B-16.2 Methane and nitrous oxide production and factors affecting its production in ruminants (Final report)

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Abstract

Methane and Nitrous oxide are classified as greenhouse-effect gasses. This study aimed at improving accuracy to estimate the production of these gasses from ruminants and examining factors involved in the production in order to obtain basic information for the reduction of these gasses. The results obtained from a series of studies on methane emission and factors affecting its production are as follows: 1)Methane production from cattle changes in relation to either milk yield or body weight gain. Therefore, methane emission per cattle products could be largely cut down by an improvement of productivity. It was pointed out by a further quantitatively analysis of the relationship between these factors that methane emission clearly decreased when cattle was given large amount of concentrate in the case of beef fattening. 2)Methane production from ruminants is affected by feed composition and environmental temperature.

Results regarding emission of nitrous oxide are as follows: 1)Nitrous oxide is hardly produced in rumen under conventional feeding systems. The emission from feces and urine in a cattle barn is also negligible. 2)Major part of nitrous-oxide-gas emission from livestock occurs during the process of making compost either from solid or liquid part of manure. It became clear by examining factors involved in nitrogen excretion from dairy and beef cattle that improvement of productivity and the reduction of nitrogen supply are effective for the reduction of nitrogen excretion.

Key Words Ruminants, Methane, Nitrous oxide, Nitrogen excretion, Milk yield

1. Introduction

Methane emission, one of green-house-effect gases, from ruminants accounts for about 16% of total methane emission from the earth. While, total nitrogen amount excreted from livestock exceeds chemical fertilizer produced. The nitrogen originated from manure partially is transformed to nitrous oxide by the process of nitrification and denitrification. It is important, therefore, for the development of technology to suppress global warming, to elucidate the amounts of methane and nitrous-oxide emitted and the factors involved in these emissions.

2. Research Objectives

It was estimated that methane gas produced by milking cows and fattening cattle accounts for 37% and 33% of total methane produced by livestock in Japan, respectively [1]. While the method to estimate the amount of methane produced from both types of cattle

being improved, a strategy to reduce its production has been examined in conjunction with productivity. The effects of feed composition and environmental conditions on methane production was also discussed.

Nitrous oxide emission from manure of livestock account for a part of the emission originated from human activities. A reduction of nitrogen excretion from livestock is one of important factors for the reduction of the emission. A strategy to reduce nitrogen excretion has been examined in milking cows and fattening cattle. A possibility of nitrous-oxide production in rumen and the rate of nitrous-oxide production from feces and urine temporarily kept in barn were also examined.

3. Materials and methods

(1) Improvement of accuracy to estimate methane production from ruminants and the factors involved in its production

① The effects of milk productivity on methane production

The relationship between 4% fat-corrected-milk (FCM) yield and methane production was analyzed by the results of 115 respiration trials with Holstein-breed milking cows. The measurement of methane production was carried out by the open-air-circuit respiration trial system [2].

② Estimation of methane production from fattening cattle and the relationship with body weight gain

The methane production was examined by using 39 head of Holstein-breed castrated male cattle and 23 head of Japanese-black castrated male cattle. Roughage given to these cattle were rice straw, Italian-ryegrass-hay wafer, steamed wood etc. and the ratio of roughage was less than 30% of total diet in all of the trials. The amount of diet ranged from the maintenance to twice maintenance on the basis of TDN content.

③ Relationship between methane production and nutrient composition in diet

The effects of nutrient composition in diet on methane production were analyzed by 250 results of respiration trials with cattle, sheep and goats.

④ The effects of environmental temperature on methane production from dairy cattle

The effects of environmental temperature (18℃ and 30-32℃) on methane production were examined by 40 results of respiration trials with Holstein breed cattle.

(2) Emission of nitrous oxide from ruminants and factors affecting it

① Nitrous-oxide production in rumen

Nitrous-oxide production before and after feeding was examined by taking gas directly from rumen of 4 dry cows and 4 milking cows.

