Dietary Molasses Enhances Ruminal Biohydrogenation and Partially Alleviates Diet-Induced Milk Fat Depression

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Summary

Milk fat depression remains a problem on dairy farms, and in recent years, incorporation of distillers grains (typically with solubles added and often dried) has contributed to this problem on some farms. In this study, we evaluated whether molasses could prevent milk fat depression in cows fed a high-risk diet. Replacing up to 5% of dietary corn with cane molasses linearly increased the yield of short- and medium-chain fatty acids in milk, indicating a positive effect on de novo fatty acid synthesis in a milk fat depression environment. Molasses, however, tended to linearly decrease milk yield and linearly decreased milk protein yield, resulting in no net effect on energy- or solids-corrected milk yield. These results indicate that the potential exists for sources of dietary sugar to prevent milk fat depression, but further research is needed to determine when sugar sources might be most effective.

Introduction

Production of ethanol is increasing rapidly in the United States. In the past 5 years alone, ethanol production capacity has more than doubled, as has production of dried distillers grains with solubles (**DDGS**). Although much work has been done to assess the effects of DDGS on productivity of lactating dairy cows, many nutritionists and dairy producers remain skeptical of its value in lactation diets. Reports of milk fat depression (**MFD**) in herds incorporating DDGS are widespread, and this issue continues to limit use of DDGS in the dairy industry. Milk fat depression is caused by an interaction of dietary factors that influence ruminal fermentation and availability of unsaturated fatty acids. Unique fatty acids produced in this rumen environment are capable of altering mammary function to decrease synthesis of milk fat. Therefore, unsaturated fatty acids provided by DDGS can lead to MFD.

One way to prevent MFD when feeding DDGS is to increase dietary fiber content; unfortunately, higher fiber diets limit energy intake and productivity. Increasing dietary sugar content may provide an alternative method of preventing MFD from DDGS. Fiber-digesting bacteria are thought to be primarily responsible for ruminal biohydrogenation of fatty acids, suggesting that dietary molasses may be capable of enhancing biohydrogenation of unsaturated fatty acids. Complete biohydrogenation of unsaturated fatty acids eliminates potential negative effects on milk fat synthesis; therefore, molasses may be capable of preventing diet-induced MFD. Our objective was to determine whether replacing corn grain with molasses at up to 5% of diet dry matter (**DM**) would prevent MFD from a high-concentrate ration including DDGS.

Experimental Procedures

Twelve second-lactation Holstein cows (134 days in milk) were randomly assigned to square and sequence within square in a replicated 3 × 3 Latin square design balanced for carryover effects. The control diet, formulated with the intention of causing MFD, included 36.6% forage and 21.2% corn DDGS, resulting in a diet with 26.2% neutral detergent fiber, 46.4% non-fiber carbohydrate, and 4.4% crude lipid. The remaining 2 diets were identical to the control diet except for the inclusion of cane molasses at 2.5 or 5% of diet DM to replace a portion of the corn grain. Composition and nutrient densities for the experimental diets are shown in Table 1. A common base mix representing 95% of diet DM was prepared daily, and ground corn grain, molasses, or both were added to complete each total mixed ration. Throughout the experiment, cows were housed in a tie-stall facility, milked twice daily (0500 and 1600 hours), and fed twice daily (0630 and 1700 hours) for ad libitum intake.

Treatment periods were 28 days, with 14 days for diet adaptation and 14 days for sample and data collection. All cows were treated with Posilac (Monsanto, St. Louis, MO) on days 1 and 15 of each period. To avoid potential interactions of dietary treatments with the Posilac treatment schedule, feed samples, DM intake, milk yield, and milk samples were collected on days 16, 19, 22, 25, and 28 of each period. Two milk samples were collected at each milking on these days, and milk samples were analyzed to determine concentrations of fat, protein, lactose, and urea nitrogen (Heart of America DHIA laboratory, Manhattan, KS) as well as fatty acid profile.

One cow was removed from the study early in period 3 because of mastitis. Data were analyzed by using mixed models including the fixed effect of treatment and the random effects of period and cow. Linear and quadratic contrasts were used to assess the effects of molasses inclusion rate for each variable.

Results and Discussion

Feeding a high-concentrate diet including 21% corn DDGS decreased milk fat concentration from 3.28% before the study to 2.61% during the study. Despite the extreme nature of the diet (predicted NE_L density of 0.81 Mcal/lb DM), cows appeared healthy and ate well throughout the study. In addition, feed efficiency values (mean: 1.33 lb energy-corrected milk per pound of DM intake) suggest the control diet did not dramatically impair nutrient digestion.

Productivity and Milk Fat Yield

Effects of molasses inclusion on productivity in this setting are shown in Table 2. Treatments had no effect on DM intake or feed efficiency. Increasing molasses inclusion rate tended ($P = 0.09$) to linearly decrease milk yield. Molasses, however, increased milk fat concentration (linear effect, $P < 0.001$; quadratic effect, $P = 0.09$), resulting in similar yields of fat- and solids-corrected milk across treatments. Despite the highly significant effect of molasses on milk fat concentration, milk fat yield was not significantly altered by treatment.

