Effect of recombinant bovine somatotropin and a shortened or no dry period on the performance of lactating dairy cows

T. H. Klusmeyer,^{*1} A. C. Fitzgerald,^{*} A. C. Fabellar,^{*} J. M. Ballam,^{*} R. A. Cady,[†] and J. L. Vicini^{*}

^{*}Monsanto Company, LLC, St. Louis, MO 63167

[†]Elanco Animal Health, Greenfield, IN 46140

ABSTRACT

The objective of this study was to determine the effects of altering dry period length in multiparous dairy cows ($n = 341$) on milk production for a full lactation (294 d). The study used 3 commercial herds in the western United States. Cows producing greater than 8,400 kg of mature-equivalent milk were assigned to treatments 60 d before their due dates. The 4 treatments were 1) 60-d dry period, label use of recombinant bovine somatotropin (rbST; 60d-L); 2) 32-d dry period, label use of rbST (32d-L); 3) 0-d dry period, label use of rbST (0d-L); and 4) 0-d dry period, continuous use of rbST (0d-C). Cows with shortened dry periods produced 625, 1,000, and 1,042 kg of milk during the prepartum period for treatments 2 to 4, respectively. During the postpartum period, cows on the 32d-L treatment produced similar amounts of milk compared with the 60d-L treatment (11,490 vs. 11,968 kg, respectively). However, cows on the 0d-L (10,316 kg) and 0d-C (10,195 kg) treatments produced significantly lower amounts of milk during the postpartum period compared with the 60d-L treatment. Total milk production from the prepartum and postpartum periods was not altered significantly and was 11,974, 12,112, 11,310, and 11,230 kg for treatments 1 to 4, respectively. The concentrations of β -hydroxybutyrate and nonesterified fatty acids in serum after calving were decreased for cows on the 32d-L, 0d-L, and 0d-C treatments compared with cows on the 60d-L treatment, which may indicate improved metabolic status.

Key words: bovine somatotropin, milk production, shortened dry period

INTRODUCTION

Research from the previous century suggested that a 60-d dry period was optimal and that milk production decreased in the subsequent lactation when dry days

were <40 (Bachman and Schairer, 2003). Many studies were based on retrospective analyses of dairy records in which cows were not intended to have and not managed for a shortened dry period, and were not preplanned experiments (Annen et al., 2004a). In studies in which the dry period was omitted completely, there was as great as a 38% reduction in milk production in the subsequent lactation (Annen et al., 2004a; Bachman and Schairer, 2003). Cows in these preplanned experiments were low-producing and limited in numbers.

As a result of improved genetics and management of cows, milk production of today's cows at dry-off has increased dramatically. More recently, shortened dry periods have been attempted with higher producing cows. Milk production in the subsequent lactation was not different between high-producing cows given a 30-d or 60-d dry period (Bachman, 2002; Gulay et al., 2003). In contrast, milk production was decreased in the subsequent lactation for cows with a 28-d dry period compared with a 56-d dry period (Rastani et al., 2005).

The use of recombinant bovine somatotropin (rbST) in dairy cows in the United States and other countries increases milk yield at the time of dry-off and affects mammary cell numbers during lactation (Bauman and Vernon, 1993). Knight et al. (1990) reported that supplementing goats with rbST increased mammary parenchymal DNA relative to glands of nonsupplemented goats and Capuco et al. (2001) concluded that supplementing cows with rbST increased mammary cell proliferation without affecting apoptosis. The effect of a shortened or omitted dry period on milk production of high-producing cows administered rbST was investigated by Annen et al. (2004b) during the first 17 wk of the subsequent lactation. Primiparous cows with a 30-d or 0-d dry period significantly decreased milk production in the subsequent lactation compared with cows with a 60-d dry period (Annen et al., 2004b). In contrast, milk production during the same postpartum period was not affected by a shortened or omitted dry period for multiparous cows, which had a positive cumulative net marginal income. But, when adding prepartum milk, there was also no difference from the control and

Received May 18, 2009.

Accepted July 24, 2009.

¹Corresponding author: tim.h.klusmeyer@monsanto.com

the profile of cumulative marginal income was trending downward after peak milk yield. These data suggest that more data that include a longer postpartum period are needed.

The objective of this study was to replicate the study of Annen et al. (2004b) for multiparous cows and to extend these results to a full lactation. Additionally, blood and milk samples were taken in early lactation to examine some indices of postpartum cow health.

