Fatty Acid Digestibility of Fat Sources Fed to Dairy Cows and Effects on Concentration of Fat in Milk

Honors Project Thesis

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Abstract: Milk fat yield affects the price received for milk by dairy farmers, and given the rising feed costs, maximizing diet digestibility is critical for the economical viability of dairy farms. Although feeding animal-vegetable fat or coconut oil to dairy cows can increase energy intake, they sometimes cause milk fat depression (MFD). Feeding monensin has been found to increase feed efficiency and milk yield; however, it sometimes causes a decrease in milk fat percentage. The objective of this research was to determine which sources of fat fed in conjunction with monensin may optimize yields of milk and milk fat. Six rumen-cannulated Holstein cows were fed 3 different diets varying in fat sources with and without the addition of monensin. The basal diet consisted of 50% concentrate, 33.5% corn silage, and 16.5% alfalfa hay. The control diet (C) contained 2.4% fat. This diet was supplemented with animal-vegetable fat (AV) and coconut oil (CO) separately to increase energy density and concentration of total fatty acids to approximately 6.1%. These 3 diets (C, AV, and CO) were further supplemented with 260 mg/cow/day of monensin for the remaining 3 diets (CM, AVM, and COM, respectively). Compared to C, apparent digestibility of total fatty acids increased with the addition of fat in the diet. Total fatty acid digestibility was greater with CO than AV due to more digestible medium chain fatty acids in CO. Digestibility of C16 fatty acids were greater with the addition of fat. Monensin and CO increased digestibility of C18 fatty acids. The CO diet resulted in about 5 kg/d less intake compared to C and AV. Addition of CO resulted in the greatest decrease in milk yield. Milk fat yield and percentage were decreased with fat addition, especially with the feeding of CO. Although CO is not a good alternative to AV to prevent MFD in dairy cows, its use can help identify the ruminal changes in biohydrogenation promoting MFD.

Introduction: While research has been conducted on the effects of feeding animal-vegetable fat, coconut oil, and the ionophore, monensin (ELANCO Animal Health, Greenfield, IN), individually to dairy cows, little work has been done on the effects of these supplements fed together. Feeding animal-vegetable fat to dairy cows can cause a decrease in milk fat percentage due to incomplete biohydrogenation of unsaturated fatty acids during digestion (Pantoja et al., 1996), especially when monensin is fed. Monensin, however, has been found to optimize bacterial populations in the rumen and increase feed efficiency, as well as milk yield (Van Der Werf et al., 1998). Coconut oil, high in medium chain fatty acids, was used as an alternative fat source to help increase the energy density in the diet (Dohme et al., 1999).

Objective: For this experiment, three different diets varying in fat sources will be fed with and without the addition of monensin to determine which combinations will be most favorable to dairy cows for milk yield and milk fat percentage. The basal diet was comprised of 50% concentrate, 16.5% alfalfa hay, and 33.5% corn silage. The diet had 3% fat and was labeled the control diet. This diet was supplemented with animal-vegetable fat and coconut oil separately to increase energy density and fat to approximately 8%. These three diets were further supplemented with monensin to comprise the six different diets. The objectives of this research were to:

1. Measure total tract fat digestibility of diets differing in fat sources and monensin, and
2. Determine which combinations of fat sources and monensin would be the most favorable on milk yield and concentration of fat in milk.

Hypotheses: In comparison to the control diet, we expected to see a positive effect on milk yield and a slightly negative effect on milk fat percentage when monensin was added. When coconut oil was added to the control diet, we expected to see a negative effect on both milk yield and milk fat percentage but an increase in both when monensin was added. When animal-vegetable fat was added to the control diet, we expected to see no change in milk yield and a slight decrease in milk fat percentage. When monensin was added to this diet, we expected to see an increase in milk yield and a substantial decrease in milk fat percentage.

Experimental Design: Samples collected from a trial conducted in January through June 2006 were used to conduct this research. The 6 rumen-cannulated lactating Holstein cows used for this trial were housed at the OSU Waterman Dairy Complex in the tie-stall barn. The cows were between 45 and 90 days in milk at the beginning of the trial. They were milked twice daily and fed hand-mixed diets administered every 2 hours by automatic feeders. The cows were organized in a 6 x 6 Latin square design with 21-day periods. The basal diet, labeled as the control, consisted of approximately 50% concentrate, 16.5% alfalfa hay, and 33.5% corn silage. The 6 diets were as follows:

1. Control diet with neither fat nor monensin added (C),
2. C with no added fat and 260 mg/cow/day of monensin (CM),
3. C with animal-vegetable fat blend (AV),
4. AV with 260 mg/cow/day of monensin (AVM),
5. C with coconut oil (CO), and
6. CO with 260 mg/cow/day of monensin (COM).

