Reducing Dry Period Length to Simplify Feeding Transition Cows: Milk Production, Energy Balance, and Metabolic Profiles

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ABSTRACT

Sixty-five Holstein cows were used to evaluate management schemes involving altered dry period (DP) lengths on subsequent milk production, energy balance (EB), and metabolic variables. Cows were assigned to one of 3 treatments: traditional 56-d DP (fed a low-energy diet from –56 to –29 d and a moderate energy diet from –28 d to parturition; T), 28-d DP (continuously fed a high energy diet; S), and no planned DP (continuously fed a high energy diet; N). Prepartum DM intake (DMI), measured from 56 d prepartum through parturition, was lower for cows on the T treatment than for cows on the S treatment and was higher for cows on the N treatment than for cows on the S treatment. There were no differences in prepartum plasma glucose, and β -hydroxybutyric acid; there was a treatment by time interaction for prepartum plasma nonesterified fatty acid (NEFA). There was no difference in prepartum liver triglyceride (TG); postpartum liver TG was decreased for cows on the N treatment compared with cows on the S treatment, but was similar for cows on the T and S treatments. Postpartum NEFA was similar between cows on the T and S treatments, but was greater for cows on the S treatment than for cows on the N treatment. Postpartum glucose was greater for cows on the N treatment compared with cows on the S treatment and tended to be greater for cows on the S treatment than for cows on the T treatment. There was no difference in postpartum solids-corrected milk (SCM) production or DMI by cows on the T vs. S treatment. However, there was a tendency toward lower postpartum SCM production by cows on the N vs. S treatment and a tendency for greater postpartum DMI by cows on the N vs. S treatment. Postpartum EB was greater for cows on the S vs. T treatment and the N vs. S treatment. In general, T and S management schemes had similar effects on DMI, SCM, and metabolic vari-

ables in the first 70 d of the subsequent lactation. Eliminating the DP improved energy and metabolic status. (**Key words:** dry period length, transition period, energy density)

Abbreviation key: DP = dry period, DRY = contrast for DP length, EB = energy balance, HE = high energy, LE = low energy, ME = moderate energy, MGT = contrast for management scheme, N = no planned DP, NE_I = net energy intake, NE_M = net energy for maintenance, NE_P = net energy for pregnancy, S = 28-d DP, T = 56-d DP, TG = triglyceride.

INTRODUCTION

A majority of the literature indicates that to achieve maximal milk production, a nonlactating or dry period (DP) is necessary between lactations. However, this literature is mostly retrospective analysis of farm records (Sanders, 1928; Arnold and Becker, 1936; Klein and Woodward, 1943; Wilton et al., 1967; Schaeffer and Henderson, 1972; Gill and Allaire, 1976; Pandey et al., 1978; Bar-Anan and Soller, 1979; Oltenacu et al., 1980; Dias and Allaire, 1982; Keown and Everett, 1986; Funk et al., 1987; Makuza and McDaniel, 1996). Cows in these studies with less than a 6- to 8-wk DP probably were not intended to have short DP and probably were not managed for a short DP (e.g., cows carrying twins, cows with late-term abortions, cows with incorrect breeding/calving date, cows only fed the far-off diet). Therefore, it is not surprising that such analyses would show that short DP are associated with low milk production during the next lactation. There have been a few experiments with preplanned DP lengths that indicated a DP of 40 to 60 d is essential to achieve maximal milk production in the subsequent lactation (Coppock et al., 1974; Sorensen and Enevoldsen, 1991).

Several experiments designed to examine the effects of reducing the DP to approximately 4 wk have shown no difference in milk production and/or FCM in the subsequent lactation (Lotan and Adler, 1976; Bachman, 2002; Annen et al., 2003; Gulay et al., 2003). However, these studies have provided limited information regarding the effects of DP length on DMI, milk composition,

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metabolic status, and health in the subsequent lactation.

A 12 to 25% decrease in milk production can be expected in the following lactation if the DP is eliminated and cows are continuously milked from one lactation to the next lactation (Swanson, 1965; Smith et al., 1967; Remond et al., 1992, 1997). However, these studies have used low cow numbers and/or cows with extremely low milk production.

Dry matter intake decreases dramatically in the week prior to parturition (Bertics et al., 1992), resulting in a decrease in energy intake at a critical point in time. Additionally, changing cows from one diet to another in a short period of time may not allow the rumen environment adequate time to adjust (Dirksen et al., 1985). One potential solution is to shorten the DP, and feed a high energy (**HE**), low fiber diet throughout the DP and into lactation. This would eliminate the traditional management practice of changing cows from a low energy (**LE**), high fiber ration to a lactating ration, containing a higher energy density and lower levels of fiber. By supplying an HE ration and increasing the ability of the rumen to use energy substrates, a lag in net energy intake (**NE_I**) may not be as much of a limiting factor to the animal. This has the potential to increase DMI, eliminate unnecessary stresses, and decrease the incidence of metabolic disorders during the transition period. All of these factors would significantly increase productivity, as well as increase the health of dairy cows.

The objective of this experiment was to determine the effects of varying DP length and prepartum diet on the metabolic profile, subsequent lactation, and energy balance (**EB**) of periparturient dairy cattle. We hypothesized that shortening the DP and feeding one HE diet for the entire gestation-lactation cycle would result in improved EB and metabolic status, with similar milk yield in the subsequent lactation.

MATERIALS AND METHODS

Cows and Treatments

Sixty-five Holstein cows were selected from the University dairy herd for this experiment. All cows had to fulfill the following selection criteria: 1) carrying a single fetus, 2) <400 DIM, 3) producing at least 20 kg of milk/d at 90 d prepartum, and 4) having a decrease in milk production of $\leq 15\%$ in the week before initiation of the experiment. In addition, if cows were receiving bST administration, this was ceased at 120 d prepartum. From 90 d prepartum through 57 d prepartum, all cows were fed a HE diet (Table 1). From 76 d to 57 d prepartum, DMI, milk production, milk composition, SCC, BW, and BCS were determined for later use as

covariate measurements. Concentrations of plasma NEFA, glucose, and BHBA from 76 and 75 d prepartum were analyzed and used as covariate measurements. The University of Wisconsin, College of Agriculture and Life Sciences, Animal Care and Use Committee approved all procedures.