MATERIALS AND METHODS

Animals and Experimental Design

The study was conducted in 3 commercial herds in the United States. Herds were located in Idaho, Nebraska, and Kansas. All sites followed the same experimental design and the data were pooled from the 3 sites. The study consisted of 1) a 60-d pretreatment period, 2) the period between 60 d before due date and parturition (traditional dry period), and 3) a 294-d (42-wk) subsequent lactation period.

A total of 341 lactating multiparous Holstein cows were assigned to the study (Idaho = 122 cows, Nebraska = 61 cows, and Kansas = 158 cows). All cows were between 155 and 161 d carried calf (**DCC**) at the start of a 60-d pretreatment period. All cows were selected to meet the following criteria before assignment to the study: 1) lactation number of the first experimental lactation for the study was at least 2; 2) had 4 functional quarters; 3) BCS of 2.75 or greater during the last 14 d of the pretreatment period; 4) received rbST (Posilac; 500 mg sometribove zinc suspension; Monsanto Company, St. Louis, MO) in the first experimental lactation of the study; 5) had a minimum 305-d mature-equivalent milk yield of 8,400 kg for the first lactation of the study; 6) had a milk SCC that was less than 750,000 cells/mL during a test that occurred in the last 30 d of the pretreatment period; 7) had a mean milk production of at least 22.7 kg of milk/d from d 20 to 34 before treatment assignment; and 8) was in good general health.

Following the 60-d pretreatment period, cows were randomly assigned to 1 of 4 treatments: 1) 60-d dry period, label use of rbST (**60d-L**); 2) 32-d dry period, label use of rbST (**32d-L**); 3) 0-d dry period, label use of rbST (**0d-L**); and 4) 0-d dry period, continuous use of rbST (**0d-C**). Cows on the 60d-L and 32d-L treatments received their last rbST injection 27 to 14 d before dry-off. Cows on the 0d-L treatment discontinued rbST supplementation at calving. All cows, except those on the 0d-C treatment, resumed supplementation with rbST every 14 d beginning during wk 9 or 10 after calving and continued until the end of the second lacta-

tion, as stated on the product label. Cows on the 0d-C treatment continued rbST supplementation, without interruption, throughout the study.

Cows were dried off weekly. Intramammary antibiotics were used in an attempt not to confound milk yield results with potential infections that might occur during the dry period. Cows assigned to the 60d-L treatment were dried off at 215 to 221 DCC and were administered with a long-duration, intramammary cephalixin (ToMorrow, 300 mg per quarter, Fort Dodge Animal Health, Fort Dodge, IA). Four weeks later, cows assigned to the 32d-L treatment were dried off at 243 to 249 DCC and were administered with a short-duration, intramammary cephalixin (ToDay, 200 mg per quarter, Fort Dodge Animal Health). The intent of the study was that cows on the 0-d treatments would not be dried off; however, because it was not economically worth milking cows at low production and because dairy producers would not milk cows below a certain level of production, it was determined to dry off cows when milk yield was less than 11 kg/d when averaged over a 7-d period. In the event that 0-d cows were dried off, they were administered the short-duration cephalixin. Cows assigned to the 0-d treatments that were never dried off were not treated prophylactically with a mastitis therapy.

All cows were fed and housed with a lactation group until they were dried off. Cows assigned to the 60-d group were moved to the far-off dry cow group after dry-off. These cows were moved subsequently to the close-up group when they were approximately 250 DCC. At dry-off, all cows assigned to the 32d-L treatment were moved to the close-up dry cow group, except for cows in Kansas, which were moved to the far-off group for a 2-wk period before moving to the close-up group. Cows assigned to both of the 0-d treatments remained in the lactation group until calving, unless they were dried off. Cows dried off before 243 DCC were moved to the far-off dry group and moved to the close-up group after 250 DCC. Cows dried off on or after 243 DCC were moved to the close-up group. Following calving, all cows were moved to a lactation group. All diets were fed as a TMR and were fed ad libitum with free access to potable water.

Cows were milked 3 times per d and yield was recorded electronically at each milking. Milk samples from one milking were collected monthly and analyzed for fat, true protein, and SCC (Northwest Laboratories, Jerome, ID, and Heart of America DHIA, Manhattan, KS) using a Bentley Instruments 2000 and a Bentley Somacount 500 (Chaska, MN). Additional milk samples were collected during wk 2 (6–13 DIM) after calving to measure SCC. Milk samples were collected at the first milking after calving to measure IgG content. Con-

centrations of IgG in colostrum were determined by radioimmunoassay (New Mexico State University, Las Cruces, NM) according to the procedure of Richards et al. (1999) as modified by Duff et al. (2000). Two assays were completed with an average within-assay coefficient variation of 5.5% and a between-assay coefficient variation of 1%.

