Comparison of shortened and conventional dry period management strategies

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ABSTRACT

The aim of this study was to compare 2 dry-cow management strategies and evaluate the effect of shortened dry period strategy on feed intake, metabolism, and postpartum performance of dairy cows in early lactation. Twenty-nine high-yielding dairy cows were divided into 2 groups. The control (CON) group ($n = 14$) was assigned to a traditional dry period of approximately 60 d (57 ± 5.9 d) and was fed a far-off dry cow ration from dry-off to -21 d relative to expected parturition. From d -21 relative to expected parturition, the cows were switched to a precalving ration containing an additional 3 kg of concentrates. The cows of the experimental group ($n = 15$) were assigned to a shortened dry period (SDP; 35 ± 6.3 d) and were continuously fed a late-lactation diet from d -60 d relative to expected parturition until calving. After calving, both groups were fed the same lactation diet corresponding to their lactation requirements and cows were followed for 100 d of lactation. Prepartum dry matter intake of the cows assigned to an SDP and fed a late-lactation diet was approximately 4.11 kg/cow per day greater compared with the CON group during the 60 d. However, no effect of dry period strategy on postpartum dry matter intake was detected. The cows with an SDP produced approximately 2.78 kg/d (6.9%) less milk in the first 100 d of lactation than CON cows; the difference was not statistically significant. No differences were observed in live body weight, body condition score, or back-fat thickness between the treatments. Similarly, no differences existed in concentrations of plasma metabolites. The cows of the SDP group showed lower pH and increased concentrations of lactic acid and volatile fatty acids prepartum than the CON cows. Postpartum concentrations of lactic acid, volatile fatty acids, and NH_3 and pH in rumen fluid did not differ between the treatments. Shortening of the dry period did not affect the colostrum quality or birth

weights of the calves. Based on the results of this study, a traditional dry period management strategy appeared to be more favorable, considering the dry matter intake and milk production, compared with an SDP and feeding a late-lactation diet throughout the dry period.

Key words: nutrition, transition period, milk production, metabolic status

INTRODUCTION

Intensive genetic selection for productivity has resulted in a dramatic increase in milk production in modern high-yielding dairy cows. However, as milk production per cow has increased, transitioning cows from the nonlactating state to peak milk yield has grown more problematic. In general, high milk energy output in early lactation has not been matched with appropriate energy intake. The transition period is the most difficult period in the dairy cow life cycle and is accompanied by decreased DMI, whereas milk production increases in early lactation (Bertics et al., 1992; Hayirli et al., 2002). An energy deficit results in a negative energy balance (NEB) and loss of BW, body condition, and body fat reserves. Severe NEB negatively affects immune and reproductive functions, resulting in an increased culling rate. Therefore, it is appropriate to evaluate alternative management and feeding strategies for the dry and transition periods to reduce the magnitude of the NEB.

Traditionally, cows are dried off approximately 60 d before expected calving. They are fed a far-off dry cow ration based on roughage from dry-off to 21 d prepartum and are then switched to a close-up diet enriched by the addition of concentrate mixture (Hutjens, 1996; Degaris et al., 2008). The gradual addition of concentrates in the last 3 wk of pregnancy allows rumen bacteria to adapt to a lactation diet rich in concentrates to facilitate high milk production in early lactation. The NRC (2001) suggests that the required energy concentrations in the diet of dried-off cows are 4.061 MJ/kg of DM at 240 d of pregnancy, 4.396 MJ/kg of DM at 270 d of pregnancy, and 6.029 MJ/kg of DM at 279 d of pregnancy, and the required dietary MP concentrations

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are 6.0% at 240 d of pregnancy, 6.6% at 270 d of pregnancy, and 8.0% at 279 d of pregnancy. To transition a cow during the last weeks of gestation to acclimate her to a lactating ration, NRC (2001) recommends a standard close-up diet with an energy concentration of approximately 6.741 MJ/kg and a dietary MP concentration of 8.5%.

A dry period of 40 to 60 d facilitates the proliferation of mammary cells to maximize milk, fat, and protein yields in the next lactation (Capuco et al., 1997; Kuhn et al., 2005; Sawa et al., 2012). However, recent research has indicated that shortening or even omitting the dry period seems to shift milk production from the critical period shortly after calving to the weeks before calving, when the energy demands of the mammary glands for milk production can be easily matched by feed intake (Weber et al., 2013; Wiedemann et al., 2013). Moreover, short-dry-period management requires less abrupt changes in diet composition and may result in a more sustained level of feed intake, which is beneficial for the energy status (Rastani et al., 2005; Mantovani et al., 2010b) and may increase milk and milk component yields and improve the health and fertility of dairy cows during early lactation (Klusmeyer et al., 2009; O'Driscoll et al., 2012; McArt et al., 2013). In contrast, the potential risks of a reduced dry period include reduction in milk yield in subsequent lactation (Sørensen and Enevoldsen, 1991; Annen et al., 2004; Rastani et al., 2005), impaired udder health (e.g., higher milk SCC and increased mastitis incidence; Enevoldsen and Sørensen, 1992; Kuhn et al., 2006; Whist et al., 2006), and reduced colostrum quality, potentially affecting calf health (Annen et al., 2004; Rastani et al., 2005; Klusmeyer et al., 2009).

The present study compares traditional (60-d) and shortened (35-d) dry period (**SDP**) management strategies to evaluate their effects on DMI, milk production, body condition, metabolic status, colostrum quality, and birth weight (**BiW**) of the calves. The hypothesis was that shortening the dry period combined with feeding a late-lactation diet would be more beneficial, considering the DMI, milk production and other parameters, compared with the conventional dry period of 60 d and feeding a far-off and close-up dry-cow diet.

