

Feeding Corn Distillers Grains to Lactating Cows: Minimizing the Risk of Low Milk Fat

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Summary

Corn distillers grains with solubles (**DG**) are a byproduct of ethanol production, providing a cost-effective feed ingredient rich in protein, fiber, and fat. However, feeding DG at high inclusion rates has been associated with milk fat depression (**MFD**) due to its high polyunsaturated fatty acid (**PUFA**) content. Although studies in the literature report inconsistent performance responses to feeding DG, decreased milk fat yield and concentration are often observed when diets contain DG at 20% or more on a dry matter (**DM**) basis, particularly in experiments using a randomized block design. Despite this, including high levels of DG in a diet (e.g., > 20% on a DM basis) may still be a cost-effective strategy, depending on the severity of MFD and market conditions, especially when feed prices are high and milk prices are low. Furthermore, if the MFD-causing factors in DG can be controlled, feeding a high-DG diet could remain cost-effective regardless of market conditions. In our previous experiment, milk fat depression occurred even when reduced-fat DG (29% in dietary DM) was used, leading us to hypothesize that PUFA may not be the sole factor contributing to MFD. One potential factor considered was the high sulfur (**S**) concentration in DG. The high S content in DG can increase S concentration (e.g., > 0.4% in dietary DM) in DG-containing diets, potentially negatively impacting rumen fermentation and

digestion. Additionally, high S levels can reduce the dietary cation-anion difference (**DCAD**), indirectly impairing fiber digestion and milk fat yield. In this article, we introduce our previous studies, which identifies the factors of DG other than PUFA responsible for MFD and outlines a strategy to mitigate the risk of MFD from high-DG diets by eliminating the contributing factor.

Introduction

A lactation diet is often supplemented with a commercial fat source to achieve a target fatty acid (**FA**) concentration of 4 to 6% in dietary DM. The dietary FA concentration can also be increased by adding fat-rich feed ingredients, such as roasted soybeans, distillers grains, or whole cottonseeds. Research has been conducted to optimize the production of lactating cows by supplementing FA beyond the basal level, and the performance responses vary depending on the type of FA provided to lactating cows. Milk and milk fat yields are the two primary response variables studied in relation to FA supplementation. Saturated FA has gained significant attention, as feeding palmitic acid has consistently been shown to increase both milk and milk fat yields (dos Santos Neto et al., 2021). The combination of saturated FA and oleic acid has also been studied, demonstrating beneficial effects (de Souza et al., 2021). However, increasing milk and fat yields does not always translate to economic benefits. This

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is because commercial fat sources, particularly saturated FA, are expensive and contribute to higher feed costs. The economic feasibility of FA supplementation depends on the prices of milk fat, feed, and supplements, and feeding an expensive FA may not be cost-effective in some cases when feed prices are high and milk price is low.

Polyunsaturated FA is also commonly included in lactating cow diets. Rather than being provided via a direct FA supplement, PUFA is typically introduced through fat-rich feeds such as corn DG (Ramirez-Ramirez et al., 2016). However, feeding DG beyond a certain level is not recommended, as it can lead to MFD (Morris et al., 2018). This occurs due to excessive PUFA intake from DG. Nevertheless, feeding high DG is not necessarily a poor strategy. From the economic perspective, DG serves as an affordable protein and fat source compared to other protein ingredients (e.g., soybean meal) and commercial saturated FA sources. If included in moderation, DG can be a cost-effective feeding option depending on milk fat and feed prices. Additionally, there is growing public concern about reducing the environmental impact of livestock production. Feeding PUFA has been associated with decreased enteric methane production in lactating cows (Grainger and Beauchemin, 2011). Furthermore, feeding a diet with high DG showed a significant decrease in ammonia emissions from manure of lactating cows (Lee et al., 2020). If PUFA can reduce enteric methane or manure ammonia emissions without negatively affecting milk and milk fat yields, incorporating DG into dairy diets could offer both economic and environmental benefits for the industry. The current article will introduce our recent research with DG and introduce potential strategies to feed a diet high in DG with minimal or no negative production effects.