Cows were blocked by parity (primiparous or multiparous), average daily milk production between 67 and 60 d prepartum, and DIM and randomly assigned to one of 3 treatments at 59 d prepartum. The first treatment reflected traditional (**T**) dry cow management practices. These cows had a 56-d DP and were fed a LE diet from 56 to 29 d prepartum, followed by a moderate energy (**ME**) diet from 28 d prepartum to parturition (Table 1). The second treatment had a shortened (**S**) DP of 28 d, and these cows were fed a HE diet throughout lactation and the DP. The third treatment had no planned (**N**) DP and remained on a HE diet. If a cow on N dropped below 2 kg milk/d, milking ceased for the remainder of the prepartum period. An intramammary antibiotic (10 mL/quarter of Cephapirin Benzathine; Fort Dodge Animal Health, Fort Dodge, IA) was given at the time of dry off for cows on the T and S treatments.

All cows were fed a postpartum HE diet from parturition through 70 DIM. The only difference between the pre- and postpartum HE diets was addition of sodium bicarbonate and reduction in the level of vitamins in the postpartum HE diet. Cows were fed *ad libitum* intake throughout the entire experimental period. Diets were fed as a TMR at 1030 and 1530 h and were formulated to meet nutrient requirements according to NRC (2001) recommendations. Nutrient composition of the diets is presented in Table 2.

Sampling and Analyses

Dry matter intake was measured daily. Forage and concentrate samples were obtained weekly and dried to 60°C to determine DM; results were used to adjust forage-to-concentrate ratio. Weekly forage samples were composited monthly for analysis; samples of concentrates were taken monthly for analysis. Samples were dried in a forced-air oven at 60°C for 72 h, ground in a Wiley mill (1-mm screen; Arthur H. Thomas, Philadelphia, PA), and analyzed for CP, ether extract (**EE**; Ag Source Soil and Forage Laboratory, Bonduel, WI; AOAC, 1999, with modifications being the use of petroleum ether and an extraction time of 25 min), NDF, (Van Soest et al., 1991; Mertens, 1999), ADF, and lignin (Van Soest et al., 1991). Neutral detergent fiber and ADF residues were analyzed for CP (NDICP and ADICP, respectively; Goering et al., 1972). Nonfibrous carbohydrate component was calculated as $100 - [(NDF - NDICP) + EE + CP + \text{ash}]$.

Table 1. Ingredient composition of experimental diets.¹

Ingredient	LE	ME	Prepartum HE	Postpartum HE
	(% DM)			
Corn silage	55.6	43.7	29.9	29.9
Alfalfa silage	16.0	16.3	15.0	14.9
Ground corn	10.0	22.95	33.65	33.55
Corn gluten meal	2.0	3.0	4.25	4.2
Roasted soybeans, whole	0.0	4.1	13.2	13.2
Tallow ²	0.0	0.25	0.75	0.75
Megalac-Plus ³	0.0	0.25	0.75	0.75
Chopped straw	15.0	7.5	0.0	0.0
Trace-mineralized salt ⁴	0.3	0.3	0.3	0.3
Calcium carbonate	0.0	0.0	0.3	0.3
Dicalcium phosphate	0.0	0.0	0.25	0.25
Vitamin mix ⁵	0.6	0.6	0.6	0.35
Blood meal	0.0	0.25	0.25	0.25
Yeast culture ⁶	0.5	0.5	0.5	0.5
Magnesium oxide	0.0	0.3	0.3	0.2
Sodium bicarbonate	0.0	0.0	0.0	0.6

¹LE = Low energy, far-off diet; ME = moderate energy, close-up diet; prepartum HE = high energy diet fed prepartum; and postpartum HE = high energy diet fed postpartum.

²Fatty acid composition (g/100 g of fatty acids) of tallow (Max-Fat, Des Moines, IA) was 2.6% C14:0, 23.7% C16:0, 2.8% C16:1, 1.0% C17:0, 17.7% C18:0, 40.5% C18:1, 5.9% C18:2, 0.9% C18:3, and 4.9% others.

³Megalac-Plus (Church and Dwight Co., Inc., Princeton, NJ).

⁴Contains 0.55% Mn, 0.55% Zn, 0.35% Fe, 0.14% Cu, 0.008% I, 0.006% Se, and 0.002% Co.

⁵Contains 3304 IU/g of DM of vitamin A, 1101 IU/g of DM of vitamin D, and 55 IU/g of DM of vitamin E.

⁶Diamond V XP Yeast Culture, Cedar Rapids, IA.

Cows were milked twice daily when lactating (prepartum and postpartum), and milk production was recorded at each milking. Milk samples were obtained from 4 consecutive milkings every 2 wk and analyzed for fat, protein, lactose, TS, and SCC using infrared

spectrometry (AOAC, 1999; AgSource Milk Analysis Laboratory, Menomonie, WI), and weighted means were computed according to milk yield. Colostrum samples were taken at the first milking, frozen (−20°C), and later analyzed for fat and protein using infrared spectrometry (AOAC, 1999; Dairy Laboratories Service, Dubuque, IA). Concentration of IgG in the colostrum was determined by single radial immunodiffusion using a commercial kit (VMRD, Inc., Pullman, WA; Fleenor and Stott, 1981). Body weight was recorded weekly for each cow, and calf BW was measured within 24 h of calving. Body condition score was recorded weekly for each cow by 3 individuals (Wildman et al., 1982).

