep and goats) contribute 15 to 20% of the methane emissions caused by human activities (CAST 2004). Carbon is given off as CO_2 when plant material decomposes in the presence of oxygen. When oxygen is absent the decomposition process emits CH_4. Soil micro-organisms convert CH_4 to CO_2 and thus soils are able to absorb CH_4 (Fig. 1). When organic materials decompose in submerged or water-laden soils, the anaerobic (without oxygen) conditions cause the release of CH_4. In the agricultural soils of western Canada, CH_4 emissions can occur in wetland areas and during brief periods when low-lying soils are submerged during snowmelt or after high precipitation (GHGMP 2005).

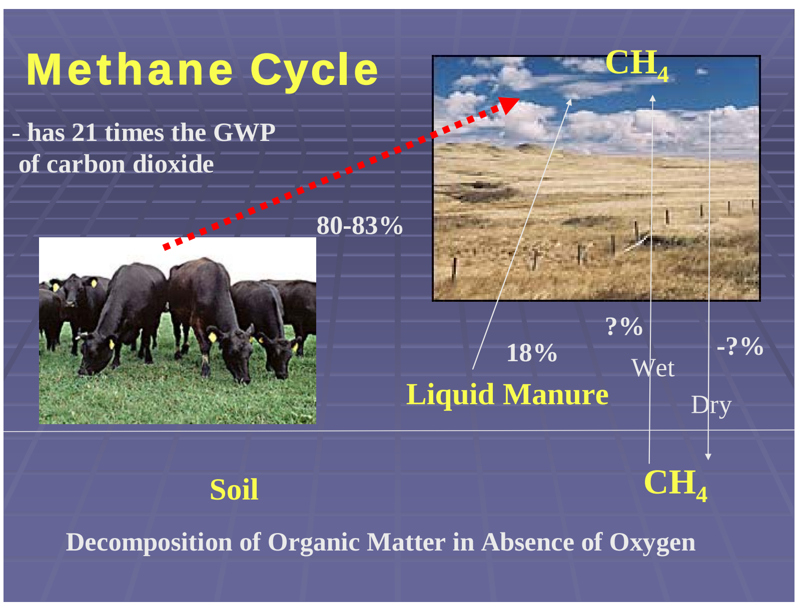


Figure 1. Methane Cycle

The amounts of CH_4 produced by ruminant animals are related to differences in levels of feed intake and extent of digestion, which are influenced by such factors as species, body weight (age), level of production, lactation stage, diet etc. Methane yield also tends to decrease as feed quality increases. For example, a six fold decrease in CH_4 emission was observed when grazing cattle were switched to a high quality feedlot diet (Harper et al. 1999). Boadi and Wittenberg (2002) in Canada observed that a reduction in forage *in vitro* organic matter digestibility (i.e., decline in forage quality) also resulted in an increase in CH_4 emissions when animals were fed *ad libitum*.

Strategies to Reduce Enteric Methane Emissions

Manipulation of Rumen Fermentation

There are a number of mechanisms that can affect the rumen fermentation process within the animal that subsequently will reduce enteric CH_4 emissions. A number of recent reviews on this subject (Boadi et al. 2004; Ominski and Wittenberg 2006) are available that evaluate the pros and cons of the addition of fats to cattle diets, ionophores, defunation, bacteriocins, probiotics, and use of alternative hydrogen acceptors or sinks (e.g., organic acids: malate and fumarate etc). to mitigate CH_4 emissions.