Why Feeding DG to Lactating Cows

In the U.S., approximately one-third of the total corn harvest (5 billion bushels) is used for ethanol production (<https://afdc.energy.gov/data/10339>), making DG widely available as a livestock feed ingredient. Corn distillers grains are a rich source of protein, fiber, and fat, offering a cost-effective alternative feedstuff. There are various types of DG, each with a slightly different nutrient composition. NASEM (2021) categorized DG into three types: high fat, low fat, and high protein. The high-fat DG contains about 30% CP, 32% NDF, and 11.5% total FA on a DM basis and is considered traditional DG. The low-fat DG, also known as reduced-fat DG, is similar in CP and NDF contents with the traditional DG; however, total FA is about 3.5%-units lower. The high-protein DG contains greater protein (about 39% CP, 38% NDF, and 6.5% total FA) than other DG products. Discussing the different types of DG as feed ingredients for lactating cows is beyond the scope of this article. Because reduced-fat DG is likely the most popular and available currently, we have been using it in our research, and the results discussed in this article are based on that.

Historically, feed cost has been the largest expense in dairy production. To maximize profit, both herd production and feed costs must be carefully considered. As shown in Figure 1, milk prices were low while feed costs were high in 2023, resulting in a narrow profit margin for producers. However, the situation improved significantly in 2024. Since market conditions are cyclical, a scenario like in 2023 may return, and both producers and nutritionists need to be prepared for periods of low margins. In 2024, favorable milk prices and relatively low feed costs made maximizing production through the use of high-quality feeds (e.g., protein and fat sources) a viable strategy for increasing profit.

In contrast, during 2023, when milk prices were low and feed costs were relatively high, investing in expensive, high-quality feeds to boost production may not have been the most effective approach. Instead, reducing feed costs by incorporating more affordable feed ingredients would have been a more practical strategy. Under conditions like in 2023, feeding DG could be a cost-effective choice from an economic standpoint. If production is not negatively impacted, feeding a high DG diet would be cost effective regardless of the market conditions.

Performance Responses to Feeding DG

There appear to be inconsistent responses in milk production when a diet containing DG is fed to lactating cows. This inconsistency may be due to variations in diet composition, ingredients replacing DG, and differences in experimental design. In a meta-analysis, milk yield tended to increase for a diet with an increasing inclusion of DG, while DMI, milk fat, and milk protein were not affected (Paz et al., 2013). Another meta-analysis discovered a milk yield response where the peak was 2.6 lb/cow/day with an inclusion rate of DG at 21% (DM basis) compared to diets not including DG (Hollmann et al., 2011). Additionally, Hollmann et al. (2011) reported milk fat concentration was negatively affected in DG diets compared to diets not containing DG. Benchaar et al. (2013) used 12 multiparous lactating cows in a triplicated 4 × 4 Latin square design. In 35-day periods, cows were fed diets containing 0, 10, 20, and 30% DG (DM basis) replacing flaked corn (energy source) and SBM (protein source). Milk yield increased linearly as cows receiving 30% DG produced 8.8 lb/day more milk compared to the diet with no DG. Milk protein yield decreased linearly as the DG inclusion increased up to 30%, while milk fat yield tended to increase in a quadratic manner.

Negative responses were more pronounced when diets included more than 20% DG in dietary DM, especially in longer-term randomized complete block designs (>3 weeks). A study by Zynda et al. (2022) used a randomized complete block design (5 weeks) where milk and milk fat yields decreased with DG at 20% of dietary DM compared to a SBM-based control diet. Similarly, Morris et al. (2018) fed DG at 30% (DM basis) for 11 weeks and observed milk fat yield and concentration decreases compared to a SBM-based diet. Most studies that observed low milk fat explained that high levels of PUFA in DG (Abdelqader et al., 2009) caused it. The rumen biohydrogenation pathway of linoleic acid (18:2) to stearic acid (18:0) shifts from a cis-9, trans-11 conjugated linoleic acid (CLA) intermediate to an alternative pathway with trans-10, cis-12 CLA as the intermediate (Bauman and Grinari, 2003), which downregulates milk fat synthesis in the mammary gland. Therefore, to avoid a decrease in milk fat with a diet containing high DG, the use of reduced-fat DG might be helpful. Total FA content for reduced-fat DG is about $6.5 \pm 1.0\%$ (DuFour, 2017) compared to $11.4 \pm 1.5\%$ for traditional DG (NASEM, 2021). In numerous studies, when feeding at least 20% (DM basis) reduced-fat DG to lactating dairy cows, milk production and composition remained unchanged or improved compared to SBM-based control diets (Mjoun et al., 2010; Castillo-Lopez et al., 2014; Ramirez-Ramirez et al., 2016). However, most studies that showed promising results with feeding reduced-fat DG used a Latin square design.

