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CH_4 and N_2O emissions from China's beef feedlots with ad libitum and restricted feeding in fall and spring seasons

Zhi Lin [a], Wenhua Liao [a], Yuanyuan Yang [a], Zhiling Gao [a,*], Wenqi Ma [a], Dianwu Wang [a], Yufeng Cao [b], Jianguo Li [b], Zhenjiang Cai [c]

[a] College of Resources and Environmental Sciences, Agricultural University of Hebei, 071000 Baoding, PR China
[b] College of Animal Science and Technology, Agricultural University of Hebei, 071000 Baoding, PR China
[c] Mechanical and Electric Engineering College, Agricultural University of Hebei, 071000 Baoding, PR China

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ABSTRACT

Accurately quantifying methane (CH_4) and nitrous oxide (N_2O) emissions from beef operations in China is necessary to evaluate the contribution of beef cattle to greenhouse gas budgets at the national and global level. Methane and N_2O emissions from two intensive beef feedlots in the North China Plain, one with a restricted feeding strategy and high manure collection frequency and the other with an ad libitum feeding strategy and low manure collection frequency, were quantified in the fall and spring seasons using an inverse dispersion technique. The diel pattern of CH_4 from the beef feedlot with an ad libitum feed strategy (single peak during a day) differed from that under a restricted feeding condition (multiple peaks during a day), but little difference in the diel pattern of N_2O emissions between two feeding strategies was observed. The two-season average CH_4 emission rates of the two intensive feedlots were 230 and 198 g CH_4 animal^{-1} d^{-1} and accounted for 6.7% and 6.8% of the gross energy intake, respectively, indicating little impact of the feeding strategy and manure collection frequency on the CH_4 conversion factor at the feedlot level. However, the average N_2O emission rates (21.2 g N_2O animal^{-1} d^{-1}) and conversion factor (8.5%) of the feedlot with low manure collection frequency were approximately 131% and 174% greater, respectively, than the feedlot under high frequency conditions, which had a N_2O emission rate and conversion factor of 9.2 g N_2O animal^{-1} d^{-1} and 3.1%, respectively, indicating that increasing manure collection frequency played an important role in reducing N_2O emissions from beef feedlots. In addition, comparison indicated that China's beef and dairy cattle in feedlots appeared to have similar CH_4 conversion factors.

1. Introduction

China's beef slaughters and beef cattle in stock increased by 78-fold and 70%, respectively, from 1961 to 2010, which led to a 104-fold increase in the beef meat produced. Methane and N_2O emissions from beef production in China are major contributors to the total emissions from animal production at the national and global scale. For example, the enteric CH4 from China's beef production contributed approximately 58% of enteric CH_4 from China's animal production and accounted for approximately 10% of the global enteric emission of beef production (Food and Agriculture Organization of the United Nations, 2006). In contrast, CH_4 from manure storage in China's beef production only accounted for approximately 1.3% of the national CH_4 emission from animal manure storage and accounted for approximately 2.5% of global CH_4 emissions from beef manure storage. In addition, N_2O emissions from beef production in China also play an important role in the global N_2O budget. For example, approximately 8.5% of global beef manure N_2O and approximately 5.2% of China's animal manure N_2O was attributed to beef production in China.

Due to the large CH_4 and N_2O emissions from China's beef production, efforts characterizing their role at the national, regional, or global scales have been made from different aspects. For example, Khalil et al. (1993) used the IPCC Tier 1 methodology to estimate CH_4 emissions from China's beef production during the period 1900–1988. Streets et al. (2001) calculated the enteric and manure CH_4 emissions from beef production in China, where the calculations were based upon the method and emission rates available in the China Climate Change Country Study (CCCCS, 1999). In addition, other studies estimating greenhouse gas emissions from beef production in China were also conducted

* Corresponding author. Fax: +86 312 7528200.
E-mail address: zhilinggao@hotmail.com (Z. Gao).

