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Effect of feeding an energy supplement to dairy cows pre- and postpartum on intake, milk yield, and incidence of ketosis

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Abstract

Seventy-five dry multiparous Holstein cows housed in a tie stall facility on a commercial dairy, were blocked and assigned randomly to treatments to evaluate the effect of feeding a dry energy supplement for 21 days prepartum and 21 days postpartum on animal performance. The energy supplement contained 45% beet pulp, 22% sugarcane molasses, 17% propylene glycol, and 16% calcium propionate (DM basis). The sugars in molasses were mainly glucose and sucrose. Forages and concentrates were fed separately and comprised 67 and 33% (DM basis), respectively, of the diet for dry cows and 46 and 54%, respectively, of the diet for lactating cows. In addition, each cow received 908 g per day of ground corn (85% DM; control), 454 g per day of ground corn and 454 g per day of the energy supplement (86% DM), or 908 g per day of the energy supplement on an as fed basis. Feeding the energy supplement had no effect on DM intake among dry or lactating cows, or effect on incidence of ketosis among lactating cows. Milk yield during week 1–4 postpartum by cows fed ground corn (43.9 kg per cow per day) was lower ($P = 0.073$) than by cows fed the diets containing the energy supplement at the low (46.3 kg per cow per day) and high levels (44.5 kg per cow per day). After the feeding of the energy supplement was discontinued after week 3, milk yield by cows previously fed the energy supplement at the low (53.4 kg per cow per day) and high levels (52.7 kg per cow per day) was greater ($P = 0.006$) than that by cows fed ground corn (50.1 kg per cow per day). Cows previously fed the energy supplement at either level also had higher yield of milk fat ($P = 0.027$) and protein ($P = 0.061$) than cows fed ground corn. Feeding an energy supplement containing beet pulp, sugarcane molasses, propylene glycol, and calcium propionate to Holstein cows improved milk yield, especially when fed at the low level.

Keywords: Dairy cow; Energy supplement; Ketosis; Milk yield

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1. Introduction

Ketosis is a metabolic condition characterized by increased concentrations of ketone bodies in blood (ketonemia), urine (ketonuria), milk (ketolactia), and other body fluids (Geishauser et al., 1998). The major ketone bodies are β-hydroxybutyrate (BHBA), acetoacetate, and acetone. Ketosis is classified as subclinical or clinical depending on severity (Baird, 1982; Kronfeld, 1982; Moore and Ishler, 1997; Geishauser et al., 1998).

Ketosis causes economic losses to the dairy industry because of decreased milk production and reproductive efficiency, as well as increased involuntary culling and veterinary costs (Detilleux et al., 1994; Geishauser et al., 1998). Feeding animals glycogenic materials not metabolized in the rumen, such as propionate (Van Soest, 1994) and propylene glycol (Grummer et al., 1994; Van Soest, 1994; Christensen et al., 1997), is helpful in treating ketosis. Calcium propionate administered within 24 h of calving has also successfully treated milk fever (Goff et al., 1996), which together with fatty liver, are the other major metabolic diseases of dairy cows that occur within the first 2 weeks of lactation (Veenhuizen et al., 1991; Goff et al., 1996; Goff and Horst, 1997).

Supplementation of grass silage-based diets with glucose (Chamberlain et al., 1985; Rooke et al., 1987), sucrose (Chamberlain et al., 1985; Huhtanen, 1987) and/or xylose (Huhtanen, 1987) increased flow of microbial protein and nonprotein N to the small intestines. The increased supply of rapidly fermentable carbohydrates allowed ruminal microbes to capture excess ruminal ammonia N and synthesize microbial protein. Feeding readily available carbohydrates in the form of molasses was also reported to increase milk production by dairy cows, but it did not affect intake (Morales et al., 1989; Oldick et al., 1997).

The objectives of this study were to evaluate effects of feeding a commercial mixture of 45% beet pulp, 22% sugarcane molasses, 17% propylene glycol, and 16% calcium propionate (Sweet Lac™ Transition Formula (SLTF); Westway Trading Corporation Inc., Tomball, TX, USA) to multiparous Holstein cows for 21 days prepartum and 21 days postpartum on DM intake, milk production, milk composition, and incidence of ketosis. The sugars in molasses were largely glucose and sucrose.

