



Effect of feeding an energy supplement prepartum and postpartum on milk yield and composition, and incidence of ketosis in dairy cows

P. Mandebvu^{a,*}, C.S. Ballard^a, C.J. Sniffen^a, D.S. Tsang^a,
F. Valdez^b, S. Miyoshi^c, L. Schlatter^b

^a W. H. Miner Agricultural Research Institute, Chazy, NY 12921, USA

^b Kemin Americas Inc., Des Moines, IA 50301, USA

^c Zen-Noh National Federation of Agricultural Co-operative Associations, Tokyo, Japan

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Abstract

Forty dry pregnant multiparous Holstein cows housed in a free stall barn on a commercial dairy were blocked and assigned randomly to treatments to evaluate the effect of feeding an energy supplement for 3 weeks prepartum and 3 weeks postpartum on milk production and composition, and incidence of ketosis. The energy supplement, which was in powder form, contained 78.43% propionic acid, 21.36% calcium, 0.155% zinc and 0.053% copper (DM basis). Diets were fed as total mixed rations (TMR) for ad libitum intake and contained (DM basis) approximately 56% forage and 44% concentrate for dry cows, and 44% forage and 56% concentrate for lactating cows. In addition, cows fed the supplemental diet received 0.11 kg per day of the energy supplement (DM basis). Prepartum DM intake by cows fed the TMR containing the energy supplement and cows fed the control TMR were 13.1 ± 2.6 and 12.6 ± 1.9 kg per day, respectively. Feeding cows the TMR containing the energy supplement decreased milk fat percentage ($P = 0.02$) and fat yield ($P = 0.02$), compared with cows fed the control TMR, during weeks 1–3 postpartum. There were no differences between treatments in milk yield, milk CP, milk true protein, milk urea N and somatic cell counts during weeks 1–3 postpartum, and urine ketone scores during weeks 1 and 2 postpartum. Feeding cows the TMR containing the energy supplement tended ($P = 0.07$) to decrease serum non-esterified fatty acids during week 1 postpartum, and decreased subclinical ketonuria during week 1 ($P = 0.03$) and week 2 ($P < 0.01$) postpartum compared with the control TMR. After feeding of the energy supplement was discontinued at week 3, cows previously fed the TMR containing the energy supplement tended ($P = 0.17$) to continue to produce milk containing

Abbreviations: ADF, acid detergent fiber; ADL, acid detergent lignin; BHBA, β -hydroxybutyrate; CP, crude protein; DM, dry matter; N, nitrogen; NDF, neutral detergent fiber; NEFA, non-esterified fatty acids; TMR, total mixed ration(s)

* Corresponding author. Tel.: +1-518-846-7121x126; fax: +1-846-7774.

E-mail address: mandebvu@whminer.com (P. Mandebvu).

a lower fat percentage during weeks 4–8 postpartum compared to cows fed the control TMR. There were no differences in milk yield, change in body condition score, milk CP, milk true protein, milk urea N, and somatic cell counts between treatments during weeks 4–8. Feeding an energy supplement containing largely propionic acid to Holstein cows for 3 weeks prepartum and 3 weeks postpartum lowered milk fat yield and tended to decrease the concentration of non-esterified fatty acids, thus suggesting lowered catabolism of adipose tissue in early lactation. Feeding this supplement to close up dry cows through early lactation could prevent fat mobilization and subclinical ketosis normally associated with calving.

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1. Introduction

Following calving, the dairy cow undergoes a transition from a relatively high fiber diet to a lactation diet that generally is higher in energy and lower in fiber. During this period, the amount of energy required for maintenance of body tissues and milk production usually exceeds the amount of energy in the diet (Goff and Horst, 1997). This nutrient deficit makes the cow susceptible to metabolic diseases, such as ketosis and milk fever, which usually occur within 3 week of thereby calving slowing adaptation to the postpartum diet.

Feeding energy supplements that will not be metabolized in the rumen, such as calcium propionate, soon after calving has been successfully used to treat metabolic disorders such as milk fever (Goff et al., 1996). However, Ballard et al. (2001) failed to observe any benefits in alleviating ketosis from feeding an energy supplement containing 16% calcium propionate to dry cows in a high producing dairy herd suffering from mild ketosis, even though an improvement in subsequent in milk yield was observed. Ketosis is characterized by increased concentration of ketone bodies in blood (ketonemia), urine (ketonuria), milk (ketolactia) and other body fluids (Geishauser et al., 1998), and is classified as subclinical or clinical depending on severity (Baird, 1982; Kronfeld, 1982; Moore and Ishler, 1997; Geishauser et al., 1998). The major ketone bodies are β -hydroxybutyrate (BHBA), acetoacetate, and acetone.