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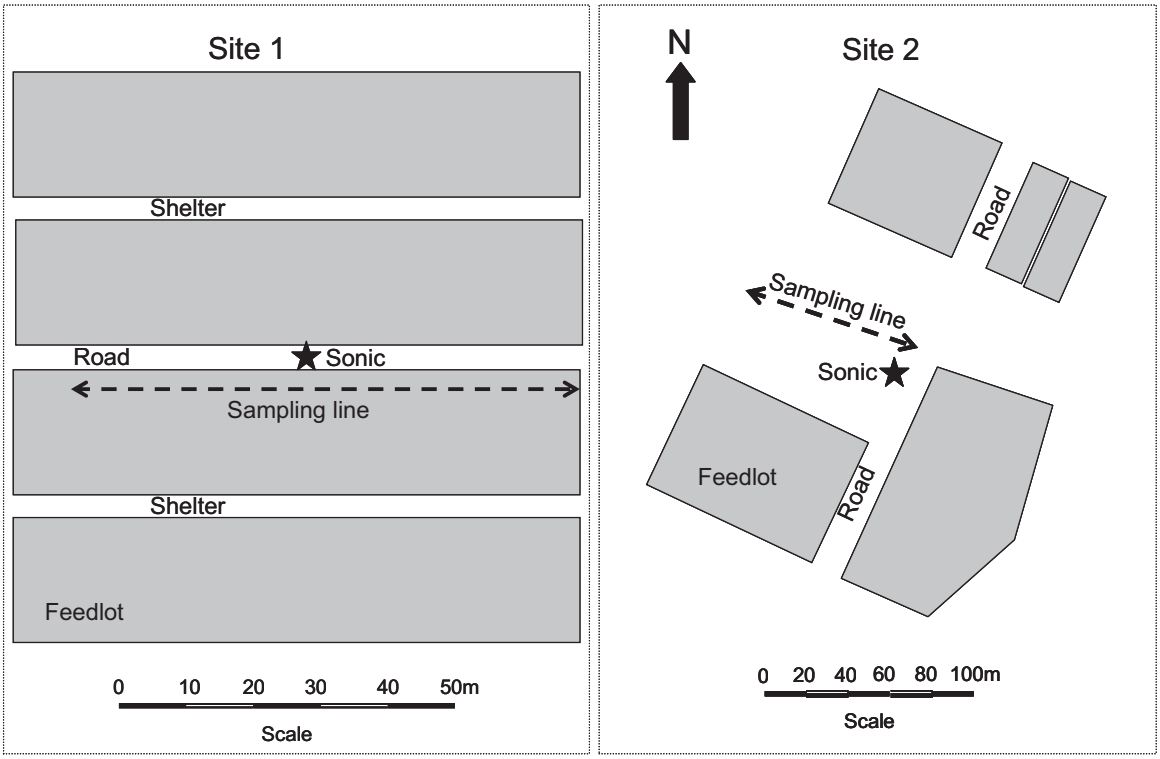

Fig. 1. Layout of the beef feedlot and instruments during experimental periods. Site 1 in Cangzhou applied restricted feeding strategy, and Site 2 in Hengshui applied ad libitum feeding strategy.

(Braatz et al., 1996; Dong et al., 1996; Yamaji et al. 2003). Through these previous efforts, it can be seen that the estimation is mainly based upon the default emission factors from the IPCC methodology due to the lack of intensive in situ measurements of emissions from China's beef operations.

Beef cattle in China were raised under various conditions e.g., intensive vs. extensive operations, temperate vs. cold regions, ad libitum vs. restricted feeding. The impacts of the above factors on greenhouse gas emissions from China's beef production have not been investigated yet. It is difficult to provide insightful management practices to mitigate greenhouse gases emissions from beef production due to the lack of an accurate understanding of the characteristics of CH_4 and N_2O emissions. Uncertainties in the emission estimates are large due to the complexities involved in beef production (Oenema et al., 2005), and clarification of greenhouse gases emissions from beef production in China is essential to aid decision-making processes (Kanemoto et al., 2014). Therefore, it is necessary to carry out field campaigns to evaluate the characteristics of CH_4 and N_2O emissions from beef production in China.

In this study, a widely used inverse dispersion technique (Flesch et al., 1995, 2004) in conjunction with an auto-sampling unit (Zhu et al., 2014), which has the potential to minimize spatio-temporal variability due to its large footprint area and frequent estimates, was employed to quantify CH_4 and N_2O emissions from one intensive beef feedlot applying ad libitum feeding and a low manure collection frequency and one feedlot with a restricted feeding strategy and a high manure collection frequency to indicate their impacts on (1) the diel variation of CH_4 and N_2O emissions and (2) CH_4 and N_2O conversion factors of beef production in the North China Plain.

2. Materials and methods

2.1. Description of the experimental sites

Two intensive beef (mainly simmental) feedlots located in Cangzhou and Henshui in the North China Plain (NCP) were selected to characterize their CH_4 and N_2O emissions. In these two feedlots, the initial bodyweights (BW) of beef cattle were 250–300 kg animal^{-1} and finisher BWs were about 550 kg animal^{-1}. Field measurements were carried out from September 3 to 28 2013 (fall) and from May 16 to June 12 2014 (spring) in Cangzhou and from October 21 to November 19 2013 (fall) and from March 15 to April 11 2014 (spring) in Hengshui. During the experimental period, the number of beef cattle were 290–312 animals with an average BW of ~420 kg animal^{-1} in four pens at the Cangzhou feedlot and 1105–1251 animals with an average BW of ~430 kg animal^{-1} held in four pens at the Hengshui feedlot. The stocking densities were approximately 12 and 20 m^2 animal^{-1}, respectively (Fig. 1). In addition, the feedlot floor in Cangzhou was earthen and the manure was manually removed each day (i.e., high manure collection frequency). The Hengshui feedlot was paved with bricks, and manure was manually removed once a week (low manure collection frequency). There were no significant CH_4 and N_2O emission sources, such as animal operations that existed around the selected experimental feedlots.

During the measurement period, the restricted feeding strategy[1] at the Cangzhou feedlot was applied and the beef cattle were fed twice a day at 0800 h and 1730 h. At the Hengshui

[1] For the Canghou feedlot with restricted feeds, cattle were provided with predetermined amount of feeds that can be consumed completely, basically no residual can be left. With this strategy, the eating duration can be narrowed within a short period, usually less than 1 h. But for Hengshui feedlot ad libitum strategy, feeds were provided twice day just to keep the cattle have enough to eat, and the eating may occur all time of a day. Generally the ad libitum feeding is considered a strategy that can increase the daily dry matter intake.