Effects of Prepartum Dietary Carbohydrate Source and Monensin on Periparturient Metabolism and Lactation in Multiparous Cows

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ABSTRACT

Eighty-five multiparous Holstein cows were used in a completely randomized design with restrictions to evaluate the effects of prepartum carbohydrate (CHO) source and monensin on periparturient dry matter intake (DMI), blood parameters, and lactation performance of dairy cows. Dietary treatments were arranged in a 2 × 2 factorial arrangement with a conventional (CONV) dry cow diet and a nonforage fiber source (NFFS) dry cow diet not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin as a top dressing. The CONV diet contained 70% forage and the NFFS diet contained nonforage fiber sources such that 28% of the forage was replaced with cottonseed hulls and soyhulls. The experimental diets (CONV and NFFS) were fed throughout the entire dry period (for 60 d before parturition). Monensin was top dressed once daily starting 28 d (27 ± 1.8 SD) before the expected calving date and continued until parturition. After parturition, all cows received the same lactating cow diet. During the last 28 d of gestation, cows receiving the NFFS diets prepartum had greater DMI (15.8 vs. 11.9 kg/d), DMI as a percentage of body weight (2.1 vs. 1.6% of body weight), plasma glucose (67.4 vs. 64.6 mg/dL), and serum insulin concentrations (0.59 vs. 0.45 ng/mL), and lower plasma nonesterified fatty acid concentrations (185 vs. 245 μ Eq/L) compared with cows receiving the CONV diets prepartum. Average milk production or composition during the first 56 d of lactation was not significantly affected by prepartum source of CHO, monensin, or their combination; however, there was a trend for the prepartum CHO source to affect milk production over time. Supplementation of monensin as a top dressing for 28 d prepartum had no effect on periparturient measurements. The prepartum diet did not affect postpartum DMI, blood glucose, nonesterified fatty acids, insulin concentrations, or liver triglyceride content. Results from this research demonstrated that

partly replacing conventional dietary carbohydrate sources with NFFS, cottonseed hulls and soyhulls, in the dry cow diet improved or maintained the prepartum DMI and therefore enhanced the prepartum metabolic status, as indicated by key blood metabolite concentrations. This greater prepartum DMI may potentially increase milk production during early lactation.

Key words: nonforage fiber source, monensin, prepartum feeding, periparturient metabolism

INTRODUCTION

The transition period, defined as the last 3 wk prepartum and the first 3 wk postpartum (Grummer, 1995), is a time of substantial physiological adaptations associated with parturition and lactogenesis (Bauman and Currie, 1980). Proper management of the transition cow is necessary to ensure a healthy and successful lactation. If cows are not properly managed during this time, they can be susceptible to metabolic diseases such as ketosis, fatty liver, or displaced abomasum. These metabolic diseases may, in part, be caused by nutrient imbalances or deficiencies or a depressed DMI before parturition, when nutrient demands may result in a negative nutrient balance. To meet nutrient demands, the animal will mobilize adipose tissue reserves (Bell, 1995); therefore, it is important to provide an adequate supply of glucose precursors to stimulate and maintain DMI and reduce adipose tissue mobilization.

One potential feeding strategy to increase DMI during the prepartum period is to include nonforage fiber sources (NFFS) in the diet. Nonforage fiber sources, such as soyhulls and cottonseed hulls, are by-products of food-processing plants and may be economical sources of fiber. Nonforage fiber sources have NDF values similar to forages but particle sizes similar to concentrates (Pereira et al., 1999). Ipharraguerre and Clark (2003) suggested that partial substitution of forages by soyhulls may improve the performance of dairy cows when forages constitute 50% or more of dietary DM and the supply of effective fiber is adequate. Dry cow diets, which usually contain more than 50% of the DM as forage, present an opportunity for using NFFS to replace forages in an attempt to increase DMI during

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the prepartum period. Ordway et al. (2002) reported a greater prepartum DMI when NFFS, cottonseed hulls, and soyhulls were included in the ration, compared with traditional dry cow feeding strategies (16.3 vs. 12.0 kg/d, respectively). Digestion of NDF, as well as the rate of passage, may be higher for NFFS compared with forages (Bhatti and Firkins, 1995; Firkins, 1997).

Monensin sodium is an ionophore that alters rumen fermentation to favor rumen production of propionate, which is the main precursor of glucose synthesis (Richardson et al., 1976). Monensin has been shown to reduce prepartum blood NEFA and BHBA concentrations when administered before parturition as a ruminal bolus (Stephenson et al., 1997) or as a controlled-release capsule (CRC; Duffield et al., 1998). Prepartum supplementation of monensin as a top dressing has been shown to increase the prepartum propionate supply (Arieli et al., 2001), reduce postpartum blood NEFA concentrations during wk 1 of lactation, and potentially increase DMI postpartum (Vallimont et al., 2001). These results suggested that prepartum monensin supplementation may enhance the energy metabolism of periparturient cows and has the potential to improve the health and production of cows during the postpartum period.

The hypothesis of this research was that through the additive effects of including NFFS in the dry cow diet plus prepartum monensin supplementation, periparturient feed intake and energy metabolism of cows can be improved and can therefore lead to greater production in early lactation. The objectives of this research were to determine whether inclusion of NFFS in the prepartum diet, supplementation with monensin prepartum, or their combination would improve the animal and lactational performance of periparturient Holstein dairy cows. Animal performance was defined as the responses of DMI, blood metabolites, and hepatic triglyceride (TG) content from -28 to 56 d of parturition. Lactational performance was defined as the responses of milk production and milk composition during the first 56 d of lactation.

MATERIALS AND METHODS

Experimental Design and Treatments

This experiment was conducted under the approval of The Pennsylvania State University Animal Care and Use Committee. Eighty-five multiparous Holstein dairy cows were used in a completely randomized design with restrictions to compare the effects of feeding prepartum diets with different carbohydrate (CHO) sources and monensin during the prepartum period on periparturient DMI, blood metabolites, liver TG content, and lactational performance. Treatments were arranged in a

2 × 2 factorial. Cows received either a conventional dry cow diet (CONV; Table 1) or an NFFS diet (Table 1) not supplemented or supplemented with 330 mg/cow per d of monensin as a top dressing from -28 d to parturition. The dose of monensin chosen was similar to the amount of monensin (300 mg/cow per d) studied in a previous experiment (Vallimont et al., 2001). Supplementing monensin as a top dressing rather than as a component of the TMR provided an opportunity to control monensin consumption by each cow. Most cows readily consumed the top dressing because it was very palatable. Cows were dried off 60 d before the expected calving date and started to receive their respective experimental diets (CONV or NFFS); therefore, the experimental diets (CONV or NFFS) were provided to cows during the entire dry period (d -60 to -29 = adaptation period; d -28 to parturition = experimental period), and monensin was provided during the experimental period only. The CONV diet contained 70% forage and the NFFS diet contained nonforage fiber sources such that 28% of the forage was replaced with cottonseed hulls and soyhulls. Treatments were designated as CONV(-), CONV(+), NFFS(-), and NFFS(+), with the (-) and (+) being without and with monensin, respectively. After parturition, all cows received the same lactating cow diet (Table 2).