Blood samples were taken at 1300 h on −76, −75, −30, −21, −14, −7, +1, +7, +14, and +35 d relative to calving date in Vacutainer tubes (Becton Dickinson, Franklin Lakes, NJ) containing potassium oxalate and sodium fluoride as a glycolytic inhibitor. Samples were centrifuged at 915 × g, 4°C, for 15 min immediately after sample collection, and plasma was decanted and stored at −20°C until later analysis. Plasma was analyzed for NEFA (NEFA-C kit; Wako Chemical USA, Richmond, VA; Johnson and Peters, 1993), glucose (kit number 510A; Sigma Chemical, St. Louis, MO; Raabo and Terkildsen, 1960), and BHBA (Gibbard and Watkins, 1968). Liver biopsies were obtained on −30, +1, and +35 d relative to calving date, frozen in liquid nitrogen,

Table 2. Nutrient composition of experimental diets.¹

Composition	LE	ME	Prepartum HE	Postpartum HE
	(% DM)			
DM, %	45.1	49.2	55.1	55.6
NE _L , ² Mcal/kg	1.50	1.69	1.75	1.71
CP	10.6	13.1	16.8	16.9
NDF	39.2	31.4	23.2	23.2
ADF	25.4	20.1	14.6	14.5
NFC ³	43.1	49.5	51.1	51.6
Ether extract	2.3	3.5	5.8	5.8
Lignin	4.1	3.2	2.3	2.3
NDICP ⁴	1.1	1.8	3.0	3.0
ADICP ⁵	0.8	0.8	0.9	0.9
Ash	5.9	5.5	6.1	5.5

¹LE = Low energy, far-off diet; ME = moderate energy, close-up diet; prepartum HE = high energy diet fed prepartum; and postpartum HE = high energy diet fed postpartum.

²Calculated according to NRC (2001).

³NFC = Nonfiber carbohydrates. Calculated by difference: 100 − [(NDF − NDICP) + CP + ether extract + ash].

⁴NDICP = Neutral detergent insoluble CP.

⁵ADICP = Acid detergent insoluble CP.

and stored at -20°C until analysis. Liver samples were analyzed for triglyceride (TG) content as previously described (Vazquez-Anon et al., 1994), except results were expressed on a DNA basis (Labarca and Paigen, 1980).

Energy Calculations

Net energy intake was determined by multiplying the weekly DMI by the calculated energy density of the diet. Energy density of the diet was calculated according to NRC (2001) considering a discount factor based on TDN intake above maintenance. Energy required for body maintenance (NE_M) was computed using the equation $\text{NE}_M = \text{BW}^{0.75} \times 0.08$ (NRC, 2001). Pregnancy requirements (NE_P) were computed using the equation $\text{NE}_P = [(2 \times 0.00159 \times \text{days pregnant} - 0.0353) \times (\text{calf BW}/45)]/0.14 \times 0.64$ (NRC, 2001). Milk energy was calculated using the equation $\text{NE}_L = \text{MP} \times [(0.0929 \times \text{F}) + (0.0563 \times \text{P}) + (0.0395 \times \text{L})]$, where MP = milk production (kg), F = fat percentage in the milk, P = true protein percentage in the milk, and L = lactose percentage in the milk (NRC, 2001). Estimated EB prepartum was calculated on a weekly basis using the equation $\text{EB} = \text{NE}_I - (\text{NE}_M + \text{NE}_P + \text{NE}_L)$. Estimated EB postpartum was calculated on a weekly basis using the equation $\text{EB} = \text{NE}_I - (\text{NE}_M + \text{NE}_L)$.

Statistical Analyses

Data were analyzed as repeated measures using the mixed models procedure of SAS (1999). Pre- and postpartum periods were analyzed separately. All measurements, except those from blood and liver, were reduced to weekly means before statistical analysis. The statistical model used for analysis of all measurements, except liver TG, included treatment effect, parity, week, interaction of parity and treatment, and interaction of treatment and week. The terms specified for the random statement were cow and block nested within parity. The covariance structure used to best fit the model was selected based on Akaike's information criterion (SAS, 1999). All data were covariately adjusted except for liver measurements.

The statistical model used for analysis of liver TG measurements included treatment effect, parity, day, interaction of parity and treatment, and interaction of treatment and day. Liver data from the 30-d prepartum time point was pooled for S and N because there was no difference in treatments to these groups at this point. The pooled data were analyzed against the data from the T treatment group at 30 d prepartum. The remaining liver TG data were analyzed as repeated measures using the time points of 1 and 35 d postpartum.

Two contrast statements were used to interpret treatment effects. The first contrast examined the effect of management schemes (MGT) or T compared with S. This contrast was not strictly a comparison of DP length because the prepartum dietary scheme was not consistent between treatments. The second contrast determined the effect of DP length (DRY) or S compared with N, as these treatments were fed the same diets throughout the experimental period with the only difference being length of DP. If a treatment contrast was significant in the model, differences between treatments were determined using the PDIFF option (SAS, 1999). Least squares means and standard errors of the means are reported. Significance was declared at $P < 0.05$, and trends were discussed at $P < 0.15$.

RESULTS AND DISCUSSION

Actual days dry were similar to planned days dry with treatments having 54 ± 7 , 30 ± 5 , and 5 ± 6 d dry for T, S, and N, respectively. Gestation length was similar across treatments (mean $\pm$ SD: 276 ± 7 , 279 ± 5 , and 280 ± 5 d for T, S, and N, respectively).

Mean prepartum DMI was 2.9 kg/d greater for S compared with T ($P < 0.001$) and 1.4 kg/d greater for N compared with S ($P < 0.001$). Differences in prepartum DMI were present until 3 wk prepartum for MGT, and from 5 wk prepartum to parturition for DRY (Figure 1). Concurring with our data, Gulay et al. (2003) found no difference in DMI between cows with a 60-d DP and a 30-d DP for the last 4 wk prepartum.

Mean postpartum DMI was 19.1, 19.6, and 20.7 kg/d for cows on the T, S, and N treatments, respectively (MGT: $P = 0.4$, DRY: $P < 0.15$). There was a tendency for cows on the N treatment to have a higher DMI compared with cows on the S treatment, with significant differences during wk 1 to 3 postpartum ($P < 0.05$). Similar postpartum DMI between cows on the T and S treatments is consistent with the findings of Gulay et al. (2003).