Our previous study (Morris et al., 2018) used a randomized complete block design where reduced-fat DG was fed at 29% (DM basis) continuously for 11 weeks. In that study, a decline in milk fat yield and energy corrected milk (ECM) for reduced-fat DG compared to a control diet (SBM-based) was observed, and

the difference became more pronounced as the experiment progressed (Figure 2). In the last week of the experiment, milk fat yield decreased by about 35% for the DG diet compared with the control, where the DG diet provided additional 210 g/day of PUFA compared to the control diet. Interestingly, the 35% decrease in milk fat yield with additional PUFA of 210 g/day was quite severe and this much severe depression of milk fat yield was not often observed in previous studies although additionally PUFA was provided directly from oils (Abdelqader et al., 2009; Rico et al., 2015). This led us to speculate that PUFA in DG may not be the sole factor contributing to MFD.

Determining Factors of DG Other Than PUFA Causing Low Milk Fat

Sulfur concentration in DG is relatively high compared to SBM ($0.71 \pm 0.144\%$ vs. $0.41 \pm 0.033\%$; NASEM, 2021); therefore, primarily replacing SBM with DG in a diet increases dietary S concentration. We previously observed a 0.2 percentage point increase in dietary S when DG (29% of dietary DM) fully replaced SBM and soyhulls (0.21% vs. 0.41% S on a DM basis; Morris et al., 2018). The recommended dietary S level for lactating cows is 0.15 to 0.25% to maximize fiber digestibility (NASEM, 2021). Excess S can cause both direct and indirect negative effects on dairy cows. An oversupply of S can directly reduce rumen pH, rumen fermentation, and fiber digestibility (Drewnoski et al., 2014; Wu et al., 2021), while also acting as a trace mineral antagonist (Ivancic and Weiss, 2001). Indirectly, S decreases the dietary cation-anion difference (DCAD; $\text{mEq/kg DM} = \text{Na} + \text{K} - \text{Cl} - \text{S}$); therefore, adding DG to a diet lowers DCAD due to its high S concentration. Typically, DCAD is about 200 mEq/kg DM for lactating cow diets without additional cation supplementation. However, diets containing 20 to 30% DG (DM basis)

reduce DCAD to approximately 0 to 100 mEq/kg DM . A meta-analysis (Iwaniuk and Erdman, 2015) showed that DMI, milk yield, milk fat yield, and DM and NDF digestibilities increased when DCAD rose from 0 to 500 mEq/kg DM . Therefore, we hypothesized that high S in DG could be another factor contributing to negative production responses in two different ways: a direct high-S effect and an indirect S effect via low DCAD.

To test our hypothesis, we conducted an experiment with 60 lactating cows fed the following experimental diets: 1) a SBM-based diet (SBM), 2) the SBM diet with DG at 30% (DM basis) by replacing mainly SBM and soyhulls (DG), 3) the SBM diet with additional dietary S by supplementing sodium bisulfate (SBM+S), 4) the SBM diet with corn oil (SBM+CO), and 5) the DG diet with elevated DCAD (300 mEq/kg) by supplementing sodium bicarbonate and potassium carbonate (DG+DCAD). All diets (Table 1) were formulated to meet or exceed all nutrient requirements for lactating cows according to NASEM (2021). The experiment included a 10-day covariate period, followed by 5 weeks of experimental period. More details about the study can be found in Clark et al. (2024).

When the SBM diet was formulated to meet the requirements of all nutrients, the level of DCAD was 178 mEq/kg of DM. The SBM+S and SBM+CO diets had DCAD similar to SBM (198 and 165 mEq/kg of DM, respectively). By the experimental design, substituting mainly soybean meal and a fat supplement for DG in the DG diet resulted in an increase in dietary unsaturated FA without altering total FA. To investigate the PUFA effect as a factor of DG, total FA content was formulated to be similar between SBM+CO and SBM but resemble the PUFA content and composition between SBM+CO and DG. To investigate the direct S

effect as a factor of DDGS, sodium chloride in the SBM diet was replaced with sodium bisulfate. This resulted in an increase in S concentration in SBM+S compared with SBM and resembled the S concentration in the DG diet. However, by the experimental design, the SBM+S diet had the DCAD similar to that of the SBM diet. By increasing the level of potassium carbonate and sodium bicarbonate in the DG+DCAD diet, K and Na concentration was elevated compared to the DG diet, which resulted in increased DCAD to about 330 mEq/kg DM.