Management and Feeding of Cows

At dry off (60 d before the expected calving date), cows were housed in 2 free-stall facilities with access to a dry lot, located at the Pennsylvania State University Dairy Cattle Research and Education Center (University Park, PA). Cows were moved to a tunnel-ventilated tie-stall barn at approximately d 28 (27 ± 1.8 SD) before expected calving date and remained there through d 56 postpartum. Once dry cows were moved to this facility, they were exercised for 3 h/d in an open dry lot until calving. Dry cows were moved with their feed to box stalls just before calving and returned to the tie-stall facility the following morning. Postpartum cows were milked at 0600 and 1800 h. Milk production was recorded daily. All health-related treatments were recorded while cows were in the study.

In the tie-stall facility, cows were fed individually for ad libitum intake of their experimental diets once daily at approximately 0800 h (cows were group-fed the experimental diets when in the free-stall facilities). Feed refusals were weighed before feeding, and the amount of feed offered was adjusted daily to allow a 10% refusal. Feed was pushed up to cows approximately 4 to 6 times per day. After parturition, all cows received the same lactating cow diet. All diets were formulated based on NRC (2001) guidelines, offered as a TMR, and adjusted

Table 1. Ingredient and chemical composition of the conventional dry cow diet (CONV) and the nonforage fiber source dry cow diet (NFFS) fed to cows during the last 28 d before parturition

Item	CONV	SEM	NFFS	SEM
Ingredient, % of DM				
Corn silage	44.8	—	35.1	—
Alfalfa hay	—	—	6.9	—
Grass hay	25.2	—	—	—
Cottonseed hulls	—	—	15.6	—
Soyhulls	6.0	—	15.6	—
Canola meal	8.3	—	7.3	—
Cookie meal ¹	4.9	—	4.9	—
Fish meal	2.07	—	1.7	—
Blood meal	2.07	—	1.7	—
Feather meal	2.07	—	1.7	—
Wheat middlings	1.9	—	4.0	—
Distillers corn	1.2	—	2.4	—
Molasses, liquid	0.6	—	2.5	—
Minerals and vitamins premix	1.0 ²	—	0.7 ³	—
Chemical composition				
Samples, n	14		14	
CP, % of DM	13.4	0.4	14.8	0.2
Soluble CP, % of CP	33.1	0.7	34.1	0.7
ADF, % of DM	29.6	0.9	30.0	0.8
NDF, % of DM	46.7	1.2	43.6	0.9
NFC, ⁴ % of DM	27.8	0.9	30.0	0.7
Fat, % of DM	3.8	0.1	4.5	0.1
NE _L ⁵ , Mcal/kg	1.50	<0.01	1.56	<0.01
Ca, % of DM	0.65	0.04	0.65	0.02
P, % of DM	0.36	0.01	0.41	0.01
Mg, % of DM	0.34	0.02	0.34	0.01
K, % of DM	1.60	0.03	1.53	0.04

¹Dried bakery by-product.

²Minerals and vitamins contained 0.39% aragonite (CaCO₃), 0.21% magox, 0.14% salt, 0.13% vitamin E, 0.02% vitamin A, D, and E (mix contained a minimum of 3,913 ppm of vitamin A, 81.5 ppm of vitamin D, and 54,375 ppm of vitamin E), 0.02% dairy TM II (mix contained a minimum of 122,449 ppm of Mn, 40,816 ppm of Cu, 122,449 ppm of Zn, and 10,294 ppm of Fe), and 0.02% Ca sulfate.

³Minerals and vitamins contained 0.22% aragonite (CaCO₃), 0.10% magox, 0.14% salt, 0.15% vitamin E, 0.05% selenium premix, 0.02% vitamin A, D, and E, and 0.02% dairy TM II.

⁴NFC = [100 - (NDF + CP + fat + ash)].

⁵Estimated based on NRC (2001) guidelines.

for changes in DM weekly. For the first 7 d after calving, 1.5 kg of grass hay was offered daily along with the TMR.

Monensin was incorporated into a pellet with 170.5 g of distillers grains as a carrier. The daily dose of monensin was preweighed and labeled for the appropriate cow and date and top dressed beginning 28 d before expected calving. The monensin treatment was stopped at calving. To adapt cows to monensin, for the first 3 d of monensin supplementation, the cows were given 85 g of the grain monensin carrier. Monensin pellets were top dressed daily and hand-mixed into the top portion of the feed after the animals returned from the exercise lot.

Measurement and Sample Collection

Samples of the TMR were collected weekly and stored at -20°C for DM and chemical analysis. As-fed feed intake of each cow was measured daily from 28 d before

expected calving date until 56 d postpartum. Daily DMI was calculated by adjusting daily as-fed feed intake to DM percentage of the weekly TMR sample. Body weights were measured weekly in the last 28 d prepartum. Postpartum BW was measured at each milking and the average weekly BW was calculated. Body condition was scored weekly from dry off through 56 d postpartum by 2 people using a 1 to 5 scale (1 = thin to 5 = overweight; Wildman et al., 1982). Body condition scores were averaged to obtain a single weekly value.