② Nitrous-oxide emission from feces and urine in cattle barn

Model trial to measure nitrous-oxide emission from feces and urine temporarily kept in cattle barn was carried out with an assumption that feces and urine is kept in cattle barn for 24 hours, by using feces-urine mixture (feces 10 : urine 1) in a small chamber (float type, about 10L capacity). Nitrous-oxide emission from dry cows was also measured with the

respiration trial chamber.

③ Estimation of nitrogen excretion from milking cows and a method for the reduction

Factors influencing nitrogen excretion into feces and urine were analyzed with the 95 cases of nitrogen-balance trials in relation to 4% FCM.

④ Estimation of nitrogen excretion from fattening cattle and a method for the reduction

Nitrogen-balance trials were carried out with 62 head of Holstein and Japanese-black castrated male cattle and factors influencing nitrogen excretion from fattening cattle were examined in relation to body weight gain.

4. Results and discussion

(1) Improvement of accuracy to estimate methane production from ruminants and the factors involved in its production

① The effects of milk productivity on methane production

There was a significant correlation between 4% FCM yield and methane production per FCM (CH4/FCM, L/kgFCM) as shown in Fig 1. It was clear that methane production per FCM decreases as FCM yield increases, while methane production itself increases. In the light of this, total methane production both in Japan and in the world can be reduced by the reduction of the cattle number through the improvement of individual productivity even while increasing total production to some extent.

② Estimation of methane production from fattening cattle and the relationship with body weight gain

The effects of breeds (Holstein and Japanese black) and the level of roughage given (either more than or less than 20% of total diet on the basis of dry matter) on the relationship between dry matter intake (DMI, kg) and methane production were examined. In the group receiving roughage more than 20% of total diet, there was no effect of breed but there was significant correlation between DMI and CH4. On the other hand, in the group receiving roughage less than 20%, there was no correlation between DMI and CH4, and the estimated value of methane production from DMI was much lower than the previous estimation. It became clear, when cattle was given very small amount of roughage, that methane production was lower in Japanese black than in Holstein.

Methane production per daily gain (CH4/DG, L/kg) was examined in the group of animals whose DG was more than 0.45kg. It was shown that CH4/DG linearly declined with the increase of DG (Fig.2).

From these results, the following became clear: 1) Methane production markedly was suppressed and there was a difference between the breeds, when animals received low ratio of roughage; 2) In the case of fattening cattle as same as milking cattle, improvement of productivity, such as improvement of daily gain, is effective for the reduction of methane production per products.

③ Relationship between methane production and nutrient composition in diet

Equation to estimate methane production from digestible nutrient intakes as predictor variables was established by the multiple regression analysis.

DM < 10kg CH4 = 5.590 -4.53·10-2DCP +5.70·10-2DNFE +9.00·10-2DCF

DM ≧ 10kg CH4 = 98.3 -10.24·10-2DCP +2.99·10-2DNFE +21.18·10-2DCF

Considering from partial coefficient of multiple-regression equation, methane production is decreased with the increase of digestible-crude-protein (DCP) intake and is increased with the increase of digestible-carbohydrate intake. Especially, methane production per digestible-crude-fiber intake was remarkably higher than that per digestible-NFE intake. It is necessary, therefore, to optimize the balance of nutrients in the diet for the efficient reduction of methane production from ruminants while maintaining the digestion characteristics of ruminants, which require plant fiber.

④ The effects of environmental temperature on methane production from dairy cattle

The following equation was obtained by the regression analysis between DMI and methane production depending on the environmental temperature:

18℃ : CH4 = 35.97+2.757·10-2DMI r=0.917

30~32℃ : CH4 = 63.27+2.678·10-2DMI r=0.782

In the case that cattle received same amount of DM, methane production was higher under high environmental temperature. When DMI was 5-10kg, which was around maintenance level, methane production was about 10% higher than at 18℃.