The chemical and fatty acid composition of the diets are provided in Tables 1 and 2, respectively.

Table 1. Chemical composition of the experimental diets.[1]

Item[2]	C	CM	AV	AVM	CO	COM
DM, %	63.6	63.2	64.0	63.7	63.7	63.2
	---------------------------------- % of DM------------------------------------					
NDF	33.4	33.9	29.3	30.0	28.2	28.8
Forage NDF	18.6	18.6	18.6	18.6	18.6	18.6
ADF	23.1	23.1	19.7	19.9	19.2	19.5
Crude Protein	16.6	16.5	16.4	16.9	16.9	16.3
Ash	5.57	5.62	5.48	5.45	5.31	5.34
Fatty acids	2.45	2.37	5.82	5.77	6.24	6.53
NFC	41.0	40.7	42.0	40.9	42.3	42.0

[1] Treatment diets were: C = control with no fat and monensin, CM = control plus monensin, AV = animal-vegetable ___blend, AVM = AV plus monensin, CO = coconut oil, and COM = CO plus monensin.

[2] DM = Dry matter, NDF= neutral detergent fiber, ADF= acid detergent fiber, and NFC = non-fiber carbohydrates.

Table 2. Fatty acid composition of experimental diets.[1]

Fatty acid	C	CM	U	UM	CO	COM
	------------------------ % of supplemental fatty acids----------------------					
8:0	0.05	0.06	0.15	0.12	5.41	5.40
10:0	0.01	0.04	0.06	0.03	3.86	3.85
12:0	0.47	0.73	0.47	0.29	29.70	29.55
14:0	0.2	0.5	0.8	0.7	11.4	11.3
16:0	16.9	17.2	19.8	19.8	12.0	11.9
16:1c9	0.00	0.07	1.49	1.50	0.00	0.00
18:0	3.41	3.42	6.19	6.59	2.47	2.69
18:1 t all	0.52	0.69	2.47	2.31	0.18	0.20
18:1 c all	20.2	19.6	28.2	28.0	11.8	11.6
18:2 c9c12	48.7	47.7	33.0	33.0	19.8	19.9
18:3 all	7.27	8.07	3.95	3.98	2.62	2.78

[1] Treatment diets were: C = control with no fat and monensin, CM = control plus monensin, AV = animal-vegetable blend, AVM = AV plus monensin, CO = coconut oil, and COM = CO plus monensin.

Methods: Representative samples from the total mixed ration (TMR) and refusal were collected and weighed to determine the daily nutrient intake for each cow. Total pounds of feed offered were also adjusted daily according to pounds of refusal from the previous day. Fecal samples were taken to determine total tract digestibility and nutrient output with the use of chromic oxide, an indigestible marker.

Each sample collected was weighed and dried to determine percentage of dry matter. Fecal samples were further analyzed by atomic absorption spectrometry to determine chromium concentration for calculation of fecal excretion.

Fatty acid analyses were conducted for each of the TMR, refusal, and fecal samples as reviewed by Palmquist and Jenkins (2003). The fatty acids were methylated with 5 mL of 10% methanolic HCl (2 h at 90℃). Nonadecanoic acid (19:0) was used as an internal standard. After adding 1mL hexane and 10 mL of 6% K_2CO_3, the samples were centrifuged (5 min, 500 x *g*). The organic layer added to 1g each of Na_2SO_4 and charcoal was centrifuged. The supernatants were transferred into 1-mL gas-liquid chromatogragh (GLC) auto sampler vials, capped, and stored at -20℃ until GLC analysis.

Retention times were determined with methyl ester standards and used to identify peaks. Fatty acid methyl esters were separated by using a HP 5890 Series II gas chromatograph and quantified with the ChemStation software using 19:0. Helium was used as the carrier gas. The GLC conditions were described in Reveneau et al. (2005). Milk samples were collected each period and analyzed for milk fat percentage by the DHI Cooperative, Inc. (Columbus, OH). Milk yield was measured at each milking by a automated metering device within the milking system. Data were analyzed using SAS (2004), and significance was $P < 0.05$ for main effects and $P < 0.10$ for interactions.

Results: The digestibility of DM was similar among diets (Table 3). Compared to C, apparent digestibility of total fatty acids increased with the addition of fat in the diet. Total fatty acid digestibility was greater with CO than AV due to more digestible medium chain fatty acids in CO. Digestibility of C16 fatty acids were greater with the addition of fat. Monensin and CO increased digestibility of C18 fatty acids. The CO diet resulted in about 5 kg/d less intake compared to C and AV (Table 4). Addition of CO resulted in decreased milk yield. Milk fat percentage and yield were decreased feeding fat, especially with the feeding of CO. There tended to be an interaction between monensin and source of fat whereby monensin decreased milk fat yield when fed with AV and increased it when fed with CO.