MATERIALS AND METHODS

Experimental Design, Animals, and Diets

The experiment included 29 high-yielding dairy cows, which were divided into 2 groups according to breed, parity, milk yield in the previous lactation, and live BW. There were 14 cows (12 Holstein-Friesian and 2 Czech Fleckvieh) in the control (**CON**) group and 15

cows (13 Holstein-Friesian and 2 Czech Fleckvieh) in the experimental group (**SDP**). Mean milk yield in the previous lactation (mean = 299 d) was 9,088 kg (SD = 2,061 kg) for the CON group and 8,801 kg (SD = 2,189 kg) for the SDP group. There were 7 primiparous and 7 multiparous (parities 1–3) cows in the CON group and 8 primiparous and 7 multiparous (parities 1–4) cows in the SDP group. Mean BW was 618 kg (SD = 76 kg) for the CON group and 596 kg (SD = 69 kg) for the SDP group.

Cows were housed in a freestall stable with beds littered with straw, and they were followed from –60 d precalving to d 100 of lactation. The diets were based on maize silage, lucerne silage, lucerne hay, ensiled crushed maize cobs with bracts, fresh brewer grains, and concentrate mixture. The ingredient composition of the diets is reported in Table 1. Table 2 shows the composition of the concentrate mixtures included in the diets. The diets were formulated according to NRC (2001) guidelines and fed in the form of TMR *ad libitum*. The CON group, assigned to the conventional dry period of 57 d (SD = 5.9 d), was fed a far-off dry cow ration (**TMRD**) from dry-off to 21 d prepartum. Approximately 21 d before planned calving, the concentrate mixture (3 kg/d) was added to their diet. The SDP group, assigned to an SDP of 35 d (SD = 6.3 d), was continuously fed a late-lactation diet (**TMR2**) from d –60 to calving. After calving, all cows in both groups were fed TMR2 first 7 d postpartum and the early-lactation diet from d 8 to 100 of lactation, corresponding to their lactation requirements.

Measurements, Sampling Procedures, Analytical Methods, Calculations, and Estimates

Cows were equipped with electronic identification chips to allow automatic measurement of their feed intake. Intake was recorded electronically by software using the automatic feeding system of Insentec BV (Marknesse, the Netherlands) with troughs on tensometric scales. Once per month, samples of feed (both TMR and ingredients) were taken. Dry matter content was determined by drying samples of feed at $102 \pm 3^\circ\text{C}$ to a constant weight immediately after their collection. The standard AOAC International (2005) procedures were used to determine the content of CP, crude fat, starch, and ash in the feed. Crude protein content ($6.25 \times \text{N}$) was determined using a Kjeltec 1030 Auto Analyzer (Foss Tecator AB, Höganäs, Sweden), and crude fat content was determined with a Soxtec 1043 extraction system (FOSS Tecator AB). Mineral element (i.e., Ca, K, Mg, and Na) concentrations were determined by atomic absorption spectrometry (Solaar M-6; TJA Solutions Ltd., Northampton, UK), and the

Table 1. Ingredients of diets (g/kg of DM, unless otherwise specified) for cows with conventional (control, CON) and shortened dry periods (SDP)

Component	Diet ¹			
	TMR1	TMR2	TMRD	TMRDC
Ingredient				
Maize silage	521	385	435	431
Lucerne silage	521	446	399	395
Ensiled crushed maize cobs with bracts	223	182	0	0
Legume-cereal silage	0	425	762	754
Lucerne hay	37	24	145	144
Brewers grain	298	243	0	0
Wheat straw	30	0	36	36
Energie MG ²	37	20	0	0
DO1 ³	342	0	0	215
DO2 ³	0	284	0	0
Premin EX28 ⁴	0	0	15	14
Premin Porod ⁵	0	0	0	22
Chemical analysis				
DM (g/kg)	497.66	466.42	430.75	475.10
CP	176.96	170.99	140.17	164.16
Crude fat	46.14	31.43	18.39	30.78
Crude fiber	179.78	192.81	291.40	243.66
Starch	184.91	175.02	51.62	99.35
PDIA ⁶	64.81	58.06	44.57	57.14
PDIE ⁷	105.00	98.91	78.69	93.64
PDIN ⁸	115.06	108.50	83.36	103.24
NE _L (MJ/kg of DM)	6.66	6.33	5.49	5.94
ADF	230.63	247.80	354.05	300.86
NDF	371.91	394.54	486.87	432.76
Ash	82.48	79.83	86.43	90.95
Ca	11.46	12.23	12.62	13.66
P	4.12	4.39	2.65	3.80
Na	3.14	3.35	1.56	2.66
K	14.08	15.03	15.95	14.94
Mg	3.53	3.77	2.81	3.38

¹TMR1 = early-lactation diet fed from d 8 to 100 postpartum for both CON and SDP groups; TMR2 = late-lactation diet fed from d -60 relative to expected calving until calving (d 0) for the SDP group, and from d 1 to 7 postpartum in both CON and SDP groups; TMRD = far-off dry cow diet fed from d -60 to -21 relative to expected parturition for the CON group; TMRDC = precalving diet fed from d -21 relative to expected parturition until calving (d 0) for the CON group.

²Commodity Trading s.r.o. (Olomouc, Czech Republic); contained 50% glycerol and 50% molasses.

³DO1 = concentrate mixture in the feed ration TMR1 and TMRDC; DO2 = concentrate mixture in the feed ration TMR2.

⁴VVS Verměřovice, s.r.o., (Verměřovice, Czech Republic); contained per 1 kg: 10 g of Ca, 100 g of P, 50 g of Mg, 60 g of Na, 1,300 mg of Cu, 6,000 mg of Zn, 9,000 mg of Mn, 40 mg of Co, 100 mg of I, 35 mg of Se, 900,000 IU of vitamin A, 120,000 IU of vitamin D₃, and 3,000 mg of vitamin E.

