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Management of Dry and Transition Cows to Improve Energy Balance and Reproduction

Ric R. GRUMMER, Milo C. WILTBANK, Paul M. FRICKE, Rick D. WATTERS and Noelia SILVA-DEL-RIO

Department of Dairy Science, University of Wisconsin-Madison, 1675 Observatory Dr., Madison, Wisconsin 53711, USA

Abstract. Fertility of dairy cows has decreased for the past several decades. Measures of energy balance (EB; e.g. change in EB, EB nadir, cumulative negative EB, or duration of negative EB) are related to reproductive performance. Our research group has concluded that modification of diets fed during the dry or transition period are unlikely to have significant effects on postpartum EB and fertility. Rather, more radical alterations in dairy management are needed if energy status of postpartum cows is to be improved. We have examined the potential to alter EB by shortening or eliminating the dry period. In an initial study, the effects of a 56, 28, and 0 d dry period on ovarian dynamics and reproductive performance of dairy cows were examined. Postpartum EB was improved by reducing the dry period; however, only significantly for the 0 d dry period. Cows on the 0 d dry period did not experience negative EB. Improvements in EB were a reflection of lower milk production and greater feed intake. Consistent with the improvements in EB, time to first ovulation and first service, first service conception rate, services per conception, and days open were all improved by reduction of dry period length. Because small animal numbers were used in the study, a second study was conducted on a commercial dairy with many more animals to determine if results from the initial trial could be duplicated. A comparison was made between a 55 and 34 d dry period. Shortening the dry period resulted in fewer days to first ovulation, fewer days open, and a greater percentage of cows pregnant at 150 days in milk, although the improvements in the latter two variables were only significant for cows in their third or greater lactation. A current study is being performed in a large commercial dairy to examine the effects of eliminating the dry period on reproduction utilizing a large commercial dairy.

Key words: Energy balance, Transition cows, Reproduction, Dry period length

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Fertility has decreased for the past several decades during a period when there have also been dramatic changes in management, nutrition, milk production, and genetics in commercial dairy operations [1–3]. Energy balance has probably the best-established nutritional relationship with reproductive performance. Energy balance is the difference between energy consumed and energy required for maintenance, pregnancy and milk production. Postpartum EB is more closely related to energy consumed than milk yield [4, 5]. Deficiencies in minerals, vitamins, or amino acids can adversely affect reproductive performance, but unlike energy, those deficiencies can be corrected relatively easily by increasing density of the nutrient in the diet. In contrast, there are limits to energy density of diets fed to dairy cattle. Feeding additional grain or fat, in an attempt to increase dietary energy density, can adversely affect feed intake, digestive processes, or both. Therefore, increasing energy intake by dairy cattle is very difficult to achieve. The best strategy for doing that may be to increase total feed intake rather than to increase dietary energy density to the point at which animal performance may be compromised.

The documented relationships between various estimates of EB (change, nadir, cumulative, duration, body condition score (BCS) or BCS change) and reproductive efficiency have primarily been established from analysis of postpartum data. A common observation is an increase in time to resumption of ovarian cyclicity as negative EB increases [1, 6]. Early resumption of ovarian cyclicity is important because fertility at first breeding may increase as the number of estrous cycles prior to breeding increases [7]. The metabolic signal(s) which translate negative EB into delayed onset of ovarian activity have not been determined but may include glucose, nonesterified fatty acids (NEFA), beta-hydroxybutyrate concentrations (BHBA), IGF-1, leptin, or growth hormone [8]. There have been few studies designed to specifically examine the relationship between energy status during the dry or transition period (3 wk prior to calving until 3 wk postcalving) and reproductive performance or potential metabolic signals that influence reproduction. Britt [9] hypothesized that oocyte quality may be adversely affected by physiological conditions long before ovulation and fertilization, i.e. during the transition period. However, it has never been proven that endocrine or metabolic imbalances during this time affect fertility of dairy cows. Body condition score at calving has been related to reproductive efficiency [10, 11], but as will be discussed later, it is very difficult to influence BCS by altering energy density of dry cow diets. Although dry matter (DM, i.e., energy) intake before calving has been related to uterine disease postpartum and poor reproduction [12, 13] cause and effect has not been established.