Although DMI was not affected by treatments except that SBM+CO decreased as the experiment progressed (interaction of treatment by week, $P < 0.05$; data not shown). Milk yield was not affected by treatment as well. The main production measure that was affected by treatments was milk fat as expected. While milk fat concentration tended to decrease by 17% (tendency; $P = 0.06$), milk fat yield was only numerically decreased (14%; $P = 0.13$) for DG compared with SBM (Figure 3). The numerical difference in milk fat yield between DG and SBM likely occurred due to 2 kg/day greater milk yield for DG compared with SBM. The decline in milk fat led to a numerical decrease in ECM and significant decrease in ECM per unit of DMI for DG compared to SBM. Diet-induced MFD commonly occurs when a high DG diet was fed, and it was often explained by high supply of dietary PUFA (Ramirez-Ramirez et al., 2016). In the current study, although FA content was similar, PUFA concentration was 32% greater for DG compared to SBM (Table 1). We hypothesized that the high S content in a DG diet may be another dietary factor of DG causing MFD. However, we did not observe any differences in intake, milk production, milk fat yield, or nutrient digestibility between SBM and SBM+S (data not shown), suggesting that about 0.4% dietary S in DG was not likely a direct factor associated with the reduced production responses to feeding DG.

As expected, diet-induced MFD was present for SBM+CO, as both milk fat yield and concentration declined (Figure 3), while milk and protein yields were not negatively affected (data not shown). Although data were not shown in this article, we observed that de novo ($< C16$) and mixed ($C16$) milk FA decreased and preformed ($> C16$) FA increased for the SBM+CO diet compared with SBM and that C18:1 trans-10 and C18:2 trans-10, cis-12 for SBM+CO increased by 173 and 150%, respectively, compared with SBM, which are common for cows on diet-induced MFD (Bauman and Griinari, 2003). Therefore, it was clear that high PUFA in DG was one of the dietary factors associated with MFD.

We also hypothesized that a decrease in DCAD when the inclusion of DG in a diet is high would be one of the factors causing MFD. We found that although nutrient digestibility and milk yield were not affected by increased DCAD (data not shown), milk fat concentration and yield (Figure 3) tended to increase compared with the DG diet, resulting in increased ECM (data not shown). The result confirms that increasing DCAD of a DG diet ($> 20\%$ of DDGS in dietary DM) can be an effective strategy to alleviate or eliminate negative effects of high DG diets. Previously, effects of DCAD on positive milk fat yield in lactation cows have been explained with better rumen environments (e.g., pH), leading to more complete biohydrogenation through the normal pathway (Apper-Bossard et al., 2010). However, C18:1 trans-10 and C18:2 trans-10, cis-12 did not differ in milk between DG and DG+DCAD in the current study (data not shown), although DG+DCAD tended to increase milk fat concentration and yield. Instead, our results suggest that the effect of DCAD on milk fat likely occurred via a post-absorptive effect rather than a ruminal effect.

Although a meta-analysis by Iwaniuk and Erdman (2015) showed improved DM and NDF digestibilities with increasing DCAD, we did not observe a change in nutrient digestibility and the increase in milk fat for DG+DCAD compared with DG did not occur due to increasing nutrient digestibility (Clark et al., 2024). In addition, we also did not observe any change in milk FA profile for DG-DCAD versus DG (data not shown), and this is likely strong evidence that the increase in milk fat with increased DCAD in the current study may have been associated with post-absorptive effects rather than ruminal effects. In addition, no difference in most amino acid concentrations in plasma (except for His) between DG and DG+DCAD also supports that increased DCAD did not affect the rumen environment.

A decrease in DCAD as a factor of DG causing MFD is also supported by our previous study (Figure 4). We observed an increase in milk fat concentration and yield and ECM when DCAD of a DG diet (20% of DG in dietary DM) was increased from 62 to 187 mEq/kg DM by adding potassium carbonate and sodium bicarbonate (Zynda et al., 2022). In that study, however, milk fat yield for the DG diet with increased DCAD was still numerically lower compared with a soybean meal-based diet (control; 1.55 vs. 1.27 kg/day). This was the reason why we increased DCAD for the DG-DCAD diet much greater than the DCAD level of the SBM diet (330 vs. 178 mEq/kg DM) to determine if the risk of low milk fat could be further alleviated. The previous and current study (Zynda et al., 2022; Clark et al., 2024) support that a decrease in DCAD was the factor causing MFD for a diet containing high DG in addition to PUFA.