Prepartum milk and SCM production were significantly different for MGT and DRY contrasts (Figure 2) with significant treatment by time interactions ($P < 0.001$ for milk production and $P < 0.01$ for SCM production). Differences in prepartum milk production were present from wk 8 through wk 4 prepartum for MGT and from wk 5 prepartum through parturition for DRY (Figure 2A). Additional milk produced prepartum was 422 kg/cow for cows on the S treatment compared with cows on the T treatment and 328 kg/cow for cows on the N treatment compared with cows on the S treatment. Prepartum SCM production differed for cows on the T treatment compared with cows on the S treatment (P

Figure 1. Dry matter intake (kg/d) of cows with different dry period lengths and management schemes. Treatments are no planned dry period (N; ■), shortened 28-d dry period (S; ▽), and traditional 56-d dry period management scheme (T; ●). Values are means $\pm$ SE. Prepartum: T vs. S, $P < 0.001$; S vs. N, $P < 0.001$; treatment $\times$ time, $P < 0.001$ (SE = 0.32). Postpartum: S vs. N, $P < 0.15$ (SE = 0.38). Asterisks (*) indicate that DMI differed ($P < 0.05$) between S and N at that time point; plus signs (+) indicate that DMI differed ($P < 0.05$) between T and S.

< 0.001) and for cows on the S treatment vs. cows on the N treatment ($P < 0.001$; Figure 2B).

Mean postpartum milk production was 4.5 kg/d greater for cows on the T treatment compared with cows on the S treatment ($P < 0.01$) and was 4 kg/d greater for cows on the S treatment compared with cows on the N treatment ($P < 0.05$; Table 3). Differences existed at wk 1, 2, and 6 through 10 for T vs. S and at wk 2, 3, 4, 5, 8, and 10 postpartum for S vs. N ($P < 0.05$; Figure 2A). When milk production was adjusted to SCM, cows on T and S treatments had similar production (Table 3); cows on the N treatment still had lower production than those on the S treatment. Although other researchers have not calculated SCM, they have found no differences in FCM yield when comparing subsequent milk production by cows with 60- vs. 30-d DP (through 150 DIM; Lotan and Adler, 1976; through 70 DIM, Gulay et al., 2003). However, these researchers have also reported no difference in milk production for cows with a 60- vs. 30-d DP (Lotan and Adler, 1976; Gulay et al., 2003). Sorensen and Enevoldsen (1991) reported a 2.8-kg/d decrease in 4% FCM in the subsequent lactation when DP was reduced from 7 to 4 wk. Coppock et al. (1974) reported a decrease in milk production during the subsequent lactation for cows with a DP < 40 d. Our data are in agreement with that of others (Swanson, 1965; Smith et al., 1967; Remond et al., 1997), who reported that cows with no DP produced 12 to 25% less milk than cows with a 60-d DP. Swanson

Figure 2. A) Milk production (kg/d) of cows with different dry period lengths and management schemes. Treatments are no planned dry period (N; ■), shortened 28-d dry period (S; ▽), and traditional 56-d dry period management scheme (T; ●). Values are means $\pm$ SE. Prepartum: T vs. S, $P < 0.001$; S vs. N, $P < 0.001$; treatment $\times$ time, $P < 0.001$ (SE = 0.77). Postpartum: T vs. S, $P < 0.01$; S vs. N, $P < 0.01$; treatment $\times$ time $P < 0.05$ (SE = 1.9). Asterisks (*) indicate that milk production differed ($P < 0.05$) between S and N at that time point; plus signs (+) indicate that milk production differed ($P < 0.05$) between T and S. B) Solids-corrected milk production (kg/d) of cows with different dry period lengths and management schemes. Treatments are no planned dry period (N; ■), shortened 28-d dry period (S; ▽), and traditional 56-d dry period management scheme (T; ●). Values are means $\pm$ SE. Prepartum: T vs. S, $P < 0.001$; S vs. N, $P < 0.001$; treatment $\times$ time, $P < 0.001$ (SE = 0.7). Postpartum: S vs. N, $P < 0.05$; treatment $\times$ time $P < 0.1$ (SE = 1.4). Asterisks (*) indicate that SCM differed ($P < 0.05$) between S and N at that time point; plus signs (+) indicate that SCM differed ($P < 0.05$) between T and S.

Table 3. Effect of dry period length or prepartum management scheme on postpartum milk production, SCM, and milk components from 1 to 70 DIM.

Item	Treatment ¹			SE ²	Contrast ³	
	N	S	T		DRY	MGT
					P <	
Milk production (kg/d)	33.9	37.9	42.44	1.21	0.01	0.01
SCM (kg/d)	33.5	37.6	39.9	1.4	0.03	NS ⁴
Fat (%)	3.92	4.08	3.86	0.10	NS	0.1
Fat yield (kg/d)	1.32	1.53	1.57	0.06	0.02	NS
Protein (%)	3.14	2.97	2.83	0.49	0.01	0.05
Protein yield (kg/d)	1.05	1.12	1.17	0.04	NS	NS
Lactose yield (kg/d)	1.67	1.86	2.07	0.07	0.04	0.05
SCS ⁵	2.97	2.56	3.37	0.11	NS	0.15

¹Treatments include: N = no planned dry period, S = shortened (28-d) dry period, and T = traditional (56-d) dry period.

²Pooled standard error of least squares means.

³DRY = Effects of 28- vs. 0-d dry period; MGT = effects of 56- vs. 28-d management scheme.

⁴P > 0.15.

⁵SCS = Log₂ (SCC/100,000) + 3.

(1965) reported a 25% decrease in FCM in genetically identical animals with no DP compared with their 60-d DP counterparts.

A nonsecretory state, where epithelial cells of the mammary gland do not contain secretory vesicles, is reached by 35 d prepartum with a 60-d DP (Capuco et al., 1997). Beyond 35 d prepartum, the presence of secretory vesicles in epithelial cells increased as parturition approached in cows with 60- and 0-d DP (Capuco et al., 1997). However, at 7 d prepartum, only 62% of mammary epithelial cells demonstrated secretory activity in cows with no DP, while 98% of the epithelial cells had secretory activity in cows with a 60-d DP (Capuco et al., 1997). Based on these data and milk production data from our experiment and that of others (Swanson, 1965; Smith et al., 1967; Remond et al., 1997), a DP is necessary to achieve maximal milk production in the subsequent lactation.