The objectives of this study were to evaluate the effects of feeding an energy supplement containing propionic acid, calcium propionate, zinc propionate and copper carbonate (NutraCALTM; Kemin Americas Inc., Des Moines, IA) to multiparous Holstein cows from 3 weeks prepartum through 3 weeks postpartum on milk production and milk composition, and incidence of ketosis.

2. Materials and methods

2.1. Cows, diets, and management

Forty pregnant Holstein cows housed in a free-stall barn on a commercial dairy farm in northeastern New York state, were blocked by parity, expected month of calving and predicted transmitting ability, and randomly assigned to one of the two treatments. Cows

in each block were of the same parity, calved in the same month and had similar genetic potential for milk production. One of the diets, which were both fed as total mixed rations (TMR), did not contain (control) or contained NutroCAL™ (Kemin Americas Inc., Des Moines, IA), a dry energy supplement in powder form, which contained 78.43% propionic acid, 21.36% calcium, 0.155% zinc and 0.053% copper on a DM basis, and was fed for 3 weeks prepartum and 3 weeks postpartum. All cows were fed the control TMR during weeks 4–8 postpartum.

The TMR detailed in [Table 1](#) were formulated using the Cornell Net Carbohydrate and Protein System (CNCPS version 2.12; Cornell University, Ithaca, NY), and contained (DM basis) approximately 56% forage and 44% concentrate for dry cows, and 44% forage and 56% concentrate for lactating cows. The dry cow TMR was formulated for a 658 kg cow consuming 12 kg of DM per day. The lactating cow TMR was formulated for a 658 kg cow consuming 28 kg of DM and producing 49.9 kg of milk per day containing 3.7% fat and 3.4% CP. Cows assigned to the test diet received 0.11 kg of NutroCAL™ per day, which comprised 0.9 and 0.4%, respectively, of the close-up dry and lactation TMR.

Cows were penned by treatment, group-fed for ad libitum intake once a day, and had free access to clean water. Following calving, cows that were being fed the close-up control TMR were moved to the control fresh group while cows that were being fed the TMR containing NutroCAL™ were moved to the NutroCAL™ fresh group, and at about 3 weeks postpartum cows were moved again to high producing groups, where they stayed until 8 weeks postpartum within their treatment assignments. The animal stalls were bedded with sand, and were replenished twice monthly.

Cows were milked thrice daily in a double-12 parallel milking parlor at 03:00, 11:00, and 19:00 h and milk yield was recorded from which a weekly average for each cow was calculated for weeks 1–8 postpartum.

Cows were scored for body condition 1 week prepartum, and weekly thereafter until week 8. Scoring was based on a five-point scale with 0.25 U intervals, where 1 = emaciated, and 5 = obese ([Wildman et al., 1982](#)). Change in body condition score during weeks 1–3 and 4–8 postpartum, respectively, was calculated as the difference between the final and initial body condition scores during each period. Reproductive performance was assessed as days to first service, services per conception and days to conception. Animals were monitored for health problems throughout the study. Reproductive management practices, such as the use of prostaglandins, were similar for both treatment groups.

2.2. *Sampling and chemical analyses*

Silages were sampled at the beginning of the study and monthly thereafter, and high moisture corn, feed by-products and concentrate mixes were sampled at the beginning of the study and when new deliveries were made. Feed samples were sent to Dairy One (Ithaca, NY), where after being dried at 60 °C and ground to pass a 1 mm screen in a Wiley mill, they were analyzed for DM by drying a 1 g sample in duplicate at 100 °C in a conventional oven for 24 h, ash by igniting 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, with α -amylase and residual ash, without sodium sulfite), acid detergent fiber (ADF, with residual