Blood samples were collected from the study cows during wk 1 and 2 after calving using evacuated serum tubes containing clot activator (SST; Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ). Immediately after sample collection, samples were centrifuged at $1,500 \times g$ at room temperature for 15 min. Serum was collected and stored at -20°C until analysis. Serum was analyzed for NEFA (NEFA C kit, Wako Chemicals USA, Inc., Richmond, VA), BHBA (Ranbut kit, Randox Laboratories Ltd., Oceanside, CA), and P and Ca by a Roche Hitachi 917 Chemistry Analyzer (University of Illinois Clinical Pathology Laboratory, Urbana, IL).

Statistical Analysis

Data were analyzed using the Proc Mixed procedure of SAS (version 9.1, SAS Institute, Cary, NC). Fixed effects included treatment, herd, and treatment by herd interaction. Data for total milk production and milk composition were reduced to a single measure per animal before analysis. Data for blood variables were separate measures for wk 1 and 2 per animal, with week modeled as a repeated factor in the analysis. For the analysis of milk production, the following covariates were included in the model: 1) 14-d milk production immediately before the traditional 60-d dry-off, 2) 14-d milk production immediately before the traditional 60-d dry-off by treatment interaction, and 3) DIM for the first experimental lactation before potential dry-off. Covariates were tested for a common slope and the unequal slope model was appropriate for the 14-d milk production covariate (Milliken and Johnson, 2002), which resulted in the additional covariate $\times$ treatment term.

Total milk production was broken down into prepartum and postpartum milk and was analyzed similarly to total milk production. For the analysis of milk composition, the 14-d pretreatment milk composition, expressed as a deviation from the herd means, was used as a covariate. No covariate was used for the analysis of actual days dry, blood metabolites, and IgG in colostrum. Each of the shortened dry period treatments was then compared with the 60d-L treatment group and differences were declared significant at $\alpha < 0.05$.

Two sets of analyses were performed for total milk production. The first, referred to as the full data set, included all cows that completed two-thirds of the subse-

quent lactation period (196 DIM). The second, referred to as the reduced data set, was similar to the first data set except that it included only cows that were dried off within ± 7 d of the target dry days. Target days dry, based on actual management of cows, were 60, 32, and 0 for 60d-L, 32d-L, and both 0-d treatment groups, respectively.

RESULTS AND DISCUSSION

Milk Yield

Full Data Set. A total of 282 cows assigned to the treatments completed two-thirds of the subsequent lactation period (Table 1) and were used in the statistical analysis for the full data set. The range for percentage of cows in each treatment that completed two-thirds of the 294-d lactation period was 80–85% and no pattern related to treatments was observed for removal. The major reasons for removal were mastitis, teat injury, leg and back injuries, lameness, low milk production, failure to follow protocol, and metabolic diseases.

Actual days dry could deviate from targeted days dry because of differences between actual calving date and the predicted calving date. As stated in Grummer and Rastani (2004), shortened dry periods are a more feasible management practice when breeding dates are more accurate. More important, the study was designed to predetermine the dry length of a cow and, if milk yield was reduced to a level in which a farm would likely stop milking her, then the cow was dried off earlier and the data for those cows were included. Because farms do not have the luxury of excluding cows that dry off early, this data set allows for estimating the commercial consequences of the dry-off decisions. The actual dry days for the cows on the 60d-L and 32d-L treatments averaged 61 and 36 d, respectively, and were near the targeted dry days (Table 1); however, the actual dry days for the cows on the 0d-L and 0d-C treatments averaged 9 and 8 d, respectively. Actual dry days had a wide range, which was from 0 to 65 d for these 2 continuous treatments.

A plot of average daily milk yields during the 60 d before calving, the traditional dry period, and 294 d of the subsequent lactation is presented in Figure 1. Additionally, least squares means for milk production during the approximately 60-d prepartum period, milk production during the approximately 294-d postpartum period, and total milk produced are presented in Table 2. As expected by design, cows with shorter dry periods produced more milk during the 60-d prepartum period than cows with the 60-d dry period. Cows with the 32-d dry period produced 619 kg more milk, which was significant ($P < 0.05$) when compared with the control.

