B-16.8 Estimation of Methane and Nitrous Oxide Emission from Animal Production (Final report)

Contact Person Fuminori Terada
Head
Energy Metabolism Laboratory, Department of Animal Nutrition,
National Institute of Animal Industry,
Ministry of Agriculture, Forestry and Fisheries
Norinkenkyu-Danchi P.O.Box 5, Tsukuba, Ibaraki 305, Japan
Tel: +81-298-38-8655, Fax: +81-298-38-8606
Email: sakura04@niai.affrc.go.jp

Total Budget for FY1999 3,904,000Yen (FY1999; 3,900,000Yen)

Abstract

In order to improve the accuracy of estimation methods of methane (CH_4) and nitrous oxide (N_2O) emission from the animal production system in Japan and Asia, three experiments were conducted. The obtained findings were as follows; 1) Methane emission from goats measured by open circuit respiration chambers fed low quality rice straw based diets was 30.4±7.5 L per day per kg dry matter intake (DMI), and the value was higher than that of good quality grass based diets. Methane emission was increased by ammonia treatment of rice straw, but there was no significant effect of urea addition. Urea treatment of rice straw increased the digestibility of diet and reduced ($p>0.05$) CH_4/DMI and CH_4/digestible organic matter intake (DOMI). 2) Methane emission from buffaloes fed Ruzi grass hay and different levels of soybean meal was measured using facemask system. Buffaloes produced a mean of 18.8 L/kg DMI CH_4, and it was equivalent to 4.2% of gross energy intake. 3) Using waste treatment process swine waste emitted 5-15g CH_4 and 1-4g N_2O per 1 m^3 and the CH_4 and N_2O emissions could be reduced with adequate treatment at more than 40L $m^{-3}min^{-1}$ aeration.

Key Words Ruminants, Methane, Nitrous oxide, Waste, Swine

1. Introduction

Environmental crisis from global warming or the commonly called 'greenhouse effect' is a major issue in these days. Methane and N_2O are potential greenhouse gases produced from animal production system. Methane emission from ruminants account for about 16% of total CH_4 emission from the earth and N_2O emission from animal wastes is 6% of total N_2O emission [1]. Therefore, it is important to develop the technology needed to estimate CH_4 and N_2O emission from the animal production accurately to elucidate the amounts of the gases emitted from animal production system to suppress global warming.

2. Research Objectives

Methane gas produced by ruminant livestock in Japan is estimated using the equation based on DMI[2] and the method is very useful with *Bos taurus* under the temperate forages and cereal grains. However, feed quality is widely different among the Asian countries. Moreover, in Asia, there are many buffaloes and zebu cattle, and they contribute a major part of the global CH_4 emission from ruminants. Therefore, it is needed to get more information concerning CH_4 emission from different ruminant species in Asian countries considering different diets.

Improper handling and/or treatment of livestock waste have caused the emission of harmful gases from livestock production facilities[1]. Recent studies showed that the livestock waste contributes significantly to the emission of CH_4 and N_2O, which are major greenhouse gases. However, the information on CH_4 and N_2O emissions during the treatment of livestock waste are little is known and reliable estimations of the gases are needed. Therefore, three experiments were conducted to furnish the following objectives.

The objectives of the experiments were: 1) to measure the CH_4 emission from goats fed rice straw based diets and to screen the technologies to suppress CH_4 emission when fed low quality diets, 2) to collect the data of CH_4 emission from buffaloes, and 3) to determine CH_4 and N_2O emissions from swine waste treatment process.

3. Materials and methods

Experiment 1. Methane emission from goats fed rice straw based diets

Sixty Japanese native goats fed on 16-rice straw based diets were used to measure CH_4 emission using open circuit respiration chambers. Preliminary experiments were also conducted to justify the effect of CH_4 suppression by chemical or physical treatments of rice straw.