Table 1
Composition of total mixed rations (TMR) and amounts fed on DM basis

	Dry cows		Lactating cows	
	Control	NutroCAL™	Control	NutroCAL™
Ingredient composition (% of DM)				
Corn silage	37.82	37.47	17.83	17.75
Alfalfa silage	–	–	26.56	26.44
Grass silage	18.33	18.16	–	–
High moisture shell corn	16.28	16.12	25.81	25.70
Whole cottonseed with lint	3.58	3.55	9.01	8.97
Ground wheat grain	–	–	0.08	0.12
Energy booster ^a	–	–	0.56	0.56
Animal fat	–	–	0.05	0.05
Soybean hulls	–	–	0.35	0.35
Brewers grain dry	3.62	3.59	1.49	1.49
Corn distillers dry with solubles	2.31	2.29	0.72	0.71
Wheat middlings	2.26	2.24	0.80	0.80
Whole roasted soybeans	–	–	2.63	2.62
Soybean meal (49% CP as fed)	2.97	2.94	5.40	5.38
Canola meal	4.71	4.67	0.41	0.40
Blood meal	2.65	2.62	1.63	1.63
Corn gluten meal	0.74	0.73	2.02	2.02
Fish meal	–	–	0.01	0.01
Magnesium sulfate	1.06	1.05	–	–
Limestone	1.35	1.34	–	–
Trace mineral–vitamin mix	2.32	2.30	4.62	4.62
NutroCAL™ ^b	–	0.94	–	0.38
Chemical composition ^c				
Neutral detergent fiber	37.70	37.40	29.3	29.1
Non-fiber carbohydrates	33.90	34.30	38.0	38.2
Crude protein	15.40	15.20	18.7	18.6
Calcium	0.72	1.02		
Phosphorus	0.37	0.36		
Potassium	1.04	1.03		
Magnesium	0.34	0.33		
Chloride ion	0.03	0.03		
Sulfur	0.29	0.36		

^a Energy booster contained hydrolyzed animal fat (tallow) preserved with butylated hydroxytoluene and sodium silicoaluminate (Milk Specialties Company, Dundee, IL).

^b Contained 78.43% propionic acid, 21.36% calcium, 0.155% zinc and 0.053% copper.

^c Calculated using the chemical composition of the dietary ingredients.

ash), and acid detergent lignin (ADL) (Van Soest et al., 1991). Soluble N was determined as the difference in N concentration of sample before and after soaking in borate phosphate buffer at pH 6.8 (Krishnamoorthy et al., 1982). Non-fiber carbohydrates were calculated as the difference between 100 and the sum of CP, NDF (minus CP in NDF), fat and ash. Analysis of Ca, P, Mg, K, Na, Fe, Zn, Cu and Mn were conducted using a Thermo Jarrell Ash IRIS Advantage inductively coupled plasma radial spectrometer (Model ICAP 61, Thermo Jarrell Ash, Ithaca, NY). Sulfur was analyzed using a Leco Model SC-432 (Leco, St. Joseph, MI).

Table 2

Chemical composition of the major feedstuffs used in total mixed rations fed to dry and lactating Holstein cows

	Corn silage	Alfalfa silage	High moisture shell corn	Whole cottonseed	Dried brewers grains	Soybean meal ^a	Canola meal	Dried blood meal ^b	Whole roasted soybeans	NutroCAL ^{TMc}
DM (%)	34.0	50.4	78.0	91.0	92.0	90.7	92.7	93.3	92.5	95.0
Composition (% of DM)										
Crude protein (CP)	8.3	20.8	9.5	23.0	21.5	55.6	36.7	80.0	34.7	
Soluble CP	4.8	10.8	4.2	3.0	2.4	10.6	9.5	2.9	3.1	
Neutral detergent fiber-CP	9.3	16.0	4.5	5.5	23.0	1.8	11.0	–	1.7	
Neutral detergent fiber	46.3	46.0	3.4	57.0	49.1	6.1	31.5	–	16.6	
Non-fiber carbohydrate	45.7	37.2	85.4	4.5	38.4	29.1	27.9	–	30.4	
Lignin	3.4	6.0	0.2	14.3	6.4	0.2	4.0	–	0.5	
Fat	3.5	4.5	4.8	16.8	8.5	3.2	6.6	0.8	15.0	
Ash	5.50	7.50	1.40	4.20	5.51	7.77	8.34	2.77	5.00	21.57
Calcium	0.21	1.13	0.02	0.16	0.33	0.32	0.73	0.32	0.35	21.36
Phosphorus	0.25	0.34	0.24	0.64	0.55	0.65	1.13	0.26	0.55	
Magnesium	0.17	0.29	0.12	0.41	0.16	0.28	0.58	0.24	0.25	
Potassium	1.09	2.76	0.40	1.00	0.09	2.27		0.10	1.76	
Sodium	<0.00	<0.00	<0.00	0.02	0.23	0.02		0.35		
Sulfur	0.09	0.18	0.10	0.26	0.32	0.36		0.37	0.27	
Chloride	<0.00	<0.00	0.05	<0.00	0.17	<0.00	0.11	0.30		
Composition (mg/kg of DM)										
Iron	206	192	245	80	266	229		4064	175	
Zinc	24	25	16	32	30	50		5	62	1550
Manganese	16	31	7	18	40	33		6	39	
Copper	5	11	2	5	23	16		11	20	530

^a Soybean meal 49% CP as fed.^b Ring spray.^c Contains 78.43% propionic acid.