Table 1. Summary of number of cows in study and average dry days for total cows, all cows that completed two-thirds of lactation (full data set), and cows that completed two-thirds of lactation and were within 7 d of targeted days dry (reduced data set)

Item	Treatment ¹				SEM
	60d-L	32d-L	0d-L	0d-C	
Cows assigned to treatment (n = 341)					
Cows in each treatment (n)	90	82	84	85	—
Cows in full data set (n = 282)					
Cows in each treatment (n)	76	66	71	69	—
Percent of all cows	84	80	85	81	
Days dry	61	36*	9*	8*	1.3
Cows in reduced data set (n = 217)					
Cows in each treatment (n)	58	52	53	54	—
Percent of full data set	76	79	75	78	
Days dry	61	33*	1*	1*	0.5

¹Treatments: 60d-L = 60-d dry period, label use of recombinant bovine somatotropin (rbST); 32d-L = 32-d dry period, label use of rbST; 0d-L = 0-d dry period, label use of rbST; 0d-C = 0-d dry period, continuous use of rbST.

*Means within a row differ ($P < 0.05$) from 60d-L treatment.

Cows in the 0-d dry groups were treated identically through calving and produced an average of 1,015 kg more milk ($P < 0.05$) than the control. Postpartum milk production was not altered for cows on the 32d-L treatment compared with the 60d-L treatment. In contrast, cows on the 0d-L and 0d-C treatment produced significantly less milk by more than 1,650 kg compared with cows on the 60d-L treatment ($P < 0.05$). Yet total milk yield, which includes the 60-d prepartum and the 294-d postpartum periods, was 11,974 kg/cow for the 60d-L group and 12,112, 11,310, and 11,230 kg/cow for the 32d-L, 0d-L, and 0d-C groups, respectively. Total milk production for cows in each of the shortened dry period groups was not altered significantly compared with the controls, even though total milk produced by the cows on the 0d-L and 0d-C treatments was numerically lower by more than 660 kg. To avoid a type II error, one needs to exercise caution when making decisions based on no difference between 2 treatment groups. A more conservative standard to declare no difference would be to increase the α -level. The 0d-L and 0d-C treatments had less total milk compared with the 60-d standard at $P < 0.103$ and $P < 0.081$, respectively. In contrast, the cows with the 32-d dry period had similar total milk ($P > 0.15$).

Others reported that shortening the dry period (30–35 d) of multiparous cows (Annen et al., 2004b; Pezeshki et al., 2007) or a combination of primiparous and multiparous cows (Bachman, 2002; Gulay et al., 2003) did not affect milk production in the subsequent lactation compared with cows with a traditional dry period (56–60 d). Rastani et al. (2005) reported that shortening the dry period (28 d) for a combination of primiparous and multiparous cows decreased milk production in the subsequent lactation compared with

cows with a dry period of 56 d. Annen et al. (2004b) reported that multiparous cows with a 0-d dry period produced a similar amount of milk in the subsequent lactation (17 wk) compared with cows with the 60-d dry period; this is different from our study, which lasted 294 d. Annen et al. (2004b) also reported that primiparous cows with a 0-d dry period produced significantly less milk in the subsequent lactation compared with cows with the 60-d dry period. Because of that substantial difference, primiparous cows were not included in this follow-up study. Andersen et al. (2005) and Rastani et al. (2005) reported that a combination of primiparous and multiparous cows with a 0-d dry period significantly decreased milk production in the subsequent lactation compared with the control. In this study, multiparous cows on the 32d-L treatment had a sufficient dry period to maximize milk production in the subsequent lactation; however, cows on the 0d-L and 0d-C treatments produced lower amounts of milk in the subsequent lactation. This suggested that a dry period was needed to allow redevelopment of the mammary gland in late gestation. The additional milk produced by the cows on the 32d-L, 0d-L, and 0d-C treatments during the prepartum period resulted in a similar amount of total milk produced for all the treatments and would be beneficial to dairy producers.

