PERFORMANCE AND METABOLIC MEASURES OF LACTATING DAIRY COWS FED DIETS SUPPLEMENTED WITH EITHER MOSTLY SATURATED OR MORE UNSATURATED FATTY ACIDS

J. K. BERNARD

ABSTRACT

A 10-wk lactation trial was conducted during the late summer and early fall of 2006 using 45 late lactation Holstein cows (199.7 ± 66.3 DIM and 32.0 ± 5.2 kg milk/d) to determine the effect of feeding supplemental mostly (85%) saturated (SAT) or more (50%) unsaturated (UNS) fatty acids on the performance and select metabolic measures. The first 2 wk of the trial served as a standardization period and all cows were fed the control diet without any supplemental fat other than whole cottonseed. At the end of wk 2, cows were blocked by parity and randomly assigned to one of three treatments with each block for 8 wk. Treatments included a control (no supplemental fat other than whole cottonseed), or the equivalent of 1 kg/d of mostly saturated or more unsaturated fatty acids. Dry matter intake, milk yield, and milk composition were similar among treatments. Average DMI, milk yield, and milk fat and protein percentage were 23.8 kg/d, 32.5 kg/d, 3.47%, and 3.23%, respectively. The BW and BCS of the cows were similar throughout the trial and all cows gained similar amounts of weight and condition. Concentrations of total cholesterol, HDL, and LDL in the blood were higher for cows fed diets supplemented with UNS compared with either control or SAT. Triglyceride and BUN concentrations were similar among treatments. Concentrations of NEFA were higher for UNS whereas insulin concentrations were higher for SAT than either control or UNS. There were no differences in internal body temperature among treatments but there was an interaction of treatment and time of day during wk 4 related to higher body temperatures for cows fed UNS at 0500 through 0530 compared with control and SAT and again at 0930 through 1030 compared with SAT. These results indicate that supplemental SAT or UNS did not significantly alter intake or performance of cows that have been through heat stress and were in late lactation; however feeding UNS did increase cholesterol and NEFA concentrations along with lowered insulin and tended to keep body temperature higher than either control or SAT-supplemented diets.

INTRODUCTION

Supplemental fats are frequently added to the diet of lactating dairy cows to improve energy intake, especially during the summer when heat stress depresses intake. Previous research has demonstrated that calcium salts of long chain fatty acids can lower intake in some cases, but milk yield is sustained. Recently, Harvatine and Allen (2005) reported changes in select blood metabolic when cows were fed fat supplements that were mostly saturated or unsaturated. Fats have a lower heat increment and theoretically should reduce the total amount of heat generated by the cow which would reduce heat stress, but this has not been documented. This trial was conducted to determine the effect of the mostly saturated or unsaturated fat supplements on intake, production, heat stress and select blood metabolites of late lactation dairy cows that were exposed to heat stress.

MATERIALS AND METHODS

Forty-eight lactating Holstein cows were selected from the dairy herd at the Tifton Campus of the University of Georgia. All protocols were approved by the Institute of Animal Care and Use Committee of the University of Georgia. Before beginning the trial, all cows were trained to eat behind Calan doors (American Calan Inc., Northwood, NH). Cows were housed in a 4 row free stall barn equipped with 91 cm fans mounted over the feed alley and free stalls every 6.1 m. The fans were programmed to automatically come on when the temperature in the barn exceeded 23ºC. The fans were fitted with high pressure misters programmed to operate when the fans were running until the relative humidity exceeded 85%. Cows were provided access to an exercise lot once daily at approximately 0830 through 0900.

After all cows were trained to eat behind the Calan doors, cows were fed the control diet (Table 1) for 2 wk. At the end of the preliminary period, cows were blocked by parity. Within each block, cows were assigned randomly to one of three treatments. Treatments included control (no supplemental fat), supplemental mostly (85%) saturated fatty acids (SAT, prilled fatty acids, Energy Booster 100, MSC, Dundee, IL) or more (50%) unsaturated fatty acids (UNS, calcium salts of long chain fatty acids, Megalac, Church & Dwight Inc., Princeton, NJ). The ingredient composition of experimental diets is outlined in Table 1.