2. Materials and methods

2.1. Animals, diets, and feeding

Seventy-five close-up (21 ± 3.0 day) dry multiparous Holstein cows were selected from a 180 cow commercial dairy with a herd average milk production of 10,431 kg per cow per 305 days. Selected cows were blocked by parity, month of calving, 305 days mature equivalent milk production, and predicted transmitting ability, and assigned randomly to one of three dietary treatments. Cows were housed in a tie stall facility for the duration of the study. Feeding areas of adjacent animals were physically separated from each other with wooden boards to allow measurement of individual feed intake.

Basal diets fed to the close-up dry and lactating cows (Tables 1 and 2) were formulated using a linear program that utilized a modification of the NRC (1988) standards. Nutrient

Table 1
Composition of the basal (control) diets fed to close-up dry and lactating Holstein cows

	Close-up dry cow diet (% of DM)[a]	Lactating cow diet (% of DM)[a]
Composition		
Ground corn	–	25.9
Far-off dry cow concentrate[b]	14.0	–
Close-up dry cow concentrate[b]	19.0	–
Lactating cow concentrate[b]	–	27.9
Corn silage	46.0	26.8
Alfalfa grass silage[c]	–	19.4
Grass hay	21.0	–
Chemical[d]		
Forage NDF	32.7	23.0
CP	15.3	18.4
Nonstructural carbohydrates	34.5	36.6
Calcium	0.55	0.83
Potassium	1.33	1.39
Magnesium	0.35	0.30

[a] Cows received 908 g per day of ground corn (85% DM; control), 454 g per day of ground corn and 454 g per day of Sweet Lac™ Transition Formula (86% DM; SLTF1), or 908 g per day Sweet Lac™ Transition Formula (SLTF2).

[b] Composition of concentrate mixes is in Tables 2 and 3.

[c] Alfalfa grass silage high in alfalfa was fed to dry cows at the beginning of the study, and alfalfa grass silage high in grass was fed to lactating cows.

[d] Chemical composition calculated from the chemical analyses of the individual dietary ingredients is shown in Table 3.

composition of diets was calculated using chemical composition of forages, ground corn, and concentrates (Table 3). The dry cow basal diet was formulated for a 635-kg cow consuming 10.0 kg of DM per day. Each dry cow also received 908 g per day of ground corn (control), 454 g per day of ground corn and 454 g per day of SLTF (SLTF1), or 908 g per day of SLTF (SLTF2) on an as fed basis. As a percentage of projected total DM intake, ground corn comprised 9.1% of the control diet, 4.5% of the SLTF1 diet with 4.5% of SLTF, and SLTF comprised 9.1% of the SLTF2 diet. The DM contents of ground corn and SLTF, respectively, were 85 and 86%. The basal lactation diet was formulated for a 586-kg cow consuming 24.7 kg of DM and producing 45.4 kg of milk daily. Lactating cows were individually fed ground corn and concentrate using a robotic grain feeder six times a day based on each individual animal's level of milk production. In addition, each lactating cow received 454 g per day of SLTF (diet SLTF1) or 908 g per day of SLTF (diet SLTF2) as a replacement for ground corn (control) on an as fed basis. The SLTF was fed by hand at 6.00 and 17.00 h daily.

Cows were fed treatment diets for 21 days prepartum and 21 days postpartum, after which all cows were fed the control diet. Corn silage was limit fed and alfalfa grass silage was fed ad libitum. Amounts of ground corn, concentrates, and forages offered and refused were recorded for over 3 consecutive days every week from 21 days prepartum to 28 days postpartum.

Table 2
Composition of the concentrates fed to dry and lactating Holstein cows

Ingredient	Far-off dry cow concentrate (% of DM)	Close-up dry cow concentrate (% of DM)[a]	Lactating cow concentrate (% of DM)
Corn distillers	–	25.4	10.2
Animal fat	–	–	2.2
Megalac®[b]	–	–	1.6
Ground corn	34.6	49.0	–
Molasses	5.2	3.5	1.7
Urea	–	–	1.5
Soybean meal[c] (55% CP)	20.4	12.4	35.3
Soybean hulls	–	–	22.0
Canola meal	20.8	–	–
Corn gluten meal (67% CP)	–	–	1.5
SoyPlus®[d]	–	–	10.0
Blood meal	6.5	5.6	3.8
Dicalcium phosphate	2.2	–	3.0
Selenium–Vitamin E supplement	1.2	–	0.1
Selenium supplement	–	–	0.3
Magnesium sulfate	3.2	4.1	–
Magnesium oxide	0.7	–	0.3
Calcium sulfate	0.8	–	1.4
Salt	1.9	–	1.3
Limestone	–	–	1.5
Sodium bicarbonate	–	–	1.9
Trace mineral supplement[e]	0.3	–	–
Vitamin supplement[f]	2.2	–	0.4

