GLOBAL EMISSION RATE OF NITROUS OXIDE FROM CATTLE THEMSELVES

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ABSTRACT

Methane (CH_4) emission from enteric fermentation and nitrous oxide (N_2O) emission from animal waste have been investigated. However there appear to be no quantitative data of *in vivo* production of N_2O. Accordingly, in our first experiment three dry Holstein cattle were studied in separate flow-through type metabolic chambers for a 24-hour period to clarify whether N_2O is released from cattle themselves. The daily N_2O emission from the chambers ranged between 4.8 and 12.7 (mean, 10.0) mg N_2O -nitrogen. In the second experiment, the first 24-hour N_2O emission from fresh waste mixture (feces: urine = 10: 1) was 2.8 mg N_2O-nitrogen for dry dairy cattle. In the third experiment, the N_2O concentration in the rumen gas phase showed a tendency to increase at 3 hours after feeding. This increase was 9 ± 11 ppb. From these results, the daily and yearly N_2O emissions from cattle were calculated to be 5.2 ± 4.15 mg N_2O-nitrogen and 2.64 ± 1.65 g N_2O -nitrogen, respectively. The global N_2O emission from cattle was estimated to be 3560 ± 2220 tons N_2O-nitrogen per year, based on our results and the global cattle population (FAO, 2000). This N_2O emission from cattle was approximately 0.02% of the total global N_2O emission and approximately 0.17% of the global N_2O emission from cattle and feedlots.

1. INTRODUCTION

Methane (CH_4) and nitrous oxide (N_2O) are very important greenhouse gases, because these gases have higher greenhouse warming potential than carbon dioxide (IPCC, 2001). The CH_4 emission from enteric fermentation and the N_2O emission from animal waste management have been investigated. The total global N_2O budget was estimated to be 17.7 Tg (=10^{12} g)-Nitrogen/year (IPCC, 2001). Cattle and feedlots are responsible for 26% of N_2O emissions from anthropogenic sources (8.1 Tg-Nitrogen) (IPCC, 2001). Although the nitrate reduction reaction may release small amounts of N_2O in the gut (Jones 1972, Kaspar and Tiedje, 1981), animals themselves are thought to be very small sources of N_2O (IPCC, Revised 1996). The highly anoxic environment of the gut should favor the formation of NH_3/NH_4^+ instead (Tiedje, 1988). However there appear to be no quantitative data of *in vivo* production of N_2O.

Accordingly, we investigated the contribution of direct N_2O emission from cattle to global N_2O emission.

2. MATERIALS AND METHODS

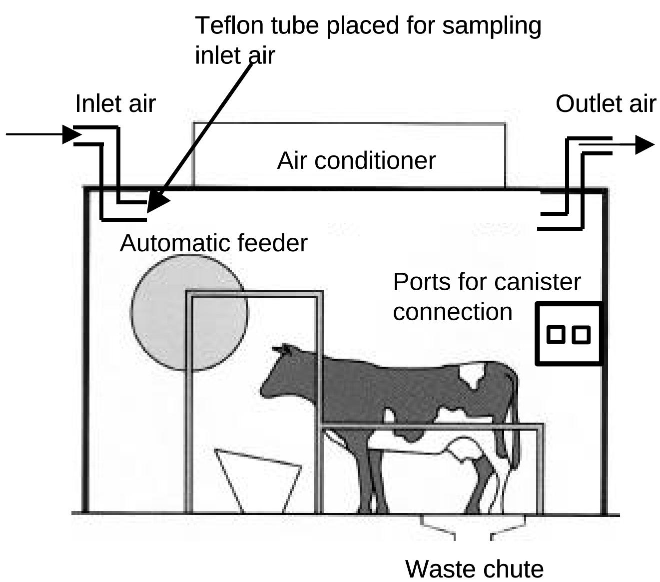

Figure 1. The volume of the cow chamber was 14,000 L. The air flow rate throughout each chamber was controlled as described in the text. A teflon tube was placed inside the inlet pipe, and the other end was connected to a port located on the side of the chamber. This allowed sampling of the air just before entering the chamber. The other port was used to sample air in the chamber. Waste were dropped through an opening on the floor just behind the cow leading to a waste separating device on the floor below.

2.1 EXPERIMENT 1

Three dry Holstein cattle were housed in separate indirect open-circuit respiration chambers (Iwasaki et al., 1982) where the flow rate, temperature, and humidity were monitored for a 24-hour period. They were fed at 9:30 and 16:30. Figure 1 illustrates the chamber and its configuration. During each experiment the airflow through the 14,000L chamber was controlled at a constant rate (300 – 350 L/min) and varied <1.5%. Animal waste dropped through a 40 X 70 cm opening beneath the hindside of the cow. Samples of the chamber air were taken from the port located on the side of the chamber where evacuated canisters could be connected. In order to sample the air prior to entry into the chamber, a teflon tube was connected from the location of the air inlet to one of the ports on the side of the chamber. The amount of N_2O emitted by each experimental cow was the difference between the amount of N_2O leaving the chamber and [the amount of N_2O entering the chamber, namely N_2O emission = (flow rate * ((outlet N2O concentration) – (inlet N_2O concentration)).