Cows in the full data set, on average, produced milk with 4.20% fat, 3.69% true protein, and 3.95 SCC linear score during the prepartum period. Because there was no milk from cows in the 60d-L group, there is no comparison to the 60-d standard dry period. During the postpartum period, the composition of milk fat was not altered significantly by treatments (Table 3). Cows on the 0d-L and 0d-C treatments produced milk with a higher content of true protein during the entire post-

Table 2. Least squares means for milk production of cows given different dry period lengths

Item	Treatment ¹				SEM
	60d-L	32d-L	0d-L	0d-C	
Full data set					
Prepartum milk (kg)	6 ²	625*	1,000*	1,042*	48.6
Postpartum milk (kg)	11,968	11,490	10,316*	10,195*	298.5
Total milk (kg)	11,974	12,112	11,310†	11,230†	297.5
Reduced data set					
Prepartum milk (kg)	7 ²	678*	1,244*	1,185*	46.4
Postpartum milk (kg)	11,754	11,469	9,859*	10,108*	362.9
Total milk (kg)	11,759	12,144	11,095	11,273	363.9

¹Treatments: 60d-L = 60-d dry period, label use of recombinant bovine somatotropin (rbST); 32d-L = 32-d dry period, label use of rbST; 0d-L = 0-d dry period, label use of rbST; 0d-C = 0-d dry period, continuous use of rbST.

²Although no milk is produced by cows in the 60d-L treatment during this period, the value is not equal to zero because of being a least squares mean derived from an unbalanced design.

*Means within a row differ ($P < 0.05$) from 60d-L treatment.

†Means within a row differ ($P < 0.15$) from 60d-L treatment.

partum period compared with the 60-L cows, whereas cows on the 32d-L group had similar true protein content compared with cows on the 60d-L treatment. The SCC of milk produced during the postpartum period was altered significantly by treatments. Cows on the 32d-L treatment had a lower SCC compared with the 60d-L treatment and cows on the 0d-C treatment had a higher SCC compared with the 60d-L treatment.

Similar to this study, others (Gulay et al., 2003; Annen et al., 2004b; Rastani et al., 2005; Pezeshki et al., 2007) have reported that shortening the dry period (28–35 d) did not change the content of fat and CP in milk produced in the subsequent lactation compared with the control. Omitting the dry period did not alter fat content of postpartum milk compared with the control cows (Annen et al., 2004b; Andersen et al., 2005;

Figure 1. Average milk production from 60 d before expected calving until 294 d postpartum for cows that had 60-d dry period, label use of recombinant bovine somatotropin (rbST; 60d-L); 32-d dry period, label use of rbST (32d-L); 0-d dry period, label use of rbST (0d-L); or 0-d dry period, continuous use of rbST (0d-C).

Table 3. Least squares means for composition of prepartum and postpartum milk produced by cows given different dry period lengths

Item	Treatment ¹				SEM
	60d-L	32d-L	0d-L	0d-C	
Full data set					
Prepartum ²					
Fat (%)	—	4.06	4.27	4.26	0.144
True protein (%)	—	3.56	3.85	3.65	0.141
SCC (linear score)	—	3.81	3.96	4.09	0.200
Postpartum					
Fat (%)	3.59	3.57	3.70	3.59	0.081
True protein (%)	3.00	3.02	3.15*	3.11*	0.030
SCC (linear score)	2.68	2.02*	2.90	3.37*	0.205
Reduced data set					
Prepartum ²					
Fat (%)	—	4.29	4.19	4.54	0.187
True protein (%)	—	3.67	3.69	3.87	0.203
SCC (linear score)	—	3.84	3.72	4.05	0.273
Postpartum					
Fat (%)	3.54	3.62	3.71	3.58	0.101
True protein (%)	3.00	3.04	3.21*	3.11*	0.035
SCC (linear score)	2.64	2.02*	2.89	3.44*	0.239

¹Treatments: 60d-L = 60-d dry period, label use of recombinant bovine somatotropin (rbST); 32d-L = 32-d dry period, label use of rbST; 0d-L = 0-d dry period, label use of rbST; 0d-C = 0-d dry period, continuous use of rbST.

²Milk samples are not available for cows assigned to the 60d-L group during the prepartum period; however, there were no differences ($P > 0.10$) among any of the remaining 3 treatments.

*Means within a row differ ($P < 0.05$) from 60d-L treatment.

Rastani et al., 2005). When postpartum milk production was decreased by omitting the dry period, CP content of postpartum milk was increased compared with the control for a combination of primiparous and multiparous cows (Andersen et al., 2005; Rastani et al., 2005) or primiparous cows (Annen et al., 2004b). However, omitting the dry period did not alter CP content of postpartum milk compared with the control when multiparous cows produced similar amount of milk postpartum (Annen et al., 2004b).