[a] Pre-calving.
[b] Megalac® is rumen inert fat containing 85% fat and 12% calcium on DM basis (Church & Dwight Co. Inc., NJ, USA).
[c] Solvent extracted.
[d] Contains 60% rumen escape protein (West Central Cooperative, Ralston, IA, USA).
[e] Contains 7.4% calcium, 0.3% magnesium, 10.1% sulfur, 25,000 mg/kg iron, 150,000 mg/kg zinc, 100,000 mg/kg manganese, 2000 mg/kg cobalt, 25,000 mg/kg copper, 2000 mg/kg iodine, and 625 mg/kg selenium.
[f] Contains 35,946 IU/g Vitamin A, 12,247 IU/g Vitamin D, and 44,535 kg/IU Vitamin E.

Cows were milked three times per day at 6.00, 14.00, and 22.00 h using a tie stall milk line system, and milk volume was recorded twice weekly during milking at 6.00 and 14.00 h from week 1 to 8 postpartum. Total milk yield for each day from the three times milkings was computed using the formula below, which was developed by Dairy One (Ithaca, NY, USA).

$$\text{Milk yield (kg per day)} = \text{constant} \times (\text{milk yield at 6.00 h} + \text{milk yield at 14.00 h})$$

where

$$\text{constant} = \frac{1}{(\text{intercept for measured milking 1}) + (\text{intercept for measured milking 2}) + [(\text{slope}) \times (\text{total of the intervals preceding both measured milkings})]}$$

Table 3
Chemical composition of feedstuffs fed to dry and lactating Holstein cows

Chemical	Corn silage	Grass hay	Alfalfa grass silage		Ground corn	Concentrate mix			SLTF[c]
			MGS[a]	MAS[b]		Far-off dry cow	Close-up dry cow	Lactating cow	
DM (%)	24.7	81.3	29.6	32.2	84.9	88.0	88.3	90.4	85.7
DM basis									
Ash (%)	5.4	–	–	10.9	1.5	5.3	7.3	11.9	10.5
CP (%)	8.9	8.5	16.6	18.8	7.9	23.8	24.8	35.7	11.3
ADF (%)	30.9	44.2	37.5	31.3	5.8	9.0	9.2	17.1	16.0
NDF (%)	49.9	58.3	53.9	44.5	26.2	14.4	17.7	24.8	21.5
Hemicellulose (%)	19.0	14.1	16.4	13.2	20.4	5.4	8.5	7.7	5.5
Cellulose (%)	27.0	–	–	28.2	5.7	6.5	6.7	14.7	9.7
ADL (%)	3.9	–	–	3.1	0.1	2.5	2.5	2.4	1.2
NFC (%)	32.1	23.3	21.5	21.2	60.5	54.2	45.1	21.6	56.0
Fat (%)	3.4	–	–	6.1	3.9	5.9	5.1	7.2	1.8
Calcium (%)	0.39	0.63	0.96	0.62	0.08	0.37	1.26	2.17	0.70
Phosphorus (%)	0.31	0.22	0.33	0.41	0.27	0.66	0.86	1.10	0.57
Potassium (%)	1.27	0.94	2.41	3.12	0.41	0.94	1.03	1.46	1.92
Magnesium (%)	0.24	0.15	0.30	0.29	0.11	0.72	1.07	0.41	0.29
Chloride (%)	0.29	0.30	0.66	1.13	0.09	0.46	0.46	0.73	–
Iron (mg/kg)	252.0	436.0	330.0	238.0	47.0	168.0	397.0	654.0	422.0
Manganese (mg/kg)	26.0	27.0	45.5	47.0	15.0	24.0	105.0	99.0	48.0
Zinc (mg/kg)	32.0	16.0	24.5	26.0	30.0	66.0	214.0	122.0	28.0
Copper (mg/kg)	7.0	7.0	9.0	9.0	2.0	–	25.0	27.0	9.0

[a] Mostly grass silage.
[b] Mostly alfalfa silage.
[c] Sweet Lac™ Transition Formula.