Because of the paucity of research that directly examines how dry or transition period energy feeding affects reproduction, the major focus of this paper will be to review if there are relationships

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Correspondence: RR Grummer (e-mail: rgrummer@wisc.edu)

Table 1. A comparison of two trials that evaluated feeding strategies for far-off dry cows

	Dann *et al.* [18][1, 3]			Silva-del-Río *et al.* [19][2, 4]	
Far-off dry cow treatment/parameters	1.30 Mcal NEl/kg *ad libitum*	1.59 Mcal NEl/kg *ad libitum*	1.59 Mcal NEl/kg restricted	1.32 Mcal NEl/kg *ad libitum*	1.54 Mcal NEl/kg *ad libitum*
Prepartum body condition, scale 1–5	3.04	3.16	2.94	3.25	3.25
Postpartum body condition change	–0.23	–0.33	–0.16	–0.59	–0.62
Postpartum EB, % of requirement or Mcal NEl/d	105	102	108	–2.5	–5.6
Milk, kg/d	39.4	36.9	37.0	43.3	48.5
Fat, %	3.59	3.77	3.58	3.65	3.62
Liver TG, % or μg/μg DNA	2.5	2.6	1.4	3.6	3.2
NEFA, μEq/L	786	792	627	393	461
BHBA, mg/dL	8.1	9.0	6.6	6.4	7.8
Total health disorders	29	51	37	57	52

[1] Dann *et al.* [18]: wk 1–8 postpartum for milk parameters, body condition, EB, and health disorders and d 1–10 for blood and liver measurements. [2] Silva-del-Río *et al.* [19]: wk 1–15 for milk parameters, body condition, EB, and health disorders, wk 1–10 for blood measurements, and d 1 and 35 postpartum for liver TG. [3] Prepartum body condition, P=0.003; Liver TG, P=0.14; BHBA, P=0.03; other parameters P≥0.15 or insufficient animals for statistical analysis (health disorders). [4] Milk, P=0.04; NEFA, P=0.06; BHBA, P=0.07; EB, P=0.01; other parameters P≥0.15 or insufficient animals for statistical analysis (health disorders).

between energy feeding during this period and EB postpartum. Additionally, the effects of altering the gestation-lactation cycle by shortening or eliminating the dry period on postpartum EB and reproduction will be discussed.

Prefresh Transition Period

Factors affecting feed intake during the final 3 wk prior to calving have been reviewed [14]. Animal characteristics, diet, and management influence feed intake. Animal and diet factors have been researched more intensely than management factors. Breed and parity affect prepartum dry matter intake (DMI); however, these are "fixed" effects that will not be considered as tools to influence energy status. Body condition score reflects management, but it is an animal factor that influences feed intake. Cows with BCS>4.0 have lower feed intake during the final 3 wk prepartum than cows with BCS≤4.0 [15]. Because BCS at calving is related to reproductive efficiency [10, 11], modification of BCS during the dry period could theoretically be a strategy to influence reproduction. However, in two recent studies that examined feeding diets to meet or greatly exceed (~150%) NRC [16] energy requirements for the entire dry period the researchers observed only small effects on BCS (less than .15 BCS points, 5 point scale). Low feed intake and the short duration of time probably precludes significant BCS gain, particularly during the final 3 wk prior to calving.