There was no parity by treatment interaction for milk production in this experiment, which had 41 primiparous cows and 24 multiparous cows. Both primiparous cows and multiparous cows with shortened or no DP experienced a numerical decrease in milk production compared with their counterparts on a 56-d DP (39.8, 36.1, and 31.6 kg/d for primiparous cows on treatments T, S, and N, respectively, and 43.4, 39.9, and 36.3 for multiparous cows on treatments T, S, and N, respectively). A recent study (Annen et al., 2003) reported that primiparous, but not multiparous cows (second or greater lactation prior to treatment) had a decrease in milk production with a 30-d DP or no DP compared with a 60-d DP (40.1, 32.2, and 34.6 kg/d for primiparous cows on 60-, 30-, and 0-d DP, respectively, and 45.6, 42.0, and 45.5 for multiparous cows on 60-, 30-,

and 0-d DP, respectively). In addition, a retrospective analysis of DHIA records also indicated that, as age at calving increased, the need for days dry decreased (Dias and Allaire, 1982). The discrepancy between these data sets is unclear, but could be due to differences in genetic potential for milk production between the cows or management of the cows on the different experiments.

There was a tendency for increased milk fat percentage postpartum for cows on the S treatment compared with cows on the T treatment ($P < 0.1$), but no difference in milk fat yield between cows on the S and T treatments (Table 3). In addition, there was no difference in milk fat percentage for cows on the S treatment compared with cows on the N treatment, but milk fat yield was lower for cows on the N treatment compared with cows on the S treatment ($P < 0.05$). Gulay et al. (2003) and Lotan and Adler (1976) reported no difference in milk fat percentage and milk fat yield in the subsequent lactation for cows with 30- and 60-d DP. However, Sorensen and Enevoldsen (1991) reported a decrease in milk fat yield in the subsequent lactation for cows with a 4-wk DP compared with a 7-wk DP. Remond et al. (1992) reported no difference in milk fat yield from cows with no DP compared with a 60-d DP. Cows on the S treatment had a greater plasma NEFA concentration postpartum compared with cows on the N treatment; therefore, the greater milk fat yield from cows on the S vs. N treatment may be due to greater use and uptake of circulating NEFA by the mammary gland.

Milk protein percentage was greater for cows on the N treatment compared with cows on the S treatment ($P < 0.01$) and greater for cows on the S treatment compared with cows on the T treatment ($P < 0.05$; Table

Table 4. Effect of dry period length or prepartum management scheme on calf weight, BCS at calving, and postpartum BCS loss and BW loss.

Item	Treatment ¹			SE ²	Contrast ³	
	N	S	T		DRY	MGT
					P <	
Calf weight (kg)	43	43	43	1	NS ⁴	NS
BCS at calving ⁵	3.88	3.87	3.87	0.07	NS	NS
Postpartum BCS loss ⁶	0.56	0.81	1.37	0.08	0.05	0.001
Postpartum BW loss (kg) ⁷	16	45	68	9	0.001	0.05

¹Treatments include: N = no planned dry period, S = shortened (28-d) dry period, and T = traditional (56-d) dry period.

²Pooled standard error of least squares means.

³DRY= Effects of 28- vs. 0-d dry period; MGT = effects of 56- vs. 28-d management scheme.

⁴ $P > 0.15$.

⁵BCS (5-point scale where 1 = thin to 5 = obese; Wildman et al., 1982) at calving = prepartum BCS within 1 wk of calving.

⁶Postpartum BCS loss = BCS at calving – minimum BCS postpartum.

⁷Postpartum BW loss = BW at wk 1 postpartum – minimum BW postpartum.

3). However, there were no differences in milk protein yield. Gulay et al. (2003) reported no differences in milk protein percentage or protein yield for cows with 30- and 60-d DP. However, Sorensen and Enevoldsen (1991) reported an increased protein yield for cows with a 7- vs. a 4-wk DP (calculated milk protein percentage was 3.4 and 3.5%, respectively). Contrary to our data, Remond et al. (1992) reported an increase in milk protein yield from cows with no DP compared with cows with a 60-d DP. Based on our data and others, shortening the DP does not appear to affect milk protein yield, but eliminating the DP will result in an increase to no effect on milk protein yield. In our experiment, the difference in milk protein percentage was due to less volume being secreted with the same amount of protein being produced.

Lactose yield was 0.21 kg/d greater for cows on the T treatment compared with cows on the S treatment ($P < 0.05$) and 0.19 kg/d greater for cows on the S treatment compared with cows on the N treatment ($P < 0.05$; Table 3). The lactose data are consistent with milk production data. Remond et al. (1992) reported a tendency for increased lactose yield in cows with a 60-d DP compared with cows with no DP.

In our experiment, there were no treatment effects on SCS. This finding is in agreement with previous research, providing no evidence of an effect of DP length on incidence of mastitis (Enevoldsen and Sorensen, 1992; Remond et al., 1992; Gulay et al., 2003). However, some data indicate that there is a decreased rate of new IMI for cows during the DP with a DP of 31 to 60 d compared with a DP >60 d (Rindsig et al., 1978), and a DP <30 d compared with a DP >30 d (Natzke et al., 1975). Additionally, cows with a DP <30 d had more

infected quarters respond to therapy during the DP (Natzke et al., 1975).

Protein percentage in colostrum was lower for cows on the N treatment compared with cows on the S treatment (9.54 and 12.83%, respectively; $P < 0.01$); protein percentage of the colostrum from cows on the T and S treatments was similar (12.58 and 12.38%, respectively). This reflected a decrease in IgG concentration for the colostrum from cows on the N treatment compared with cows on the S treatment (49.8 and 77.9 g/L; $P < 0.01$). It is critical that calves receive at least 100 g of IgG within the first hour after birth (NRC, 2001). Calves receiving colostrum from cows on the N treatment would need to consume 2 L of colostrum (49.8 g/L IgG) to receive the necessary IgG, whereas calves receiving colostrum from cows on the S treatment would need to consume 1.3 L of colostrum (77.9 g/L IgG). Therefore, colostrum from cows on the N treatment is adequate to support the needs of the calf, as calves can easily consume 2 L of colostrum (NRC, 2001).