Cows were body condition scored (Wildman et al., 1982) when they entered the close-up dry cow group, and on a weekly basis from week 1 to 8 postpartum. Body condition scores (BCS) were based on a 5-point scale with 0.25-unit intervals, where 1 = emaciated to 5 = obese. Nineteen cows fed the control diet, 20 cows fed the SLTF1 diet, and 20 cows fed the SLTF2 diet were monitored at 24 h potpartum for retained placentas, daily for the first 3-week postpartum for displaced abomasum, metritis, and milk fever, and daily throughout the study for lameness, clinical mastitis, and scours. Sixteen cows fed the control diet, 20 cows fed the SLTF1 diet, and 20 cows fed the SLTF2 diet were monitored for days to first service. Cows known to have had previous reproductive problems were not used in the assessment of treatment effects on animal reproductive performance.

2.2. Sampling and chemical analyses

Fresh samples of alfalfa grass and corn silages, grass hay, and concentrates were sent to Dairy One (Ithaca, NY, USA) where they were dried at 60°C and ground to pass through a 1-mm screen using a Wiley Mill (Model 3; Arthur H. Thomas Co., Philadelphia, PA, USA) for chemical analyses. The ground samples were analyzed for DM by drying a 1-g sample in duplicate at 100°C in a conventional oven for 24 h, ash by burning a 2-g sample in duplicate at 600°C for 2 h in a muffle furnace (Method 942.05; AOAC, 1995), fat (Method 920.39; AOAC, 1995), N (Method 984.13; AOAC, 1995), neutral detergent fiber with residual ash (NDF, using α-amylase and sodium sulfite), acid detergent fiber (ADF), and acid detergent lignin (ADL) (Van Soest et al., 1991). Nonstructural carbohydrates were calculated as the difference between 100 and the sum of crude protein (CP), NDF, fat, and ash. Hemicellulose was determined as the difference between NDF and acid detergent fiber, and cellulose as the difference between acid detergent fiber and acid detergent lignin. Analysis of Ca, P, Mg, K, Na, Fe, Zn, Cu, Mn, and Mo were conducted using a Thermo Jarrell Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer (model ICAP 61; Thermo Jarrell Ash, Ithaca, NY, USA). Chloride ion was analyzed using a Brinkman Metrohm 716 Titrino titration unit with a silver electrode (Model 716; Brinkman Instruments Inc., Westbury, NY, USA).

Milk samples were collected from one milking for each cow once a week during week 1–8 postpartum, and sent to Dairy One (Ithaca, NY, USA) for analysis of fat, protein, and urea N by infrared procedures (Foss 4000; Foss Technology, Eden Prairie, MN, USA), and analysis of somatic cell count by an infrared procedure (Foss 5000; Foss Technology, Eden Prairie, MN, USA). Milk samples collected from other commercial dairy farms were used as internal standards for analysis of milk components. These standards were stored under refrigeration at 0–4°C for a maximum of 14 days. Standards were analyzed for fat (Method 905.02; AOAC, 1995), N (Method 991.22; AOAC, 1995), and somatic cell count (AOAC Official Method 975.16; AOAC, 1995) to provide the wet chemistry values used to develop standard curves used in the respective infrared procedures.

Ten blocks of cows were randomly selected from the total of 25 blocks in the study for blood sampling. Blood was drawn at 15.00 h from the tail vein using two 9.5 cm^3 volume serum separator vacutainer tubes 7 days prepartum, and 7, 14, and 28 days postpartum. Samples were chilled in ice, returned to the laboratory, and centrifuged for 15 min at $1500 \times g$. Serum was aliquoted into two sub-samples. The first sub-sample was analyzed for NEFA using a commercial diagnostic kit (Wako Pure Chemical Ind., Ltd., Osaka, Japan). The second sub-sample was sent to the Fletcher Allen Health Care Inc., medical laboratory (Burlington, VT, USA) for analysis of alkaline phosphatase, aspartate aminotransferase, glucose, cholesterol, uric acid, and creatinine using a Vitros 950 Autoanalyzer (Ortho-Clinical Diagnostics Inc., Rochester, NY, USA). Urine was sampled at weekly intervals from 7 to 28 days postpartum, and ketones measured using Ketostix (Bayer Corp., Elkhart, IN, USA).