Chloride ion was analyzed using a Brinkman Metrohm 716 Titrino titration unit with a silver electrode (Model 716; Brinkman Instruments Inc., Westbury, NY).

Milk samples were collected weekly during the afternoon milking from weeks 1–8 and sent to Dairy One (Ithaca, NY) for analyses of fat, CP and true protein by infrared procedures (Foss 4000; Foss Technology, Eden Prairie, MN), and analysis of somatic cell count by infrared procedures (Foss 5000; Foss Technology, Eden Prairie, MN). Milk samples collected from other commercial dairy farms were used as external standards in the 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 (Method 975.16; AOAC, 1995) to provide the values that were used to calculate standard curves used in the respective infrared procedures.

Blood samples were collected from the tail vein using one 10 ml volume serum separator vacutainer tubes 1 week prepartum, and weeks 1 and 2 postpartum. Samples were chilled in ice, taken to the laboratory and centrifuged at ambient temperature for 15 min at 500 × g, and the serum divided into two equal sub-samples. The first sub-sample was analyzed for non-esterified fatty acids (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) for analysis of glucose, insulin, alkaline phosphatase, aspartate aminotransferase, cholesterol, creatinine, albumin, serum proteins, uric acid, blood urea N and bilirubin using a Vitros 950 Autoanalyzer (Ortho-Clinical Diagnostics Inc., Rochester, NY). Urine was sampled 1 week prepartum, and weeks 1 and 2 postpartum, and ketones were measured using Ketostix (Bayer Corp., Elkhart, IN).

2.3. Statistical analysis

Lactational performance data were divided into two sets covering periods of weeks 1–3 postpartum when cows assigned to the test diet received 0.11 kg of NutroCAL™ per day, and weeks 4–8 postpartum when the feeding of NutroCAL™ was discontinued. Data for milk yield and composition, and body condition score were analyzed as repeated measures using the PROC MIXED procedure of the SAS (version 6.12; 1996). Cow, block, treatment and week served as class variables, and treatment by block was the random effect used to test treatment. The PROC MIXED procedure was chosen because in dairy cows milk production and other related parameters often display strong autocorrelation. The statistical model was:

$$Y_{ijk} = \mu + \tau_i + \tau\gamma_{ij} + \beta_k + \tau\beta_{ik} + e_{ijk},$$

where μ is the overall mean, τ_i the effect of the i th treatment, $\tau\gamma_{ij}$ the interaction between treatment and block (γ_j the effect of the j th block), β_k the k th week, $\tau\beta_{ik}$ the interaction between treatment and week, and e_{ijk} the residual error, assumed to be randomly distributed. In the repeated statement, week was the repeated variable, and the options for subject and type, respectively, were cow and compound symmetry. The PROC MIXED procedure was also run using the autoregressive covariance matrix option in place of compound symmetry. The compound symmetry was chosen in place of autoregressive covariance matrix because both the Akaike's Information Criterion and Schwarz's Bayesian Criterion of parameters measured for compound symmetry were closer to zero and the difference between the two

Criteria was smaller than those for autoregressive covariance matrix, showing that the compound symmetry covariance structure had a better variance fit (Littell et al., 1996).

The blood and reproductive parameters were analyzed as a factorial arrangement of treatments, with treatment and block serving as class variables. Qualitative data for urine ketone scores were analyzed using a χ^2 -test.

Since animals were group-fed with no replications of pens within treatment, the investigators assumed: (1) no pen effect because the pens were of the same size with similar bunk space, stall design, flooring, water accessibility and animal density; and (2) that errors within pens were independent (St-Pierre and Jones, 1999), allowing for cow to serve as the experimental unit. Dry matter intake was calculated by dividing the total intake for each pen by the number of animals in that pen.