Conclusion

Incorporating DG as a replacement for soybean meal and commercial fats can reduce feed costs. However, the inclusion rate of DG must be carefully managed because it may lead to MFD. Depending on market prices for milk and feed, a high inclusion of DG could be a cost-effective strategy, particularly during periods of high feed costs and low milk prices, such as in 2023. Even when market conditions are favorable, including high levels of DG in the diet can increase the income if the risk of MFD is mitigated. Our series of experiments with DG demonstrated that reduced-fat DG can still cause MFD when included at approximately 30% of dietary DM. We found that the cause of MFD was not solely due to PUFA but also related to DCAD, which decreases with high DG inclusion due to its high S content. Our two experiments showed that adjusting the DCAD of a high-DG diet can minimize or eliminate MFD in lactating cows. If the risk of MFD is controlled, an inclusion of high DG in a diet (> 20% in dietary DM) would be a highly cost-effective strategy, regardless of milk and feed market prices

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Table 1. Ingredient composition of dietary treatments (% of DM) used in Clark et al. (2024).

Ingredients ²	Diets ¹				
	SBM	DG	SBM+S	SBM+CO	DG+ DCAD
Corn silage and haylage	52.4	52.4	52.4	52.4	52.4
Corn grain ground	13.3	11.0	12.7	13.3	10.0
Soybean meal	16.1	0.8	16.1	16.1	0.8
Soyhulls	13.1	2.7	12.3	13.1	1.8
DDGS	0.0	29.6	0.0	0.0	29.6
Fat	2.1	0.0	2.1	0.0	0.0
Corn oil	0.0	0.0	0.0	2.1	0.0
Minerals and vitamins	2.86	3.36	2.52	2.86	3.36
Sodium bisulfate	0.00	0.00	1.74	0.00	0.00
Potassium carbonate	0.14	0.14	0.14	0.14	0.34
Sodium bicarbonate	0.00	0.00	0.00	0.00	1.70
Chemical composition					
CP, %	16.1	16.4	16.3	16.8	16.5
Starch, %	28.4	28.3	28.5	28.7	27.1
NDF, %	30.2	30.7	29.8	29.7	30.5
FA, %	4.7	4.7	4.8	4.7	4.7
PUFA, % of FA	30.8	45.7	30.7	45.5	45.4
S, %	0.22	0.44	0.37	0.23	0.40
DCAD, mEq/ kg DM	178	42	198	165	330

¹SBM = soybean meal-based diet; DG = diet containing 29.6% dry distillers grains with solubles (DDGS; DM basis); SBM+S = SBM with increased dietary S; SBM + CO = SBM with corn oil; and DG + DCAD = DG with elevated DCAD.

²CP = crude protein, NDF = neutral detergent fiber, FA = fatty acids, PUFA = polyunsaturated fatty acids, and DCAD = dietary cation-anion difference.