2.3. Statistical analyses

Data were analyzed using the general linear model procedure of SAS (1993) in a randomized block design. Data collected during the dry period for DM intake, and during weeks 1–4, and 5–8-postpartum for milk production, milk composition, and DM intake were analyzed with the model below. Milk somatic cell count data were transformed to the natural logarithm and analyzed as the linear somatic cell count.

$$Y_{ij} = \mu + \alpha_i + \beta_j + W_k + \beta W_{jk} + E_{ijk}$$

where μ is the overall mean, α_i the effect of the ith treatment ($i = 1-3$), β_j the effect of the jth block ($j = 1-25$), W_k the effect of the kth week ($k = 1-4$, or 5–8), βW_{jk} the interaction between week and block, and E_{ijk} is the residual error, assumed to be normally distributed.

The BCS obtained during the close-up dry period were used as a covariate in the analysis of BCS during weeks 1–4, and 5–8. The model statement for BCS analysis included block, close-up dry period BCS, and treatment BCS. Blood parameters, urine ketone scores, and days to first service were analyzed as a factorial arrangement of treatments, with treatment and block as class variables. If treatment differences were significant, orthogonal contrasts were performed to test the control diet against diets containing the SLTF (control versus SLTF1 + SLTF2; contrast 1) and to test the two SLTF feeding levels (SLTF1 versus SLTF2; contrast 2). Qualitative data for animal heath and reproductive performance was analyzed using a χ^2-test.

3. Results

3.1. DM intake, milk yield, milk composition, and BCS

The chemical composition of the major dietary ingredients (Table 3) was consistent with reported values (NRC, 1988).

Although dry cows were fed SLTF dietary treatments for 21 days prepartum, DM intake was reported only for 14 days (Table 4) since some cows calved earlier than projected. Feeding SLTF had no effect on DM intake by dry or lactating cows (Table 5). Cows produced about 36 kg of milk per cow per day in week 1 and reached about 52 kg of milk per cow per day in week 5 (Fig. 1). Feeding SLTF tended to increase milk production versus control ($P = 0.073$) during week 1–4 postpartum, while cows fed SLTF1 tended to produce more milk than cows fed SLTF2 ($P = 0.057$).

Table 4
Dry matter intake by close-up dry Holstein cows fed the ground corn (control), or diets in which ground corn was replaced by Sweet Lac^{TM} Transition Formula (SLTF) at a low (SLTF1) or high level (SLTF2) for 2 weeks prepartum

	Treatment			S.E.M.	*P*
	Control	SLTF1	SLTF2		
Concentrates (kg per day)					
Ground corn	0.77	0.39	0.00	–	–
SLTF	0.00	0.39	0.78	–	–
Far-off dry cow concentrate	1.41	1.41	1.41	–	–
Close-up dry cow concentrate	1.86	1.86	1.86	–	–
Total concentrates	4.04	4.05	4.05	–	–
Forages (kg per day)	7.26	7.33	7.44	0.067	0.146
Total dry matter intake (kg per day)	11.30	11.38	11.49	0.067	0.133

Table 5
Dry matter intake, lactation performance, milk composition, and body condition score of lactating Holstein cows fed the ground corn (control), or diets in which ground corn was replaced by Sweet Lac^{TM} Transition Formula (SLTF) at a low (SLTF1) or high level (SLTF2) from week 1 to 4 postpartum

	Treatment			S.E.M.	Treatment, *P*	Orthogonal contrasts, *P*[a]	
	Control	SLTF1	SLTF2			1	2
Dry matter intake (kg per day)							
Concentrates							
Ground corn	5.71	5.50	5.23	–	–		
SLTF (kg per day)	0.00	0.39	0.78	–	–		
Lactating cow concentrate	7.03	6.97	7.02	–	–		
Total concentrates	12.74	12.86	13.03	–	–		
Forages	7.61	7.69	7.77	0.10	0.532		
Total dry matter intake	20.35	20.55	20.80	0.32	0.601		
Lactation performance (kg per day)							
Milk	43.9	46.3	44.5	0.67	0.034	0.073	0.057
Fat	1.71	1.78	1.76	0.04	0.434		
Protein	1.41	1.45	1.41	0.02	0.359		
Milk composition (%)							
Fat	3.96	3.91	4.07	0.07	0.283		
Protein	3.25	3.20	3.22	0.03	0.519		
Milk urea N (mg/dl)	15.9	16.0	16.5	0.30	0.262		
Linear SCC[b]	5.0	4.5	4.9	0.14	0.056	0.150	0.054
Body condition score[c]	3.05	3.08	3.08	0.02	0.441		

[a] Orthogonal contrasts between control vs. SLTF1 and SLTF2 (contrast 1), and SLTF1 vs. SLTF2 (contrast 2).