Calf birth BW was recorded, and calving difficulty was scored based on a 5-point scale (1 = no problem, 2 = slight problem, 3 = needed assistance, 4 = considerable force, 5 = extreme difficulty; National Association of Animal Breeders, Columbia, MO). Milk production was recorded daily through 56 d postpartum. Milk samples were collected weekly from 2 consecutive milkings until 8 wk postpartum. Morning and evening samples were analyzed separately to allow for adjustments resulting

Table 2. Ingredient and chemical composition of the lactating cow TMR

Item	Percentage of DM	SEM
Ingredient		
Corn silage	24.5	—
Alfalfa haylage	14.8	—
Alfalfa hay	9.6	—
Grain mix ¹	16.2	—
Canola meal	4.9	—
Cookie meal ²	6.8	—
Dry corn	13.6	—
Soybeans, roasted	4.6	—
Liquid molasses	4.0	—
Sodium bicarbonate	0.7	—
Bentonite	0.4	—
Chemical composition		
Samples, n	9	
CP, % of DM	17.2	0.3
Soluble CP, % CP	35.0	1.2
ADF, % of DM	21.9	0.8
NDF, % of DM	33.8	0.8
NFC, ³ %	35.8	0.6
Fat, % of DM	5.5	0.1
NE _L , ⁴ Mcal/kg	1.67	<0.01
Ca, % of DM	0.87	0.03
P, % of DM	0.41	0.02
Mg, % of DM	0.32	0.01
K, % of DM	1.74	0.21

¹Grain mix contained 30.87% corn distillers grain, 30.87% wheat middlings, 28.99% Turbomeal (a soybean meal product; J. L. Moyer and Sons Inc., Turbotville, PA), 2.57% fish meal, 3.74% aragonite (CaCO₃), 1.32% salt, 1.08% magox, 0.27% selenium premix, 0.16% dairy TM II (mix contained a minimum of 122,449 ppm of Mn, 40,816 ppm of Cu, 122,449 ppm of Zn, and 10,294 ppm of Fe), and 0.13% vitamin A, D, and E (mix contained a minimum of 3,913 ppm of vitamin A, 81.5 ppm of vitamin D, and 54,375 ppm of vitamin E).

²Dried bakery by-product.

³NFC = [100 - (NDF + CP + fat + ash)].

⁴Estimated based on NRC (2001) guidelines.

from differing yields between the morning and evening milking.

Blood samples were collected via puncture of the coccygeal blood vessels into evacuated tubes approximately 3 h postfeeding. Samples were collected once weekly on wk 4, 3, and 2 before the expected calving date. From 1 wk before to 3 wk after parturition, samples were collected on every Monday, Wednesday, and Friday, and then once weekly on wk 4 and 5 postpartum. The actual blood sampling dates were at d -27 (± 2.1), -21 (± 1.9), -14 (± 2.1), -7 (± 1.0), -5 (± 0.7), -3 (± 0.7), -1 (± 0.5), 1 (± 0.6), 3 (± 0.8), 5 (± 0.8), 7 (± 0.7), 9 (± 0.7), 11 (± 0.6), 13 (± 0.6), 15 (± 0.6), 17 (± 0.7), 19 (± 0.7), 22 (± 0.8), 28 (± 1.1), and 35 (± 0.9 SD) relative to parturition. Plasma collection tubes for glucose contained potassium oxalate and sodium fluoride. A second set of plasma collection tubes contained only sodium heparin. Serum collection tubes contained a clot activator. Blood tubes for plasma collection were immediately placed on ice and centrifuged within 1 h at $3,300 \times g$ for 15 min at 4°C. Blood tubes for serum collection were allowed

to remain at room temperature for 1 h to clot and then centrifuged at $3,300 \times g$ for 15 min at room temperature. Plasma and serum samples were recovered and frozen at -20°C for future analyses.

Liver samples were collected from a total of 31 cows by percutaneous biopsy at d -28 (-27 ± 3.3), -14 (-12 ± 4.2), 1 (3 ± 1.5), 14 (15 ± 2.3), and 28 (29 ± 3.3 SD) relative to calving. Only 20 cows with liver TG values for all 3 postpartum sampling days were included in the statistical analysis. Preparation for liver biopsy consisted of clipping the area surrounding the incision site between the 11th and 12th ribs. The surgical area was then scrubbed with a soap solution. Local anesthesia was achieved by injection of a local anesthetic (Lidocaine 2%, Phoenix Pharmaceutical Inc., St. Joseph, MO). Ultrasound was used to determine the depth of the liver and to avoid blood vessels and scar tissue from previous biopsies. A small (1-cm) cutaneous incision was made, the trocar and cannula biopsy instrument were inserted, and a core of tissue was removed from the liver. Approximately 2 g of sample was obtained for analysis. Liver samples were blotted to remove excess blood and connective tissue and snap-frozen in liquid N. Samples were stored at -80°C until further analysis.

Analytical Procedures

Samples of the stored TMR were thawed at room temperature and dried for 48 h at 55°C in a forced-air oven and grounded in a Wiley mill (A. H. Thomas, Philadelphia, PA) through a 1-mm screen. Samples of the TMR were composited by month and analyzed for DM, CP, soluble CP, ADF, NDF, and minerals by wet chemistry (Dairy One Forage Testing Laboratory, Ithaca, NY; Table 1). Dry matter was determined by drying at 135°C for 2 h (method 930.15; AOAC, 2005). Nitrogen was determined by combustion (method 990.03; AOAC, 2005; Leco FP-528 Combustion Analyzer; Leco Instruments Inc., St. Joseph, MI) and multiplied by 6.25 to obtain CP. Soluble CP was determined by using a sodium borate-sodium phosphate buffer procedure (Roe and Sniffen, 1990). Acid detergent fiber and NDF were determined by using the Ankom A200 Filter Bag Technique (Ankom Technology, Macedon, NY) according to Van Soest et al. (1991). Minerals were determined by using a Thermo Jarrell Ash IRIS Advantage HX Inductively Coupled Plasma Radial Spectrometer (Thermo Instrument Systems Inc., Waltham, MA). Milk samples were analyzed for content of fat, true protein, lactose, and MUN by using an infrared spectroscopic method (method 927.16; AOAC, 2005; MilkoScan 4000, Foss Electric, Hillerød, Denmark), and SCC using the optical somatic cell counting method (method 978.26; AOAC, 2005; Fossomatic 4000, Foss Electric) by Pennsylvania

Table 3. Allocation for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Variable	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
Cows, n	24	23	19	19				
305-d mature-equivalent production, kg	11,051	11,233	11,138	11,378	436.65	0.78	0.61	0.94
Lactation number ²	2.2	2.6	2.3	2.3	0.32	0.82	0.46	0.54
Initial BW, ³ kg	784	765	756	739	27.68	0.26	0.46	0.96
Initial BCS ⁴	3.3	3.2	3.2	3.3	0.07	0.71	0.96	0.47

¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

²Lactation number after calving.

³BW = BW at dry off (60 d before the expected calving).

