Effects of Dietary Lipid Supplements and Feeding Level on Milk Production and Methane Emissions in Holstein Dairy Cows

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Introduction

Methane is a potent greenhouse gas (GHG) and climate pollutant (Jones et al., 2023). Emissions from enteric fermentation and manure are major sources of anthropogenic methane (CH_4) (Smith et al., 2021). However, we must contend with the reality that the global demand for dairy products is projected to increase due to population growth and rising incomes (Bojovic and McGregor, 2023). This growing demand for dairy is expected to increase methane emissions if measures are not taken (Li et al., 2023). Yet, the short atmospheric lifetime for methane (7 to 12 years) presents a unique opportunity to reduce its impact on climate change in a short period (Mar et al., 2022). Lowering enteric methane emissions without compromising productivity, efficiency, animal health, and human food safety is a valuable strategy for decarbonizing the dairy industry while achieving food security.

Developing strategies to reduce methane emissions can be grouped into three categories: dietary interventions, breeding for low-methane emission animals, and advanced manure management. Breeding can take several generations to cause a significant reduction in methane emissions (Lassen and Difford, 2020). Manure management to reduce methane production is feasible under intensive operations (Sefeedpari et al., 2019). Inhibiting ruminal methanogenesis using dietary approaches offer the potential for positive immediate environmental impact, are adaptable across various farming systems, and can be designed to meet the needs of different production systems.

Dietary ingredients and technologies being evaluated to reduce methane production include bromoform technologies (e.g. red seaweed), fatty acids (FA), 3-nitrooxypropanol (3-NOP), essential oils, tannins, saponins, ionophores, and nitrates. Dietary supplementation of *Asparagopsis taxiformis* has been proven effective at reducing methane production because it contains bromoform, a halogenated compound that inhibits ruminal methanogenesis (Sofyan et al., 2022). However, bromoform and iodine toxicity in milk are a potential safety concern (Muizelaar et al., 2021). Additionally, the availability and cost of seaweed represent key challenges for the industry (De Bhowmick and Hayes, 2023). Alternatively, dietary 3-NOP supplementation reduces methane yield up to 30.9% (Kebreab et al., 2023) but has demonstrated minor or no improvements in milk production (Melgar et al., 2021; van Gastelen et al., 2024). Products like essential oils, tannins, saponins, nitrates, and ionophores present variability in study outcomes when fed to cattle (Almeida et al., 2021). Feedings lipids is potentially advantageous because they are available in the market, are safe to use, and a well-established supply chain is available.

Fatty acids reduce methanogenesis via several mechanisms. First, replacing fermentable organic matter (OM) with FA dilutes the substrate available for methanogenesis (Alstrup et al., 2015). Second, specific FAs directly inhibit fibrinolytic bacteria and methanogens, decreasing methane production (Amanullah et al., 2021). Lastly, biohydrogenation of unsaturated FAs to saturated FAs acts as a minor hydrogen sink, diverting hydrogen from methanogenesis (Zhang et al., 2019). The dilution effects and microbial inhibition contribute significantly to methane reduction. In contrast, the hydrogen sink effect from biohydrogenation is relatively modest. Patra (2013) reported a 3.77% reduction in methane emissions for each percentage unit increase of lipids within dairy cattle diets. More recently, de Ondarza et al. (2024) found a 3.91% reduction in methane yield of 3.91% per unit of rumen-available lipids. Despite their benefits, lipid feeding should be limited to 6 to 7% of total dry matter of the diet due to adverse effects on intake and fiber digestibility at higher feeding levels (Beauchemin et al., 2008).

Fatty acids have unique effects on metabolism, opening new frontiers to enhance productivity. For example, palmitic acid (C16:0), a saturated FA, has improved energy partitioning toward milk production, increasing yields of milk and energy-corrected milk (de Souza and Lock, 2018). On the other hand, unsaturated FA (UFA), such as oleic acid (C18:1), promote energy partitioning toward tissue gain, supporting body condition and recovery during lactation (Abou-Rjeileh et al., 2023). So, we must consider how dietary FAs uniquely modulate nutrient partitioning and milk synthesis while also evaluating changes in methane production to define the effects of individual dietary FAs on enteric GHG emissions. Our objective was to assess the impact of two dietary lipid supplements on milk production and composition and ruminal GHG emissions.