[b] Linear somatic cell counts calculated by transforming the somatic cell counts in milk to the natural logarithm.

[c] Treatment × week interaction was not significant ($P > 0.10$).

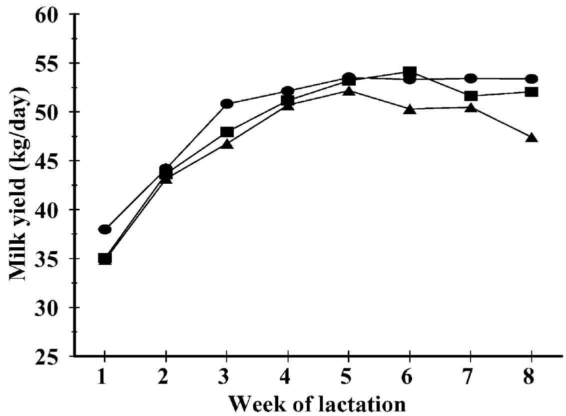

Fig. 1. Weekly milk production (kg per day) by lactating Holstein cows fed diets containing 454 g per day of Sweet Lac™ Transition Formula (SLTF1, ●) or 908 g per day of Sweet Lac™ Transition Formula (SLTF2, ■) as a replacement for ground corn (control, ▲) on an as fed basis.

Although feeding of SLTF was stopped after week 3, cows previously fed SLTF tended to have a higher BCS ($P = 0.090$) and produced more milk ($P = 0.002$), milk fat ($P = 0.009$), and milk protein ($P = 0.029$) during weeks 5–8 than cows previously fed the control diet (Table 6). Milk produced in weeks 5–8 by cows previously fed SLTF2 had a higher concentration of milk urea N ($P = 0.012$) and linear somatic cell count ($P = 0.018$) when compared with milk produced by cows previously fed SLTF1.

Table 6
Lactation performance, milk composition, and body condition score of Holstein cows fed the ground corn (control), or diets in which ground corn was replaced by Sweet Lac™ Transition Formula at a low (SLTF1) or high level (SLTF2) from weeks 5 to 8 postpartum

	Treatment			S.E.M.	Treatment, *P*	Orthogonal contrasts, *P*[a]	
	Control	SLTF1	SLTF2			1	2
Lactation performance (kg per day)							
Milk	50.1	53.4	52.7	0.75	0.006	0.002	0.504
Fat	1.65	1.83	1.79	0.05	0.027	0.009	0.583
Protein	1.41	1.48	1.46	0.02	0.061	0.029	0.380
Milk composition (%)							
Fat	3.34	3.44	3.40	0.08	0.646		
Protein	2.83	2.79	2.78	0.02	0.227		
Milk urea N (mg/dl)	16.4	15.9	17.0	0.30	0.043	0.877	0.012
Linear SCC[b]	4.9	4.4	5.0	0.17	0.039	0.362	0.018
Body condition score[c]	2.89	2.91	2.96	0.23	0.092	0.090	0.159

[a] Orthogonal contrasts between control vs. SLTF1 and SLTF2 (contrast 1), and SLTF1 vs. SLTF2 (contrast 2).
[b] Linear somatic cell counts calculated by transforming the somatic cell counts in milk to the natural logarithm.
[c] Treatment × week interaction was not significant ($P > 0.10$).

Table 7
Concentration of serum parameters in blood sampled from Holstein cows fed ground corn (control), or diets in which ground corn was replaced by Sweet Lac^{TM} Transition Formula at a low (SLTF1) or high level (SLTF2) prepartum and postpartum