Table 3. Least square means of apparent total tract digestibility of dry matter and fatty acids.[1]

Item	C	CM	AV	AVM	CO	CO	SEM	Mon	Fat	Source	MxF	MxS
Dry Matter %	67.0	64.3	66.7	69.5	66.5	65.8	1.5	NS	NS	0.19	0.14	NS
Total Fatty Acid %	69.2	72.8	69.5	74.7	88.2	91.3	4.3	0.13	0.01	<0.01	NS	NS
All 16 %	64.5	65.2	75.5	78.8	79.0	82.2	3.9	NS	0.01	NS	NS	NS
All 18 %	73.5	76.8	68.5	75.0	81.0	88.7	4.5	0.05	NS	<0.01	NS	NS

[1] Treatment diets were: C = control with no fat and monensin, CM = control plus monensin, AV = animal-vegetable blend, AVM = AV plus monensin, CO = coconut oil, and COM = CO plus monensin; SEM = standard error of mean and NS = not significant; statistical contracts were: Mon = Effect of monensin (C+AV+CO vs CM+AVM+COM), Fat = effect of no fat versus fat (C+CM vs others), Source = effect of fat source (AV+AVM vs CO+COM), MxF = interaction of monensin and fat, and MxS = interaction of monensin and fat source.

Table 4. Least square means of dry matter intake, yields of milk and milk fat, and milk fat percentage.[1]

Item	C	CM	AV	AVM	CO	COM	SEM	Mon	Fat	Source	MxF	MxS
Dry Matter Intake, kg/d	20	19.3	19.8	19.0	15.5	14.8	0.7	0.08	<0.01	<0.01	NS	NS
Milk, kg/d	33.9	33.1	34.3	31.7	30.5	30.1	2.0	0.06	0.01	<0.01	NS	0.15
Milk fat, %	3.23	3.18	2.96	2.79	2.37	2.50	0.19	NS	<0.01	<0.01	NS	NS
Milk fat, kg/d	1.08	1.05	1.01	0.87	0.71	0.74	0.05	0.15	<0.01	<0.01	NS	0.08

[1] Treatment diets were: C = control with no fat and monensin, CM = control plus monensin, AV = animal-vegetable blend, AVM = AV plus monensin, CO = coconut oil, and COM = CO plus monensin; SEM = standard error of mean and NS = not significant; statistical contracts were: Mon = Effect of monensin (C+AV+CO vs CM+AVM+COM), Fat = effect of no fat versus fat (C+CM vs others), Source = effect of fat source (AV+AVM vs CO+COM), MxF = interaction of monensin and fat, and MxS = interaction of monensin and fat source.

Discussion: The diets supplemented with CO provided more than 2/3 of the fatty acids (FA) as medium chain FA, and the AV diets provided more than 2/3 of the FA as linoleic acid, in agreement with the treatment structure. The diets supplemented with fat had 3.7 percentage units higher FA with similar other dietary chemical composition as control, except for lower non-forage NDF.

The control diet resulted in a higher fraction of endogenous fat and proportionally more fecal fat, thereby resulting in a lower fat digestibility. The CO diets were more digestible than the AV diets, but this was due to the large amount of medium chain FA in CO versus long chain FA in AV. Medium chain FA, being shorter, are more easily absorbed.

Fat increased C16 digestibility. Monensin increased the digestibility of C18 FA, most likely by increasing the proportion of more digestible unsaturated FA from incomplete biohydrogenation by ruminal bacteria. This inhibition might also explain the observed MFD. The CO diets increased C18 digestibility, but this was likely due to the low concentration of C18 compared to C16.

Unlike our hypothesis, CO also led to MFD. This may be attributed to coconut oil's undesirable taste and smell, resulting in it being less favorable to the cows. The CO diet resulted in about 5 kg/d less intake compared to C and AV. The decrease in intake with CO might have limited energy for milk fat synthesis, and further analysis of omasal and milk FA will help elucidate the mechanism of MFD with CO supplementation.

Decreased milk production tended to occur with the addition of monensin. The CO and COM diets resulted in the greatest decrease in milk yield.

Conclusion: While monensin led to increased digestibility, it tended to reduce dry matter intake and milk yield. Although CO is not a good alternative to AV to prevent MFD in dairy cows, its use can help identify the ruminal changes in biohydrogenation that promotes MFD.

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