⁵VVS Verměřovice s.r.o.; contained per 1 kg: 100 g of Ca, 20 g of P, 25 g of Mg, 25 g of Na, 500 mg of Cu, 2,500 mg of Zn, 2,000 mg of Mn, 10 mg of Co, 60 mg of I, 10 mg of Se, 200,000 IU of vitamin A, 41,000 IU of vitamin D₃, and 1,000 mg of vitamin E.

⁶Ruminally undegraded feed protein digested in the small intestine.

⁷Metabolizable protein supply.

⁸Ruminally degradable nitrogen.

P concentration was determined photometrically [Spekol 11 spectrophotometer (Analytik Jena AG, Jena, Germany); ISO, 2005].

Cows were milked twice daily, once between 0430 and 0515 h and once between 1630 and 1715 h, through a 10-point side open (tandem) parlor. Calved cows were followed for 100 DIM. Milk yield was recorded automatically at each milking for each animal and mean daily milk yield was calculated. In addition, the data

from the milk control records were obtained to analyze milk yields for standardized lactation (305 d). Blended milk samples from 2 consecutive collections (a.m. and p.m.) were taken from each cow with intervals of 14 d through first 100 DIM and were pooled for determination of fat, protein, lactose, and urea. In addition, blended milk samples from SDP cows were taken at d -60 and -40 before planned calving. The milk was preserved with 2-bromo-2-nitropropane-1,3-diol and cooled

Table 2. Composition of concentrate mixtures

Ingredient (g/kg of DM)	DO1 ¹	DO2 ²
Wheat	215	265
Barley	0	210
Rapeseed meal	145	200
Soybean meal	170	145
Triticale	180	0
Pea meal	0	100
Lupine seed	85	0
Premin DO1 ³	80	0
Premin DO2 ⁴	0	60
Soda bicarbonate	0	20
Aminoplus ⁵	80	0
C16 Lodestar ⁶	45	0

¹Concentrate mixture in the early-lactation diet fed from d 8 to 100 postpartum (TMR1) and in the precalving diet fed from d -21 relative to expected parturition until calving (d 0) for the control (CON) group (TMRDC).

²Concentrate mixture in the late-lactation diet fed from d -60 relative to expected calving until calving (d 0) for the shortened dry period (SDP) group, and from d 1 to 7 postpartum in both CON and SDP groups (TMR2).

³VVS Verměřovice s.r.o. (Verměřovice, Czech Republic); contained per 1 kg: 127 g of CP, 133 g of Ca, 33 g of P, 40 g of Mg, 52 g of Na, 630 mg of Cu, 3,160 mg of Zn, 4,860 mg of Mn, 21 mg of Co, 53 mg of I, 18 mg of Se, 403,000 IU of vitamin A, 73,500 IU of vitamin D₃, 1,200 mg of vitamin E, and 4,700 mg of niacinamide.

⁴VVS Verměřovice; contained per 1 kg: 175 g of Ca, 31 g of P, 43 g of Mg, 91 g of Na, 1,000 mg of Cu, 5,300 mg of Zn, 4,860 mg of Mn, 20 mg of Co, 47 mg of I, 27 mg of Se, 667,000 IU of vitamin A, 86,500 IU of vitamin D₃, and 1,440 mg of vitamin E.

⁵Ag Processing Inc. (Omaha, NE); rumen-undegradable protein.

⁶Berg + Schmidt Malaysia Sdn. Bhd. (Selangor Darul Ehsan, Malaysia); rumen-protected fat.

to 4 to 6 °C until analysis. Milk components were analyzed in a commercial laboratory using a MilkoScan FT 2 instrument (Foss Electric A/S, Hillerød, Denmark). Milk urea concentration was determined enzymatically using the Urea/Ammonia Assay Kit (Megazyme International Ireland, Bray, Co. Wicklow, Ireland). Somatic cell count data were obtained from milk production control records. Somatic cell count was transformed to linear score (LS) using the following formula: $LS = \log_e(SCC)/0.6931 - 3.6439$, where SCC is the SCC in thousands per milliliter (Schukken et al., 2009). Fat-corrected milk (containing 4% fat) yield was calculated as follows: $FCM (kg/d) = \text{milk yield (kg)} \times [0.4 + 0.15 \times \text{fat (\%)}]$. Energy-corrected milk (containing 4% fat and 3.4% protein) yield was calculated as follows: $ECM (kg/d) = \text{milk yield (kg)} \times [0.25 + 0.122 \times \text{fat (\%)} + 0.077 \times \text{protein (\%)}]$. The relative changes in milk fat, milk protein, lactose, and urea concentrations in the first 100 DIM were calculated as the average per group (SDP or CON) at selected sampling days (i.e., 14, 28, 42, 56, 70, 84, and 98 d postpartum). The BW was measured automatically at each milking. Dried-off cows were weighed every 14 d. The BCS was evaluated

every 14 d from d -60 before calving until the end of the experiment (100 DIM) by the same assessor, using a scale from 1 to 5 with 0.25-point increments (Edmonson et al., 1989). Along with the evaluation of BCS, back-fat thickness (**BFT**) was measured in the pelvic area dorsal to the hip joint (Schröder and Staufenbiel, 2006), using the ultrasound apparatus SonoVet 2000 (Samsung Medison Co. Ltd., Seoul, South Korea), with a linear probe (L2-5/170CD) at 5.5 MHz.