Calf BW and cow BCS at calving were not affected by treatments (Table 4). Postpartum BCS loss was greater for cows on the T treatment compared with cows on the S treatment (0.56 units; $P < 0.001$) and were greater for cows on the S treatment compared with cows on the N treatment (0.25 units; $P < 0.05$; Table 4). Postpartum BW loss data are in agreement with BCS loss data; cows on treatment T lost 22 kg more than cows on treatment S ($P < 0.05$), and cows on treatment S lost 30 kg more than cows on treatment N ($P < 0.001$). Similarly, cows with a 60-d DP lost more body condition postpartum (Gulay et al., 2003) and BW postpartum (Lotan and Adler, 1976) compared with cows with a 30-d DP. Remond et al. (1997) reported

Figure 3. Energy balance (Mcal/d) of cows with different dry period length or management schemes. Treatments are no planned dry period (N; ■), shortened 28-d dry period (S; ▽), and traditional 56-d dry period management scheme (T; ●). Values are means $\pm$ SE. Prepartum: T vs. S, $P < 0.05$; S vs. N, $P < 0.10$; treatment $\times$ time, $P < 0.001$ (SE = 0.94). Postpartum: T vs. S, $P < 0.05$; S vs. N, $P < 0.001$; treatment $\times$ time, $P < 0.001$ (SE = 1.06). Asterisks (*) indicate that energy balance differed ($P < 0.05$) between S and N at that time point; plus signs (+) indicate that energy balance differed ($P < 0.05$) between T and S.

that cows with no DP gained 24 kg BW in the first 9 wk postpartum compared with their 60-d DP counterparts that lost 28 kg BW. In our experiment, cows with no DP experienced a BW loss of 16 kg in the first 70 d of lactation. The discrepancy between our data and those of Remond et al. may be related to differences in postpartum milk production (19.5 vs. 33.9 kg/d).

Mean prepartum EB was greater for cows on treatment S compared with cows on treatment T (6.5 vs. 5.0 Mcal/d; $P < 0.05$) and tended to be greater for cows on treatment S compared with cows on treatment N (6.5 vs. 5.3 Mcal/d; $P < 0.1$; Figure 3). Differences existed at wk 5, 4, 3, and 1 prepartum for cows on the S treatment vs. cows on the N treatment and at 5 through 2 prepartum for cows on the T treatment vs. cows on the S treatment ($P < 0.05$; Figure 3). The EB difference between cows on the S and N treatments from 5 to 3 wk prepartum was primarily due to the difference in milk production. At 1 wk prepartum, the EB difference is also related to greater DMI for cows on treatment N vs. cows on treatment S. The EB difference between cows on the T and S treatments is primarily due to the additional milk output from cows on the S treatment during wk 5 through 4 prepartum as well as the consumption of a diet with higher energy density by cows on the S treatment.

Postpartum mean EB was 2.9 Mcal/d greater for cows on treatment S vs. cows on treatment T (−4.1 vs. −7.0;

Figure 4. Plasma NEFA concentrations (μ Eq/L) of cows with different dry period length or management schemes. Treatments are no planned dry period (N; ■), shortened 28-d dry period (S; ▽), and traditional 56-d dry period management scheme (T; ●). Values are means $\pm$ SE. Prepartum: treatment $\times$ time, $P < 0.001$ (SE = 7). Postpartum: S vs. N, $P < 0.001$; treatment $\times$ time, $P < 0.05$ (SE = 34). Asterisks (*) indicate that NEFA differed ($P < 0.05$) between S and N at that time point; plus signs (+) indicate that NEFA differed ($P < 0.05$) between T and S.

$P < 0.05$) and 4.8 Mcal/d greater for cows on treatment N vs. cows on treatment S (0.7 vs. −4.1; $P < 0.001$). Differences existed during wk 1 through 8 postpartum for cows on treatment S vs. cows on treatment N and during wk 2 through 5 postpartum and at wk 7, 9, and 10 postpartum for cows on treatment T vs. cows on treatment S ($P < 0.05$; Figure 3). The greater postpartum EB for cows on the N treatment compared with cows on the S treatment is due to decreased milk production and the tendency for increased DMI. There were no significant differences in NE_I or NE_L for cows on treatment T vs. cows on treatment S, but there was a tendency for NE_M to be greater for cows on treatment S compared with cows on treatment T was due to changes in postpartum BW.

There was a treatment by time interaction for prepartum plasma NEFA concentrations ($P < 0.001$), which is the result of a numerical increase of 128 μ Eq/L for cows on treatment T from 5 wk to 1 wk prepartum compared with lesser increases of 34 and 27 μ Eq/L for cows on treatments S and N, respectively. Postpartum concentrations of plasma NEFA were not affected by MGT, but were affected by DRY ($P < 0.001$); cows on treatment N had a lower concentration of NEFA compared with cows on treatment S through 2 wk postpartum (Figure 4). In a previous study, concentrations of NEFA were similar between cows with 30- and 60-d DP (Lotan and Adler, 1976). Plasma NEFA concentrations from our experiment reflect a greater postpartum EB

Figure 5. Liver triglyceride (TG) concentration ($\mu\text{g}/\mu\text{g}$ of DNA) of cows with different dry period length and management schemes. Treatments are no planned dry period (N; black bars), shortened 28-d dry period (S; bars with hatch marks), and traditional 56-d dry period management scheme (T; white bars). Treatments S and N are pooled at the -30-d time point (gray bar). Values are means $\pm$ SE. Prepartum: T vs. pooled, $P = 0.54$ (SE = 0.5). Postpartum: T vs. S, $P > 0.05$; S vs. N, $P < 0.05$; treatment $\times$ time, $P < 0.1$ (SE = 3.3).

for cows on treatment N compared with cows on treatment S, which was primarily due to decreased milk production and increased DMI.