Experiment 2. Methane emission from buffaloes

Using the facemask system that we proposed last year project report, CH_4 emission from buffaloes fed Ruzi grass hay and different levels of soybean meal were measured. Diets digestibilities were also determined.

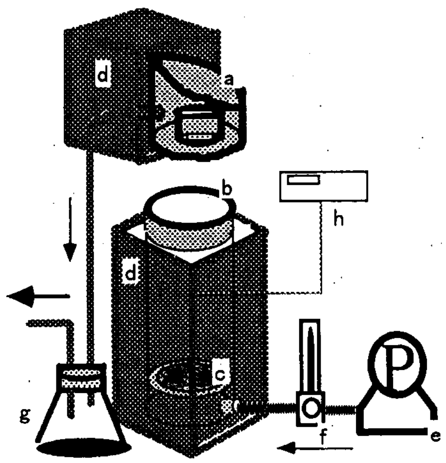

Figure 1. Composting apparatus

a: Cap with accumulated water holding,
b: Reactor, 52L of active volume (0.3m ID x 0.73m depth),
c: Stainless-steel mesh,
d: Styrofoam supported with polywood board,
e: Aeration pump, f: Flow mater.

Experiment 3. Determination of CH_4 and N_2O emissions from swine waste treatment process

As illustrated in Fig.1, the composting apparatus consisted of a small reactor (52L), a cap with a condensed-water trap, an aeration pump, an air flow meter, a water trap and a data logger (Thermodac E, ETO Electrics Ltd., Japan) connected to thermocouples. The reactor was covered with styrofoam (30 mm) and supported with a plywood board to prevent heat loss. The initial water content and nitrogen content were 70.7±2.0% of wet base and 3.5±0.5% of dry base, respectively.

Bench-scale activated sludge units (10L operational volumes) were operated at 20°C. The units were set for a 24 hour-cycle. Two types of aeration programs were conducted. For the conventional one, a continuous aeration for 21 hours was adopted, while for the intermittent aeration, aeration was done at one-hour intervals (Fig.2). Swine feces and urine mixtures were used as the influent wastewater, which contained the following; 1670 mgL^{-1} BOD, 303 mgL^{-1} TN (163 mgL^{-1} NH_4-N).

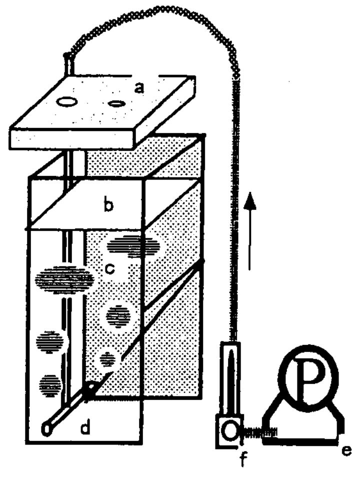

Figure 2. Bench –Scale activated sludge unit

a: Cap,
b: Head space,3L,
c: Reactor(10L of active volume)
d: diffuser
e: Aeration pump,
f: Flow mater

4. Results and discussion

Experiment 1. Methane emission from goats fed rice straw based diets

Methane emissions from goats fed rice straw based diets are shown in Table 1. Methane/gross energy intake (GEI), CH_4/DMI and CH_4/digestible organic matter intake (DOMI) values were higher for those rice species that shows higher digestibility but the values non-significant. Digestibility of the whole diet was improved by addition of urea or grains, the CH_4/DMI increased, but CH_4/DOMI did not increase. Fiberization did not increase the digestibility and reduce CH_4 emission. Ammonia treatment increased digestibility significantly but CH_4/DOMI was also increased. Urea treatment increased digestibility and CH_4/DMI, CH_4/DOMI were decreased. The mean CH_4/kgDMI of goats fed rice straw based diets was 30.4L(±7.5), and that was lower than the value of good quality grass based diets (Fig. 3).