Throughout the trial, cows were individually fed once daily in amounts to provide a minimum of 5% refusal. Feed was pushed up at least twice daily. The amount of feed offered and refused was recorded daily. Cows were milked twice daily at approximately 0300 and 1500. Individual milk yield was recorded electronically (Alpro, DeLaval, Kansas City, MO), summed for each day and averaged each week. All cows were administered rBST according to label (Posilac, Monsanto Dairy Business, St. Louis, MO). When animals were diagnosed with mastitis or any other disease, care and treatments were provided and the information recorded. One cow on each treatment was removed from the trial because of mastitis (n = 2) or bovine leukosis virus (n = 1).

Samples of experimental diets and ingredients were collected three times each week, composited, and dried at 55ºC for 72 h. The DM content of the ingredients was used to adjust rations as necessary to maintain desired proportions of each ingredient in each TMR. Samples were ground to pass through a 1-mm screen using a Wiley Mill (Arthur B. Thomas, Philadelphia, PA). Samples were analyzed for DM (forages according to Goering and Van Soest [1970] and grains, mixed feeds, concentrates, and byproducts according to AOAC [1990]), CP (Leco FP-528 Nitrogen Analyzer, St. Joseph, MI), and ADF and NDF (Van Soest et al., 1991), fat by acid hydrolysis, ash, and mineral (AOAC, 1990). Fat supplements were not analyzed for fatty acid composition.

Milk samples were collected from two consecutive p.m. and a.m. milkings during each week of the trial. Samples were shipped for analyses of fat and protein using a Foss 4000 equipped with an A filter (Foss North America, Eden Prairie, MN). Body weights were recorded on two consecutive days during the standardization period and end of wk 4 and 8 of the experimental period. To minimize variation, BW was recorded after the PM milking before animals had access to feed or water. The BCS was recorded at the end of the preliminary period and during wk 4 and 8 according to Wildman et al. (1982).

Core body temperature of each cow was recorded at 5 min intervals over a 3-d period using a HOBO water temperature probe (Onset Computer Corp., Boure, MA) inserted into the vagina during the last week of the preliminary period and wk 4 and 8 of the experimental period. Environmental conditions within the free stall barn were recorded throughout the trial simultaneously at 5 min intervals using an automatic recorder (Onset.Computer Corp.). The THI was recorded using temperature and dew point according to NOAA (1976). For each cow within each collection, data were averaged by 30 min intervals for statistical analysis. Respiration rates were recorded by two individuals during the last week of the preliminary period and wk 4 and 8.

Two whole blood samples were collected from each cow via coccygeal venipuncture during wk 4 and 8. Tubes were allowed to clot, and serum was harvested by centrifugation. Samples were analyzed at the University of Georgia Veterinary Diagnostic Laboratory in Tifton for total cholesterol, HDL, LDL, triglycerides, blood urea N and glucose using a Bodhringer Mannheim/Hitachi 912 automated chemistry analyzer (Roche Laboratory Systems, Indianapolis, IN). A second sample was analyzed for non-esterified fatty acid and insulin concentrations as outlined by Hockett et al. (2005).

Intake, milk yield and composition, body weight and condition score, and body temperature data were subjected to analyses of covariance using PROC MIXED procedures (SAS Inst., Inc., Cary, NC). Sums of squares were partitioned to DIM at the beginning of the trial, block, covariate, treatment, week, and week x treatment. Cow within treatment was included as a random variable and week was considered a repeated measure. Blood metabolite data and change in body weight or condition score were subjected to analysis of variance using the same model without a covariate. When significance was observed between treatments ($P < 0.10$), the PDIFF option was used for mean separation.

RESULTS AND DISCISSION

Experimental diets contained similar concentrations of CP, NDF, ADF, NSC, and minerals (Table 2.). The NE_l and fat concentrations were slightly lower for the control diet compared with SAT and UNS as planned. The supplemental fat sources averaged 99.7% fat by acid hydrolysis for SAT and 79.1% for UNS (DM basis).