Blood samples were obtained from the coccygeal vein at 0900 h and samples of rumen fluid were taken using a probe at d -60, -25, and -7 relative to expected parturition and at d 3, 10 and 25 relative to calving. Blood was collected into heparinized plasma tubes. Immediately after their collection, all tubes were centrifuged at $797 \times g$ for 20 min at room temperature (~20°C). Blood plasma after centrifugation was divided into 3 aliquots and stored at -18°C until analysis. Blood plasma was analyzed in a commercial laboratory Veterinary laboratory (VLAB, Brno, Czech Republic) on an automatic analyzer (Roche Hitachi; Randox Laboratories Ltd., Crumlin, UK) using set f. Hormones were determined by the immunofluorescence technique on the Immulite apparatus (Siemens Medical Solutions Diagnostics, Los Angeles, CA). Samples of rumen fluid were obtained using a probe and preserved with 1 mL of ethanol until immediate analysis after their collection in a commercial laboratory (Institute of Animal Science, Prague UHřetev, Czech Republic) on an Ionosep 2003 isotachophoretic analyzer (Recman Laboratory Systems, Ostrava-Hrabůvka, Czech Republic).

Colostrum IgG concentrations were measured on the first milking with a colostrodoser and the values were adjusted to the concentrations of IgG at 20°C. The BiW of calves were measured at the time they were moved into individual pens, approximately 2 h after calving.

Statistical Analyses

Data were statistically analyzed using SAS software (version 9.1; SAS Institute Inc., Cary, NC). Precalving and postcalving data were analyzed separately. Milk production data were analyzed using a linear model with 3 fixed effects: 2 dichotomous (group and parity) and 1 continuous (previous lactation). The values for the CON or SDP level were estimated using the LSMEANS function. Concentrations of plasma metabolites and parameters of rumen fluid were analyzed using a linear model with 2 dichotomous fixed effects (group and parity); DMI, BW, BCS, BFT, colostral IgG concentrations, and BiW were tested by the *t*-test. Stillborn calves (*n* = 2) and twins (*n* = 3) were excluded from the statistical analysis of BiW.

Table 3. Least squares means for DMI, BW, BCS, back fat thickness (BFT), concentrations of colostrum IgG, birth weights (BiW) of calves, milk yield, and milk content in the first 100 d of lactation for cows assigned to conventional (control, CON) or shortened dry periods (SDP) in the first 100 DIM¹

Parameter	Prepartum (−60 d to calving)			Postpartum (1 to 100 DIM)		
	Mean CON ± SE	Mean SDP ± SE	<i>P</i> -value	Mean CON ± SE	Mean SDP ± SE	<i>P</i> -value
DMI	13.00 ± 0.75 ^a	17.11 ± 0.76 ^b	<0.001	21.48 ± 0.65	20.77 ± 0.71	>0.05
BW	674 ± 17	703 ± 13	>0.05	610 ± 16	606 ± 15	>0.05
BCS	3.58 ± 0.20	3.58 ± 0.18	>0.05	2.56 ± 0.24	2.78 ± 0.16	>0.05
BFT	16.1 ± 2.8	15.5 ± 1.90	>0.05	10.7 ± 1.60	10.3 ± 1.10	>0.05
IgG (g/L)				72.82 ± 4.27	80.42 ± 4.60	>0.05
BiW (kg)				44.69 ± 1.20	44.08 ± 1.17	>0.05
	Group ²			Parity ³	Previous lactation ⁴	
	Mean CON ± SE	Mean SDP ± SE	<i>P</i> -value	<i>P</i> -value	<i>P</i> -value	
Milk (kg)	40.02 ± 1.22	37.24 ± 1.18	>0.05	>0.05	<0.0001	
Fat (g/kg)	4.30 ± 0.11	4.37 ± 0.11	>0.05	>0.05	>0.05	
Protein (g/kg)	3.08 ± 0.04	3.17 ± 0.03	>0.05	>0.05	<0.01	
Lactose (g/kg)	4.83 ± 0.03	8.46 ± 0.03	>0.05	>0.05	0.05	
FCM (kg)	41.71 ± 1.31	39.06 ± 1.27	>0.05	>0.05	<0.01	
ECM (kg)	40.30 ± 1.27	37.97 ± 1.23	>0.05	>0.05	<0.0001	
Urea (mmol/L)	5.35 ± 0.16	5.41 ± 0.16	>0.05	>0.05	>0.05	
SCS ⁵	3.48 ± 0.44	3.24 ± 0.43	>0.05	>0.05	>0.05	

^{a,b}Means within a row with different superscript letters differ ($P < 0.05$).

¹The milk production data were analyzed using a linear model with 3 fixed effects: 2 dichotomous (group and parity) and 1 continuous (previous lactation). The values for the CON or SDP level were estimated using the LSMEANS function of SAS (SAS Institute Inc., Cary, NC).

²Treatments were the CON group assigned to a dry period of 57 d (SD = 5.9 d) and the SDP group assigned to an SDP of 35 d (SD = 6.3 d).

³The cows were classified into primiparous cows (CON: $n = 7$; SDP: $n = 8$) and multiparous cows (CON: $n = 7$ C; SDP: $n = 7$).

⁴Factor to represent milk yield in the previous lactation (305 d).

⁵Linear SCS.

RESULTS AND DISCUSSION

Changes in DMI, BW, BCS, and BFT

The average DMI, BW, BCS, and BFT are reported in Table 3. The relative changes in DMI, BW, BCS and BFT are illustrated in Figures 1, 2, 3 and 4, respectively.

Average DMI of the cows assigned to a SDP and fed a late-lactation diet was approximately 4.11 kg/cow per day greater, compared with the CON group, from d −60 until calving. Postpartum DMI was not affected by the treatment. No differences existed in BW, BCS, and BFT.