Others (Gulay et al., 2003; Annen et al., 2004b; Andersen et al., 2005; Rastani et al., 2005; Pezeshki et al., 2007) have reported that shortening or omitting the dry period did not change the SCC in milk produced in the subsequent lactation compared with the control. In this study, cows on the 32d-L treatment decreased SCC in postpartum milk, suggesting an improvement in mammary health status. However, SCC results for the 0-d treatments were not consistent. Cows on the 0d-C treatment increased SCC in postpartum milk compared with the control, but cows on the 0d-L treatment were managed similarly and SCC was similar to the control cows.

As described in the Statistical Analysis section, several covariates were evaluated to understand factors that have a potential effect on total milk yield responses to altered dry periods. Factors examined were the level of milk production immediately before the traditional

60-d dry-off (74–61 d before due date), the level of milk for the lactation before potential dry-off (305 mature-equivalent for the first experimental lactation), the length of lactation before potential dry-off (DIM for the first experimental lactation), and the SCC in the last 2 mo before traditional 60-d dry-off. Level of milk for the previous lactation and SCC did not affect responses to shortened dry period. The length of the previous lactation had a significant effect on the milk yield responses, and the effect was consistent across the 4 treatments. The level of milk production in the 14 d before the traditional 60-d dry-off had a significant influence ($P < 0.0001$), but only on cows with a 32-d dry period. When regressing total milk produced (prepartum + postpartum milk) against milk production in the 2 wk before making a dry-off decision, the slopes of the response curve for cows with 60-d or 0-d dry periods were not different from zero (Figure 2). In contrast, when correlating total milk yield against pretreatment milk, cows with 32-d dry periods had a significantly positive slope, suggesting that selecting high-producing cows at the time of dry-off and extending their lactation another 4 wk resulted in substantially more total milk. It is reasonable to conclude that, on average, higher producing cows are more likely to not spontaneously dry off in the next 28-d period and that they would produce more milk in the 28 d before dry-off. Contrary to speculation of others (Dias and Allaire, 1982), these higher produc-

Figure 2. Total milk yield (60 d prepartum + 294 d postpartum) by pretreatment milk yield for cows that had 60-d dry period, label use of recombinant bovine somatotropin (rbST; 60d-L); 32-d dry period, label use of rbST (32d-L); 0-d dry period, label use of rbST (0d-L); or 0-d dry period, continuous use of rbST (0d-C). Data points for each treatment group are predicted mean total milk at 5 levels of pretreatment milk: 17.2, 28.6, 33.5, 37.6, and 51.7 kg/d, representing the minimum, 25th percentile, median, 75th percentile, and maximum pretreatment milk values in the data set, respectively. Probabilities that lines deviate from zero were $P > 0.15$, $P < 0.0001$, $P > 0.15$, and $P > 0.15$, respectively.

ing cows were not adversely affected by the shorter dry period. Cows producing greater than 33.5 kg of milk at the time of a 60-d dry-off produced more total milk when dried off for a 32-d dry period than the average production of cows with a 60-d dry period.

Reduced Data Set. The reduced data set represented cows that dried off within 7 d of the targeted dry period. This was done in order to understand the biology of cows with specific dry period lengths. As an example, this data set removes the effect of a cow that was assigned to a 0d-L treatment and actually had 65 d dry that would make her more biologically similar to cows in the 60d-L group. Of these cows, 217 completed two-thirds of the subsequent lactation period, were dried off within ± 7 d of the target dry days, and were used in the statistical analysis for the reduced data set, which was 75 to 79% of the cows in the full data set (Table 1). Clearly, when using the 7-d criteria, 25% of cows deviated from their targeted lengths of dry period but yields and differences from the 60d-L group of milk during the prepartum and postpartum periods were remarkably similar regardless of which data set was used (Table 2). Likewise, milk composition was similar for cows in both the reduced and full data sets (Table 3).