3. Results

3.1. Lactational performance

The control and NutroCALTM TMR contained similar nutrient concentrations (percentage of DM), which were approximately 37% NDF and 15% CP for dry cows (Table 1), and 29% NDF and 19% CP for lactating cows. Chemical analyses of major TMR ingredients (Table 2) are consistent with reported values (NRC, 2001).

Prepartum DM intake by cows fed the TMR containing the energy supplement and cows fed the control TMR were 13.1 ± 2.6 and 12.6 ± 1.9 kg per day, respectively. Postpartum average DM intake for both treatments was 24.7 ± 1.5 kg per cow per day among fresh cows and 26.9 ± 1.3 kg per cow per day among high group cows. 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 weeks 7 or 8. NutroCALTM-fed cows had lower milk fat percentage ($P = 0.02$) and fat yield ($P = 0.02$) compared with cows fed the control TMR during weeks 1–3 postpartum (Table 3). Overall, there were no treatment differences in milk yield, milk CP, milk true protein, milk urea N and somatic cell counts. Even though the feeding of NutroCALTM was stopped after week 3, cows previously fed the TMR containing NutroCALTM continued to produce milk containing a numerically ($P = 0.17$) lower fat percentage during weeks 4–8 compared to cows previously fed the control TMR. There were no treatment differences in milk yield, milk CP, milk true protein, milk urea N, somatic cell counts and change in body condition score during weeks 4–8.

3.2. Serum blood chemistry profile

Non-esterified fatty acids ($P = 0.07$), alkaline phosphatase ($P = 0.06$), and albumin ($P = 0.06$) tended to be lower in blood sampled 1 week postpartum from cows fed the TMR containing NutroCALTM (Table 4). The serum of cows fed the TMR containing NutroCALTM had a lower concentration of creatinine in week 1 ($P = 0.02$) and week 2 ($P = 0.03$), but there were no differences for serum aspartate aminotransferase, cholesterol, proteins, uric acid, blood urea N or bilirubin concentrations between treatments.

Table 3
Lactational performance, milk composition, and body condition score of lactating Holstein cows^a

	Control	NutroCAL TM	S.E.M.	<i>P</i>
Weeks 1–3 postpartum (fresh group cows)				
Milk (kg per day)	42.3	40.2	2.10	0.49
Fat				
Percentage	5.17	4.48	0.193	0.02
kg per day	2.20	1.79	0.115	0.02
Crude protein				
Percentage	3.42	3.44	0.070	0.81
kg per day	1.46	1.36	0.081	0.42
True protein				
Percentage	3.26	3.29	0.073	0.77
kg per day	1.38	1.29	0.078	0.45
Milk urea N (mg/dl)	16.2	15.5	0.58	0.38
Somatic cell counts (× 1000)	405	567	131.4	0.39
Change in body condition score ^b	−0.37	−0.33	0.064	0.72
Weeks 4–8 postpartum (high group cows)				
Milk (kg per day)	51.1	50.1	2.10	0.74
Fat				
Percentage	3.95	3.70	0.127	0.17
kg per day	2.01	1.86	0.099	0.30
Crude protein				
Percentage	2.77	2.79	0.049	0.83
kg per day	1.41	1.40	0.063	0.90
True protein				
Percentage	2.60	2.61	0.051	0.94
kg per day	1.32	1.31	0.060	0.87
Milk urea N (mg/dl)	16.1	15.8	0.43	0.70
Somatic cell counts (× 1000)	250	210	86.6	0.75
Change in body condition score ^c	−0.63	−0.63	0.075	1.00

^a Average dry matter intake across treatments was 24.7 kg per cow per day (weeks 1–3) and 26.9 kg per cow per day (weeks 4–8).

^b Difference between the final (week 3) and initial (week 1) body condition scores.

^c Difference between the final (week 8) and initial (week 4) body condition scores.