⁴BCS = BCS (1 to 5 scale) at dry off (60 d before the expected calving).

DHIA (University Park). Plasma samples were analyzed for glucose (Stanbio Enzymatic Glucose Kit 1075; Stanbio Laboratory Inc., Boerne, TX) based on the method of Trinder (1969), BHBA (Standbio LiquiColor Kit 2440; Stanbio Laboratory Inc.) based on the method of Williamson et al. (1962), and NEFA (Wako NEFA C Kit; Biochemical Diagnostics Inc., Edgewood, NY) based on a method modified according to the procedure of Johnson and Peters (1993). Serum samples were analyzed for concentrations of insulin by using an RIA (Coat-A-Count Insulin Kit number TKINX; Diagnostic Products Corp., Los Angeles, CA). Liver TG content was determined by Hantzsch condensation with the modifications described by Foster and Dunn (1973). Values are reported on a percentage of wet weight basis. Hepatic expression of glucogenic enzymes, pyruvate carboxylase, and cytosolic phosphoenolpyruvate carboxykinase was also determined, and results were reported in Karcher et al. (2007).

Statistical Analysis

The experiment was conducted as a completely randomized design with randomization restricted to balance for expected calving date, previous lactation 305-d mature-equivalent milk production, lactation number, and initial BCS and BW at dry off (60 d before parturition; Table 3). The prepartum results included measurements from 85 cows and postpartum results from 79 cows. Six cows were removed from the postpartum portion of the experiment. All these cows were culled shortly after calving for various health-related reasons. Prepartum and postpartum results were analyzed separately. Allocation measurements and changes of BW and BCS were analyzed by using PROC GLM (SAS Institute, 1999). The general linear model included fixed effects of source of CHO, monensin, and the interaction of CHO and monensin. Calving difficulty score was analyzed by using PROC NPAR1WAY (SAS Insti-

tute, 1999) to test the fixed effects of CHO and monensin (Wilcoxon-Mann-Whitney test) and the interaction of CHO and monensin (Kruskal-Wallis test). The incidences of health-related disorders were analyzed by using PROC FREQ (SAS Institute, 1999) to test the fixed effects of CHO and monensin (Fisher's exact test) and the interaction of CHO and monensin (chi-square test). Data that were measured serially were analyzed as repeated measures by using PROC MIXED (SAS Institute, 1999). The general linear mixed model included fixed effects of CHO, monensin, the interaction of CHO and monensin, sampling time, and sampling time-related interactions. Degrees of freedom were estimated by using the Kenward-Roger option in the MODEL statement (Kenward and Roger, 1997). Cow nested within the interaction of CHO and monensin was used as the random effect. Time of sampling (day or week) was used in the REPEATED statement. The time series covariance structure was modeled by using 3 different covariance structures (spatial power, antedependence, and unstructured covariance) for each variable tested (Littell et al., 1996). The structure resulting in the lowest Akaike and Bayesian information criteria was used to measure the final analysis of the individual tests (Littell et al., 1998). The PDIF option was used for multiple comparison tests. Data are presented as means ± standard deviations or least squares means ± standard errors of the means. Statistical significance was declared at $P \leq 0.05$ and a tendency toward significance was declared at $0.05 < P \leq 0.11$.

RESULTS AND DISCUSSION

Health Records and Calving Measurements

Incidences of health-related disorders were similar among treatments and were comparable to previous studies conducted in the same location (Dann et al., 1999; Vallimont et al., 2001; Table 4). Supplementation of monensin during the last 28 d of gestation showed

Table 4. Incidences of twinning and health-related disorders for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition

Variable	Prepartum treatment			
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)
Cow, n	24	23	19	19
Twinning	1	0	3	1
Ketosis	3	3	5	6
Displaced abomasum	0	1	1	4
Calved with mastitis	7	2	2	5
Mastitis during 56 DIM	5	7	4	2
Milk fever	0	1	2	1
Retained placenta	2	3	5	2
Metritis	3	2	3	1
Diarrhea	1	2	1	2

an impact on calf birth BW (monensin effect: $P = 0.05$; Table 5); however, this effect of prepartum monensin supplementation on calf birth BW may have been influenced by the relatively greater incidence of twinning recorded for the NFFS(–) treatment group (3 of the 19 cows). The incidence of twinning was not related to treatments; therefore, when data on twin calves were excluded, calf birth BW became similar among treatments. Calving difficulty score tended (CHO effect: $P = 0.10$ and 0.03 before and after excluding the twin calves, respectively) to be affected by the prepartum source of CHO. However, the median calving difficulty scores before and after excluding the twin calves were 1 (no assistance), and the mean calving difficulty scores for all treatments were less than 2 (slight problem). Together with similar BW and calf birth BW, the difference in calving score between the NFFS and CONV diets was not considered to be an effect of prepartum source of CHO.

Prepartum DMI, BW, and BCS

Prepartum DMI was greater (CHO effect: $P < 0.01$) for cows receiving the NFFS diets compared with those receiving the CONV diets (15.8 vs. 11.9 kg/d, respec-

tively; Table 6 and Figure 1). Dry matter intake, as a percentage of BW, reflected the DMI results (2.1 vs. 1.6% of BW for the NFFS and CONV diets, respectively; CHO effect: $P < 0.01$). The average prepartum DMI for the NFFS diets recorded in the current study was similar to that in a previous study using similar NFFS in the prepartum diet (16.3 kg/d of DMI or 2.2% of BW; Ordway et al., 2002). A comparison made by Ordway et al. (2002) showed that the mean prepartum intake for the NFFS diets reported by Ordway et al. (2002) and in the current study were greater than the prepartum intake (12.0 kg/d) for other studies that used traditional dry cow diets. Allen (2000) suggested that substituting NFFS for forages in the diet might increase DMI when intake was regulated by distention in the reticulorumen. However, the effect of NFFS on DMI was inconsistent and factors other than distention in the reticulorumen might have been involved in the regulation of DMI (Allen, 2000). These factors may include the source, amount, and physical forms of forages (Grant, 1997) and NDF concentration from forages (Ipharraguerre and Clark, 2003). Ipharraguerre and Clark (2003) suggested that when forages constitute 50% or more of dietary DM and supply adequate effective fiber, partial replacement of forages with soyhulls may improve the performance of cows. Dry cow diets usually contain more than 50% of forage (total dietary DM). The greater prepartum DMI for the NFFS diets observed in the current study and in that of Ordway et al. (2002) provided evidence for substituting NFFS for forages in the dry cow diet as a strategy to alleviate the depressed voluntary DMI during the prepartum period.