Liver TG concentrations at 30 d prepartum were similar between cows on treatment T and cows on treatments S and N (Figure 5). Postpartum liver TG concentrations were not affected by MGT over time (Figure 5). However, liver TG concentration was less for cows on treatment N compared with cows on treatment S ($P < 0.05$). There was a tendency for a treatment by time interaction for postpartum liver TG concentration ($P <$

0.1). Liver TG increased from d 1 postpartum to d 35 postpartum in cows on treatment T, and liver TG decreased over the same time period with cows on treatments S and N. Continual accumulation of TG in the liver of cows on treatment T probably reflects greater negative EB and lipid mobilization than for cows on treatments S and N.

There were no prepartum treatment differences in plasma BHBA and glucose concentrations (Table 5). Lotan and Adler (1976) reported similar prepartum glucose concentrations in cows with 30- and 60-d DP. There were no treatment effects on postpartum plasma BHBA (Table 5). Mean postpartum plasma glucose concentration was 4 mg/dL greater for cows on treatment N compared with cows on treatment S (Table 5; $P < 0.01$), and there was a tendency for cows on treatment S to have a greater glucose concentration postpartum compared with cows on treatment T (Table 5; $P < 0.15$). As expected, postpartum glucose concentration is greater in cows with decreased milk production and better energy balance (N vs. S and S vs. T). Lotan and Adler (1976) reported greater glucose concentrations in cows with 30- vs. 60-d DP from 3 to 6 wk postpartum.

Shortening the DP and feeding one HE diet for the entire gestation-lactation cycle improved EB in the subsequent lactation, and eliminating the DP decreased plasma NEFA, decreased liver TG accumulation, and increased EB in the periparturient period. These improvements in metabolic status may result in a decrease in postpartum metabolic disorders. However, there are not enough cows in this experiment to determine statistically whether the incidence of metabolic disorders around calving differed because of treatments. The incidence of the following disorders for cows on treatments T, S, and N, respectively, is displaced abomasum (1 of 21, 1 of 23, 2 of 21), clinical milk fever (1 of 21, 3 of 23,

Table 5. Effect of dry period length or prepartum management scheme on plasma metabolites.

Metabolite	Treatment ¹			SE ²	Contrast ³	
	N	S	T		DRY	MGT
<i>P</i> < .						
Prepartum						
BHBA (mg/dL)	6.4	6.4	6.2	0.2	NS ⁴	NS
Glucose (mg/dL)	61	60	61	1	NS	NS
NEFA (uEq/L)	125	132	131	7	NS	NS
Postpartum						
BHBA (mg/dL)	6.6	7.8	8.3	0.9	NS	NS
Glucose (mg/dL)	59	55	53	1	0.01	0.15
NEFA (uEq/L)	235	394	403	47	0.001	NS

¹Treatments include: N = no planned dry period, S = shortened (28-d) dry period, and T = traditional (56-d) dry period.

²Pooled standard error of least squares means.

³DRY = Effects of 28- vs. 0-d dry period; MGT = effects of 56- vs. 28-d management scheme.

⁴ $P > 0.15$.

1 of 21), ketosis (1 of 21, 1 of 23, 0 of 21), mastitis (2 of 21, 6 of 23, 3 of 21), metritis (2 of 21, 0 of 23, 0 of 21), and retained placenta (3 of 21, 1 of 23, 2 of 21). Definitions of these disorders are described in LeBlanc et al. (2002).

CONCLUSION

Shortening the DP from 56 to 28 d along with feeding one consistent HE diet does not have appreciable positive or negative effects on DMI, SCM, and plasma energy metabolites. However, shortening the DP and feeding a consistent diet improved EB and decreased the amount of body reserves mobilized during the first month postpartum. This is in agreement with our initial hypothesis that shortening the DP and feeding one HE diet for the entire gestation-lactation cycle would result in improved EB and metabolic status in the subsequent lactation. Eliminating the DP improved metabolic status, as indicated by decreased plasma NEFA, decreased liver TG accumulation, and increased EB, in the periparturient period. This improvement was probably due to an increased DMI and a decrease in postpartum milk production.