3.3. Animal health and reproduction

No cows developed ketosis prepartum. Feeding NutroCALTM reduced the incidence of ketonuria during week 1 ($P = 0.03$) and week 2 ($P < 0.01$) postpartum (Table 5). The average pH of urine in prepartum cows was 5.8 ± 0.58 . Urine sampled prepartum was used to monitor the animal dietary cation–anion balance. Adjustment of dietary cation–anion balance in the diet of dairy cows during the last weeks of pregnancy is done to prevent parturient paresis (Goff and Horst, 1994). Incidences of other health problems such as mastitis, metritis, milk fever, retained placentas and displaced abomasums were similar for

Table 4
Concentration of serum parameters in blood sampled from Holstein cows prepartum and postpartum^a

Weeks postpartum	Control	NutroCAL TM	S.E.M.	P
Glucose (mg/dl)				
–1	65.7	63.3	2.13	0.435
1	53.7	56.3	2.17	0.403
2	54.3	54.1	3.55	0.975
Insulin (UIU/ml)				
–1				
1	9.6	11.3	1.20	0.332
2	10.7	10.6	0.78	0.911
Non-esterified fatty acids (Ueq/l)				
–1	692.3	750.4	78.10	0.606
1	838.5	625.0	77.61	0.073
2	660.6	540.7	78.11	0.292
Alkaline phosphatase (IU/l)				
–1	47.3	42.7	2.34	0.181
1	45.9	38.0	2.71	0.057
2	41.4	36.4	2.66	0.201
Aspartate aminotransferase (IU/l)				
–1	92.6	103.5	9.17	0.415
1	149.4	129.3	21.66	0.523
2	149.5	134.4	17.62	0.554
Cholesterol (mg/dl)				
–1	101.4	111.2	7.93	0.393
1	94.0	91.7	3.54	0.654
2	117.5	112.1	5.60	0.498
Creatinine (mg/dl)				
–1	1.22	1.22	0.031	1.000
1	1.13	1.01	0.033	0.024
2	1.08	0.96	0.035	0.026
Albumin (g/dl)				
–1	2.90	2.85	0.040	0.361
1	2.83	2.72	0.039	0.061
2	2.92	2.82	0.052	0.194

^a Serum proteins, uric acid, blood urea N, and bilirubin concentrations were similar ($P > 0.20$).

both the treatment groups. No cows in the study became lame. Days to first service, services per conception and days to conception were similar among treatments (Table 6).

4. Discussion

When propionic acid is released from NutroCALTM during ruminal fermentation, some of it is absorbed across the rumen wall into blood and transported to the liver where it is converted to glucose via gluconeogenesis (Van Soest, 1994; Danfaer et al., 1995) as

Table 5

Number of animals that developed ketonuria and reproductive performance of lactating Holstein cows

Week of lactation	Urine ketone concentration (mg/dl) ^a	Control	NutroCAL TM	P ^b
1	0–16	12	18	0.03
	17–79	6	0	0.03
	80–159	2	2	1.00
2	0–16	10	19	<0.01
	17–79	8	0	<0.01
	80–159	2	1	0.50

^a Ketosis is classified as negative = 0–16 mg/dl ketone concentration in urine, subclinical = 17–79 mg/dl, clinical = 80–159 mg/dl. No cows had a urine ketone score \geq 160 mg/dl.

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

shown by the numerical increase in serum blood glucose levels from feeding NutroCALTM during 1 week postpartum. The glucose is used to meet some of the cow's demand in energy by providing oxaloacetate, which is used to convert acetate to energy as adenosine triphosphate (Van Soest, 1994). Animals not receiving the supplemental diet would have to meet this demand in energy through mobilization of body fat reserves resulting in increased concentrations of NEFA in blood and ketone bodies in blood, milk and urine (Veenhuizen et al., 1991; Studer et al., 1993; Grummer et al., 1994; Smith et al., 1997).

The lower urine ketone values during weeks 1 and 2 postpartum and tendency of lower serum NEFA at 1 week postpartum observed in cows fed NutroCALTM compared with cows fed the control TMR suggests depressed fatty acid mobilization from adipose tissue, which would explain the lower milk fat during 1–3 weeks postpartum by cows fed the supplemental diet. Waterman et al. (2002) reported that feeding NutroCALTM to grazing beef cows reduced milk fat content. Evidence (Goff et al., 1996) also exists that shows that feeding calcium propionate to periparturient dairy cows lowers NEFA and reduces subclinical ketosis. Data from intra-ruminal infusion of propionic acid have shown decreased NEFA

Table 6

Reproductive performance of lactating Holstein cows

	Control	NutroCAL TM
Days to first service		
N	20	20
Median	76	66
Mean ^a	90.7 \pm 31.0	81.8 \pm 33.1
Services per conception		
N	20	20
Mean ^a	1.9 \pm 2.0	1.9 \pm 1.1
Days to conception		
N	20	20
Median	88	119
Mean ^a	124.0 \pm 70.1	129.8 \pm 52.5

^a $P > 0.10$.

and milk triglyceride precursors linked to reduced lipolysis in adipose tissue in dairy cows (Hurtaud et al., 1993). Hurtaud et al. (2000) showed that reduced fat mobilization from duodenal infusions of glucose led to a low yield of C₁₈, which in turn decreased milk fat. These studies show that decreased metabolism of adipose tissue reduces the availability of fatty acids to the mammary gland.