Nutritional and Management Strategies

Forage Quality and Maturity

Boadi and Wittenberg (2002) reported that forage quality has a significance impact on enteric CH_4 emissions. Cattle given hay of high (61.5% *in vitro* organic matter digestibility [IVOMD]), medium (50.7% IVOMD) and low (38.5% IVOMD) qualities had significantly higher dry matter intake and lower enteric CH_4 emissions as forage quality increased. In another study the authors observed the same phenomenon on pasture (Boadi et al. 2002). Steers grazing during the early period of the grazing season had 44 and 29% less energy lost as methane compared to steers grazing during the mid and late grazing periods, respectively. Further, steers experienced a 54% decline in enteric emissions upon entry verses exit of the grazing paddock. Beneficial forage fermentation characteristics resulting in a CH_4 reduction can be attributed to higher biomass availability and better pasture quality. It can be concluded that enteric CH_4 emissions are highest when the animal is presented with poor-quality forage and has limited ability to select higher-quality forage components as a consequence of reduced dry matter availability (Ominski and Wittenberg 2006). In contrast, a study by Pinares-Patino et al. (2003) evaluating beef cows grazing on a monospecific pasture of timothy at four stages of maturity: early vegetative, heading, flowering and senescence observed organic matter intake and CH_4 emissions lower only at heading. Although the research trial was designed to decrease species selection, it did not limit selection of plant parts. Thus, the lack of response associated with maturity may be attributed to animal selection during grazing. Very selective grazing behaviour has been observed in beef cattle that can result in better animal grazing performance than what the forage sward composition would reveal (Iwaasa and Schellenberg 2006; Iwaasa et al. 2006).

Forage Processing and Preservation

Grinding or pelleting of forages to improve the utilization by ruminants has been shown to decrease CH_4 losses per unit of feed intake by 20-40% when fed at high intakes (Johnson et al. 1996). The explanation for the decline in CH_4 production is due to the lower fibre digestibility, decreased ruminally available organic matter and faster rate of passage associated with ground or pelleted forages (LeLiboux and Peyraud 1999). The main limitation to the potential use of more processed forage feed to reduce CH_4 emission is the economical cost to cattle producers. There is limited research information (none from Canada) regarding the effects of ensiling on decreasing enteric CH_4 emissions. Woodward et al. (2001) from New Zealand observed some the of highest CH_4 losses reported in the literature associated with feeding ryegrass silage and lotus silage. This would not be unexpected since digestion is reduced in the rumen with ensiled forages due to the extensive fermentation that occurs during silage making. Often silage additives such as bacterial inoculants and organic acids are added to the ensiling process to enhance the quality and palatability. These ensiling additives can lower acetic acid and increase propionate production and thus reduce enteric CH_4 emissions (Shingfield et al. 2002).

Pasture Management

Several Canadian research studies have examined the impact that pasture and grazing management has on enteric CH_4 emissions. A study by McCaughey et al. (1997) reported that CH_4 production was greatest for steers continuously grazing at low stocking rates (1.1 steer ha^{-1}; 307 L d^{-1}) and least for steers grazing continuously at high stocking rates (2.2 steers ha^{-1}; 242 L d^{-1}). A possible explanation for these observed results for the higher stocking rate may be due to lower forage availability and intake for the grazing animal. When pastures were rotationally grazed, stocking rates had no effect on CH_4 production. At low stocking rates, CH_4 production was 9% lower on rotational grazing than continuous grazing. Measurements of CH_4 production from grazing beef cows found a 25% reduction in CH_4 losses with alfalfa+grass pastures (7.1% of GEI) compared to grass-only pastures (9.5% of GEI) (McCaughey et al. 1997). Boadi et al. (2002) observed early grazing of alfalfa+grass pastures reduced CH_4 production by 29 to 45% in steers compared to grazing at mid and late seasons. Pasture quality is the critical factor in ensuring lower CH_4 emissions from grazing animals in any particular grazing system.