(2) Emission of nitrous oxide from ruminants and factors affecting it

① Nitrous-oxide production in rumen

Nitrous oxide content of the gas in rumen before feeding was similar to that of the air inside of cattle barn, and that of the gas in rumen after feeding only showed slightly higher tendency. It was also suggested that feed composition does not influence nitrous oxide concentration of the gas in rumen.

② Nitrous-oxide emission from feces and urine in cattle barn

It was estimated from the model trial using small chamber that the amount of nitrous oxide emitted for 24 hours from the feces and urine excreted by a dry cow and a milking cow were 3mgN/day/head and 13mgN/day/head, respectively. The amount of nitrous oxide emitted from a dry cow (originated from cow itself, and, from feces and urine) measured by respiration trial chamber was 8.9mgN/day. The emission of nitrous oxide from a dairy cow in cattle barn, ranging 3-13 mgN/day/head, accounted for only 0.6% of nitrous oxide emitted from dairy production. Majority of the gas was emitted either during the process of compost making from feces and urine or from the manure applied to the field as fertilizer.

③ Estimation of nitrogen excretion from milking cows and a method for the reduction

Nitrogen excretion into feces and urine accounted for 39% and 24% of nitrogen intake in milking cows, respectively. Totally 63%, about 2/3, of nitrogen intake was excreted. The relationship of nitrogen in feces, urine, milk and accumulated nitrogen to nitrogen intake was examined on the basis of metabolic body weight. While nitrogen excretion into feces and urine quadrically increases with the increase of nitrogen intake, productivity was not improved so much. Therefore, nitrogen excretion per FCM yield (N/FCM, g/kg) was examined in order to work on a strategy for the reduction of nitrogen excretion without sacrificing productivity. Correlations of N/FCM against FCM, body weight, dry matter intake, dry matter digestibility and crude protein (CP) content were, -.533, -.101,-.208,-.176 and .302, respectively. Correlation between N/FCM and FCM was the highest. N/FCM quadrically decreased with the increase of FCM. It was suggested that improvement of productivity

resulted in the relative decrease in nitrogen excretion.

The correlation between N/FCM and CP showed the second highest value. The relationship between nitrogen excretion and CP contents was examined using 29 data with the FCM yield ranging 22-25kg, which was almost the average of the data for this analysis. While nitrogen accumulation increased with the increase in CP contents, the movement of nitrogen into milk hardly increased and urinary excretion linearly increased. This fact suggested that surplus of CP supply caused the increase in urinary excretion.

In the light of this, the following equation was obtained to estimate nitrogen excretion (N/FCM) per FCM yield in milking cows by using FCM(in logarithms), CP, DMI as independent variables:

N/FCM=-14.48*ln(FCM)+0.806*CP+0.769*DMI+31.4 R2=0.864, RSD=0.92

As all of the independent variables applied in this equation were essential in feed formulation, the formulation intending the reduction of nitrogen excretion is considered to become feasible by applying this equation.

④ Estimation of nitrogen excretion from fattening cattle and a method for the reduction

There was clear difference in nitrogen excretion from cattle between at the early and latter stage of fattening, although there was no effect of breeds (Holstein and Japanese black). Fecal nitrogen excretion per metabolic body weight decreased at the latter stage of fattening but urinary excretion dramatically increased. It was also suggested that about half of the nitrogen excreted into feces would be metabolic nitrogen originated from rumen-microorganism protein or the like.

Furthermore, an equation to estimate nitrogen excretion into feces and urine was established from body weight, dry matter intake and crude protein content as predictor variables on the basis of these results.

FUN = 16.74*DMI + 8.54*CP + 0.108*BW - 154.3 R2=0.960

It was also clear that nitrogen excretion into feces and urine per daily gain (FUN/DG, g/kg) exponentially decreased with the increase of dairy gain.

FUN/DG = 99.2x(1/DG) + 0.831xBW-325 R2=0.953

It was considered from these results that the reduction of crude protein content in diets, and the improvement of dairy gain are important factors for the reduction of fecal nitrogen excretion from fattening cattle.

6. References

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