2.2 EXPERIMENT 2

It is possible that some of the observed N_2O elevation measured in the chambers was due to gases produced in the waste reservoirs beneath the floor of the chamber. To investigate the possibility of significant emission from the dropped animal wastes, we performed experiments on the waste reservoirs.

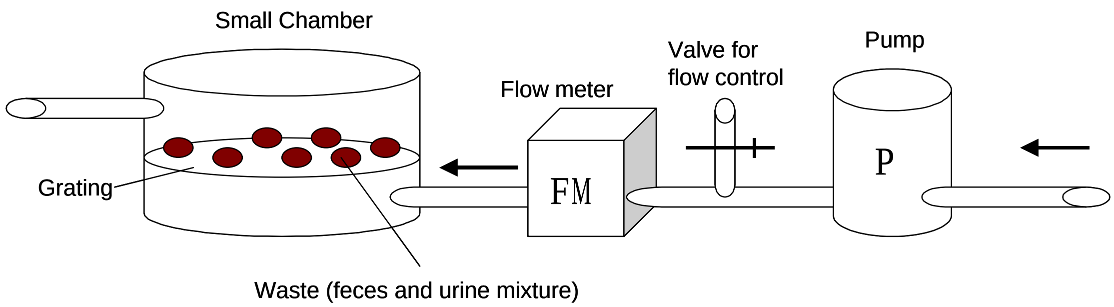

Figure 2. Diagrams for measuring nitrous oxide emission from waste (feces and urine mixture)

We took feces and urine samples from three dry Holstein cattle and four lactating Holstein cattle, and mixed feces and urine at a rate of 10 to 1. We covered these waste mixtures and ventilated the chamber (Figure 2.). We extracted several air samples during 24 hours, and analyzed N_2O concentration in the samples.

2.3 EXPERIMENT 3

Gas samples were directly collected from the rumen of three dry Holstein cattle and four lactating Holstein cattle through the rumen cannula before feeding and three hours of after feeding. They were fed on four kinds of diets: dry cattle, 100 - 40 % forage and 0 - 60 % concentrate; lactating cattle, 40 - 60 % forage and 60 - 40 % concentrate.

2.4 Analysis methods

The N_2O concentration was determined using a gas chromatograph (Shimadzu GC-14A, Japan) equipped with a ^{63}Ni electron capture detector

(ECD). In N_2O analysis, the interfering O_2 contained in the injected air samples was separated by a precolumn (Porapac N, 1.0 m) and vented by a 10-port valve. The precolumn and the [main column] (Porapac Q, 3.0 m) were run with 30 mL min^{-1} 5 % CH_4 in air of carrier flow at 85 C. Calibration was performed using N_2O standard gases.

3. RESULTS AND DISCUSSIONS

3.1 NITROUS OXIDE EMISSOION FROM THE CHAMBER

The concentrations of N_2O measured in Experiment 1 are shown in Figure 1. The N_2O concentrations of air samples just before reaching the chamber (incoming air) were relatively constant, and ranged from 314 ppb to 329 ppb (mean value, 321 ppb), which value was virtually identical to the global mean (314 ppb) (IPCC, 2001). The N_2O amounts inside the flow-through chamber ranged from 321 ppb to 385 ppb (mean value, 339 ppb). Although methane production significantly increases after feeding (Williams et al., 1999), the increase in N_2O concentration after feeding was not significant. There were no clear peaks after feeding at 9:30 and 16:30; however, the N_2O concentration in daytime hours (348 ± 16 ppb) tended to be higher compared to that at night (330 ± 5 ppb).

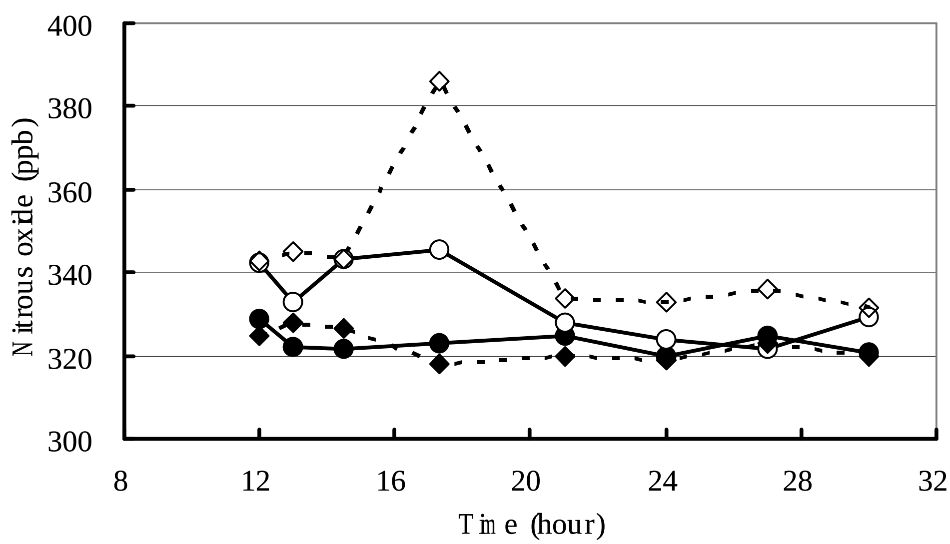

Figure 3. Measured nitrous oxide concentrations inside the flow-through chamber for cow A (open circle with solid line) and B (open lozenge with dashed line), and in the air just before entering the chambers for cow A (solid circle with solid line) and cow B (solid lozenge with dashed line). Arrows represent each time (9:30 and 16:30) the cows were fed.