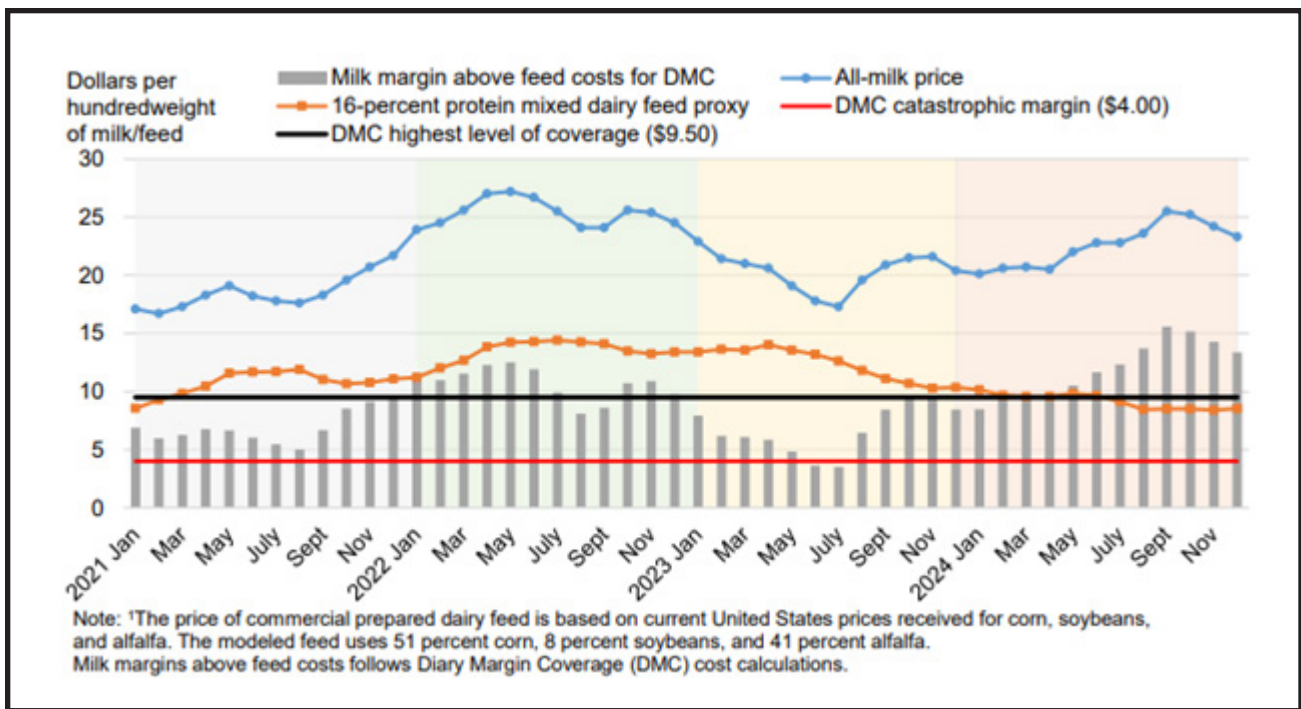


Figure 1. All-milk price, dairy feed value, and milk above feed cost (USDA Economic Research Service, Livestock, Dairy, and Poultry Outlook: Feb 2025).



