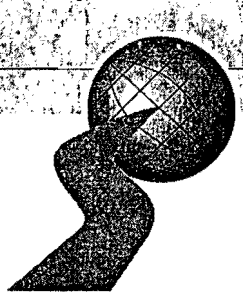

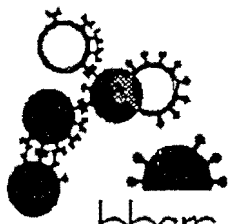

Controlling Methane and the Nitrogen Cycle on Farms

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Dietary Factors Affecting Methane Production

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1. Summary

We are studying the dietary factors affecting methane (CH4) production in ruminants to seek a practical means for reducing CH4 production as well as to predict CH4 emission. Although CH4 production was changed by the quality and quantity of diet, CH4 production per unit dry matter intake (DMI) was relatively constant among sheep, goats and cattle. The equation estimating CH4 production in ruminants obtained from the data of 190 total energy balance trials was CH4 (l/day)= $-17.766 + 42.793X - 0.849X^2$ ($r=0.966$) where X is the DMI (kg/day). The total CH4 emission by all livestock including ruminants, pigs and horses was 0.345 teragrams/year in Japan. However, this equation may not be applicable to animals given poor quality feed such as those in tropical areas. Therefore, the effect of feeding poor quality feed on CH4 production was determined. The results suggest that CH4 production was about 10% higher compared with the estimated value obtained from the equation though more data is needed to confirm the correction factor. Moreover, the effects of various unsaturated fatty acids feeding was studied for an inhibition of CH4 production. Our results have shown that CH4 production decreased as the number of double bonds of fatty acids increased. However, the relationship between the level and type of fatty acid and the conditions of feeding on CH4 production should be studied further. Considering the valuable ability of ruminants to convert low quality feeds into useful products, the importance of research work to establish a better nutritional balance toward low-CH4 and high productivity must be emphasized.

2. Current research interests

2.1 Results obtained in our laboratory

Effects of the quality and quantity of diets The ruminants have the unique digestive system. The rumen, a large "fore-stomach," is a continuous fermentation system. During the fermentation process in the rumen, methanogenic bacteria produce a considerable quantity of methane (CH4). However, the amount of CH4 production in ruminants is strongly influenced by the level and type of diet.

Table 1 shows the effects of hay to concentrate ratios on CH4 production in heifers, sheep and goats. Although high concentrate diet reduced methane production significantly, there were no significant differences in CH4 production per unit dry matter intake (DMI) among animal species. It suggests a possibility to make the estimation equation of CH4 production from DMI.

The relationship between DMI and CH4 production was investigated with data during 190 total energy balance trials with dairy and beef cattle, sheep, and goats. As the amount of DMI increased, CH4 production per unit DMI decreased. Therefore, the relationship between DMI (X, kg/day) and CH4 production (l/day) was shown as a quadratic form (Fig.1). The significant regression equation was $CH4 = -17.766 + 42.793X - 0.849X^2$ ($r=0.966$).

Table 1. Least square means for daily methane (CH4) production in heifers, sheep and goats consuming various diets.

	Heifer	Sheep	Goats	Effects
CH4 (l)	230.9a	34.3b	25.2b	**
CH4/DM (l/kg)	28.4	25.9	27.1	NS
CH4/CF (l/kg)	148.1	132.2	147.8	NS
CH4/NFE (l/kg)	56.6	51.9	53.3	NS
	H100	H70	H30	Effects
CH4 (l)	93.0a,b	115.0a	82.5b	*
CH4/DM (l/kg)	26.0a,b	29.9a	25.4b	*
CH4/CF (l/kg)	90.2a	135.2b	202.8b	**
CH4/NFE (l/kg)	61.6a	59.1b	41.1b	**

Hay-concentrate ratio:H100; hay 100%, H70; hay 70%, H30; hay 30%.
DM: Dry matter, CF: Crude fiber, NFE: Nitrogen free extracts.
Level of significance: NS Not significant; ** P<0.01; * P<0.05.
a,b: Means in the same row within animal and within treatment with different superscripts differ (P<0.05) by Student's t test.

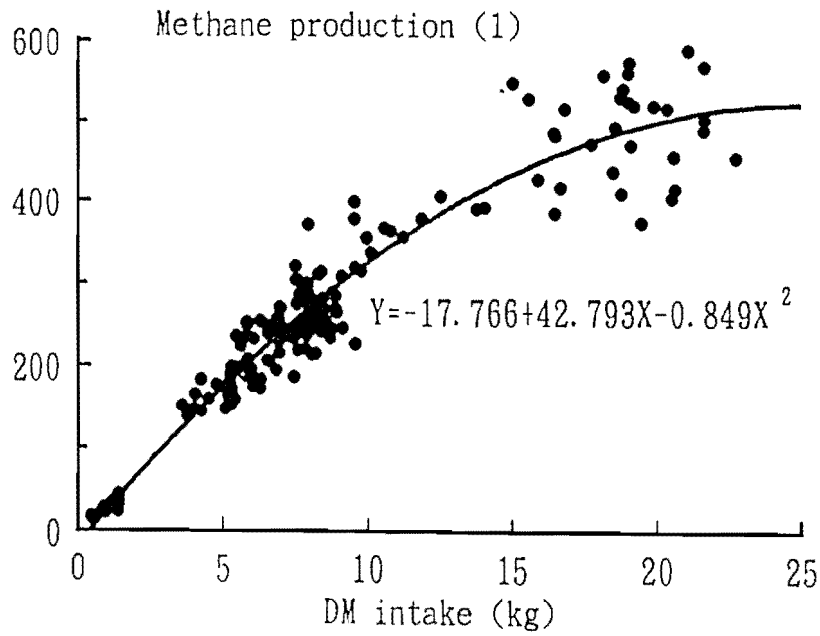

Fig. 1. Relationship between dry matter (DM) intake (kg/d) and methane production (l/day).