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REFERENCES

- Annen, E. L., M. A. McGuire, J. L. Vicini, and R. J. Collier. 2003. Effect of Posilac (bST) and dry period management strategy on milk yield. *J. Dairy Sci.* 86(Suppl. 1):154. (Abstr.)
- Arnold, P. T. D., and R. B. Becker. 1936. Influence of preceding dry period and of mineral supplementation on lactation. *J. Dairy Sci.* 19:257–266.
- Association of Official Analytical Chemists. 1999. *Official Methods of Analysis*. Vol. 1. 16th ed. AOAC, Arlington, VA.
- Bachman, K. C. 2002. Milk production of dairy cows treated with estrogen at the onset of a short dry period. *J. Dairy Sci.* 85:797–803.
- Bar-Anan, R., and M. Soller. 1979. The effects of days open on milk yield and on breeding policy postpartum. *Anim. Prod.* 29:109–119.
- Bertics, S. J., R. R. Grummer, C. Cadorniga-Valino, and E. E. Stoddard. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation. *J. Dairy Sci.* 75:1914–1922.
- Capuco, A. V., R. M. Akers, and J. J. Smith. 1997. Mammary growth in Holstein cows during the dry period: Quantification of nucleic acids and histology. *J. Dairy Sci.* 80:477–487.
- Coppock, C. E., R. W. Everett, R. P. Natzke, and H. R. Ainslie. 1974. Effect of dry period length on Holstein milk production and selected disorders at parturition. *J. Dairy Sci.* 57:712–718.
- Dias, F. M., and F. R. Allaire. 1982. Dry period to maximize milk production over two consecutive lactations. *J. Dairy Sci.* 65:136–145.
- Dirksen, G. U., H. G. Liebich, and E. Mayer. 1985. Adaptive changes of the ruminal mucosa and their functional and clinical significance. *Bovine Pract.* 20:116–120.
- Enevoldsen, C., and J. T. Sorensen. 1992. Effects of dry period length on clinical mastitis and other major health disorders. *J. Dairy Sci.* 75:1007–1014.
- Fleenor, W. A., and G. H. Stott. 1981. Single radial immunodiffusion analysis for quantitation of colostral immunoglobulin concentration. *J. Dairy Sci.* 64:740–747.
- Funk, D. A., A. E. Freeman, and P. J. Berger. 1987. Effects of previous days open, previous days dry, and present days open on lactation yield. *J. Dairy Sci.* 70:2366–2373.
- Gibbard, S., and P. J. Watkins. 1968. A micro-method for the enzymatic determination of D- β -hydroxybutyrate and acetoacetate. *Clin. Chim. Acta* 19:511–521.
- Gill, G. S., and F. R. Allaire. 1976. Relationship of age at first calving, days open, days dry, and herd life to a profit function for dairy cattle. *J. Dairy Sci.* 59:1131–1139.
- Goering, H. K., C. H. Gordon, R. W. Hemken, D. R. Waldo, P. J. Van Soest, and L. W. Smith. 1976. Analytical estimates of nitrogen digestibility in heat damaged forages. *J. Dairy Sci.* 55:1275–1280.
- Gulay, M. S., M. J. Hayen, K. C. Bachman, T. Belloso, M. Liboni, and H. H. Head. 2003. Milk production and feed intake of Holstein cows given short (30-d) or normal (60-d) dry periods. *J. Dairy Sci.* 86:2030–2038.
- Johnson, M. M., and J. P. Peters. 1993. An improved method to quantify nonesterified fatty acids in bovine plasma. *J. Anim. Sci.* 71:753–756.
- Keown, J. E., and R. W. Everett. 1986. Effect of days carried calf, days dry, and weight of first calf heifers on yield. *J. Dairy Sci.* 69:1891–1896.
- Klein, J. W., and T. E. Woodward. 1943. Influence of length of dry period upon the quantity of milk produced in the subsequent lactation. *J. Dairy Sci.* 26:705–713.
- Labarca, C., and K. Paigen. 1980. A simple, rapid, and sensitive DNA assay procedure. *Anal. Biochem.* 102:344–352.
- LeBlanc, S. J., T. F. Duffield, K. E. Leslie, K. G. Bateman, J. TenHag, J. S. Walton, and W. H. Johnson. 2002. The effect of prepartum injection of vitamin E on health of transition dairy cows. *J. Dairy Sci.* 85:1416–1426.
- Lotan, E., and J. H. Adler. 1976. Observations on the effect of shortening the dry period on milk yield, body weight, and circulating glucose and FFA levels in dairy cows. *Tijdschr. Diergeneesk.* 101:77–82.
- Makuza, S. M., and B. T. McDaniel. 1996. Effects of days dry, previous days open, and current days open on milk yields of cows in Zimbabwe and North Carolina. *J. Dairy Sci.* 79:702–709.
- Mertens, D. R. 1999. Variation in aNDF results with modifications of the filter bag method. National Forage Testing Association, Technical Session Papers and Committee Reports to the Board and Membership, Topeka, KS.
- National Research Council. 2001. *Nutrient Requirements of Dairy Cattle*. 7th ed. National Academy Press, Washington, DC.
- Natzke, R. P., R. W. Everett, and D. R. Bray. 1975. Effect of drying off practices on mastitis infection. *J. Dairy Sci.* 58:1828–1835.
- Olteneacu, P. A., T. R. Rounsaville, R. A. Milligan, and R. L. Hintz. 1980. Relationship between days open and cumulative milk yield at various intervals from parturition for high and low producing cows. *J. Dairy Sci.* 63:1317–1327.
- Pandey, R. S., D. S. Bhatnagar, and M. Gurnani. 1978. Inheritance of dry period and its effect on subsequent lactation yield in Tharparkar cattle. *Indian Vet. J.* 55:935–939.
- Raabo, E., and T. C. Terkildsen. 1960. The enzymatic determination of blood glucose. *Scand. J. Clin. Lab. Invest.* 12:402–407.

- Remond, B., A. Ollier, and G. Miranda. 1992. Milking of cows in late pregnancy: Milk production during this period and during the succeeding lactation. *J. Dairy Res.* 59:233–241.
- Remond, B., J. Rouel, N. Pinson, and S. Jabet. 1997. An attempt to omit the dry period over three consecutive lactations in dairy cows. *Ann. Zootech.* 46:399–408.
- Rindsig, R. B., R. G. Rodewald, A. R. Smith, and S. L. Spahr. 1978. Complete versus selective dry cow therapy for mastitis control. *J. Dairy Sci.* 61:1483–1497.
- Sanders, H. G. 1928. The variations in milk yields caused by season of the year, service, age, and dry period, and their elimination. *J. Agric Sci. (Camb.)* 18:209–251.
- SAS. 1999. User's Guide: Statistics. Version 8 Edition. SAS Inst., Inc., Cary, NC.
- Schaeffer, L. R., and C. R. Henderson. 1972. Effects of days dry and days open on Holstein milk production. *J. Dairy Sci.* 55:107–112.
- Smith, A., J. V. Wheelock, and F. H. Dodd. 1967. Effect of milking throughout pregnancy on milk secretion in the succeeding lactation. *J. Dairy Res.* 34:145–150.
- Sorensen, J. T., and C. Enevoldsen. 1991. Effect of dry period length on milk production in subsequent lactation. *J. Dairy Sci.* 74:1277–1283.
- Swanson, E. W. 1965. Comparing continuous milking with sixty-day dry periods in successive lactations. *J. Dairy Sci.* 48:1205–1209.
- Van Soest, P. J., J. B. Robertson, and B. A. Lew. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.* 74:3583–3597.
- Vazquez-Anon, M., S. Bertics, M. Luck, and R. R. Grummer. 1994. Peripartum liver triglyceride and plasma metabolites in dairy cows. *J. Dairy Sci.* 77:1521–1528.
- Wildman, E. E., G. M. Jones, P. E. Wagner, R. L. Boman, H. F. Troutt, Jr., and T. N. Lesch. 1982. A dairy cow body condition scoring system and its relation to selected production characteristics. *J. Dairy Sci.* 65:495–501.
- Wilton, J. W., E. B. Burnside, and J. C. Rennie. 1967. The effects of days dry and days open on the milk and butterfat production of Holstein-Friesian cattle. *Can. J. Anim. Sci.* 47:85–90.