Materials and Methods

Thirty-six multiparous Holstein cows [147.1 ± 5.9 DIM (mean ± SD), 2.6 ± 0.8 parity; 158 ± 8 DIM, 2.6 ± 0.8 parity] were enrolled in a study with a split-plot Latin square design. The study was conducted to test the interaction between feeding a diet with two types of lipid supplements with different FAs compositions and three fat-feeding levels. Cows were assigned to one of 2 main plots (FA type): a blend of palmitic and oleic acids (PO; Megalac®) or high palmitic acid (HP; Wilfarin®). Within each plot, cows were randomly assigned to a sequence of 3 supplementation levels of dietary FA: 0, 1.5, or 3.0% in a 3 × 3 Latin square design with three 21-d periods. At the end of each period, during a 3-d collection, dry matter intake (DMI), milk yield (MY), milk composition, body weight (BW), body condition score (BCS), and enteric methane (CH_4), carbon dioxide (CO_2), and hydrogen (H_2) emissions were evaluated. Data were analyzed using a mixed model with fixed effects of plot, FA level, period, square, plot × FA level, and the random effect of cow nested in the square. Preplanned contrasts compared HP 1.5% vs. PO 1.5% and HP 3.0% vs. PO 3.0%.

Results

Dry matter intake did not show significant differences between FA type; however, as the level of FA supplementation increased, there was a reduction in DMI ($P < 0.05$). Milk yield positively responded to FA supplementation, specifically at higher dose levels. At the 3% supplementation level, cows receiving PO had significantly greater milk yields than those receiving PO (42.9 vs. 40.6 kg/d; $P < 0.05$). Cows fed HP at 1.5% or 3.0% FA had higher milk fat content than PO (4.56% vs. 4.39% and 4.63% vs. 4.30%; $P < 0.05$). Cows fed HP at 1.5% or 3.0% FA had higher milk protein content than PO (3.54% vs. 3.43% and 3.54% vs. 3.34%; $P < 0.05$). Fat, lactose, and total solids yields increased with higher FA supplementation for both products ($P < 0.05$). As the dietary FA levels increased for both HP and PO, it resulted in a reduction of methane production (g/d), methane intensities (g/kg of milk or ECM), and methane yields (g/kg of DMI), with no significant differences between FA type ($P < 0.05$). Feed efficiencies (milk/DMI or ECM/DMI) improved as FA levels increased for both supplements ($P < 0.05$), with cows fed PO at 1.5% or 3.0% FA showing greater feed efficiency (MY/DMI) compared to those on HP ($P < 0.05$). Carbon dioxide emissions decreased as the FA dose increased ($P = 0.05$), though no differences were observed between FA type. Interestingly, hydrogen emissions showed a slight reduction in cows fed HP as FA levels increased ($P < 0.05$), a trend not observed in cows receiving PO. Furthermore, as FA levels increased, there was a reduction in body weight, mainly in cows supplemented with the PO product ($P < 0.05$). Fatty acid treatment (i.e., plot) did not affect body condition score (BCS) at any supplementation level.

Conclusion

We conclude that despite a reduction in dry matter intake at higher FA levels, milk yield was positively affected, particularly in cows receiving PO. Cows supplemented with HP had increased milk fat and protein contents compared to those receiving PO. Both FA sources, HP and PO, effectively reduced methane production, intensities, and yields alongside carbon dioxide emissions, with a slight reduction in hydrogen emissions observed in cows supplemented with HP. Feeding high palmitic acid led to a 4.6% reduction in methane intensity for each 1% increase in dietary fatty acids, while PO resulted in a 3.75% reduction per 1% fatty acid increase. These findings confirm that FA supplementation can serve as a viable strategy to enhance milk production efficiency and reduce greenhouse gas emissions in lactating dairy cows.

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