Week[a]	Treatment			S.E.M.	Treatment, *P*	Orthogonal contrasts, *P*[b]	
	Control	SLTF1	SLTF2			1	2
Glucose (mg/dl)							
−1	65.8	59.9	59.7	3.00	0.289		
1	57.6	51.3	55.1	2.17	0.166		
2	52.9	54.7	55.6	2.65	0.755		
4	63.7	55.8	58.4	5.21	0.551		
NEFA[c] (uEq/l)							
−1	367.0	236.4	277.8	80.47	0.509		
1	457.3	369.9	566.3	75.96	0.201		
2	359.3	288.3	384.0	54.56	0.453		
4	295.4	278.9	285.8	37.09	0.953		
Creatinine (mg/dl)							
−1	1.20	1.23	1.39	0.06	0.087	0.160	0.077
1	1.02	1.06	1.15	0.05	0.222		
2	0.92	0.99	0.99	0.06	0.564		
4	0.85	0.87	0.93	0.04	0.287		
Uric acid (mg/dl)							
−1	0.81	0.93	0.86	0.08	0.519		
1	1.04	1.01	1.04	0.09	0.957		
2	1.28	1.03	1.07	0.08	0.083	0.029	0.735
4	1.33	1.09	1.15	0.12	0.333		
AST[d] (IU/l)							
−1	73.1	69.0	62.2	8.16	0.646		
1	108.4	98.6	90.6	9.13	0.340		
2	114.2	98.5	93.0	10.29	0.328		
4	82.2	83.3	79.2	6.06	0.890		
AlkPhos[e] (IU/l)							
−1	42.7	45.2	45.2	2.52	0.781		
1	40.7	44.1	44.0	2.60	0.603		
2	40.8	43.8	40.5	4.07	0.825		
4	39.5	45.5	42.8	3.15	0.412		
Cholesterol (mg/dl)							
−1	94.6	101.0	98.2	6.11	0.757		
1	73.0	85.6	87.7	3.72	0.028	0.009	0.695
2	85.2	101.2	101.6	6.28	0.129		
4	132.8	146.4	161.4	8.19	0.072	0.047	0.227

[a] Weeks postpartum.
[b] Orthogonal contrasts between control vs. SLTF1 and SLTF2 (contrast 1), and SLTF1 vs. SLTF2 (contrast 2).
[c] Nonesterified fatty acids.
[d] Aspartate aminotransferase.
[e] Alkaline phosphatase.

3.2. Serum blood chemistry profile

There were no differences for serum glucose, NEFA, aspartate aminotransferase, or alkaline phosphatase among treatments (Table 7). The serum of dry cows fed SLTF2 tended to have a higher ($P = 0.087$) concentration of creatinine. Feeding SLTF to lactating cows at either level decreased serum uric acid in week 2 ($P = 0.029$), and increased serum cholesterol in week 1 ($P = 0.009$) and week 4 ($P = 0.047$).

3.3. Animal health and reproduction

The number of cows that were fed the control, SLTF1 and SLTF2 diets, respectively, that had mastitis were 2, 1 and 4 ($P = 0.995$), metritis were 0, 0 and 1 ($P = 0.990$), milk fever were 2, 0 and 0 ($P = 0.975$), and retained placentas were 2, 1 and 4 ($P = 0.995$). No cows in the study developed a displaced abomasum, became lame or scoured. Treatment had no effect on ketonuria (Table 8).

Days to first service were similar among treatments (Table 9). There was no voluntary waiting period before first breeding, and if there were no reproductive problems at calving,

Table 8
Number of Holstein cows fed ground corn (control), or diets in which ground corn was replaced by Sweet Lac™ Transition Formula at a low (SLTF1) or high level (SLTF2) postpartum that developed ketonuria

Week of lactation	Urine ketone score[a]	Treatment			P[b]
		Control	SLTF1	SLTF2	
1	1	17	18	16	>0.995
	2	0	1	3	0.990
	3	2	1	1	>0.995
	4	0	0	0	–
2	1	19	18	19	0.995
	2	0	2	0	0.975
	3	0	0	0	–
	4	0	0	1	0.990
3	1	17	18	20	0.995
	2	1	1	0	0.995
	3	1	1	0	0.995
	4	0	0	0	–
4	1	15	20	18	0.990
	2	4	0	2	0.990
	3	0	0	0	–
	4	0	0	0	–
Total		19	20	20	

[a] Ketosis level is denoted by: 1 = negative (0–16 mg/dl ketone concentration); 2 = subclinical (17–79 mg/dl ketone concentration); 3 = clinical (80–159 mg/dl ketone concentration) and 4 = clinical (>160 mg/dl ketone concentration).

[b] Statistical analysis conducted using a χ^2-test.

Table 9
Days to first service of Holstein cows fed ground corn (control), or diets in which ground corn was replaced by Sweet Lac^{TM} Transition Formula at a low (SLTF1) or high level (SLTF2)

Item	Treatment			S.E.M.	*P*
	Control	SLTF1	SLTF2		
Mean	57.0	62.4	51.1	4.50	0.180
Median	48.0	58.5	45.0	–	–
Number of cows observed	16	20	20		

the cow was bred on the first heat. Cows fed SLTF1 had a numerically higher number of days to first service, expressed as a mean or median.