The depression in milk fat observed in cows fed the supplemental diet might, therefore, be accounted for if the mammary synthesis of milk fat is regarded as a function of mobilization. In this hypothesis, the mammary gland is considered to be dependent on blood lipids for long-chain acids and acetate for short-chain acids, which are reduced by inhibition of fat mobilization in adipose tissue. About half of milk fatty acids, the short-chain fatty acids, are formed *de novo* by the mammary gland utilizing BHBA and acetate and the other half, mainly long-chain acids, are taken preformed from the blood (Van Soest, 1994; Bell, 1995). The mammary gland fatty acid synthetase uses butyryl-CoA as a primer and uses acetyl-CoA for chain elongation. Endogenous BHBA is formed as 3-hydroxybutyrate during hepatic ketogenesis via incomplete oxidation of NEFA (Bell, 1995). In addition, during early lactation when cows are in negative energy balance and circulating NEFA are relatively high, mammary uptake of NEFA may account for as much as 40% of milk fatty acids (Bell, 1995), which might have contributed significantly to the higher fat content in milk produced by cows fed the control diet in our study.

In contrast to the higher incidence of subclinical ketosis among cows fed the control diet our data also showed no differences in change in body condition, which would otherwise suggest that fat mobilization was similar between treatments. However, this lack of differences in change in body condition might be an indication that this subjective measurement was not as sensitive as urine and serum clinical analyses in picking up small differences in adipose tissue mobilization.

Failure to observe a milk production response by cows fed the supplemental diet could have been because the 86 g of propionate from NutroCAL™ may have been too low to yield significant amounts of glucose, the primary precursor for mammary lactose synthesis. The availability of glucose has an important impact on milk yield because lactose is the major osmoregulator for mammary uptake of water.

High levels of aspartate aminotransferase and alkaline phosphatase enzymes in the bloodstream, together with elevated levels of albumin, serum protein, cholesterol, uric acid, blood urea N or bilirubin, is indicative of liver disease. In this study, lack of treatment differences in these liver enzymes and blood metabolites between treatments indicates that there was no treatment effect on liver function. The higher levels of creatinine, which measure N excretion from muscle tissue breakdown, indicates greater mobilization of body reserves by cows fed the control diet.

5. Conclusions

Feeding cows NutroCAL™ to Holstein cows for 3 weeks prepartum and 3 weeks postpartum lowered the milk fat percentage and fat yield during weeks 1–3 postpartum, tended to decrease serum NEFA during week 1 postpartum, and decreased subclinical ketonuria during weeks 1 and 2 postpartum compared to feeding cows the control TMR. Dry calcium

supplements such as NutroCAL™ that can be fed as part of the TMR could offer a practical means to prevent fat mobilization and subclinical ketosis when fed to close up dry cows through early lactation.