No differences were observed between treatments in DMI, milk yield or milk composition (Table 3). Based on the 2001 Dairy NRC equation of 2.5% decrease in DMI for each 1% dietary inclusion of UNS, it would be expected that UNS would have decreased DMI by 5% rather than the observed 3%. Milk protein concentrations were numerically higher for both SAT (3.31%) and UNS (3.27%) compared with control (3.11%), but these differences were not significant ($P = 0.13$, SE = 0.03). Because there were no differences in milk yield or composition, yield of 3.5% FCM was similar among treatments. Harvatine and Allen (2005) reported lower DMI when cows were supplemented with UNS than SAT, but milk yield was similar for both treatments. These researchers reported higher milk protein percentage with SAT compared with UNS, but milk protein yield was similar. Dairy efficiency (kg 3.5% FCM/kg DMI) was similar between treatments (Table 3) and averaged 1.36 which is lower than desired (1.5). The lower efficiency reflects the advanced stage of lactation and effects of chronic heat stress that the cows had been subjected to before beginning the trial. Cows had similar initial BW and BCS and gained similar amounts of BW and condition during the trial.

Concentrations of select blood metabolites and endocrine secretions are presented in Table 4. Total cholesterol ($P = 0.009$) and LDL ($P = 0.02$) concentrations were higher with UNS compared with control and SAT. Concentrations of HDL where lower ($P = 0.009$) for control than either SAT or UNS. No differences were observed in triglyceride, BUN or glucose concentrations between treatments. Cows fed UNS had higher ($P = 0.02$) NEFA compared with control. Insulin concentrations were higher ($P = 0.05$) with SAT compared with control or UNS. Harvatine and Allen (2005) observed higher NEFA concentrations and lower insulin concentrations when cows were fed diets supplemented with UNS compared with SAT. This was consistent with cows mobilizing some body condition, most likely due to the lower DMI of UNS, and lower DMI being associated with lower insulin.

The environmental temperatures and THI inside the free stall barn were highest during the preliminary period than either wk 4 or 8 of the experimental period. Average temperature and THI was 19.2 ºC (range 7.6 - 28.3 ºC) and 64.6 (range 50.7 - 75.4) during wk-4 and 15.7 ºC (range 8.6 - 24.4 ºC) and 61.9 (range 53.0 - 70.7) during wk-8. The temperatures cooled earlier during the fall of 2006 than normal. There were periods of heat stress (THI > 72) during both the preliminary period and wk-4, but environmental temperatures had cooled sufficiently so that cows would not have been under chronic heat stress conditions during the trial. By wk-8 of the experimental period, heat stress would not be considered to be present. Body temperature and respiration rate data were analyzed separately for wk 4 and 8 because of the differences in environmental conditions. Although there were no differences among treatments in body temperature during wk 4 ($P = 0.86$, Table 5), there was a tendency for an interaction of treatment and time of day ($P = 0.06$) because of slightly higher body temperatures with UNS at 0500 through 0530 compared with control and SAT and again at 0930 through 1030 compared with SAT (Figure 1). Behavioral data were not collected, but 0500-0530 would correspond to a meal after the a.m. milking and the 0930 - 1030 to the period when cows immediately after the cows were turned into the exercise lot. No differences were observed between treatments during wk 8. Respiration rates were similar among treatments during wk 4, but were higher ($P = 0.06$) for cows fed UNS during wk 8 than control or SAT.

CONCLUSIONS

The results of this trial indicate that supplemental SAT or UNS did not significantly alter intake or performance of cows that have been through heat stress and were in late lactation; however feeding UNS did increase cholesterol and NEFA concentrations along with lowered insulin and tended to keep body temperature higher than either control or SAT-supplemented diets.

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Table 1. Composition of experimental diets supplemented with mostly saturated (SAT) or more unsaturated (UNS) fatty acids (% of DM).

Ingredient	Control	SAT	UNS
Alfalfa hay	5.89	5.89	5.89
Corn silage	34.33	34.33	34.33
Brewers grains, wet	13.14	13.14	13.14
Whole cottonseed	6.87	6.87	6.87
Ground corn	21.58	19.52	19.23
Molasses, liquid	0.98	0.98	0.98
Citrus pulp	6.38	6.38	6.38
Saturated FA[1]		1.67	
Unsaturated FA[2]			1.96
Soybean meal, 48% CP	5.30	5.69	5.69
Prolak[3]	2.75	2.75	2.75
Sodium bicarbonate	0.59	0.59	0.59
Potassium magnesium sulfate	0.20	0.20	0.20
Limestone	0.39	0.39	0.39
Magnesium oxide	0.20	0.20	0.20
Salt, white	0.20	0.20	0.20
Potassium carbonate	0.49	0.49	0.49
Availa-4[4]	0.04	0.04	0.04
Yeast culture	0.25	0.25	0.25
Premix[5]	0.45	0.45	0.45