Health

Grummer and Rastani (2004) reviewed reasons to reconsider the dry period and suggested that nonmilk

factors, such as the potential to simplify grouping of cows or promoting a less negative energy balance and its associated effect on postpartum health, would increase productivity. Milk and blood were sampled in early lactation as indices of health. As observed for milk yield, analyses of the reduced and full data sets resulted in similar conclusions regarding health. Results from both analyses for health variables are presented in Table 4, but only results for the full data set will be discussed in the text. Milk fat, protein, and SCC were tested during d 6 to 13 of lactation to determine whether there were acute effects of shortened or eliminated dry periods on mammary performance, and there were no effects ($P > 0.05$). This is especially surprising when comparing cows that were dry for 60 d compared with cows that had essentially continuous milk production. In contrast, colostrum collected from the first milking was similar between cows with 60- and 32-d dry periods, yet cows with 0-d dry periods had significantly less IgG. In this study, colostrum production was reported by milkers in some of the cows in late gestation on the 0d-L and 0d-C treatments and is in agreement with Annen et al. (2004b). This may have decreased the concentration of IgG in colostrum of cows with no dry period. Conceivably, total IgG production could be similar, or even greater, but secreted over more days or milkings. Therefore, identifying when to collect colostrum, to ensure that high-quality colostrum is available to feed

Table 4. Least squares means for nutrient composition of milk (6–13 DIM), IgG in colostrum (1st milking), and metabolites in serum (wk 1 and 2) of cows given different dry period lengths

Item	Treatment ¹				SEM
	60d-L	32d-L	0d-L	0d-C	
Full data set					
Milk fat (%)	5.38	5.23	4.95	4.92	0.234
Milk true protein (%)	3.44	3.65	3.59	3.53	0.080
SCC (linear score)	3.89	3.32	4.21	4.28	0.272
Colostrum IgG ² (mg/mL)	13.07	12.39	9.80*	7.40*	1.093
Serum BHBA (mmol/L)	0.764	0.643*	0.537*	0.613*	0.034
Serum NEFA ² (mEq/L)	0.550	0.373*	0.367*	0.357*	1.065
Serum Ca (mg/dL)	9.28	9.56	9.43	9.54	0.119
Serum P (mg/dL)	5.39	5.98*	5.80*	5.93*	0.117
Reduced data set					
Milk fat (%)	5.28	4.93	4.61	4.77	0.303
Milk true protein (%)	3.42	3.63	3.59	3.57	0.035
SCC (linear score)	3.94	3.16	4.60	4.29	0.333
Colostrum IgG ² (mg/mL)	13.17	12.38	8.55*	6.71*	1.111
Serum BHBA (mmol/L)	0.776	0.569*	0.473*	0.544*	0.033
Serum NEFA ² (mEq/L)	0.550	0.332*	0.335*	0.299*	1.075
Serum Ca (mg/dL)	9.22	9.60*	9.46	9.64*	0.149
Serum P (mg/dL)	5.40	5.99*	5.91*	6.05*	0.138

¹Treatments: 60d-L = 60-d dry period, label use of recombinant bovine somatotropin (rbST); 32d-L = 32-d dry period, label use of rbST; 0d-L = 0-d dry period, label use of rbST; 0d-C = 0-d dry period, continuous use of rbST.

²Analyzed as transformed natural means, and SEM values presented are back transformed.

*Means within a row differ ($P < 0.05$) from 60d-L treatment.

newborn calves, would be an important consideration for implementing continuous lactation and is not an issue for cows with a 32-d dry period.

The concentrations of BHBA and NEFA in serum after calving were decreased and the concentrations of Ca and P in serum after calving were increased for cows on the 32d-L, 0d-L, and 0d-C treatments compared with cows on the 60d-L treatment (Table 4). These data suggest that shortening or omitting the dry period resulted in cows with an improved metabolic status postpartum. Similar effects were reported in other studies. Omitting the dry period, decreased serum NEFA (Rastani et al., 2005; Andresen et al., 2007) and decreased serum BHBA (Andersen et al., 2007) postpartum compared with the control and was possibly caused by cows being in a more positive energy balance. Improved health in early lactation could be the result of a more simplified dietary management that reduces negative energy balance, which occurred in the study of Gümen et al. (2005), who also reported improved reproductive measurements. However, shortening the dry period did not affect the concentration of NEFA in cows compared with the control when milk production was not altered postpartum (Andersen et al., 2007; Pezeshki et al., 2007).

CONCLUSIONS

Multiparous cows with a 32-d dry period produced more milk in the prepartum period and produced simi-

lar amounts of postpartum and total milk compared with the 60d-L treatment. This response occurred for both the full and reduced data sets. Cows in the 32d-L treatment had lower SCC, lower serum NEFA and BHBA, and similar IgG in colostrum. Omitting the dry period resulted in similar total milk production compared with the 60d-L treatment; however, milk production was decreased significantly in the subsequent lactation for cows with no dry period. These results are from only cows treated with rbST but appear to be generally consistent with other studies in which rbST was not used.