To further investigate the effects of dietary molasses on milk fat synthesis, we measured the profile of fatty acids in milk; this summary is shown in Table 3. Adding molasses linearly decreased ($P < 0.05$) yields of *trans*-10 C18:1 and total *trans*-C18:1 fatty acids in milk. These fatty acids are nearly always elevated in cases of MFD and can be used as markers of ruminal conditions that promote MFD. In contrast, molasses inclusion did not significantly alter yield of *trans*-10, *cis*-12 CLA, the fatty acid thought to be responsible for many cases of MFD. Nevertheless, the significant decrease in milk *trans* fatty acid secretion indicates that molasses inclusion enhanced ruminal fatty acid biohydrogenation.

In severe cases of MFD, both de novo fatty acid synthesis (responsible for short- and medium-chain fatty acids in milk) and use of circulating fatty acids (the source of long-chain fatty acids in milk) are typically decreased. In the current study, inclusion of molasses did not significantly alter yields of C16 or long-chain fatty acids but linearly increased ($P < 0.01$) the yield of short- and medium-chain fatty acids. This fatty acid response indicates a specific effect of dietary molasses on de novo fatty acid synthesis in the mammary gland, resulting in partial alleviation of MFD.

Milk Protein Yield

Increasing dietary molasses linearly decreased ($P = 0.03$) milk protein yield (Table 3), with the high molasses treatment causing a 7% decrease in protein yield. Dietary crude protein was similar across diets (Table 1), and neither corn grain nor cane molasses at 5% of diet DM provided a substantial amount of the dietary protein. Therefore, it is unclear why dietary molasses decreased milk protein synthesis. Nevertheless, this problem must be addressed before this approach to preventing MFD can be applied extensively in dairy nutrition.

Table 1. Ingredient and nutrient composition of diets[1]

	Dietary molasses		
	0%	2.5%	5%
Ingredient			
Corn silage	24.7	24.7	24.7
Alfalfa hay	11.9	11.9	11.9
Corn DDGS[2]	21.2	21.2	21.2
Ground corn grain	33.9	31.4	28.9
Molasses	–	2.5	5.0
Soybean meal	4.0	4.0	4.0
Expeller soybean meal	2.6	2.6	2.6
Limestone	1.1	1.1	1.1
Trace mineral salt	0.4	0.4	0.4
Micronutrient premixes	0.2	0.2	0.2
Nutrient			
Dry matter	64.3	64.1	63.9
Crude protein	17.4	17.2	17.1
Neutral detergent fiber	26.2	26.3	26.3
Non-fiber carbohydrate	46.4	46.3	46.2
Ether extract	4.4	4.4	4.3
Ash	5.5	5.7	5.9

[1] Values other than dry matter are expressed as a percentage of diet dry matter.
[2] Dried distillers grains with solubles.

Table 2. Effects of molasses inclusion rate on productivity of lactating dairy cows

	Dietary molasses				*P* value[1]	
	0%	2.5%	5%	SEM	Linear	Quad
Dry matter intake, lb/day	57.3	57.8	56.9	2.2	0.82	0.69
Milk yield, lb/day	82.9	81.4	78.3	6.6	0.09	0.80
Milk fat, %	2.61	2.65	3.01	0.21	0.001	0.09
Milk protein, %	3.35	3.32	3.31	0.09	0.25	0.88
Milk lactose, %	4.74	4.68	4.7	0.12	0.31	0.34
Milk fat, lb/day	2.16	2.14	2.32	0.22	0.15	0.39
Milk protein, lb/day	2.76	2.67	2.56	0.18	0.03	0.91
Milk lactose, lb/day	3.97	3.86	3.73	0.37	0.11	0.95
Milk urea nitrogen, mg/dL	12.5	11.7	11.6	0.7	0.04	0.44
Fat-corrected milk, lb/day	70.6	69.7	71.0	6.0	0.86	0.64

[1] Contrasts: Linear = linear effect of molasses inclusion rate; Quad = quadratic effect of molasses inclusion rate.

Table 3. Effects of molasses inclusion rate on milk fatty acid yield

	Dietary molasses				*P* value[1]	
Yield, lb/day	0%	2.5%	5%	SEM	Linear	Quad
trans-10 C18:1	0.073	0.060	0.050	0.014	0.02	0.88
Total *trans* C18:1[2]	0.114	0.108	0.097	0.011	0.04	0.70
Total unsaturated	0.90	0.89	0.87	0.06	0.52	0.86
Short- and medium-chain (< C16)	0.58	0.58	0.69	0.09	0.01	0.17
C16	0.59	0.57	0.61	0.06	0.31	0.18
Long-chain (> C16)	0.99	1.01	1.00	0.07	0.91	0.78

[1] Contrasts: Linear = linear effect of molasses inclusion rate; Quad = quadratic effect of molasses inclusion rate.
[2] Includes *trans*-9, *trans*-10, and *trans*-11 C18:1.