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Feeding high concentrations of corn dried distillers' grains decreases methane, but increases nitrous oxide emissions from beef cattle production

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ABSTRACT

Previous research has shown that feeding high fat corn distiller' grains plus solubles (CDDGS; ~10% fat, dry matter [DM]) reduces enteric methane (CH_4) emission from beef cattle. However, feeding CDDGS (~30% crude protein [CP] DM) or wheat distillers' grains plus solubles (WDDGS; ~40% CP, DM) increases N excretion from beef cattle and the resulting increase in nitrous oxide (N_2O) from manure may offset any CH_4 mediated decrease in greenhouse gas emissions (GHG). The objective of this study was to evaluate the impact of CDDGS and WDDGS inclusion on GHG emissions from beef cattle using a life cycle assessment (LCA). The LCA was conducted using primary data for diet composition, CH_4 emission and N excretion generated in two studies using growing and finishing beef cattle. A representative model farm was simulated using the Holos GHG model (www.agr.gc.ca/holos-ghg), which included 40% DM CDDGS or WDDGS in growing and finishing feedlot diets. The simulation was made relative to the standard practice of using barley grain as the main supplemental energy source in western Canadian beef cattle diets (baseline scenario). Feeding CDDGS (14.98 kg CO_2 equivalent [CO_2e]/kg live weight) and WDDGS (15.41 kg CO_2e/kg live weight) resulted in 6.2 and 9.3% higher GHG intensity compared to the baseline scenario (14.10 kg CO_2e/kg live weight). Using high-fat distillers' grains in the diet of feedlot cattle may decrease enteric CH_4 emissions, but at high dietary levels it increases N excretion and results in a net increase in GHG emissions. To reduce environmental impact, dried distillers' grains should not be included in the diet of feedlot cattle at a level that exceeds N requirements. Manure arising from cattle fed DDGS should be land applied at a level that matches the N requirements of the crop.

1. Introduction

As estimated by Gerber et al. (2013), animal agriculture is responsible for 14.5% of global greenhouse gas (GHG) emissions. Greenhouse gas emissions from beef production systems are of particular interest as beef is associated with a greater GHG emission intensity (kg CO_2 equivalent [CO_2e] per kg product or CO_2e per kg of protein) than other livestock meat (De Vries and de Boer, 2010). Beef production systems emit GHG in the form of enteric methane (CH_4), nitrous oxide (N_2O) from use of nitrogen (N) fertilizer for crop production, CH_4 and N_2O from manure, and carbon dioxide (CO_2) from fossil fuel usage (O'Mara, 2011). The GHG emissions associated with beef arise mainly from the formation of CH_4 during enteric fermentation in the rumen, as well as the lower feed conversion efficiency and lower reproduction rates of cattle as compared to swine and poultry (De Vries and de Boer, 2010). Intake and diet composition are the two factors that have the greatest influence on enteric CH_4 emissions and N excretion in cattle (Eckard et al., 2010; Johnson and Johnson, 1995). Depending on farming practices ruminant production can also associated with land-use change emission due to deforestation for feed cropping and pasture production or grassland degradation due to overstocking (Gerber et al., 2013).

To reduce GHG emissions and dependence on fossil fuels, governments have supported the production of fuel from renewable sources leading to an exponential growth in ethanol production.

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In 2011, global ethanol production was 85 billion litres, with the United States (52.6 billion litres) and Canada (1.7 billion litres) accounting for 63.9% of production (RFA, 2012). While ethanol in the United States is produced primarily from corn, wheat accounts for one third of total ethanol production in Canada (USDA Foreign Agricultural Service, 2010). Dried distillers' grains plus solubles (DDGS) is the principal by-product of ethanol production. Due to its high energy content, DDGS most often to replaces feed grains (Klopfenstein et al., 2008), and to a lesser extent forages (Li et al., 2011) in ruminant diets. Replacing 35% of barley grain (dry matter [DM] basis) with corn-based DDGS (CDDGS) reduced enteric CH_4 emission (% of gross energy [GE] intake) from growing beef cattle fed a high forage, barley silage-based diet from 7.1% to 5.4% (McGinn et al., 2009), a response thought to be due to the fat (12.7%) in CDDGS.

Recent research has shown that replacing a mixture of 35% barley grain and 5% canola meal (DM basis) with CDDGS in a high forage diet reduced enteric CH_4 emissions from beef cattle from 7.8% to 6.6% of GE intake. However, inclusion of 40% WDDGS (DM basis) had no effect on CH_4 emissions (7.3% of GE intake; Hünerberg et al., 2013a). Similarly, replacing 40% of barley grain DM with CDDGS in a high grain diet reduced CH_4 emissions from 5.0% to 4.0% of GE intake, while WDDGS (5.5% of GE intake) had no effect on enteric CH_4 emissions (Hünerberg et al., 2013b). Results from both experiments indicated that the higher fat content of CDDGS (~10% fat) as compared to WDDGS (<5% DM fat; both DM based) was responsible for the reduction in CH_4. However, replacing barley grain (~12.0% crude protein [CP]) with CDDGS (~30% CP) or WDDGS (~40% CP; all DM basis) dramatically increased N intake and excretion in both studies (Hünerberg et al., 2013a, b). Increases in N excretion could outweigh any reduction in enteric CH_4 through increased formation of N_2O. Furthermore, higher net GHG emissions from beef cattle operations that use CDDGS or WDDGS compared to those that use cereal grains could reduce the GHG mitigation benefits of corn and wheat based ethanol production as compared to fossil fuel. Therefore, the impact of replacing cereal grains with CDDGS or WDDGS on GHG emissions from the beef production cycle needs to be evaluated in an in-depth assessment quantifying all changes in GHG emissions at the whole farm level.