From the estimation equation, average DMI and cattle populations, annual CH4 production was estimated to be 0.182 teragrams (Tg) from dairy cattle and 0.150 Tg from beef cattle. CH4 emission by ruminant livestock in Japan was estimated to be 0.332 Tg/year and total CH4 emission by all livestock including ruminants, pigs and horses was 0.345 Tg/year in Japan. It only accounts for around 0.5 % of

the total CH4 emissions from animals in the world.

The estimation equation relating methane (CH4) production mentioned above may not be applicable to the animals given poor quality feed such as those in tropical areas (Leng, 1991). Therefore, the effect of level of nitrogen intake on CH4 production was determined with 4 Holstein cows given poor quality feed. The basal diet (BD) consisted of 90% steamed wood and 10% italian ryegrass hay. The amount of BD was equivalent to 50% of metabolizable energy required for maintenance and volatile fatty acids (VFA) were infused into the rumen to satisfy the energy requirements. Almost no protein was supplied to the cows from BD and VFA. The 3 levels of nitrogen intake were no urea (U0), 50% (U50) and 100% (U100) of digestible crude protein requirements for maintenance. The results showed that the overall mean value of CH4 production was about 10% higher compared with the estimated value obtained from the estimation equation mentioned above. However, more data is needed to confirm the correction factor because no consistent effect on CH4 production was observed among treatments.

Fatty acid supplementation Methanogenic bacteria need hydrogen to form CH4, and some microorganisms in the rumen use hydrogen to hydrogenate unsaturated fatty acids. Therefore, the addition of unsaturated fatty acids to the diet may result in an inhibition of CH4 production. Our results (Table 2) have shown that CH4 production per unit feed intake in goats decreased as the number of double bonds increased although feeding saturated fatty acid had only little effect. In the experiment with lactating cows, however, no difference in CH4 production between control group and fatty acid supplementation group was shown. In this experiment, fatty acid was a mixture of saturated acid and mono unsaturated acid. These results imply that the effects of feeding fatty acid on CH4 production in the rumen vary with the nature of fatty acids and the conditions of feeding. Blaxter and Czerkawski (1966) also showed that the reduction of CH4 production by feeding fatty acids was different from theoretical expectation and the effects was varied with means to provide them to the animals. Therefore, the relationship between the level and type of fatty acid and the conditions of feeding should be studied further and practical trials to establish the method of feeding fat are needed to get maximal effect.

Table 2. Effect of calcium salts of fatty acids (CaFA) on methane production in goats fed hay and concentrate.

Item	Experiment 1			Experiment 2		
	Control	C18:0	C18:1	Control	C18:0	C18:2
Feed intake (g DM)	714	745	744	652	685	630
Amounts of CaFA (g DM)		31[1)]	31[2)]		31[3)]	31[4)]
CH4 prod. (l/kg DM)	32.4	31.2	28.8	31.9	29.1	27.9
	(100.0)	(94.4)	(89.0)	(100.0)	(91.2)	(87.4)

1) Stearic acid (18:0) 97.8%, 2) Oleic acid (18:1) 90.5%
3) Stearic acid (18:0) 93.6%, 4) Linoleic acid(18:2) 80.0%

2.2 Research objectives for the next three years

Considering the valuable ability of ruminants to convert low quality feeds into useful products, the importance of research work to establish the economically

feasible ways to reduce their CH4 production as well as to improve their productivity must be emphasized. The effective conditions for feeding fatty acids would be investigated to get their maximal effect. A better nutritional balance toward low-CH4 and high productivity also would be studied.

Since protozoa generate relatively large amount of hydrogen, methanogenic bacteria attach on the surface of protozoa. Therefore, defaunation may result in decrease in CH4 production (Itabashi et al., 1984). Moreover, manipulation of rumen fermentation to increase propionate production by the use of specific chemical additives generally results in decrease in CH4 production (Itabashi et al., 1984). Ionophores, such as monensin, lasalocid and salinomycin, are thought to have the effect. Therefore, further research to identify feed factors that influence the effect of ionophores on CH4 production and to establish practical methods of applying the technique of defaunation are needed.

Despite intensive research in this area, our understanding is far from complete. Therefore, systematic evaluation of CH4 production in ruminants associated with changes in the level and type of diets including feed additives such as fatty acids and by-pass nutrients would be investigated further in our laboratory. Techniques for achieving defaunation under practical conditions also should be developed. System models including rumen digestion and animal production models are also needed to quantify the effects and to select the best combination of these approaches under given conditions.

3. List of our recent publications regarding CH4 production in ruminants

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2) Shibata, M. 1993. CH4 emission from livestock in Japan. J. Agr. Met., 48: 707-710.
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4. References

1) Blaxter, K.L. and J. Czerkawski. 1966. Modifications of the methane production of the sheep by supplementation of its diet. J. Sci. Fd. Agric. 17:417-421.
2) Itabashi, H., T. Kobayashi and M. Matsumoto. 1984. The effects of rumen ciliate protozoa on energy metabolism and some constituents in rumen fluid and blood plasma of goats. Jpn. J. Zootech. Sci. 55:248-256.
3) Leng, R. A. 1991. Improving ruminant production and reducing methane emissions from ruminants by strategic supplementation. U.S. EPA. EPA 400/1-91/004. Washington, D.C.

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