4. Discussion

Supplementation of grass silage-based diets with sugars was reported to increase the flow of microbial protein and nonprotein N to the small intestine (Chamberlain et al., 1985; Huhtanen, 1987; Rooke et al., 1987). The rapidly fermentable carbohydrate likely supported higher ruminal microbial growth from capture of ammonia N for synthesis of microbial protein. Other researchers reported that feeding readily available carbohydrates in the form of molasses to dairy cows increased milk production by dairy cows, but did not affect DM intake (Morales et al., 1989; Oldick et al., 1997). Even though beet pulp contains as much as 47% NDF, it is often considered to be concentrate-like because its NDF is fermented rapidly by ruminal microorganisms compared to the forage fiber (Van Soest, 1994).

Propylene glycol and calcium propionate are glycogenic precursors. Propylene glycol is not fermented in the rumen, but is converted to pyruvate, which is eventually converted to glucose (Van Soest, 1994; Moore and Ishler, 1997). Propionate is released from calcium propionate, absorbed across the rumen wall into blood and transported to the liver where it is converted to glucose via gluconeogenesis (Van Soest, 1994). Glucose affects the rate of milk lactose synthesis, and hence milk volume, through an osmotic association (Kronfeld, 1982). In the present study, feeding SLTF had no effect on serum glucose or NEFA concentrations. This might be because blood was sampled 8 h after feeding the SLTF at 7.00 h. Thus, the peak blood glucose concentration may have occurred before blood was sampled (Sauer et al., 1973; Studer et al., 1993; Grummer et al., 1994). Alternatively, the level of SLTF supplementation might have been too low to have had an effect on serum glucose or NEFA concentrations.

The generally higher milk yield by cows fed the low level of SLTF may be due in part to differences in rumen pH that might have led to differences in microbial yield, and hence microbial protein flow to the intestine. It was reported that when molasses and sugars were added to diets at levels of 1–2 kg of total diet DM (Foreman and Herman, 1953; Khalili and Huhtanen, 1991), or greater than 7.5% of diet DM (Petit and Veira, 1994), depressed rumen pH resulting in decreased fiber digestibility and microbial yield. The higher level of sugars and other readily fermentable carbohydrate feeds in SLTF2 could be expected to lead to more ruminal fermentation, and hence to a larger drop in ruminal pH and lower microbial protein supply to the small intestines. Since the SLTF replaced an equal amount of ground corn, fermentation of propylene glycol and calcium propionate would yield less microbial biomass (Chamberlain et al., 1985; Nocek and Tamminga, 1991). Increasing postruminal protein supply in lactating dairy cows by feeding ruminally undegradable protein has been shown to enhance milk yield (Santos et al., 1998), and increasing intestinal protein delivery in late gestation by feeding supplemental undegradable protein was reported to improve postpartum performance, perhaps by minimizing mobilization of maternal labile protein pools to meet fetal and maternal growth requirements (Van Saun et al., 1993; Moorby et al., 1996; Huyler et al., 1999).

Lack of any effect on serum glucose and NEFA concentrations with SLTF feeding may suggest that, ketosis was not severe enough to saturate the mechanisms for the metabolism of NEFA (Smith et al., 1997). In general, ketosis is associated with high concentrations of circulating free fatty acids, which are the source for some ketone bodies, and NEFA are highly correlated with ketone bodies in the blood (Baird, 1982; Kronfeld, 1982; Veenhuizen et al., 1991; Studer et al., 1993; Grummer et al., 1994; Christensen et al., 1997; Moore and Ishler, 1997; Smith et al., 1997). In a study in which propylene glycol was fed to feed-restricted heifers and cows, Christensen et al. (1997) did not observe any correlation between plasma glucose and NEFA concentrations, even though plasma NEFA concentrations decreased with propylene glycol feeding. However, linear increases in plasma glucose, and decreases in plasma NEFA concentrations, with propylene glycol fed as part of concentrate or administration as an oral drench to Holstein cows or heifers have been reported by other workers (Sauer et al., 1973; Studer et al., 1993; Grummer et al., 1994).

5. Conclusions

Feeding an energy supplement containing beet pulp, sugarcane molasses, propylene glycol, and calcium propionate to Holstein cows, especially when fed at the low level increased DM intake by dry cows, improved milk yield and yields of milk fat and protein by lactating cows, but had no effect on the incidence of ketosis or blood glucose and NEFA concentrations among lactating cows. After feeding of the energy supplement was discontinued in week 3, cows previously fed the supplement continued to yield more milk, and milk fat and protein.

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