Forage Species and Maturity

It is recognized that CH_4 production in ruminants generally increases with forage maturity and that CH_4 yield from the ruminal fermentation of legume and legume+grass forages is also generally lower than the yield from grass forages (McAllister et al. 1996; Moss et al. 2000). Explanation for the reduced CH_4 emissions can be attributed to the lower proportion of structural carbohydrates in legumes and faster rate of passage, which shift the fermentation pattern towards higher propionate production (Johnson and Johnson 1995). In another grazing study from Utah, researchers (Olson 1997) evaluated the CH_4 emissions from cattle grazing different forage pastures (crested wheatgrass, Russian wildrye and native.) and varieties during a 30-day grazing season in the fall and spring Enteric CH_4 emissions from cattle grazing the different forage species in the fall were the same even though intake was higher and bodyweight loss was less for the Russian wildrye varieties compared to the wheatgrass. In the spring, pasture species also did not affect CH_4 emissions, but bodyweight gains for cattle consuming crested wheatgrass varieties were higher than those animals consuming Russian wildrye varieties. Results from this study shows the opportunity to use grazing management strategies to match pasture forage with animal requirements as a means of optimizing performance with no increase in enteric CH_4 emissions.

In New Zealand, research has been conducted on examining the mitigation potential of condensed tannin forage species, such as sulla *(Hedysarum coronarium*) and birdsfoot trefoil (*Lotus corniculatus*) (Woodward et al. 2002 and 2004). Results from Woodward et al. (2002) observed a 25% reduction per kg of DM intake in CH_4 emissions from dairy cows grazing the legume sulla compared to perennial ryegrass. Similar results were also observed by Woodward et al. (2001 and 2004) when birdsfoot trefoil was grazed verses perennial ryegrass-based pastures. Therefore, condensed tannins present in several forage species appear to reduce methanogenesis and may be an effective technique to lower CH_4 production. Other benefits associated with feeding condensed tannins in ruminant diets include reduced incidence of bloating, intestinal worm populations and improved nutritional benefits of by-pass protein (Ominski and Wittenberg 2006). Research is ongoing at AAFC-SPARC in this area of potential use of non-bloating legumes for grazing, such as, sainfoin (*Onobrychis viciifolia*) and cicer milkvetch (*Astragalus cicer* L.), and there potential to reduce CH_4 emissions in the Canadian production environment.

Recent Research Developments from AAFC-SPARC

In 2003, twelve pastures, each 0.8 ha in size, were utilized in a research study in which six pastures were seeded to sainfoin and the other pastures to an alfalfa+grass mixture. Seeding (first part of May 2003) was done using a disc drill seeder with 30.5 cm row spacing. Targeted seeding rates for the sainfoin (cv. Nova) and alfalfa+grass (cvs. Spredor IV + AC-Knowles) mixture were 30 kg ha^{-1} and 1 + 8 kg ha^{-1}, respectively. The experimental design was a 2 x 2 factorial (forages: sainfoin and alfalfa+grass and pasture utilization: 50 and 70%) with three replications. Methane emissions from grazing steers were measured using the SF_6 tracer gas technique which was initially developed by Johnson et al. (1994) but was modified and improved upon at AAFC-SPARC over the last three years to better measure CH_4 production (Fig. 2).

Figure 2. Methane emission rates being measured using the AAFC-SPARC SF_6 tracer gas technique for steers grazing sainfoin (pink flower) or an alfalfa+grass pasture

The SF_6 tracer gas technique is considered the best method to quantify CH_4 emissions from grazing cattle (McGinn et al. 2006) and has been used successfully in our grazing research at AAFC-SPARC in the last three years. Grazing of the sainfoin pastures were at the full bloom stage while the alfalfa was at 10% bloom for the alfalfa+grass pastures. Preliminary results from the AAFC-SPARC grazing study did not show a consistent reduction in CH_4 emissions from cattle grazing sainfoin over the three years that data were collected (Fig. 3). Only in 2006, in which similar animal production (i.e., average daily gains (ADGs)) was observed (Fig. 4) does there appear to be a reduction in CH_4 emissions for the sainfoin grazed pastures verses the alfalfa+grass pastures. Variation in CH_4 production from grazing cattle is not surprising since many studies have observed conflicting observations due to the abilities of cattle to select certain forages and plant parts with different forage qualities (Ominski and Wittenberg 2006).

Fig. 3. Average methane emissions from grazing cattle.