Experiment 2. Methane emission from buffaloes

Methane emission from buffaloes measured by the facemask method was shown in Table 2. When crude protein (CP) content in the diet increased, DMI and amount of CH_4 emission per day increased. Concerning CH_4/DMI, the diet contained 2.6% CP shows lower value than the other diets, but not significant. Average value of 16 observations is 18.8

L/kgDMI and 4.2% GE, and these values were lower than the values reported by Crutzen et al [3].

Table 1. Digestibility and methane emissions parameters (mean ±SD) from goats fed rice straw based diets

Trial No.		No. of Animals	GE digestibility (%)	CH_4/GE (%)	CH_4/DMI (L/kg)	CH_4/DOMI (L/kg)
1. Effect of species of rice	Dontokoi	4	63.0±1.3	7.04±1.20	29.7±5.1	53.2±7.9
	Koshihikari	4	61.0±1.0	6.82±0.28	29.0±1.2	52.9±2.4
	Akichikara	4	61.2±2.1	6.77±0.60	28.7±2.6	52.7±3.5
	Hokuriku147	4	65.3±2.5	7.70±0.77	31.9±3.2	55.7±3.6
2. Effect of urea addition to diet	Control	3	54.0±1.6	7.19±0.27	29.5±1.1	62.1±1.4
	Urea 1%	3	56.6±2.4	7.38±0.33	30.2±1.4	60.3±2.5
3. Effect of addition of grains	Control	4	58.2±0.3	5.99±0.60	27.6±2.8	58.8±6.2
	Barley	4	71.3±2.4	7.78±1.26	37.2±6.0	56.6±7.9
	Rice	4	73.5±2.3	8.93±0.98	42.6±4.6	62.2±5.4
	Corn	4	76.0±1.2	7.48±1.35	38.8±4.4	55.2±6.9
4. Effect of fiberization	Control	4	56.0±1.8	4.79±0.15	20.5±0.7	41.7±0.1
	Treatment	4	56.7±1.7	5.29±0.59	22.5±2.5	45.3±4.7
5. Ammonia treatment (3%)	Control	4	62.5±2.2	7.61±0.43	33.1±1.9	57.6±2.3
	Treatment	4	70.4±0.6	9.15±0.14	40.4±0.6	62.2±0.9
6. Urea treatment	Control	4	60.8±1.4	4.62±0.55	21.1±3.3	38.3±6.6
	Treatment	4	63.0±2.1	4.32±0.33	18.7±1.4	31.6±3.3

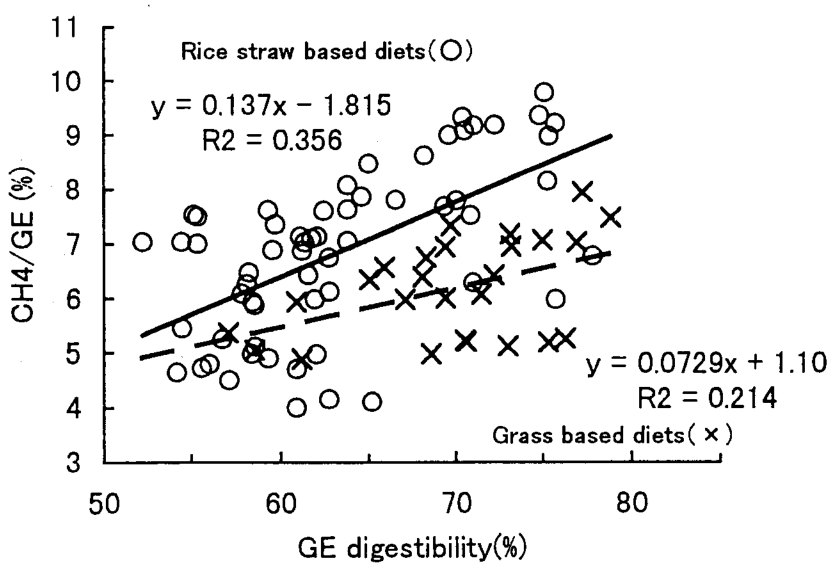

Figure 3. Relationship between gross energy (GE) digestibility and methane conversion rate (CH_4/GE, %) in goats fed rice straw based diets and grass based diets.