[1]Mostly saturated fatty acids from Energy Booster 100 (MSC, Dundee, IL)
[2]More unsaturated fatty acids from calcium salts of long chain fatty acids (Megalac, Church & Dwight Co., Princeton, NJ).
[3]H. J. Baker & Bro., Inc., Westport, NJ
[4]Zinpro Corp., Eden Prairie, MN
[5]Premix provided trace mineral and vitamins to meet NRC recommendations plus monensin sodium at the rate of 15g/907 kg DM (Elanco Animal Health, Greenfield, IN).

Table 2. Chemical composition of experimental diets.

Item	Control	SAT[1]	UNS[2]
	------------------------------	%	------------------------------
DM	45.61 ± 1.71	45.11 ± 1.69	44.48 ± 1.23
	-------------------------	% of DM	-------------------------
CP	17.84 ± 0.50	18.06 ± 0.45	17.92 ± 0.44
UIP[3]	7.41	7.48	7.42
NDF	34.70 ± 1.33	34.62 ± 1.43	34.39 ± 1.41
ADF	20.60 ± 1.18	20.12 ± 1.03	20.51 ± 0.72
Fat[3]	6.12 ± 0.49	7.22 ± 0.52	7.52 ± 0.67
NSC[4]	35.98 ± 1.94	34.59 ± 1.47	34.52 ± 1.00
Ash	6.80 ± 0.80	6.99 ± 0.42	7.10 ± 0.53
Ca	0.81 ± 0.04	0.85 ± 0.06	0.97 ± 0.05
P	0.45 ± 0.01	0.43 ± 0.01	0.43 ± 0.01
Mg	0.29 ± 0.03	0.28 ± 0.02	0.29 ± 0.03
K	1.21 ± 0.07	1.19 ± 0.03	1.17 ± 0.05
	-----------------------	Mcal/kg of DM	-----------------------
NE_l[3]	1.74	1.79	1.79

[1]Mostly saturated FA from Energy Booster 100 (MSC, Dundee, IL)
[2]More unsaturated FA from calcium salts of long chain fatty acids (Megalac, Church & Dwight CO, Princeton, NJ)
[3]Calculated using chemical analysis of dietary ingredients (NRC, 2001)
[4]Nonstructural carbohydrates

Table 3. Dry matter intake, milk yield and composition, and BW of cows fed diets containing supplemental mostly saturated or more unsaturated fatty acids.

Item	Control	SAT[1]	UNS[2]	SE	*P*
DMI, kg/d	24.0	24.0	23.3	0.7	0.71
Milk, kg/d	33.1	32.3	32.2	0.8	0.69
Fat, %	3.41	3.53	3.47	0.40	0.79
Fat, kg/d	1.13	1.14	1.12	0.06	0.64
Protein, %	3.11	3.31	3.27	0.03	0.13
Protein, kg/d	1.03	1.07	1.05	0.03	0.57
3.5% FCM, kg/d	32.6	32.5	32.0	1.1	0.94
Dairy efficiency[3]	1.36	1.35	1.37	0.07	0.91
Initial BW, kg	641.5	666.4	649.9	15.8	0.55
BW Change , kg	48.1	44.8	52.8	5.3	0.58
Initial BCS	3.04	3.15	3.06	0.08	0.64
BCS Change	0.28	0.29	0.25	0.07	0.90

[1]Mostly saturated FA from Energy Booster 100 (MSC, Dundee, IL)
[2]More unsaturated FA from calcium salts of long chain fatty acids (Megalac, Church & Dwight,Co., Princeton, NJ).
[3]Dairy efficiency is defined as kg 3.5% FCM/kg DMI.

Table 4. Concentrations of select blood metabolites of lactation cows fed diets containing supplemental mostly saturated or more unsaturated fatty acids.