ACKNOWLEDGMENTS

The authors thank D. M. Hallford, New Mexico State University, for analyzing colostrum samples. The authors also thank Chad Johnson (Cimarron Dairy, Cimarron, KS), Brandon Whitesides (Whitesides Dairy, Rupert, ID), and Richard C. James (Prairieland Dairy, Firth, NE) for assisting with data collection.

REFERENCES

- Andersen, J. B., T. G. Madsen, T. Larsen, K. L. Ingvarsen, and M. O. Nielsen. 2005. The effects of dry period versus continuous lactation on metabolic status and performance in periparturient cows. *J. Dairy Sci.* 88:3530–3541.
- Annen, E. L., R. J. Collier, M. A. McGuire, and J. L. Vicini. 2004a. Effects of dry period length on milk yield and mammary epithelial cells. *J. Dairy Sci.* 87(E Suppl.):E66–E76.

- Annen, E. L., R. J. Collier, M. A. McGuire, J. L. Vicini, J. M. Ballam, and M. J. Lormore. 2004b. Effect of modified dry period lengths and bovine somatotropin on yield and composition of milk from dairy cows. *J. Dairy Sci.* 87:3746–3761.
- 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.
- Bachman, K. C., and M. L. Schairer. 2003. Invited review: Bovine studies on optimal lengths of dry periods. *J. Dairy Sci.* 86:3027–3037.
- Bauman, D. E., and R. G. Vernon. 1993. Effects of exogenous bovine somatotropin on lactation. *Annu. Rev. Nutr.* 13:437–461.
- Capuco, A. V., D. L. Wood, R. Baldwin, K. Mcleod, and M. J. Paape. 2001. Mammary cell number, proliferation, and apoptosis during a bovine lactation: Relation to milk production and effect of bST. *J. Dairy Sci.* 84:2177–2187.
- Dias, F. M., and F. R. Allaire. 1982. Dry period to maximize milk production over two consecutive lactations. *J. Dairy Sci.* 65:136–145.
- Duff, G. C., D. A. Walker, K. J. Malcolm-Callis, M. W. Wiseman, and D. M. Hallford. 2000. Effects of pre-shipment vs. arrival medication with tilmicosin phosphate and feed chlortetracycline on health and performance of newly received beef cattle. *J. Anim. Sci.* 78:267–274.
- Grummer, R. R., and R. R. Rastani. 2004. Why reevaluate dry period length? *J. Dairy Sci.* 87(E Suppl.):E77–E85.
- Gulay, M. S., M. J. Hayen, K. C. Backman, 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.
- Gümen, A., R. R. Rastani, R. R. Grummer, and M. C. Wiltbank. 2005. Reduced dry periods and varying prepartum diets alter postpartum ovulation and reproductive measures. *J. Dairy Sci.* 88:2401–2411.
- Knight, C. H., P. A. Fowler, and C. J. Wilde. 1990. Galactopoietic and mammogenic effects of long-term treatment with bovine growth hormone and thrice daily milking in goats. *J. Endocrinol.* 127:129–138.
- Milliken, G. A., and D. E. Johnson. 2002. Two treatments in a randomized block design structure. Pages 203–232 in *Analysis of Messy Data. Volume III. Analysis of Covariance*. Chapman and Hall/CRC, Boca Raton, FL.
- Pezeshki, A., J. Mehrzad, G. R. Ghorbani, H. R. Rahmani, R. J. Collier, and C. Burvenich. 2007. Effects of short dry days on performance and metabolic status in Holstein dairy cows. *J. Dairy Sci.* 90:5531–5541.
- Rastani, R. R., R. R. Grummer, S. J. Bertics, A. Gümen, M. C. Wiltbank, D. G. Mashek, and M. C. Schwab. 2005. Reducing dry period length to simplify feeding transition cows: Milk production, energy balance, and metabolic profiles. *J. Dairy Sci.* 88:1004–1014.
- Richards, J. B., D. M. Hallford, and G. C. Duff. 1999. Serum luteinizing hormone, testosterone and thyroxine and growth responses of ram lambs fed locoweed (*Oxytropis sericea*) and treated with vitamin E/selenium. *Theriogenology* 52:1055–1066.