Prepartum DMI was not affected by prepartum monensin supplementation or the interaction of prepartum source of CHO and monensin. An earlier study with a monensin treatment similar to that in the current study also found no effect of monensin on prepartum DMI (Vallimont et al., 2001). The effect of prepartum monensin on DMI during the dry period is inconsistent. Wagner et al. (1999) reported a decreased prepartum DMI when cows were fed 24 g/t (100% DM

Table 5. Calving measurements for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Variable	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
Birth BW, kg	42.22	44.07	39.72	43.31	1.49	0.24	0.05	0.53
Birth BW, kg (excluding twins)	43.24	44.07	43.30	43.31	1.39	0.78	0.74	0.74
Calving score, ² mean	1.78	1.74	1.59	1.42	0.23	0.10	0.83	0.41
Calving score, mean (excluding twins)	1.78	1.74	1.44	1.33	0.24	0.03	0.80	0.20

¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

²Calving difficulty score (scale of 1 to 5, where 1 is no difficulty and 5 is severe difficulty).

Table 6. Prepartum DMI, BW, and BCS for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Prepartum variable	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
DMI, kg/d	12.50	11.24	15.76	15.75	0.52	<0.01	0.21	0.21
DMI, % of BW	1.66	1.54	2.02	2.08	0.09	<0.01	0.70	0.29
BW, kg	782	771	765	767	17.56	0.53	0.80	0.70
BW Δ , ² kg	16.90	26.67	3.36	37.24	20.29	0.93	0.19	0.47
BCS	3.42	3.34	3.38	3.38	0.05	0.98	0.38	0.39
BCS Δ ²	–0.08	–0.04	–0.09	–0.01	0.05	0.91	0.24	0.67

¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

² Δ calculated as change from wk –4 to –1 prepartum.

basis) of monensin in the TMR during the dry period. Petersson-Wolfe et al. (2007) observed a tendency for a lower prepartum DMI for cows receiving a monensin CRC treatment. Green et al. (1999) reported no effect of monensin CRC treatment on prepartum DMI. Stage of lactation was suggested as a factor that may potentially influence the effect of monensin on feed intake (Petersson-Wolfe et al., 2007) because of propionate supply and glucose demands by the mammary gland (Oba and Allen, 2003). Oba and Allen (2003) proposed that when glucose demands by the mammary gland

increase, such as during the time in early lactation compared with midlactation, the effect of propionate on reducing feed intake is minimized by increases in gluconeogenesis and decreases in propionate oxidation in the liver. If the dry period is considered to be a period with a relatively lower glucose demand compared with early lactation, an increased propionate supply by monensin feeding may depress feed intake, based on the assumption proposed by Oba and Allen (2003). However, the impact of monensin on prepartum intake is inconclusive in the literature, indicating that physiolog-

Figure 1. Periparturient DMI for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pre- and postpartum pooled SEM were ± 0.64 and 1.0 kg/d, respectively. Prepartum: carbohydrate effect, $P < 0.01$; week effect, $P < 0.01$; other effects, nonsignificant. Postpartum: week effect, $P < 0.01$; monensin $\times$ week interaction, $P = 0.08$; other effects, nonsignificant. The dotted line indicates the cessation of treatments.

ical stage did not seem to have an effect on DMI caused by monensin. The ratio of monensin consumption to the amount of substrate presented in the rumen may also explain the impact of monensin on intake. In the current study, the ratio of monensin consumption to substrate intake averaged 21.7 and 30.8 mg/kg of TMR DM for the NFFS(+) and CONV(+) treatments, respectively, for 3 wk prepartum. The ratio of monensin consumption to substrate intake for the CONV(+) treatment seemed to be high; however, DMI was not affected, in contrast to the report by Petersson-Wolfe et al. (2007), in which DMI tended to be depressed when the ratio was 28.6 mg/kg of TMR DM (335 mg/d at 11.7 kg/d of DMI), which was lower than the ratio for the CONV(+) treatment in the current study. Markantonatos et al. (2002) concluded that monensin supplementation prepartum may alter rumen VFA production rates; however, DMI showed a greater overall influence on VFA production rates than did monensin supplementation. The DMI observed in the current study and in other studies discussed herein did not seem to be low or inadequate. Therefore, as long as an adequate amount of substrate is presented in the rumen, monensin may not have an effect on feed intake, which may therefore explain the inconsistent effects of monensin on feed intake during different physiological stages.

Prepartum BW did not differ among treatments and averaged 771 kg (Table 6). The prepartum change in BW also did not differ among treatments and averaged 21.0 kg; however, the standard error of the mean was high. Prepartum BW and change in BW recorded in the current study were similar to those in a previous study (Ordway et al., 2002). Prepartum BCS and change in BCS were not influenced by prepartum source of CHO or supplemental monensin and averaged 3.38 and -0.06 units, respectively. Previous studies (Garnsworthy and Topps, 1982; Reid et al., 1986; Treacher et al., 1986) have reported decreased DMI and increased loss of BW and BCS in overconditioned cows at calving. An important aspect of one-group dry cow feeding programs is that cows do not become overconditioned. According to results from this research, cows receiving the NFFS diets during the entire dry period (60 d before calving) had greater DMI and maintained a normal body condition during the last 28 d of gestation.

Prepartum Blood Metabolite Concentrations

Prepartum plasma glucose concentrations were greater (CHO effect: $P < 0.01$) for cows receiving the NFFS diets compared with those receiving the CONV diets (67.4 vs. 64.6 mg/dL, respectively; Table 7). Plasma glucose concentrations remained similar among treatments until 3 d before parturition, when

plasma glucose concentrations for cows receiving the NFFS diets increased (CHO $\times$ day interaction: $P < 0.05$; Figure 2) compared with those receiving the CONV diets. The NFFS diets averaged 68.9 and 74.1 mg/dL for d -3 and -1, respectively, whereas the CONV diets averaged 62.9 and 62.9 mg/dL for d -3 and -1, respectively. Similar prepartum plasma glucose concentrations were reported for cows receiving similar types of NFFS diets (mean = 67.8 mg/dL; Ordway et al., 2002).