The differences in N_2O between incoming air and outgoing air in the chambers ranged from –3.2 ppb to 68 ppb with a mean value of 17 ppb. The daily N_2O output from the chambers was calculated to be from 4.8 to 12.7 mg N_2O-nitrogen with a mean value of 10.0 mg N_2O -nitrogen.

3.2 DAILY NITROUS OXIDE EMISSION FROM FRESH WASTE

The results of experiment 2 are shown in Table 1. The first 24-hour N_2O emission from the fresh waste, a 10:1 mixture of feces and urine, was 2.8 and 13.1 mg-Nitrogen for dry and lactating dairy cattle, respectively. These emission rates were 0.03 and 0.07 g N_2O-nitrogen per kg nitrogen in the waste.

Table 1. Nitrous oxide (N2O) emission from fresh waste of dairy cattle

	Number	N2O-N (mgN/day)	N2O-N/waste-N (%)
Dry dairy cattle	3	2.8 (0 – 8.3)	0.003
Lactating dairy cattle	4	13.1 (6.1 – 31.9)	0.007

There is very limited information available on N_2O emission from animal waste during storage and treatment (IPCC, revised 1996). Oenema and Velthof (1993) reported that N_2O losses from cattle slurry during storing for up to 6 months, with two minutes of gentle mixing twice a week, were below the detection limit (10^{-4} kg N_2O -nitrogen per kg nitrogen in slurry). Our results are approximately 1/3 – 1/2 of those in their report. Our results imply that N_2O emission from fresh waste in a barn during the first day is relatively small.

In Experiment 1 it is possible that some of the observed elevation in concentration measured in the chambers for the N_2O was due to gases produced in the waste reservoirs beneath the floors of the chambers. The results of Experiment 2 indicate that, for the dry cattle, 28% (2.8*100/10.0) of the daily N_2O emission from the chamber was derived from waste reservoirs.

3.3 NITROUS OXIDE CONCENTRATION INSIDE RUMEN

The results of Experiment 3 are shown in Table 2. The N_2O concentration of the rumen gas phase tended to increase at 3 hours after feeding. This tendency coincided with the result from Experiment 1 of higher N_2O concentration observed during the daytime. Although the N_2O concentration tended to be higher for lactating cattle than for dry cattle, the increase (11 ppb) after feeding for the lactating cattle was similar to that (9 ppb) for dry cattle. However, there were no significant differences between these data and the N_2O concentration (316 ppb) inside the animal barn. The globally averaged surface abundance of N_2O in 1998 was reported by IPCC (2001) to be 314 ppb. The

N_2O concentrations in the rumen were not significantly different from the global surface mean N_2O concentration. These results suggest that N_2O production in the rumen is relatively small compared to other sources.

Table 2. Nitrous oxide (N_2O) concentration (ppb) of rumen gas phase

	Number	Before feeding	After feeding	Barn
Dry dairy cattle	12	299 ± 11	308 ± 16	315 ± 19
Lactating dairy cattle	8	319 ± 7	330 ± 29	316 ± 3

After feeding: 3 hours after feeding

3.4 NITROUS OXYDE EMISSION FROM CATTLE THEMSELVES

Nitrous oxide emission from cattle themselves is calculated to be the difference between N_2O emission from the chamber and that from the fresh waste beneath the chamber. From the results of Experiment 1, the daily N_2O emission from the chambers ranged between 4.8 and 12.7 mg N_2O-nitrogen for dry dairy cattle. From the results of Experiment 2, the daily N_2O emission from fresh waste was estimated to be 2.8 mg N_2O-nitrogen for dry cattle. As a result, the daily and yearly N_2O emission from dry cattle were calculated to be 5.2 ± 4.2 (range: 2.0 ~ 9.9) mg N_2O-nitrogen and 2.64 ± 1.65 (0.74 ~ 3.60) g N_2O-nitrogen, respectively. These estimations could be applicable to lactating cattle as well, because there were no differences in rumen-N_2O elevation after feeding between the dry and the lactating dairy cattle.

Based on our results and the global cattle population (FAO, 2000), the global N_2O emission from cattle was estimated to be 3560 ± 2220 tons N_2O-nitrogen per year. This N_2O emission from cattle is approximately 0.02% of the total global N_2O emission and approximately 0.17 % of the global N_2O emission from cattle and feedlots. These results indicate that direct N_2O losses from cattle were very small compared to other sources such as (a) cattle waste management and (b) dung and urine deposits of grazing cattle.

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