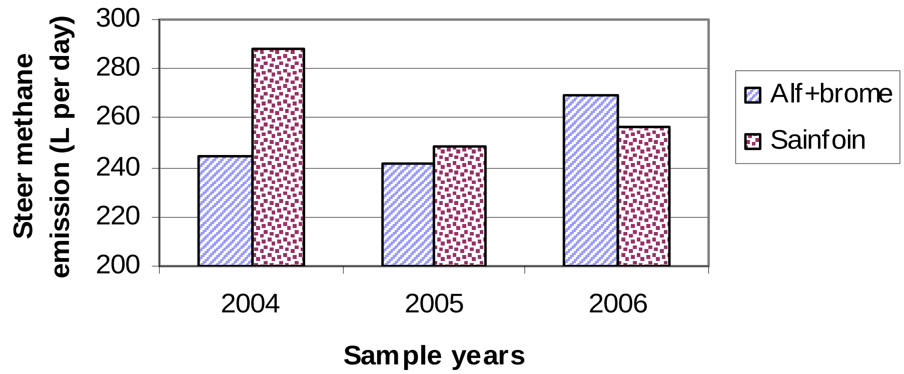
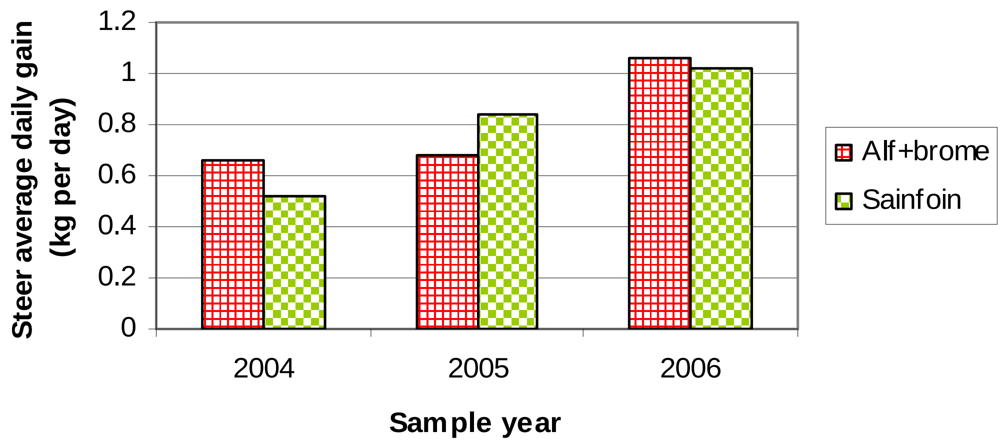


Fig. 4. Average daily gains from grazing cattle.



Due to a herbicide spray effect in 2004 the sainfoin forage production was greatly reduced. This may have required the grazing animals to be less selective in there grazing abilities and forced the animal to graze less desirable plant material (i.e., more stem material etc.) which would explain the higher CH_4 emissions observed for the sainfoin pastures in 2004. Over the last three years of this research study we have observed that steers grazing sainfoin is very distinctive (Iwaasa et al. 2006). Steers prefer to graze the top 10 to 15 cm of the flowering sainfoin plant, which is very nutritious. This in turn results in some very good animal performances (Fig. 4) compared to the alfalfa+grass pastures. Although condensing tannins have been associated with reducing CH_4 emissions in cattle it is unclear whether it is the tannin properties in the sainfoin or the unique grazing behavior of the cattle that may reduce CH_4 production.

Conclusions

There are many methods to reduce enteric methane emissions from cattle in forage-based production systems. These methods include feeding management strategies such as inclusion of legumes in forage mixes and feeding highly digestible forages, improving the feed efficiencies of feedstuff and preservation, selection of certain forage species and pasture management. However, when attempting to develop best management practices to reduce CH_4 emissions under grazing it is important to remember that the grazing animal's attribute and ability to select certain forages will have a profound effect on its performance and CH_4 production.

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