Cows receiving the NFFS diets had lower (CHO effect: $P < 0.05$) prepartum plasma NEFA concentrations than cows receiving the CONV diets (185 vs. 245 μ Eq/L, respectively; Table 7). In this study, NEFA concentrations began to increase approximately 1 wk before parturition for all treatments (Figure 3). Increases in prepartum plasma NEFA concentrations have been reported in cows force-fed refusals to minimize the effect of intake on blood metabolites, indicating that hormonal factors beyond intake affect blood metabolites before parturition (Bertics et al., 1992). In this study, however, cows receiving the NFFS diets had lower ($P < 0.05$) NEFA concentrations on d -7, -5, and -3 prepartum than cows receiving the CONV diets (CHO $\times$ day interaction: $P = 0.05$). A greater DMI may alleviate the influence of hormonal factors on blood metabolites during the prepartum period, as indicated by the lower NEFA concentrations observed in cows fed the NFFS diets in the current study.

Cows fed the NFFS diets had greater (CHO effect: $P < 0.01$) prepartum serum insulin concentrations than those fed the CONV diets (0.59 vs. 0.45 ng/mL, respectively; Table 7). Although concentrations of serum insulin declined in all treatments as parturition approached, those fed the NFFS diets maintained consistently greater insulin concentrations from d -14 to -5 and tended to have greater insulin concentrations on d -3 compared with the CONV diets (Figure 4). Increased serum insulin concentrations prepartum reflected the greater plasma glucose concentrations, likely from increased DMI.

Feeding NFFS in the dry cow diet throughout the entire dry period (for 60 d before calving) increased or maintained DMI and therefore improved the energy status (greater blood glucose and insulin and lower NEFA concentrations) of prepartum cows during the last 28 d of gestation. Supplementation of monensin as a top dressing prepartum had no effect on prepartum blood metabolite concentrations, likely because of adequate feed intake prepartum. The effect of prepartum monensin on blood metabolites as well as on DMI, as discussed previously, during the dry period is inconsistent. Vallimont et al. (2001) reported no significant differences in blood glucose concentrations with monensin supplementation top dressed in the dry period. Ste-

Table 7. Prepartum concentrations of plasma metabolites and serum insulin for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Prepartum variable ²	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
Glucose, mg/dL	65.0	64.1	66.7	68.1	1.13	<0.01	0.83	0.27
NEFA, μ Eq/L	254.6	234.5	191.1	179.5	27.44	0.03	0.55	0.87
Insulin, ³ ng/mL	0.45	0.44	0.61	0.57	0.05	<0.01	0.69	0.83

¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

²Blood were sampled on d –27 (± 2.1), –21 (± 1.9), –14 (± 2.1), –7 (± 1.0), –5 (± 0.7), –3 (± 0.7), and –1 (± 0.5 SD) relative to parturition.

³Insulin sample obtained on d –1 relative to parturition was not included.

phenson et al. (1997) reported lower blood glucose and NEFA concentrations with monensin supplementation as a ruminal bolus. Duffield et al. (2003) also reported lower blood NEFA concentrations with monensin supplementation as a CRC.

Postpartum DMI, BW, and BCS

Postpartum DMI and postpartum DMI as a percentage of BW during the first 56 d of lactation were similar among treatments and averaged 21.6 kg/d and 3.3%,

respectively (Table 8). A trend ($P = 0.08$) for a prepartum monensin supplementation $\times$ week interaction was observed on postpartum DMI (Figure 1). This interaction found on postpartum DMI was due to a lower DMI on wk 4 and 5 of lactation for cows receiving monensin prepartum compared with cows receiving no monensin; however, DMI at other time points were similar among treatments. The postpartum DMI observed in the current study was similar to that in other studies for multiparous cows in early lactation (Dann et al., 1999; Vallimont et al., 2001; Ordway et al., 2002). Substituting

Figure 2. Periparturient plasma glucose concentrations for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pre- and postpartum pooled SEM were ± 2.9 and 1.3 mg/dL, respectively. Prepartum: carbohydrate (CHO) effect, $P < 0.01$; CHO $\times$ day interaction, $P = 0.01$; other effects, nonsignificant. Postpartum: day effect, $P < 0.01$; CHO $\times$ day interaction, $P = 0.05$; other effects, nonsignificant. The dotted line indicates the cessation of treatments.

Figure 3. Periparturient plasma nonesterified fatty acid (NEFA) concentrations for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pre- and postpartum pooled SEM were ± 89.8 and $154.8 \mu\text{Eq/L}$, respectively. Prepartum: carbohydrate (CHO) effect, $P = 0.03$; day effect, $P < 0.01$; CHO $\times$ day interaction, $P = 0.05$; other effects, nonsignificant. Postpartum: day effect, $P < 0.01$; other effects, nonsignificant. The dotted line indicates the cessation of treatments.

Figure 4. Prepartum serum insulin concentrations for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pooled SEM was $\pm 0.11 \text{ ng/mL}$. Carbohydrate effect, $P < 0.01$; day effect, $P < 0.01$; other effects, nonsignificant. Sample obtained on –1 d of parturition was not included.

NFFS for forages in the dry cow diet increased prepartum feed intake. Nonforage fiber sources have a smaller particle size with a greater rate of passage and therefore can serve as an alternative to forages in the dry cow diet to maintain rumen fill and provide enough effective fiber at the same time. The greater prepartum DMI by feeding NFFS in the dry cow diet, as observed in the current study, may better prepare cows to transition onto the lactating cow diet.

Postpartum BW and change of BW did not differ among treatments and averaged 667 and –44 kg, respectively (Table 8). Postpartum BCS was not different among treatments, averaging 2.94 units (Table 8). Cows receiving the NFFS diets prepartum tended (CHO effect: $P = 0.10$) to have a greater postpartum change in BCS compared with cows receiving the CONV diets prepartum (–0.30 vs. –0.21 units, respectively). This greater loss of BCS was likely caused by the greater milk produced by cows fed the NFFS diets prepartum. The mobilization of body reserves, as indicated by the loss of BW and BCS observed in the current study during the first 8 wk of lactation, were considered to be small and within the normal range (1 to 1.5 units of BCS or 60 to 90 kg of BW by 60 d postpartum; Chase,

Table 8. Postpartum DMI, BW, and BCS during the first 56 d of lactation for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Postpartum variable	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
DMI, kg/d	21.29	21.25	21.85	21.85	0.74	0.39	0.97	0.98
DMI, % of BW	3.18	3.22	3.34	3.28	0.11	0.25	0.91	0.60
BW, kg	675	661	661	671	14	0.84	0.86	0.35
BW Δ, ² kg	–51	–38	–49	–36	12	0.85	0.18	0.97
BCS	2.96	2.86	2.96	2.96	0.05	0.31	0.34	0.28
BCS Δ ²	–0.24	–0.19	–0.29	–0.31	0.06	0.10	0.75	0.55

¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.²Δ calculated as change from wk 1 to 4 postpartum.