The increased prepartum DMI observed in the present study could possibly have been due to the higher palatability and nutritional quality of the lactation diet compared with the dry-cow diet. Transition to TMRD at d −60 before planned calving resulted in a pronounced decrease in the DMI of cows in the CON group. The DMI of cows in the SDP group decreased progressively until approximately 1 wk before calving. Thus, we can hypothesize that the DMI of cows in the CON group was influenced by the switch to a dry-cow diet rich in forage with low energy concentration and lower palatability. Similar to other studies, considerable

reduction in DMI in the last week before parturition (Bertics et al., 1992; Weber et al., 2013) was observed in both groups. Also in accordance with other studies, the highest DMI in both groups was observed after the peak of lactation (Ingvarthsen and Andersen, 2000; Weber et al., 2013). The prepartum DMI of cows assigned to SDP was not altered in 2 out of 3 studies (Gulay et al., 2003; Jolicoeur et al., 2010). One study (Rastani et al., 2005) reported an increase. In contrast to our results, Jolicoeur et al. (2010) observed an increase in postpartum DMI, and both Gulay et al. (2003) and Rastani et al. (2005) observed a numerical increase in feed intake postpartum when the dry period was reduced from 8 to 4 wk ($P > 0.05$). These results suggest that DMI is influenced by more factors than simply the length of the dry period. Lower DMI can be possibly influenced by fat mobilization (Dann et al., 2006; Weber et al., 2013). Feeding postcalving cows a high-energy diet could increase DMI and milk yield and improve the energy status of cows compared with animals fed a low-energy diet (Law et al., 2011).

Care should be taken when the condition of cows is evaluated. Body weight is of limited relevance for the estimation of body fat mobilization because the portion of body fat relative to BW change varies greatly, depending on age (Klawuhn and Staufenbiel,

Figure 1. Relative changes in DMI from -60 d prepartum to 100 DIM in cows assigned to a conventional (control, CON) or shortened dry period (SDP). The P -values for the selected dates were calculated in intervals of 10 d.

1997), and is influenced by DMI and time since last feeding (Schröder and Staufenbiel, 2006). In addition, the frame size of the animal must be considered. Body condition score is a subjective measure and depends on the judgment of the assessor. Back-fat thickness is likely a more objective and precise measure. According to Klawuhn and Staufenbiel (1997), a change in BFT of 1 mm corresponded to a gain or loss of approximately 5 kg of body fat. The prepartum BCS (3.58) of cows in the present study corresponded with the BCS recommended in the literature (Hutjens, 1996; Al Ibrahim et al., 2010). Overall, those authors suggested that an ideal BCS near calving is from 3 to 3.5 to stimulate DMI and alleviate the magnitude of NEB in early lactation. To achieve optimal BCS before calving, some authors (Contreras et al., 2002) has suggested managing cows to achieve a BCS of approximately 3.0 rather than the traditional 3.5 to 3.75 at dry-off, particularly because cows with high BCS, BFT, and BHBA concentrations showed the lowest DMI already before calving (Hayirli et al., 2002; Weber et al., 2013). Similar to our results, recent research (Santschi et al., 2011a; Soleimani et al.,

2012) did not detect any effect of dry period length (60 vs. 35 d) on the BW or BCS of the cows. In contrast, Weber et al. (2013) observed that BW was affected ($P < 0.05$) by dry period length during their entire study.

Concentrations of Colostrum Immunoglobulins and BiW of Calves

The least squares means for the concentrations of colostrum IgG and BiW of calves of cows assigned to the conventional dry period or SDP are shown in Table 3. The concentration of IgG ranged from 52 to 90 g/L (average $\pm$ SD = 73 ± 14.16 g/L) for the CON group and from 55 to 105 g/L (average $\pm$ SD = 80 ± 15.94 g/L) for the SDP group ($P > 0.05$). The average ($\pm$ SD) BiW of calves were 44.69 ± 4.33 kg for CON and 44.08 ± 4.06 kg for SDP calves ($P > 0.05$). Eight bullocks and 5 heifers were born in the CON group and 7 bullocks and 5 heifers were born in the SDP group. Stillborn calves and twins were excluded from the statistical analysis of BiW. Two calves were stillborn in the SDP group, and 1 was from twins.

Figure 2. Relative changes in BW from -60 d prepartum to 100 DIM in cows assigned to a conventional (control, CON) or shortened dry period (SDP). Intervals were 10 d. No significant differences existed between the groups ($P > 0.05$).

There was 1 set of twins in the CON group and 2 sets of twins in the SDP group.

Data on the relationship of dry period management and calf vitality, growth, and health are lacking in the

literature. Similar to our results, shortening of the dry period has not been shown to affect colostrum quality (Rastani et al., 2005; Watters et al., 2008) or calf BiW (Gulay et al., 2005; Rastani et al., 2005; Pezeshki et al.,

Figure 3. Relative changes in BCS from -60 d prepartum to 100 DIM in cows assigned to a conventional (control, CON) or shortened dry period (SDP). Intervals were 10 d. No significant differences existed between the groups ($P > 0.05$).

Figure 4. Relative changes in back fat thickness (BFT) trough –60 d prepartum to 100 DIM in cows assigned to a conventional (con, CON) or shortened dry period (SDP). Intervals were 10 d. No significant differences existed between the groups ($P > 0.05$).

2008). Decreased IgG concentration in colostrum has been observed in continuously milked cows (Annen et al., 2004; Rastani et al., 2005; Klusmeyer et al., 2009). Smaller calf BiW was associated with a 51 to 60-d dry period compared with longer dry periods (Atashi et al., 2013). Fetal growth and calf BiW is also affected by maternal diet (Wu et al., 2006). As reviewed by Funston et al. (2010), increased global nutrient supply throughout gestation as well as increased protein supplementation of dams in late gestation increased calf BiW (Larson et al., 2009).

Milk Production

Additional prepartum milk production from cows assigned to the SDP was 15.60 ± 1.65 kg milk/cow per day. The prepartum milk contained 4.59% fat and 3.98% protein. Hence, cows with an SDP produced approximately 390 kg of milk during extended lactation prepartum (approximately 25 d).

