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# Ammonia and greenhouse gas emissions at beef cattle feedlots in Alberta Canada

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ABSTRACT

This study was conducted at beef cattle feedlots, over two years in southern Alberta Canada, and focused on deriving the ammonia, methane, nitrous oxide and carbon dioxide emissions from two feedlots from June/July to October. Line-averaging sensors were used to measure ambient gas concentrations in the vicinity of the feedlots, and an inverse dispersion method was used to calculate emissions. Results show that ammonia and methane emissions were consistent with that measured from other studies. Both feedlots lost about 40% of the nitrogen feed intake as ammonia. The emission of nitrous oxide, when compared on a greenhouse gas bases, was similar to the methane emission. A diet difference between feedlots coincided with a slight difference in feedlot methane emission. There was good agreement between previously reported ammonia and methane emission rates and those derived in our feedlot study. Further evaluation of the underlying relationships causing variation in emissions should follow. A key to understanding emissions at commercial feedlots is to fully engage the management data available.

## 1. Introduction

Beef cattle feedlots, where thousands of cattle are grouped together to enable greater control of feed management and meat production, are hot spots in the agricultural landscape for ammonia ($NH_3$), methane ($CH_4$) and nitrous oxide ($N_2O$). Ammonia emitted from cattle manure is affiliated with various ecosystem and human health concerns, and is also an indirect greenhouse gas (GHG). Feedlots are also sources of direct GHG's including $CH_4$ eructated from the cattle rumen and $N_2O$ and $CH_4$ emitted from cattle manure (Rahman et al. 2013). As well, cattle respire carbon dioxide ($CO_2$); however, this source is not generally considered a net GHG contributor since the carbon is assumed to be re-cycled within the agricultural system. Quantifying the emission rate of these environmentally important gases is essential to our understanding of the impact of agriculture on the ecosystem. Ideally, the emission rates of these different gases should be measured simultaneously to account for any interactions between their emissions (Leytem et al. 2011; Bai et al. 2015). For example, Hünerberg et al. (2014) found that an increase in dietary dried distillers' grain (DDG) coincided with a reduction in cattle enteric $CH_4$ emissions due to an response to fat, but a corresponding increase in DDG crude protein (CP) equated to greater manure $NH_3$ emission and the potential for increased deposition and more surface $N_2O$ emission.

There are several methods available to measure gas emissions from distinct sources (Harper et al. 2011; McGinn 2013), where each method is generally associated with a specific spatial scale. For example, at the individual animal scale, face masks, head-hood chambers, whole-animal chambers and tunnels, and a ratiometric approach using a tracer gas (e.g., $SF_6$), are used. At a larger scale encompassing emissions from entire animal facilities, micrometeorological approaches such as the inverse dispersion method (IDM) have the advantage of not interfering with the management of the animals.

Quantifying the enteric $CH_4$ emissions from a cattle feedlot using an IDM technique can be a difficult task, where the scale is large and the source distribution is not uniform due to cattle movement within the facility. Similar concerns exist for $NH_3$, but with the added difficulty that monitoring concentration is complicated due to its highly reactive nature, e.g., deposition to a crop. Despite these limitations, advancements in measurement techniques and sensors have allowed for simultaneous measurements of gas concentrations at cattle feedlots (Bai et al. 2015).] The objective of our study was to evaluate whole-feedlot emission measurements of $NH_3$, $CH_4$, $N_2O$ and $CO_2$ using IDM at two

*Abbreviations:* bLS, backwards Lagrangian stochastic; FTIR, Fourier Transfer Infrared; IDM, inverse dispersion method; LAL, line-averaging laser; N, nitrogen; NC, number of cattle; TAN, total ammonical nitrogen

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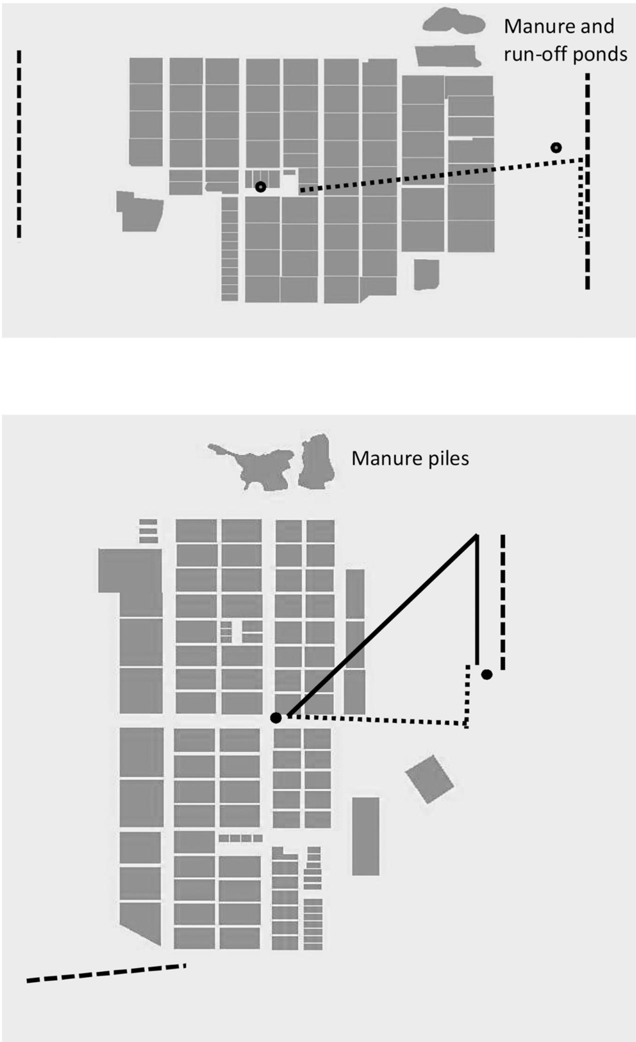