1993). Prepartum monensin supplementation or the interaction of prepartum source of CHO and monensin had no effect on postpartum DMI, BW, and BCS. Vallimont et al. (2001) also reported no effect of prepartum monensin supplementation on postpartum BCS or BCS loss.

Milk Yield and Composition

Average milk production during the first 56 d of lactation was not affected by prepartum source of CHO, monensin supplementation, or the interaction of prepartum source of CHO and monensin supplementation (Table 9). A tendency for a prepartum CHO source × week interaction was observed on milk production (CHO × week interaction: $P = 0.08$; Figure 5). This prepartum CHO source effect found on milk production over time was due to a greater milk yield for the NFFS(–) treatment on wk 1, 3, 4 ($0.05 < P \leq 0.10$), and 7 ($P \leq 0.05$) of lactation compared with the CONV(–) treatment. The differences in milk yield over time between these 2 treatment groups also explained the weak

tendency ($P = 0.11$) for a prepartum CHO source × monensin interaction on average milk production during the first 56 d of lactation [46.9 vs. 41.9 kg/d for NFFS(–) and CONV(–), respectively; $P = 0.08$]. Milk yield observed in the current study for the NFFS diets was similar to that reported by Ordway et al. (2002), who used a similar NFFS diet prepartum (45.4 and 45.7 kg/d during the first 56 d of lactation, respectively).

Percentage of milk fat was significantly ($P = 0.05$) affected by the interaction of prepartum source of CHO and monensin. This interaction resulted from the NFFS(+) treatment having a greater ($P < 0.01$) milk fat percentage than the CONV(+) treatment (4.2 vs. 3.8%, respectively; Table 9). When comparing milk fat percentage between these 2 treatment groups on a weekly basis, milk fat percentage for the NFFS(+) treatment was consistently greater ($P < 0.05$) than that for the CONV(+) treatment from wk 1 to 5 of lactation [6.0, 4.8, 4.4, 4.1, and 4.0% vs. 5.1, 4.3, 3.8, 3.6, and 3.5% for the NFFS(+) and CONV(+) treatments, respectively]; therefore, this consistent difference for milk fat percentage resulted in the interaction of source of CHO and

Table 9. Milk and milk component production during the first 56 d of lactation for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Postpartum variable	Prepartum treatment				SEM	P-value ¹		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
Milk yield, kg/d	41.90 ^b	45.00 ^{ab}	46.87 ^a	43.57 ^{ab}	2.16	0.37	0.96	0.11
Fat, %	4.00 ^{AB}	3.79 ^B	3.95 ^{AB}	4.24 ^A	0.13	0.11	0.75	0.05
Fat yield, kg/d	1.66	1.72	1.88	1.84	0.09	0.05	0.95	0.58
Protein, %	2.91	2.82	2.85	2.89	0.06	0.94	0.56	0.19
Protein yield, kg/d	1.21 ^B	1.29 ^{AB}	1.38 ^A	1.28 ^{AB}	0.06	0.12	0.88	0.09
Lactose, %	4.70	4.68	4.76	4.71	0.05	0.29	0.47	0.72
MUN, mg/dL	13.02	12.79	12.18	12.81	0.64	0.38	0.36	0.36
SCC, × 10 ³ cells/mL	365.43	393.87	479.94	398.63	128.12	0.61	0.82	0.64
SCC, linear score	3.27	3.30	3.00	3.44	0.41	0.86	0.53	0.59

^{a,b}0.5 < $P \leq 0.10$.^{A,B} $P \leq 0.05$.¹Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

Figure 5. Milk yields during the first 56 d of lactation for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (-) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pooled SEM was ± 2.5 kg/d. Carbohydrate (CHO) $\times$ monensin interaction, $P = 0.11$; week effect, $P < 0.01$; CHO $\times$ week interaction, $P = 0.08$; other effects, nonsignificant.

monensin. The greater milk fat percentage observed in cows receiving the NFFS(+) treatment could be attributed to greater body fat mobilization; however, this was not supported by blood parameter data and liver TG content. Yield of milk fat was significantly ($P = 0.05$) affected by source of CHO such that cows receiving the NFFS diets during the prepartum period had greater milk fat yield than cows receiving the CONV diets (1.86 vs. 1.69 kg/d, respectively). This greater milk fat yield was likely a result of numerically greater milk fat percentage (4.09 vs. 3.89%, respectively; CHO effect: $P = 0.11$) with similar milk yield (45.2 vs. 43.4 kg/d, respectively; CHO effect: $P = 0.37$) found for the NFFS diets compared with the CONV diets.

Percentage of milk protein did not differ among treatments; however, yield of milk protein tended ($P = 0.09$) to be affected by the interaction of prepartum source of CHO and monensin supplementation (Table 9). The NFFS(-) treatment tended to have a greater ($P = 0.03$) milk protein yield than the CONV(-) treatment (1.4 vs. 1.2 kg/d, respectively). Because milk protein percentages were similar among treatments, the difference in milk protein yield between the NFFS(-) and CONV(-) treatments was therefore a consequence of the difference in milk yield between the 2 treatments [46.9 vs. 41.9 kg of milk per d for the NFFS(-) and CONV(-) treatments, respectively; $P = 0.08$]. No effect of prepartum source of CHO or monensin supplementation was observed for milk lactose percentage, MUN, SCC, and SCC linear score.

Collectively, feeding NFFS, monensin, or their combination in the prepartum period did not significantly

alter milk production or milk components during the first 56 d of lactation. Partial replacement of forage with NFFS in the prepartum diet, however, tended to improve milk yield over time, but this effect on milk yield of replacing forage with NFFS in the prepartum diet was inconsistent throughout the experimental period. Potential reasons why feeding NFFS in the prepartum diet may have improved milk production could be the greater DMI, and therefore better energy status, in the prepartum period, which were carried over to the postpartum period. Ipharraguerre and Clark (2003) reported slight improvements in DMI and milk yield when partially replacing forage with soyhulls; however, the effects of substituting soyhulls for forage on intake and production were affected by the forage content of the basal diet and NDF concentration from forage for the soyhulls diet. Milk components observed in the current study were likely more reflective of mobilization of body reserves (fat percentage and yield) or milk yield (protein yield) than the prepartum dietary treatments; therefore, a clear prepartum effect of NFFS, monensin, or their combination could not be concluded.