The production of milk, FCM, and ECM and milk composition in the first 100 DIM are reported in Table 3. The relative changes in milk fat, milk protein, lactose, and milk urea concentrations in the first 100 DIM are illustrated in Figure 5. The cows with an SDP produced approximately 2.78 kg/d (6.9%) less milk in the first 100 DIM; the difference is not statistically significant. The concentration of milk protein was influenced by

parity ($P < 0.05$) and by milk production in the previous lactation ($P < 0.001$). The effect of the previous lactation on the production of milk, FCM and ECM was also very high ($P < 0.0001$). If the milk production in the previous lactation was higher than 100 kg, the value of milk production in next lactation increases by 2 ± 0.4 kg. No significant differences existed in mean concentrations of milk fat, protein, lactose, and milk urea. The treatment did not affect SCC in milk. But we observed 3 cows with chronic and recurring mastitis in the CON group.

The relative changes in milk yields through standardized lactation (305 d) are illustrated in Figure 6 (milk control data). Average milk productions through standardized lactation were 34.7 ± 1.3 kg (CON) and 31.6 ± 1.3 kg (SDP; $P = 0.099$). Hence, the total milk production values for 305 d were 10,583 kg (CON) and 9,638 kg (SDP). The lactation curve of cows with SDP was flatter.

Previous studies (e.g., Klusmeyer et al., 2009; Soleimani et al., 2010; Safa et al., 2013) have shown that reducing the dry period length decreases milk yield in the subsequent lactation. This has been also confirmed by retrospective studies (Atashi et al., 2013; Ghavi Hosseini-Zadeh and Mohit, 2013; Steeneveld et al., 2013). Additionally, in Gulay et al. (2005), the relative contribution of udder halves dry for 30 d to the total daily milk yield was reduced by 9.8% compared with

Figure 5. Relative changes in milk fat, milk protein, lactose, and urea concentrations in the first 100 DIM in cows assigned to a conventional (control, CON) or shortened dry period (SDP). The values were calculated as the average per group (SDP or CON) at selected sampling days (i.e., 14, 28, 42, 56, 70, 84, and 100 d postpartum). No significant differences existed between the groups ($P > 0.05$).

70-d dried udder halves through 100 DIM ($P = 0.03$). In contrast, Jolicoeur et al. (2010) reported that shortening the dry period to 35 d increased the milk yield by

3% compared with a dry period of 65 d. Soleimani et al. (2012) reported no effect of an SDP on milk yield in the first 60 d postpartum. Based on previous observations,

Figure 6. Relative changes of milk yields through standardized lactation (305 d) in cows assigned to a conventional (control, CON) or shortened dry period (SDP). No significant differences existed between the groups ($P > 0.05$).

various reasons exist for a decreased milk yield due to an SDP. Schröder and Staufienbiel (2006) concluded that a change in BCS during the first month of lactation has a stronger influence on milk yield than BCS at parturition. Thus, thinner cows produced more milk (Garnsworthy and Topps, 1982; Domecq et al., 1997). In contrast, excessive lipolysis has been associated with the increased incidence of health disorders (e.g., fatty liver, ketosis, milk fever, and displaced abomasum), resulting in reduced milk yield (Grummer, 1993; Waltner et al., 1993; Rukkwamsuk et al., 1999). As previous studies have focused mainly on limited lactation in the postcalving period (e.g., 100 DIM), it is difficult to evaluate the lactation persistency of cows with SDP. Mantovani et al. (2010a) reported that continuously milked cows produced approximately 5.5 kg/d less milk and reached the peak of lactation 10 d earlier than cows assigned a traditional dry-off period of 55 d. Gulay et al. (2003) concluded that a dry period of 30 d is sufficient to sustain milk yield. However, other studies (Pezeshki et al., 2007; Watters et al., 2008; Santschi et al., 2011a) reported a significant reduction in milk yield for second-lactation cows assigned to SDP, whereas milk yields from cows in their third-or-greater lactation were not affected. These results suggest that young cows (parity 2) are more susceptible to a reduction in dry days compared with older cows (parity ≥ 3). This hypothesis has been confirmed in a retrospective study by Kuhn et al. (2006). Based upon these observations, we could speculate that the greater milk production of cows assigned to a conventional dry period was due to the higher numbers of active and functional mammary cells compared with cows with SDP (Capuco et al., 1997; Gulay et al., 2005). Despite the milk loss observed in cows with reduced dry periods, studies by Annen et al. (2004), Andersen et al. (2005), and Rastani et al. (2005) monitored milk yield during a limited period postcalving and reported that the additional precalving milk yield compensated for the reduced milk yield at the beginning of the subsequent lactation (7, 10, and 17 wk, respectively). To our knowledge, previous studies did not report milk protein and fat composition or the quality of the additional milk produced precalving, which are important when considering the market value of the additional postpartum milk. As concentrations of milk components are negatively correlated with milk yield, the percentages of milk protein and milk fat could increase in late lactation (Rémond et al., 1992; Rémond and Bonnefoy, 1997; Mantovani et al., 2010a). Several studies have also indicated that reducing the dry period has a positive effect on milk composition in early lactation. For example, Gulay et al. (2003), Watters et al. (2008), and Soleimani et al. (2010) reported that milk protein content increased an average of 0.12%

and was accompanied by minor or no changes in milk fat content. The reported increase in milk protein content could be attributable to an improved postpartum energy balance of cows with a reduced dry period and, thus, sparing of amino acids and energy for protein synthesis (Coulon and Rémond, 1991; Rémond et al., 1992; Weber et al., 2013). Gulay et al. (2003), Annen et al. (2004), and Klusmeyer et al. (2009) noted lower SCC for cows with reduced dry periods. As the majority of mastitis cases originate during the dry period (Green et al., 2008; Collier et al., 2012), the incidence of mastitis could be lower for cows with a reduced dry period. Overall, previous studies found no effect of dry period length on mastitis incidence (Church et al., 2008; Watters et al., 2008; Santschi et al., 2011b). A recent study by Steeneveld et al. (2013) found no effect of dry period length on postpartum SCC.