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References

- AOAC, 1995. Official Methods of Analysis, 16th ed. Association of Official Analytical Chemists, Arlington, VA.
- Baird, G.D., 1982. Primary ketosis in the high-producing dairy: clinical and subclinical disorders, treatment, prevention, and outlook. *J. Dairy Sci.* 65, 1–10.
- Ballard, C.S., Mandebvu, P., Sniffen, C.J., Emanuele, S.M., Carter, M.P., 2001. Effect of feeding an energy supplement to dairy cows prepartum and postpartum on intake, milk yield, and incidence of ketosis. *Anim. Feed Sci. Technol.* 93, 55–69.
- Bell, A.W., 1995. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. *J. Anim. Sci.* 73, 2804–2819.
- Danfaer, A., Tetens, V., Agergaard, N., 1995. Review and experimental study on the physiological and quantitative aspects of gluconeogenesis in lactating ruminants. *Comp. Biochem. Physiol. Part B: Biochem. Mol. Biol.* 111, 201–210.
- Geishauser, T., Leslie, K., Kelton, D., Duffield, T., 1998. Evaluation of five cow-side tests for use with milk to detect subclinical ketosis in dairy cows. *J. Dairy Sci.* 81, 438–443.
- Goff, J.P., Horst, R.L., 1994. Calcium salts for treating hypocalcemia: carrier effects, acid–base balance, and oral versus rectal administration. *J. Dairy Sci.* 77, 1451–1456.
- Goff, J.P., Horst, R.L., 1997. Physiological changes at parturition and their relationship to metabolic disorders. *J. Dairy Sci.* 80, 1260–1268.
- Goff, J.P., Horst, R.L., Jardon, P.W., Borelli, C., Wedam, J., 1996. Field trials of an oral calcium propionate paste as an aid to prevent milk fever in periparturient dairy cows. *J. Dairy Sci.* 79, 378–383.
- Grummer, R.R., Winkler, J.C., Bertics, S.J., Studer, V.A., 1994. Effect of propylene glycol dosage during feed restriction on metabolites in blood of prepartum Holstein heifers. *J. Dairy Sci.* 77, 3618–3623.
- Krishnamoorthy, U., Sniffen, C.J., Van Soest, P.J., 1982. Nitrogen fractionation in ruminant feedstuffs for feed evaluation. In: *Proceedings of the Cornell Nutrition Conference for Feed Manufacturers*, Rochester, NY. Cornell University Press, Ithaca, NY, pp. 95–102.
- Hurtaud, C., Lemosquet, S., Rulquin, H., 2000. Effect of graded duodenal infusions of glucose on yield and composition of milk from dairy cows. Part 2: Diets based on grass silage. *J. Dairy Sci.* 83, 2952–2962.
- Hurtaud, C., Rulquin, H., Verite, R., 1993. Effect of infused volatile fatty acids and caseinate on milk composition and coagulation in dairy cows. *J. Dairy Sci.* 76, 3011–3020.
- Kronfeld, D.S., 1982. Major metabolic determinants of milk volume, mammary efficiency, and spontaneous ketosis in dairy cows. *J. Dairy Sci.* 65, 2204–2212.
- Littell, R.C., Milliken, G.A., Stroup, W.W., Wolfinger, R.D. 1996. SAS® System for Mixed Models. SAS Inst. Inc., Cary, NC.
- Moore, D.A., Ishler, V., 1997. Managing dairy cows during the transition period: focus on ketosis. *Vet. Med.* 92, 1061–1072.
- National Research Council, 2001. *Nutrient Requirements of Dairy Cattle*, 7th review ed. National Academic of Science, Washington, DC.

- SAS® User's Guide Statistics, 1996. Version 6.12, 4th ed. SAS Inst. Inc., Cary, NC.
- Smith, T.R., Hippen, A.R., Beitz, D.C., Young, J.W., 1997. Metabolic characteristics of induced ketosis in normal and obese dairy cows. *J. Dairy Sci.* 80, 1569–1581.
- St-Pierre, N.R., Jones, L.R., 1999. Interpretation and design of non-regulatory on-farm feeding trials. *J. Dairy Sci.* 82 (Suppl. 2), 177–182.
- Studer, V.A., Grummer, R.R., Bertics, S.J., Reynolds, C.K., 1993. Effect of prepartum propylene glycol administration on periparturient fatty liver in dairy cows. *J. Dairy Sci.* 76, 2931–2939.
- Van Soest, P.J., 1994. *Nutritional Ecology of the Ruminant*, 2nd ed. Cornell University Press, Ithaca, NY.
- Van Soest, P.J., Robertson, J.B., Lewis, B.A., 1991. Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal production. *J. Dairy Sci.* 74, 3583–3597.
- Veenhuizen, J.J., Drackley, J.K., Richard, M.J., Sanderson, T.P., Miller, L.D., Young, J.W., 1991. Metabolic changes in blood and liver during development and early treatment of experimental fatty liver and ketosis in cows. *J. Dairy Sci.* 74, 4238–4253.
- Waterman, R.C., Stalker, L.A., Bryant, W.D., Sawyer, J.E., Haweekins, D.E., Parker, E.E., Cox, S.H., Hartung, J.A., Valdez, F., Horton, J., Petersen, M.K., 2002. Increasing glucogenic precursors in range supplements fed to young postpartum beef cows shortens postpartum interval. *West. Sect. Anim. Sci. Proc.* 53, 58–63.
- Wildman, E.E., Jones, G.M., Wagner, P.E., Boman, R.L., Troutt Jr., H.F., Lesch, T.N., 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. *J. Dairy Sci.* 65, 495–501.