Postpartum Blood Metabolite Concentrations and Liver Triglyceride Contents

Postpartum concentrations of blood metabolites, except for BHBA, were not affected by prepartum source of CHO or monensin supplementation (Table 10). Greater prepartum plasma glucose concentrations of cows fed the NFFS diets prepartum did not carry over into the postpartum period, although the postpartum plasma glucose concentration on d 1 of lactation was greater ($P < 0.05$) for the NFFS diets compared with the CONV diets (CHO $\times$ day interaction: $P = 0.05$; Figure 3). Postpartum plasma BHBA concentrations tended ($P = 0.08$) to be affected by prepartum source of CHO such that cows receiving the NFFS diets prepartum had greater postpartum BHBA concentrations than cows receiving the CONV diets prepartum (10.2 vs. 9.0 mg/dL, respectively). This overall difference in postpartum plasma BHBA concentration between the prepartum source of CHO was due to a trend ($0.5 < P \leq 0.10$) for the NFFS diets to have greater plasma BHBA concentrations on d 11, 13, 15, and 21 of lactation compared with the CONV diets (CHO $\times$ day interaction: $P = 0.12$; Figure 6). Values were 10.8, 10.6, 10.8, and 10.2 mg/dL vs. 8.4, 8.4, 7.2, and 7.8 mg/dL for the NFFS and CONV diets, respectively, on d 11, 13, 15, and 21 of lactation. Cows fed the NFFS diets may have had greater blood BHBA concentrations than cows fed the CONV diets because of the greater milk yield produced by cows receiving the NFFS diets. Cows receiving the NFFS diets prepartum may have mobilized greater

Table 10. Postpartum concentrations of plasma metabolites, serum insulin, and liver triglyceride (TG) for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin (MON) during the last 28 d before parturition

Postpartum variable ¹	Prepartum treatment				SEM	P-value ²		
	CONV(–)	CONV(+)	NFFS(–)	NFFS(+)		CHO	MON	CHO × MON
Glucose, mg/dL	56.5	55.7	55.6	57.3	1.78	0.82	0.77	0.44
NEFA, μ Eq/L	378.9	407.9	414.5	411.2	34.51	0.53	0.68	0.60
BHBA, mg/dL	8.36	9.64	10.45	10.04	0.78	0.08	0.54	0.23
Insulin, ng/mL	0.22	0.19	0.20	0.22	0.02	0.68	0.51	0.16
Liver sample, ³ n	8	3	5	4				
Liver TG, % of wet weight	3.51	3.18	3.56	4.69	0.94	0.32	0.61	0.36

¹Blood were sampled on d 1 (± 0.6), 3 (± 0.8), 5 (± 0.8), 7 (± 0.7), 9 (± 0.7), 11 (± 0.6), 13 (± 0.6), 15 (± 0.6), 17 (± 0.7), 19 (± 0.7), 22 (± 0.8), 28 (± 1.1), and 35 (± 0.9 SD) of lactation.

²Comparison between source of carbohydrate (CHO), MON, and interaction of CHO and MON.

³n = number of animals per treatment that had TG values for d 3 (± 1.5), 15 (± 2.3), and 29 (± 3.3 SD) postpartum.

body fat reserves (as indicated by a greater loss of BCS and greater blood BHBA concentrations) to support the greater milk production. However, the degree of mobilization of body fat reserves observed in the current study was not considered to be excessive. Concentrations of blood BHBA over time for cows receiving the NFFS diets were below the cutoff value of blood BHBA (>12.5 mg/dL; LeBlanc et al., 2005) for differentiating susceptibility to clinical ketosis.

No effect of prepartum source of CHO or monensin supplementation was observed on postpartum hepatic TG concentrations (Table 10). Prepartum liver samples were collected and hepatic TG concentrations were measured; however, these hepatic TG concentrations were too low to be detected and are not included in

these data. Effect of day was significant ($P < 0.01$) such that hepatic TG contents averaged 3.4, 4.7, and 3.1% of wet weight on d 3 (± 1.5), 15 (± 2.3), and 29 (± 3.3 SD) of lactation (mean = 3.7% of wet weight; Figure 7). There are 3 categories for fatty liver based on liver TG (% of wet weight): mild (1 to 5%), moderate (5 to 10%), and severe ($>10\%$; Bobe et al., 2004). Normal liver contains less than 1% of TG. On the basis of these categories, cows in this study may have developed mild fatty livers as a consequence of body fat mobilization to compensate for negative energy balance during the first month of lactation. However, even with mild fatty livers, DMI and milk yield for cows used in this experiment did not seem to be hindered.

Figure 6. Postpartum plasma BHBA concentrations for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pooled SEM was ± 1.8 mg/dL. Carbohydrate effect, $P = 0.08$; day effect, $P < 0.01$; other effects, nonsignificant.

Figure 7. Liver triglyceride (TG) contents for cows provided a conventional dry cow diet (CONV) or nonforage fiber source diet (NFFS) not supplemented (–) or supplemented (+) with 330 mg/cow per d of monensin during the last 28 d before parturition. Pooled SEM was $\pm 1.24\%$ of wet weight. Day effect, $P < 0.01$; other effects, nonsignificant.

CONCLUSIONS

This study examined the singular effect of inclusion of NFFS (cottonseed hulls and soyhulls) in the prepartum diet or prepartum monensin supplementation as a top dressing or their additive effects on periparturient feed intake, blood parameters, and milk production. Replacing forages with NFFS in the diet fed to cows during the entire dry period increased DMI, DMI as a percentage of BW, blood glucose, and insulin concentrations, and reduced blood NEFA concentrations during the last 28 d of gestation. Supplementation of monensin as a top dressing for 28 d prepartum had no effect on periparturient feed intake, blood metabolites, and milk production. The prepartum diet did not affect postpartum DMI, blood glucose, NEFA, and insulin concentrations or hepatic TG content. Results from this research demonstrated that partially replacing conventional dietary carbohydrate sources (70%) with NFFS (28%), cottonseed hulls, and soyhulls in the dry cow diet improved or maintained prepartum DMI and therefore enhanced prepartum metabolic status, as indicated by key blood metabolite concentrations. This greater prepartum DMI may potentially increase milk production during early lactation.

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