The objective of this study was to evaluate the impact of CDDGS or WDDGS inclusion in feedlot diets on GHG emission from beef cattle using a life cycle assessment (LCA). This assessment was conducted using primary data for enteric CH_4 and N excretion generated in two experiments using growing and finishing beef cattle fed CDDGS or WDDGS (Hünerberg et al., 2013a, b).

2. Materials and methods

In order to estimate GHG emissions from beef cattle fed CDDGS or WDDGS we simulated a representative model farm, which implemented these feeding practices under typical western Canadian management conditions. This simulation was made relative to the previous feeding practice of using barley grain as the main supplementary energy source in the diet of feedlot cattle.

2.1. Description of the beef life cycle

The North American beef production cycle typically consists of a separate cow–calf and feedlot stage. Cow–calf farming or ranching operations maintain herds of mature cows. The cows are bred and the calves are raised to weaning (Beauchemin et al., 2010; Vergé et al., 2008). Cow–calf operations are usually located on pastureland that is largely unsuitable for crop production. After the calves are weaned from the cows, a proportion of the calves are retained on-farm as replacement heifers for cull cows within the breeding herd. The remaining calves destined for market (males are typically castrated) are moved into confined feedlots where they are fed until market weight. At the beginning of the feedlot phase calves are typically fed a growing (high forage) diet. To maximize energy intake and promote marbling, cattle are later transitioned to a high grain finishing diet. Finishing diets are fed until the cattle are slaughtered. Replacement heifers are typically fed a high forage diet similar to that fed during the growing phase. Replacement heifers are reintegrated into the cow herd once they reach breeding age (Beauchemin et al., 2010).

2.2. Description of the model farm

Even though CDDGS and WDDGS were fed only during the feedlot phase, emissions associated with the cow calf stage were included in our LCA. This ensures the effects of this feeding practice are cycled through the entire system to the end product, or functional unit, which in this LCA was defined as 1 kg of cattle live weight. The model farm simulated in this LCA is similar to that of Beauchemin et al. (2010); therefore only a brief description is provided.

The simulated model farm was located in the county of Vulcan in southern Alberta, Canada (Ecodistrict 793; Marshall et al., 1999) and consisted of a cow–calf operation on native mixed-grass pasture, a feedlot and the cropland required to grow barley grain and silage to feed feedlot cattle and mixed hay as winter feed for the cow herd. The soil type was a dark brown Chernozem managed under reduced tillage practices. Average growing season precipitation (May–October) for this ecodistrict is 277 mm and potential evapotranspiration is 653 mm (Marshall et al., 1999). The simulated beef herd consisted of 120 cows, four bulls, and their progeny, which were fed within a feedlot. The LCA consisted of growing the breeding stock from birth to maturity within the beef production cycle. This encompassed a time period of eight years, a representative breeding life span of cows in this production system (Bailey, 1991). The beef LCA started with the birth of the breeding stock and ended, eight years later, with the replacement and slaughter of the initial breeding stock. Total GHG emissions from the beef herd were calculated by summing the emissions for the 120 cows, four bulls, and all feedlot cattle for one complete 8-year cycle. Over the first 6 years the herd of 120 cows produced 102 calf/yr of which 98 were successfully finished in the feedlot and marketed for meat. The 102 calves produced in the seventh cycle, and an additional 22 calves from the sixth cycle, were used to completely replace the cows and bulls in the reproductive herd.

After entering the feedlot at an average body weight of 240 kg, weaned calves were fed a high forage diet comprised of 55% barley silage, 38% barley grain, 5% canola meal and 2% mineral and vitamin supplement (DM basis; baseline scenario). In the CDDGS and WDDGS scenarios, 35% barley grain and 5% of canola meal were replaced by 40% CDDGS or WDDGS, respectively (DM basis, Table 1). All three growing diets were assumed to result in a similar average daily gain (ADG) of 1.0 kg/d as predicted by NRC (2000). Once the calves reached an average body weight of 350 kg, they were switched to a 90% barley grain, 8% barley silage and 2% mineral and vitamin supplement (DM basis; baseline scenario) finishing diet. In the finishing DDGS scenarios, 40% of barley grain was replaced with CDDGS or WDDGS (DM basis). Similar to the growing phase, NRC (2000) predicted ADG during the finishing phase (1.5 kg/d) were utilized and assumed to be constant across diets. After being offered their respective growing and finishing diets for 110 and 170 d, respectively, cattle were marketed at 605 kg. Heifers required to replace cull cows in the breeding herd were fed the growing baseline diet for five months post-weaning.

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