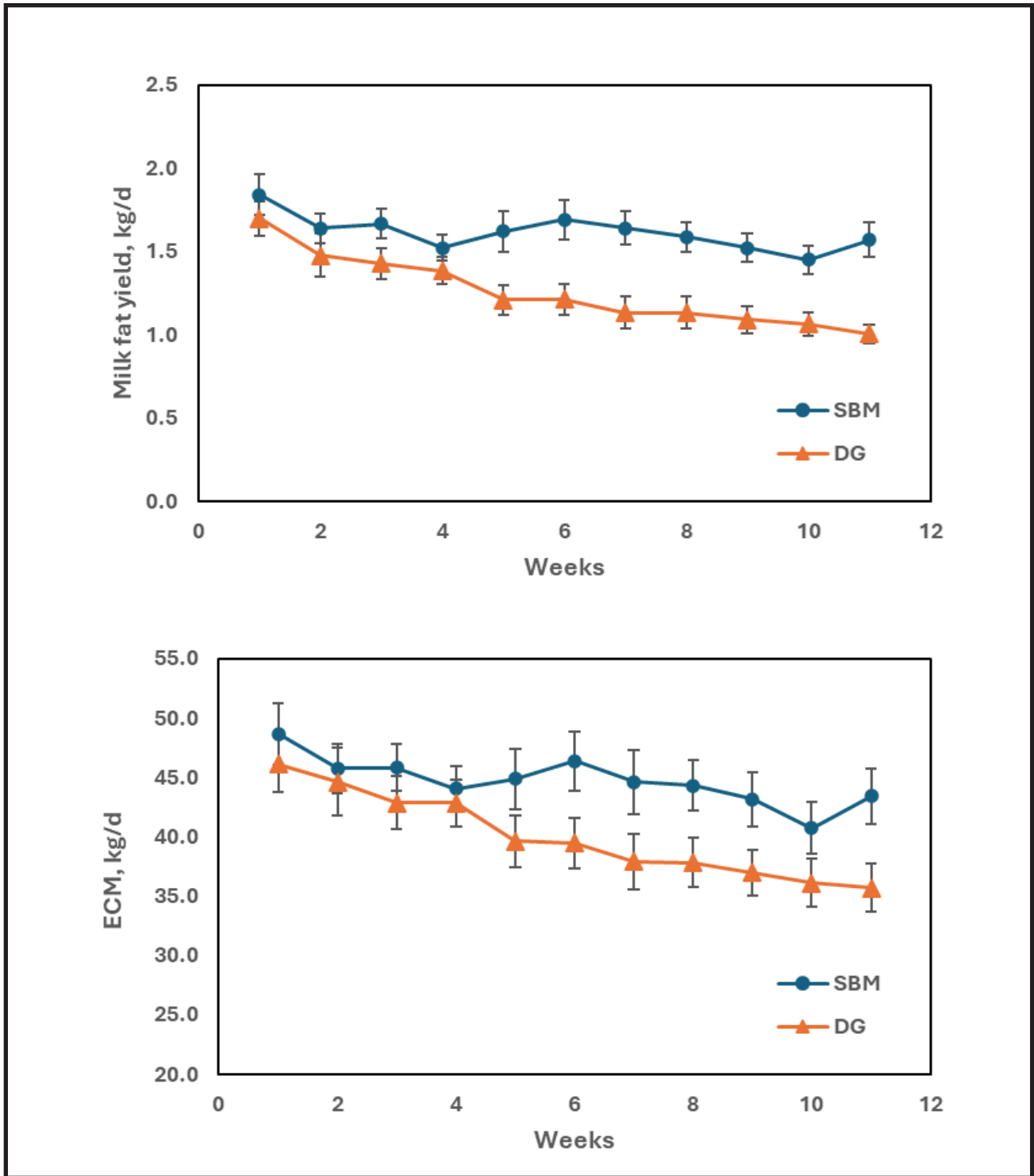


Figure 2. Milk fat yield and energy corrected milk (ECM) of cows fed a SBM-based diet or 29%-DG diet. Treatment effect for milk fat yield and ECM, $P < 0.01$. Interaction between treatment and week, $P < 0.05$ for milk fat yield and $P = 0.09$ for ECM (Adapted from Morris et al., 2018).