Table 2. Digestibility and methane emission parameters from buffaloes fed Ruzi grass based diets

Trial No.	BW	No. of Animals	% of Soybean meals	Crude protein (%)	Dry Matter Intake ($g/kg^{0.75}$)	GE Digestibility	CH_4 (L/day)	CH_4/GE (%)	CH_4/DMI (L/kg)
1	430	4	0	2.6	49	46.9^b	76^b	3.7	16.5
2	424	4	7.9	6.1	65	52.8^a	125^a	4.5	20.6
3	430	4	15.7	9.7	79	53.0^a	150^a	4.4	20.2
4	434	4	23.6	13.3	78	57.6^a	139^a	4.0	18.8

Experiment 3. Determination of CH_4 and N_2O emissions from swine waste treatment process

The amount of harmful gas emissions from the composting process of swine waste was determined by use of an experimental composting apparatus. Forced aeration (19.2~96.1 L $m^{-3}min^{-1}$) was carried out continuously, and exhaust gases were collected and analyzed periodically. The CH4 and N2O emissions could be kept lower with adequate treatment at more than 40L $m^{-3}min^{-1}$ aeration (Fig.4 and 5). Nitrous oxide may be mainly the result of the denitrification of NOx-N in the additional matured compost used as a composting accelerator (Fig.6).

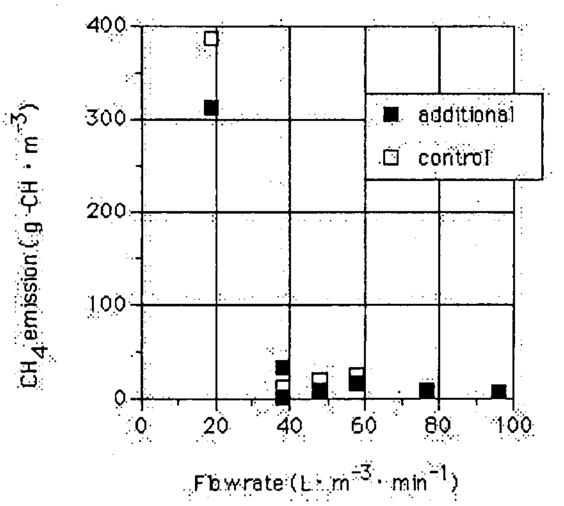

Figure 4. Effect of the flow rate of forced aeration on methane emission during composting

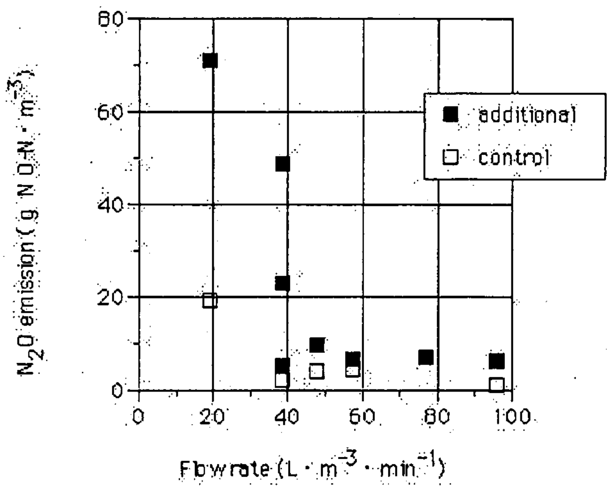

Figure 5. Effect of the flow rate of forced aeration on nitrous oxide emission during composting

With weekly turning and the addition of a bulking agent was carried out in order to decrease the moisture content and increase the air permeability. The temperature of most of the contents rose to 70°C and composting was complete within three to five weeks. Methane and N_2O emissions were high in the early stage of composting (Fig. 7).

