（Format　No. 13）

SUMMARY OF DOCTORAL THESIS

Name: DU WUCHEN

Title: Improvement of oat hay-based diet with supplementing leguminous forages for crossbred Simmental calves

（シンメンタール種交雑子牛に対するマメ科牧草の補助給与によるエンバク乾草主体飼料の改善）

The stock of beef cattle and beef production are increasing globally from 21 century, however, impacts of low nitrogen (N) utilization efficiency (NUE, ratio of retained N to N intake) and high enteric methane (CH_4) emissions of beef cattle production are the main concerns for the development of ruminant feeding system. For example, more than 70% of feed nitrogen (N) is excreted (such as in feces and urine) from livestock farming into the environment, and a low NUE could contribute more ammonia emissions to the air and more manure N outputs to the soil, which could damage air quality and lead to soil nitrification and acidification. In beef cattle feeding systems, approximately 60 to 80% of total N intake (NI) was excreted in urine, which has great potential to aggravate NH_3 emissions, and only 20 to 40% was excreted in feces. The enteric CH_4 emissions from ruminants not only represent a loss (2-12%) of diet energy but could also contribute to global warming. Globally, CH_4 emissions have increased nearly 40% globally from 1970 to 2004, and they are expected to increase 60% on the basis of proportional CH_4 emissions from expected livestock populations in 2030. Dietary manipulation, such as supplementing leguminous forage, was believed to have the potential to improve NUE and/or reduce CH_4 emissions from ruminants. Therefore, the development of a diet that can improve the NUE and reduce enteric CH_4 emissions is on demand and beneficial to both the animal husbandry and global environmental challenges.

In this research, we conducted 3 experiments to investigate how legume proportion (LP) and legume species (LS) to affect body weight gain (BWG), NUE and enteric CH_4 emissions of crossbred Simmental cattle. The forage-to-concentrate ratio was fixed at 60:40 (dry matter [DM] basis) for these 3 experiments.

In experiment (Exp) 1, 16 cattle were assigned to four diets with different oat hay (OH) to alfalfa hay (AH) ratios (60:0, AH0; 52:8, AH8; 44:16, AH16; and 36:24, AH24 on DM basis of total feed supplied) in a randomized block design. Forage dry matter intake (DMI) and total DMI increased from AH0 to AH24, and they significantly differed between AH24 and AH0 ($P<0.05$). Concentrate DMI did not differ among the four diets. The OM digestibility was significantly lower in AH24 than both AH0 and AH16 ($P<0.05$) and N digestibility tended to decrease linearly ($P<0.05$), and it was significantly lower in AH24 than AH0. No differences were found for dry matter (DM) and neutral detergent fiber (NDF) digestibilities ($P>0.05$). The BWG gradually increased from the AH0 to AH24, and it was significantly higher in AH24 than in AH0 ($P<0.05$). Fecal N (FN) output and the ratio of FN to NI increased with increasing AH proportions, whereas urinary N (UN) output, the ratio of UN to NI. The blood urea N and ruminal ammonia N concentration decreased from

AH0 to AH24 linearly, and they were significantly lower in AH24 than AH0. Although there were no differences in NUE, it still increased from AH0 to AH24, and FN and UN of calves significantly differed between AH0 and AH24. FN tended to increase linearly (P<0.05) with increasing AH proportions and it was significantly higher in the AH24 than in the AH0 group by 38% (P<0.05). However, UN tended to decrease with an increase in AH proportions and it was significantly lower in the AH24 than in AH0 by only 8.3% (P<0.05). The total volatile fatty acid (VFA) concentrations gradually increased with increasing AH proportions. CH_4 emissions and the ratio of CH_4 energy to gross energy intake did not differ from AH0 to AH16 (P>0.05), whereas it was significantly higher in AH24 than in AH16 (P<0.05).

In Exp 2, 16 cattle were assigned to 4 diets with different OH to common vetch hay (CVH) ratios (60:0, CVH0; 50:10, CVH10; 40:20, CVH20; and 30:30, CVH30 on DM basis of total feed supplied) in a randomized block design. There were no differences in forage DMI, concentrate DMI, BWG, and total VFA concentrations (P>0.05) among the four diets. The DM, OM, NDF and N digestibilities had a parabolic tendency from CVH0 to CVH30, and the highest values were observed in CVH20 (P<0.05). The fecal N (FN) output and the ratio of FN to NI increased with increasing CVH proportions, whereas urinary N (UN) output, the ratio of UN to NI, and the ruminal ammonia N concentration gradually decreased. The blood urea N and ruminal ammonia N concentrations showed a quadratic tendency from CVH0 to CVH30 and they were significantly greater in CVH10 than CVH30. NUE gradually increased from CVH0 to CVH30 although it was not significantly different. CH_4 emissions were significantly lower in CVH30 than in CVH0 and CVH20 (P<0.05) and the ratio of CH_4 energy to gross energy intake was significantly lower than in CVH10 (P<0.05).

In Exp 3, 16 cattle were allocated to four diets with 2×2 factorial arrangement of diets (2 kinds of leguminous forages (AH and CVH); 2 levels (20% and 40%) on DM basis of total feed supplied). Forage DMI and total DMI of cattle were significantly higher when fed on CVH40 than AH20 and AH40 (P<0.05). But no significant differences were found in concentrate DMI under LS (P>0.05). The digestibilities of DM, OM and NDF of cattle when fed on AH40 were significantly lower than AH20 (P<0.05). In the CVH diet groups, only NDF digestibility was significantly lower in the CVH40 than in the CVH20 (P<0.05). Both LS and LP did not significantly influence the BWG of cattle (P>0.05). Although the UN output of CVH20 and CVH40 was significantly lower than in the AH40 (P<0.05), they had relatively higher FN output, especially between CVH40 and AH20 (P<0.05). As a consequence, the RN of cattle in CVH20 and CVH40 were significantly higher than in AH40 (P<0.05). CH_4 emissions were significantly lower in CVH40 than in AH20 (P<0.05).

These findings suggested that, (1) appropriate proportions of leguminous forages in the diet could reduce CH_4 emissions and minimize the impact of volatile N excretion to the environment; (2) Too high proportion of leguminous forages in the diet could reduce nutrient digestibilities whereas the degree of reduction differs between CVH and AH; (3) CVH has greater potential to minimize the negative effects of CH_4 emissions and N excretion to the environment. Therefore, an opportunity for strategic feeding containing AH (16-20%) and CVH (30-40%) to reduce the direct impact of volatile N excretion and CH_4 emissions on the environment while maintaining BWG as well as nutrient digestibilities for crossbred Simmental cattle in dryland environments.