Concentrations of Plasma Metabolites and Parameters of Rumen Fluid

The least squares means for the concentrations of blood plasma metabolites from the d -60 before expected calving to 100 DIM are recoded in Table 4. No differences were detected in plasma concentrations of glucose, total protein, albumin, BHBA, NEFA, triacylglycerol, and cholesterol and the activity of γ -glutamyltransferase ($P > 0.05$). The postpartum concentration of plasma urea was higher in the SDP group compared with the CON group ($P < 0.05$) and postpartum concentrations of total bilirubin were higher in the CON group compared with the SDP group ($P < 0.05$). The activity of aspartate aminotransferase postpartum was greater in the CON group compared with the SDP group ($P < 0.001$). The effect of parity was significant only for prepartum concentration of BHBA ($P < 0.01$). This single significance could be a matter of chance. Most previous studies (e.g., Rastani et al., 2005; Pezeshki et al., 2007; Soleimani et al., 2012) found no effect of shortening the dry period to shorter than 40 d on basic parameters of blood, such as concentrations of glucose, BHBA, and NEFA. Watters et al. (2008), Klusmeyer et al. (2009), and Safa et al. (2013) observed decreased concentrations of BHBA and NEFA after calving for cows with SDP compared with cows given the traditional dry period of about 60 d. As reviewed by Pezeshki et al. (2010), continuously milked cows have lower concentrations of BHBA and better energy status in the subsequent lactation.

Obtained parameters of rumen fluid are recorded in Table 5. Prepartum concentrations of lactic acid, acetic acid, propionic acid, and butyric acid and, hence, concentrations of total VFA were higher in rumen fluid of cows of the SDP group compared with the CON group.

Table 4. Least squares means for prepartum and postpartum plasma metabolite concentrations

Parameter ¹	Period	Mean CON $\pm$ SE ²	Mean SDP $\pm$ SE ³	Group <i>P</i> -value ⁴	Parity <i>P</i> -value ⁵
Total protein (g/L)	Prepartum	71.79 $\pm$ 0.49	72.21 $\pm$ 0.45	>0.05	>0.05
	Postpartum	73.37 $\pm$ 0.35	73.09 $\pm$ 0.44	>0.05	>0.05
Albumin (g/L)	Prepartum	33.22 $\pm$ 0.23	33.15 $\pm$ 0.21	>0.05	>0.05
	Postpartum	33.39 $\pm$ 0.19	33.08 $\pm$ 0.25	>0.05	>0.05
Glucose (mmol/L)	Prepartum	3.43 $\pm$ 0.03	3.43 $\pm$ 0.02	>0.05	>0.05
	Postpartum	3.06 $\pm$ 0.04	3.05 $\pm$ 0.04	>0.05	>0.05
Urea (mmol/L)	Prepartum	4.01 $\pm$ 0.05	3.97 $\pm$ 0.06	>0.05	>0.05
	Postpartum	5.20 $\pm$ 0.09	5.43 $\pm$ 0.04	<0.05	>0.05
NEFA (mmol/L)	Prepartum	0.22 $\pm$ 0.01	0.22 $\pm$ 0.01	>0.05	>0.05
	Postpartum	0.46 $\pm$ 0.03	0.50 $\pm$ 0.04	>0.05	>0.05
BHBA (mmol/L)	Prepartum	0.43 $\pm$ 0.01	0.39 $\pm$ 0.01	>0.05	>0.05
	Postpartum	0.73 $\pm$ 0.03	0.79 $\pm$ 0.07	>0.05	<0.01
TAG (mmol/L)	Prepartum	0.21 $\pm$ 0.01	0.21 $\pm$ 0.01	>0.05	>0.05
	Postpartum	0.34 $\pm$ 0.02	0.34 $\pm$ 0.01	>0.05	>0.05
Cholesterol (mmol/L)	Prepartum	3.59 $\pm$ 0.07	3.53 $\pm$ 0.06	>0.05	>0.05
	Postpartum	3.70 $\pm$ 0.10	3.60 $\pm$ 0.08	>0.05	>0.05
Bilirubin (mol/L)	Prepartum	3.69 $\pm$ 0.07	3.53 $\pm$ 0.05	0.05	>0.05
	Postpartum	4.52 $\pm$ 0.13	4.21 $\pm$ 0.07	<0.05	>0.05
AST (kat/L)	Prepartum	1.41 $\pm$ 0.01	1.40 $\pm$ 0.00	>0.05	>0.05
	Postpartum	1.60 $\pm$ 0.02	1.52 $\pm$ 0.01	<0.001	>0.05
GGT (kat/L)	Prepartum	0.25 $\pm$ 0.01	0.25 $\pm$ 0.01	>0.05	>0.05
	Postpartum	0.42 $\pm$ 0.02	0.38 $\pm$ 0.01	>0.05	>0.05
Ca (mmol/L)	Prepartum	2.42 $\pm$ 0.03	2.46 $\pm$ 0.02	>0.05	>0.05
	Postpartum	2.25 $\pm$ 0.02	2.32 $\pm$ 0.03	>0.05	>0.05
P (mmol/L)	Prepartum	2.12 $\pm$ 0.06	2.06 $\pm$ 0.05	>0.05	>0.05
	Postpartum	2.01 $\pm$ 0.03	2.03 $\pm$ 0.02	>0.05	>0.05
Mg (mmol/L)	Prepartum	1.20 $\pm$ 0.21	1.17 $\pm$ 0.02	>0.05	>0.05
	Postpartum	0.97 $\pm$ 0.01	0.98 $\pm$ 0.01	>0.05	>0.05

¹TAG = triacylglycerol; AST = aspartate aminotransferase; GGT = γ -glutamyltransferase.