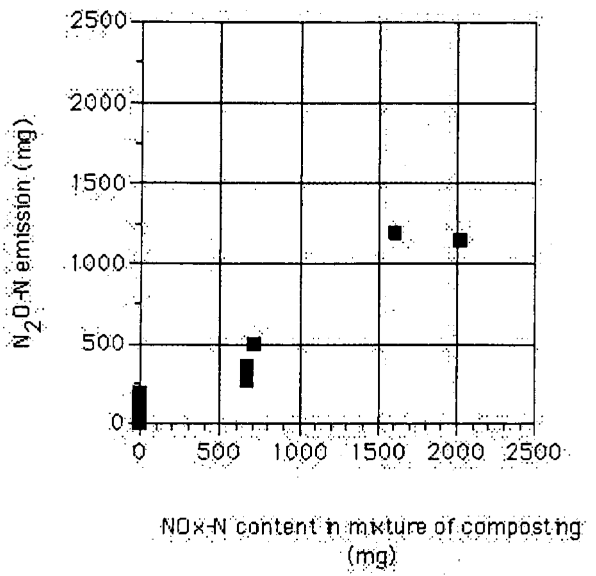

Figure 6. Relationship between NOx-N content in mixtures of composting and N_2O emission during their composting

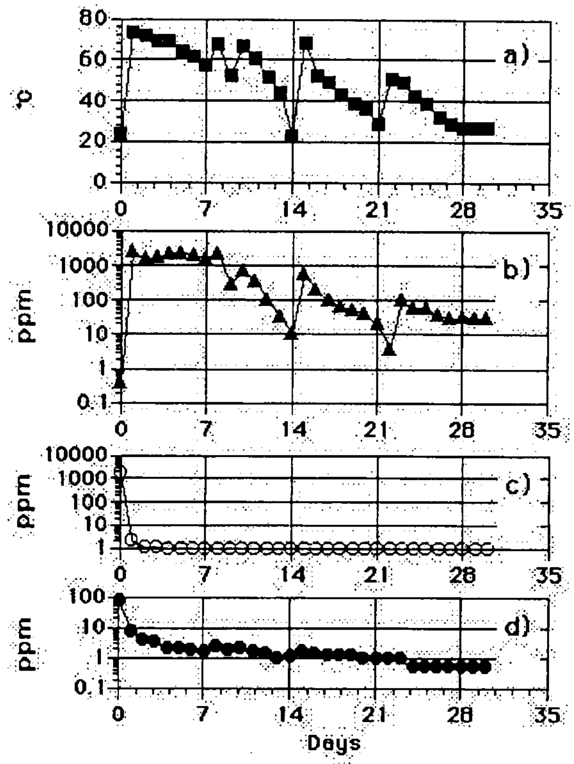

Figure 7. Changes of material temp.(a), ammonia (b), methane (c) and nitrous oxide (d) concentration of exhaust gas under 38.5 L $m^{-3}min^{-1}$aeration

About 30% of the influent nitrogen emitted as N_2O gas from fill-and-draw type activated sludge units treating swine wastewater with the conventional aeration process under $0.5kgm^{-3}d^{-1}$ BOD loading and 20°C condition. Emission of most of the N_2O was found during the first hours of aeration started just after daily changing. Emission of only less than 0.05% of the influent nitrogen was occurred as N_2O gas during the intermittent aeration process. The total emission of other harmful gases (NH_3, NO, NO_2 and CH_4) was negligible.

5. References

1) IPCC Climate Change 1995. Cambridge Univ. Press. 1996.

2) Shibata, M., F.Terada, M.Kurihara, T.Nishida, K.Iwasakki. Estimation of methane production in ruminants. Anim.Sci.Technol.(Jpn.), 64:790-796. 1993.

3) Crutzenm, P.J., I. Aselmann and W. Seiler. Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. Tellus, 38B:271-284. 1986.