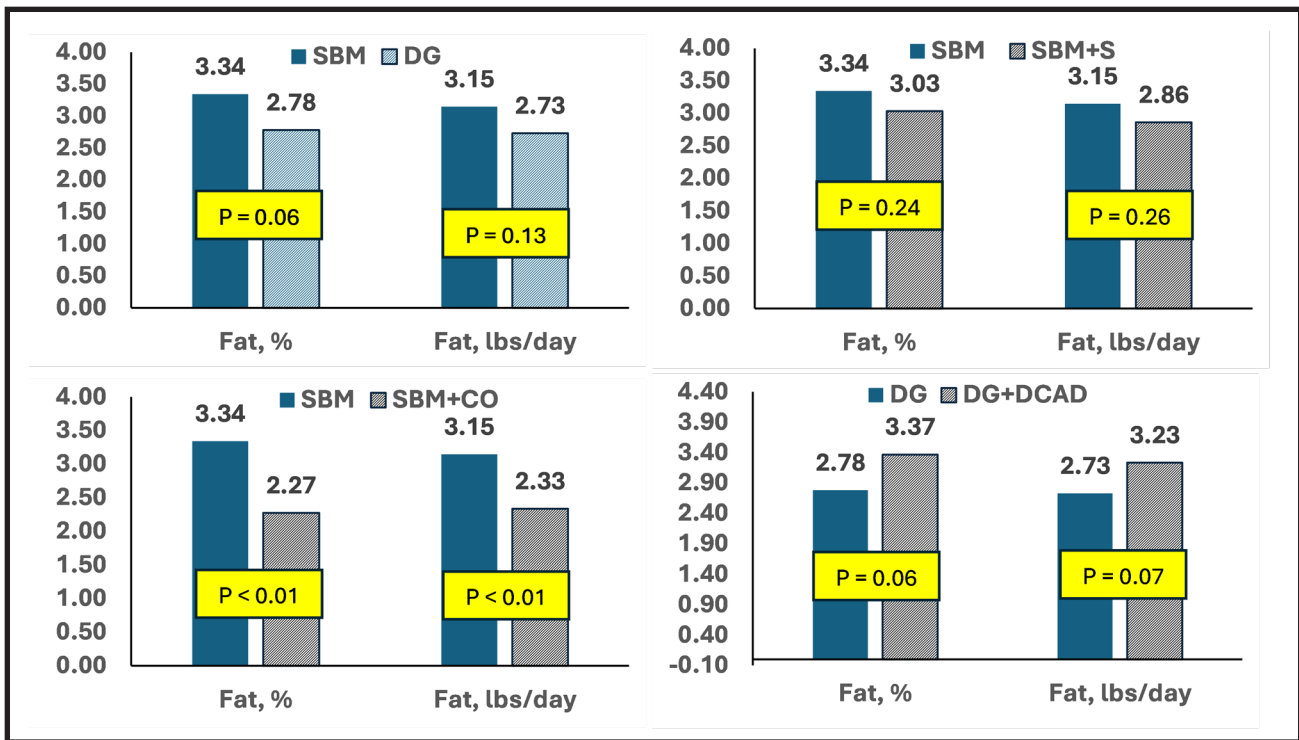


Figure 3. Milk fat concentration and yield of cows fed the soybean meal (SBM) diet, distillers grain (DG), SBM+S, SBM plus corn oil (SBM+CO), or DG with increased dietary cation-anion difference (DG+DCAD) diet (adapted from Clark et al., 2024).

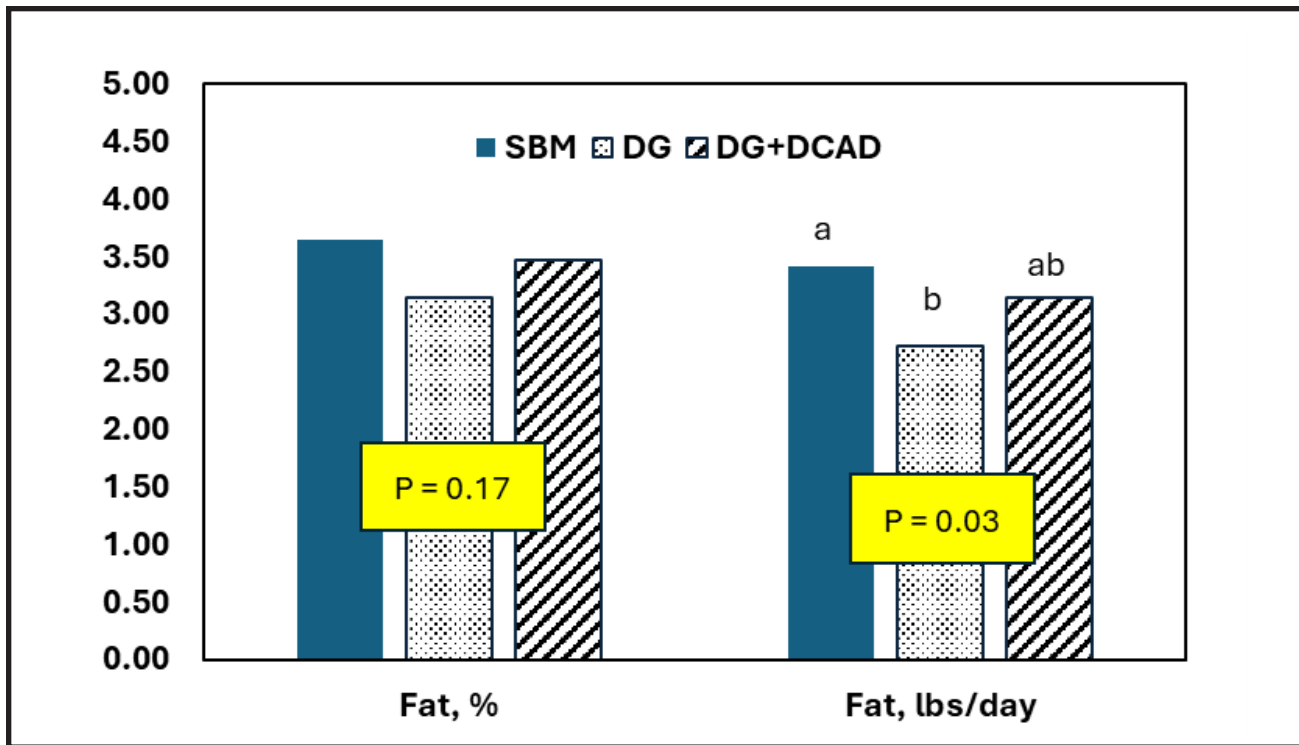


Figure 4. Milk fat concentration and yield of cows fed the SBM diet, DG, or DG+DCAD diet (adapted from Zynda et al., 2022). The inclusion rate of DG in the diet was 20% on a DM basis. The DCAD was 185, 61, and 187 mEq/kg DM for the SBM, DG, and DG+DCAD diet, respectively.