Item	Control	SAT[1]	UNS[2]	SE	*P*
			------------------------- mg/dl -------------------------		
Total cholesterol	236.47[a]	256.11[a]	290.90[b]	11.63	0.009
Triglycerides	17.50	17.80	18.26	0.63	0.69
HDL	116.46[a]	124.44[b]	129.75[b]	2.80	0.009
LDL	116.50[a]	127.70[a]	157.42[b]	9.79	0.02
BUN	13.09	13.69	13.78	0.40	0.44
Glucose	65.59	67.47	65.71	0.82	0.22
			------------------------ mEq/L ------------------------		
NEFA	0.156[a]	0.173[ab]	0.192[b]	.009	0.02
			------------------------- ng/ml -------------------------		
Insulin	0.65[c]	0.91[d]	0.58[c]	0.09	0.05

[ab]Means in the same row with unlike superscripts differ ($P < 0.05$).
[cd]Means in the same row with unlike superscripts differ ($P < 0.10$).
[1]Mostly saturated FA from Energy Booster 100 (MSC, Dundee, IL)
[2]More unsaturated FA from calcium salts of long chain fatty acids (Megalac, Church & Dwight,Co., Princeton, NJ).

Table 5. Environmental temperatures, body temperatures and respiration rate of lactation cows fed diets containing supplemental mostly saturated or more unsaturated fatty acids.

Time	Control	SAT[1]	UNS[2]	SE	*P*
Body temperature, °C					
Wk 4[3]	39.09	39.08	39.16	0.10	0.86
Wk 8[4]	38.84	38.79	38.85	0.10	0.87
Respiration rate, breaths/min					
Wk 4	66.5	72.9	70.3	3.1	0.2268
Wk 8	54.7[a]	54.5[a]	61.8[b]	2.6	0.0383

[ab]Means in the same row with unlike superscripts differ ($P < 0.05$).
[1]Mostly saturated FA from Energy Booster 100 (MSC, Dundee, IL)
[2]More unsaturated FA from calcium salts of long chain fatty acids (Megalac, Church & Dwight,Co., Princeton, NJ).
[3]October 10-12, 2006.
[4]Novermber 7 - 9, 2006

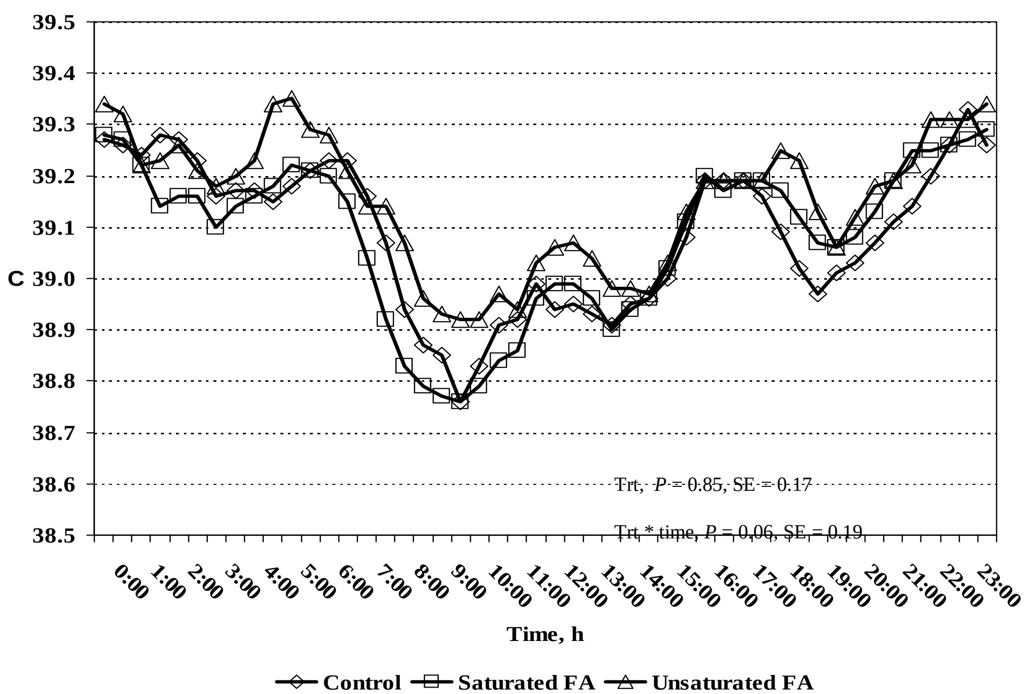

Figure 1. Body temperature (F) measured on three consecutive days during week 4 (October 10-12).