Doctoral Thesis

Studies on Mitigation of Enteric Methane Emission from Dairy Cows Based on Diets and Individual Trait Variation

（飼料と個体差に基づく乳牛からの消化管メタン排出低減に関する研究）

(Summary)

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Growing concerns about greenhouse gas (GHG) emissions from livestock and dairy farms have sparked global attention in recent years due to their connection to global warming and climate change. Methane, in particular, has emerged as a critical target for mitigation efforts, given its potent trapping potential, which is 28 times higher than that of CO_2. Anthropogenic activities, especially agricultural practices like livestock husbandry, contribute significantly to global methane emissions. Within the livestock sector, dairy cattle are particularly noteworthy for their substantial methane emissions, drawing scrutiny for their environmental impact. Addressing this challenge aligns with global commitments such as the Paris Agreement and Sustainable Development Goals (SDGs), which emphasize the importance of sustainable agriculture and climate action. Various mitigation strategies have shown promise in reducing methane emissions from dairy cows. This research aimed to investigate effective strategies for mitigating methane production from dairy cows based on the measurement in practical farm conditions, thereby contributing to sustainable agriculture and climate resilience efforts.

Cashew nutshell liquid (CNSL) is known to mitigate ruminal methane production when used as a methane inhibitor additive. Therefore, in Study 1, the efficacy of CNSL supplementation at a low level on dairy cow performance and methane emissions in farm conditions was investigated. Ten Holstein lactating cows were used in a free-stall barn with an automatic milking system (AMS). Two treatments were arranged as control (no CNSL additive, n=5) or CNSL addition (10 g/d of CNSL, n=5) for 21 days after the 7-day preliminary period (no addition). Daily methane production of dairy cows was estimated by a sniffer method. The research findings indicate that supplementing CNSL additives to the partial mixed ration (PMR) did not notably impact various parameters related to milk production performance. Although a slight increase in concentrate intake from AMS was observed, it did not affect total dry matter intake (DMI) or milk yield. CNSL supplementation did not alter PMR intake patterns throughout the day, with higher DMI during mid-day hours. While eating time followed a similar pattern, gradually declining towards late evening and early morning. Notably, reductions in methane yield (CH_4/DMI) and methane conversion factor (MCF) in the CNSL group indicated a potential mitigation effect on methane emissions, despite daily methane production remaining unaffected. Rumen characteristics like pH, oxidation-reduction potential, and protozoal population were not significantly affected. However, ruminal total volatile fatty acid (VFA) concentration tended to be lower in the CNSL group, with alterations in the molar proportions of specific VFAs. In vitro experiments also showed tendencies towards lower total gas, methane production, and VFA concentration in the CNSL group compared to the control group. These findings suggest the potential benefits of CNSL additives in methane mitigation strategies on-farm conditions.

In Study 2, to assess dietary approaches with highly digestible fiber, the effects of incorporating kraft pulp (KP) into dairy cow diets on various parameters related to feed intake, methane emissions, physiological changes, milk production, and rumen fermentation were also explored. The crossover design consisted of two experimental feeding periods involving 26 lactating dairy cows. In the first period, all cows were fed a conventional PMR for three weeks, followed by a PMR containing KP for four weeks. In the second period, the cows received the KP diet for four weeks, followed by a conventional PMR for three weeks. During the KP treatment period, 10% of the oats hay in the control PMR was replaced with KP. Methane production was measured by the sniffer method in the last week of each period. The results indicate that KP feeding significantly reduced total DMI and eating time but did not affect rumination time. Peak intake occurred between 1000 and 1400 hours, with a notable reduction during KP treatment. Methane emission parameters were lower during KP treatment. However, milk production tended to decrease with KP feeding. Milk composition remained mostly unchanged, except for higher lactose and solids-not-fat content during KP treatment. Rumen fermentation showed a trend towards lower pH with KP, but no significant changes in ammonia or VFA.

Finally, in Study 3, to evaluate the specific phenotypic differences between high and low methane-emitting cows, eighteen lactating Holstein cows were divided into low methane-emitting (LEm), mid-emitting (MEm), and high methane-emitting (HEm) groups based on a 7-day measurement of the CH_4/CO_2 ratio in respiration gas. Methane production parameters varied significantly among the groups, with LEm cows exhibiting both lower daily methane production and the lowest methane conversion factor. LEm cows exhibited lighter body weight but longer eating time, though not statistically significant. No significant differences among the cow groups were observed in milk production, DMI, or rumination time. Although PMR consumption occurred mainly between 1000 and 2200 hours for all groups, LEm cows exhibited longer eating times between 0200 and 0600 hours than other groups, suggesting potential differences in diurnal eating habits. Regarding rumen fermentation profiles, LEm cows showed a lower proportion of acetate and a higher proportion of propionate than HEm cows. Milk composition analysis revealed no differences in fat and protein content among the groups; however, some short-chain fatty acids were reduced in LEm cows. The study also investigated the rumen microbial community structure, finding that bacteria producing lactate and succinate were more prevalent in the LEm group. This prevalence may be linked to the higher ruminal propionate and lower methane production observed in the LEm group. These findings suggest that body weight and eating time may influence variations in methane production in dairy cows through alterations in the rumen microbial community

This research provides comprehensive insights into dairy cow nutrition, methane emissions, physiological traits, milk production, rumen fermentation, and microbial composition. The supplementation of CNSL showed minimal impacts on dairy cow performance but potential methane mitigation effects. Kraft pulp inclusion was found to reduce methane emissions, although it also led to reduced feed intake and milk production. Analysis of divergent methane-emitting groups highlighted variations in physiological traits, feeding behavior, methane production, rumen fermentation, milk composition, and microbial composition. These findings highlight the complexities of dairy cow management and the multifaceted nature of methane mitigation strategies, offering valuable pathways to enhance productivity while minimizing environmental impacts.