²CON = control.

³SDP = shortened dry period.

⁴Treatments were the CON group assigned to a dry period of 57 d (SD = 5.9 d) and the SDP group assigned to an SDP of 35 d (SD = 6.3 d).

⁵The cows were classified into primiparous cows (CON: n = 7; SDP: n = 8) and multiparous cows (CON: n = 7; SDP: n = 7).

Thus, mean pH of the rumen fluid of cows in the SDP group prepartum was lower compared with the CON group. This could be result of feeding a different type of diet richer in concentrates in the SDP group (TMR2) versus the CON group (TMRD). Postpartum concentrations of VFA and NH₃ and the pH of rumen fluid did not differ between the groups. After calving, both groups were fed the same lactation diet corresponding to their lactation requirements (see Tables 1 and 2). Data on the effect of dry period length on rumen parameters and health in the literature are scarce.

CONCLUSIONS

The prepartum DMI of cows assigned to an SDP of approximately 35 d and fed a late-lactation diet was approximately 4.11 kg/cow per day greater compared with the CON cows assigned to a conventional dry period of 60 d and fed a dry-cow diet. No effect of dry period strategy on postpartum DMI was detected. Greater prepartum DMI of cows in the SDP group could be the

result of feeding a late-lactation diet during this period. The BW, BCS, BFT, colostrum IgG concentration, and calf BiW were not affected by treatment. Similarly the treatment did not affect milk production of the cows. The effect of milk production on previous lactation strongly influenced production of milk, FCM, ECM, and concentrations of milk protein in next lactation. Milk protein concentrations were lower in primiparous cows. High concentrations of milk fat and milk urea, and low concentrations of milk protein and BCS <3, which could indicate an NEB in cows in early lactation, were observed in both groups. The basic parameters of blood plasma such as concentrations of glucose, BHBA, and NEFA were not affected by the treatment. The activity of aspartate aminotransferase postpartum was greater in CON cows with a conventional dry period of 60 d compared with the SDP group. Shortening the dry period to 35 d and feeding a late-lactation diet prepartum increased the production of lactic acid, acetic acid, propionic acid, butyric acid, and total VFA and decreased the rumen pH. Postpartum concentrations

Table 5. Least squares means for prepartum and postpartum concentrations of VFA and ammonium and pH of the rumen fluid

Parameter	Period	Mean CON $\pm$ SE ¹	Mean SDP $\pm$ SE ²	Group P-value ³	Parity P-value ⁴
Lactic acid (mmol/L)	Prepartum	0.28 $\pm$ 0.03	0.49 $\pm$ 0.03	3.2E-05	>0.05
	Postpartum	0.60 $\pm$ 0.04	0.57 $\pm$ 0.04	>0.05	>0.05
Acetic acid (mmol/L)	Prepartum	63.52 $\pm$ 2.12	72.05 $\pm$ 1.23	<0.01	>0.05
	Postpartum	78.08 $\pm$ 1.34	76.54 $\pm$ 1.30	>0.05	>0.05
Propionic acid (mmol/L)	Prepartum	18.84 $\pm$ 0.76	21.10 $\pm$ 0.45	0.01	>0.05
	Postpartum	23.47 $\pm$ 0.67	22.41 $\pm$ 0.68	>0.05	>0.05
Butyric acid (mmol/L)	Prepartum	12.94 $\pm$ 0.73	15.44 $\pm$ 0.39	<0.01	>0.05
	Postpartum	16.94 $\pm$ 0.44	16.78 $\pm$ 0.52	>0.05	>0.05
Valeric acid (mmol/L)	Prepartum	0.33 $\pm$ 0.04	0.42 $\pm$ 0.03	>0.05	>0.05
	Postpartum	0.51 $\pm$ 0.04	0.49 $\pm$ 0.04	>0.05	>0.05
Total VFA (mmol/L)	Prepartum	95.91 $\pm$ 3.36	109.50 $\pm$ 1.84	0.001	>0.05
	Postpartum	119.18 $\pm$ 2.30	116.79 $\pm$ 2.40	>0.05	>0.05
pH	Prepartum	6.97 $\pm$ 0.04	6.73 $\pm$ 0.04	<0.001	>0.05
	Postpartum	6.43 $\pm$ 0.06	6.55 $\pm$ 0.07	>0.05	>0.05
NH ₃ (mg of N/100 g)	Prepartum	15.95 $\pm$ 0.49	16.01 $\pm$ 0.62	>0.05	>0.05
	Postpartum	21.12 $\pm$ 1.42	18.55 $\pm$ 1.09	>0.05	>0.05

¹CON = control.²SDP = shortened dry period.³Treatments were: the CON group assigned to a dry period of 57 d (SD = 5.9 d) and the SDP group assigned to an SDP of 35 d (SD = 6.3 d).⁴The cows were classified into primiparous cows (CON: n = 7; SDP: n = 8) and multiparous cows (CON: n = 7; SDP: n = 7).

of lactic acid, VFA, and NH₃ and pH did not differ between the groups of cows (SDP vs. CON) during their first 100 DIM when all cows were fed the same lactation diet responding their lactation requirements. Based on the results of this study, we could not confirm our hypothesis. In contrast, the traditional dry period management strategy appeared to be more favorable considering the DMI, milk production, and milk persistency, compared with the SDP and feeding a late-lactation diet throughout the dry period.

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