**Fig. 1.** Location of feedlot pens and instrumentation at Feedlot A in 2015 (upper; adjacent field to east was planted to winter wheat) and Feedlot B in 2016 (lower; adjacent field to east was grassland). The dots are the location of the sonic anemometers, dotted line is FTIR $N_2O$ and $CO_2$ scanner paths, dashed lines show the $CH_4$ and $NH_3$ paths, and the solid line is the location of the $NH_3$ scanner paths.

feedlots where cattle management and production are different. The potential impact of this study will be an evalution of the usefulness of an IDM technique in assessing the accuracy of emission factors for inventory and mitigation research.

## 2. Materials and methods

### *2.1. Feedlot site information*

In 2015 a commercial feedlot close to Lethbridge, Alberta (Feedlot A; latitude 49° 45'N, longitude 112° 38'W) was monitored. The feedlot had a one-time capacity of approximately 8000 cattle (*Bos Taurus)* and an initial feedlot area of 16.2 ha (reduced to 12.5 ha later in the season due to pen reconstruction). The land to the east of the feedlot was planted to winter wheat (*Triticum aestivum* L.) the previous fall. A pasture west of the feedlot (Fig. 1) containing fewer than ten grazing cattle. The topography surrounding the feedlot was flat, with few obstructions (e.g., trees or buildings) nearby that could alter the wind flow.

In 2016, measurements were made at a feedlot about 10 km from the first feedlot (Feedlot B; latitude 49° 50'N, longitude 112° 41'W). Feedlot B had a one-time capacity of about 9500 cattle and the pen area capacity was 19.1 ha, but after accounting for empty pens the occupied area ranged from 13.6 ha in July to 10.0 ha in October 2016. The landscape surrounding feedlot B consisted of irrigated pastures (with no cattle; Fig. 1), and the irrigation schedule occasionally interfered with our equipment and restricted the measurement days available.

At Feedlot A, average number of cattle in summer and fall (our measurement period) was 5190 (ranged from 2536 to 7369) and the average weight of cattle was 557 kg as given in the feedlot record. At Feedlot B, the average number of cattle during the study period was 8110 (ranged from 7489 to 9445) and the average weight was similar to Feedlot A at 542 kg. In both feedlots, the typical residing time of cattle was about 120 days and the average daily gain was 1.5 kg $day^{-1}$.

### *2.2. Feedlot diets*

At both feedlots, several diets were fed to the cattle which varied from pen to pen, ranging from background diets (high barley and corn forage at A and high barley forage at B) to finishing diets (high grain). The ingredients of each diet (Table 1) was obtained from the feedlot weekly records. The feeds were sampled and crude protein (CP %) was analysed weekly. The CP, number of cattle (NC), and dry matter intake (DMI) was used to derive the weekly nitrogen (N) intake per animal (Table 2).

The majority of the cattle in each feedlot consumed a high grain diet (Table 1). However, the grain fed at Feedlot A was 100% barley, while at Feedlot B the grain component consisted of 35% wheat and 65% barley grain.

### *2.3. Pen manure information*

Typically, the manure in the feedlot pens is removed twice a year and spread on local fields directly, followed by tillage within 24 h. The pen runoff liquid is accumulated in ponds and is spread on crop land usually in the fall. The manure in our feedlot pens was sampled and analyzed weekly for pH, moisture content and total N. The manure sampling was done at the same pens each week, where a specific diet was fed. Only the major fed diets were considered (encompassing > 85% of the cattle), i.e., pens with few cattle on special rations were ignored. Manure was sampled by combining the freshly excreted feces from 3 or 4 animals. The single sample from each pen was immediately analyzed for pH and the wet sample weighed. The manure samples were frozen prior to analysis, dried (deriving water content), ground using a ball mill (Mixer Mill MM 2000, Retsch, Haan, Germany) and analyzed for total N concentration using flash combustion and thermal conductivity detection (Carlo Erba Instruments, Milan, Italy).

### *2.4. Atmospheric gas and turbulence measurements*

Gas emissions were determined from the feedlot using IDM. This method calculates emissions based on the enrichment in gas concentration (above the upwind background concentration) measured either over the feedlot or downwind of the feedlot, together with wind information. Gas sensors were placed in fields surrounding the feedlot in order to measure both the upwind and the downwind concentrations as descripted below.

#### *2.4.1. Feedlot A (2015)*

Several sensor configurations were used at Feedlot A over the 130 days between June 22 (DOY 173) and October 30 (DOY 303). Earlier deployment of equipment was not possible due to irrigation scheduling of the winter wheat adjacent the feedlot. Monitoring was interrupted for 20 days between August 7 (DOY 219) and 27 (DOY 239) to allow harvesting of the winter wheat and post-harvest tillage. On July 19 (DOY 200), the cattle in the eastern pen block (Fig. 1) were removed and manure was then hauled to nearby fields. Beginning September 14 (DOY 257) these pens were removed (fences and bunks), scrapped and