Although fat, rumen degradable protein, and rumen undegradable protein content of diets can affect DMI during the final 3 wk prepartum, the effects are minor compared to nonfiber carbohydrate [14, 15]. Nonfiber carbohydrate (or conversely neutral detergent fiber) is the dietary factor that has the greatest effect on prepartum feed intake [14]. Decreasing forage-concentrate ratio of pre-fresh diets does increase DMI [17]. Surprisingly, the increase in DMI occurs for sustained periods of time (i.e., 3 wk) even if cows are in positive EB at the time the additional grain is introduced. In other words, there does not seem to be a functional feedback mechanism to maintain EB when increasing energy density in the diet during the pre-fresh transition period. The obvious question is: does this increase in grain feeding and DMI carry over and have positive effects on postpartum EB and reproductive performance? A summary of 9 studies conducted between 1995 and 2005 indicated that postpartum DMI and milk production are not influenced by prepartum forage: concentrate ratio [17]. Although EB and reproductive performance were not typically reported in these studies, the absence of effects on milk yield and DMI suggests it is unlikely they would have been influenced by diets fed prepartum.

Far-off Dry Period

A factorial design was used by Dann *et al.* [18] to examine the relative importance of energy feeding during the far-off dry period versus the "close-up" dry period (24 d prepartum until calving) on postpartum lactation and metabolism. During the far-off dry period, treatments were a diet (1.30 Mcal NEl/kg DM) fed to meet 100% of NRC recommendations for energy when consumed *ad libitum*, a diet to provide 150% of NRC recommendations when fed ad libitum (1.59 Mcal NEl/kg DM), and a diet (1.59 Mcal NEl/kg DM) feed restricted to meet 80% of NRC recommendations. During the close up period (final 24 d of gestation), half the cows from each far-off treatment group were fed a diet (1.61 Mcal NEl/kg DM) at either ad libitum intake or restricted to meet 80% of NRC energy recommendations. Consistent with the previous discussion, there was little influence of close-up period treatments on postpartum lactation performance or metabolic parameters. They concluded that feeding level during the far-off period was more critical than during the prepartum period, however, far-off treatment effects on postpartum measurements were small (Table 1). Since there were no far-off treatment differences on EB, it is unlikely that reproductive performance (not monitored) would have been affected.

Silva-del-Río *et al.* [19] conducted an experiment with a 2 × 2 factorial arrangement of treatments: cows pregnant with singletons or twins and a "close-up" diet with moderate energy for 3 or 8 wk prepartum. We hypothesized that cows bearing twins, but not singletons, would benefit from being fed additional energy during the far-off dry period. The close-up diet contained 1.54 Mcal NEl/kg DM and the far-off dry cow diet contained 1.32 Mcal NEl/kg DM. Therefore, treatments were 1.32 or 1.54 Mcal NEl/kg DM during the first 5 wk of the dry period and were very similar to two of the far-off treatments employed by Dann *et al*. [18]. The far-off diet contained 55% alfalfa silage, 39% wheat straw, and 7% concentrate and was 54.4% NDF. The close up diet contained 25% alfalfa silage, 35% corn silage, 20% wheat straw, and 20% concentrate and contained 42.4% NDF. All cows were fed the same late lactation diet from 90 to 60 d prior to expected calving and the same early lactation diet after calving.

There were few interactions between pregnancy status and diet, so only the main effects of diet are shown (Table 1). Similar to results from Dann *et al*. [18], it was very difficult to alter BCS even though there were considerable treatment differences in energy intake during the far-off dry period. In contrast to data from Dann *et al*. [18], there was a significant increase in milk production due to feeding the high-energy diet during the entire dry period. This was not accompanied by an increase in DM intake; therefore, there was a significant decrease in EB postpartum for cows fed the high-energy diet for the entire dry period. This led to greater plasma NEFA and BHBA. There were no effects of diet on diameter of largest follicle at first postpartum ultrasound, days to first 10-mm follicle, or days to first ovulation. Days to first artificial insemination (AI), first service conception rate, services per conception, and days open also were not affected by diet or pregnancy status. These results and those of Dann *et al*. [18] suggest that modification of far-off dry period energy feeding strategies will not enhance reproductive performance of dairy cattle.

Post-Fresh Transition Cows

Meeting the energy needs of the immediate postpartum cow as not been actively studied. Researchers avoid doing studies on fresh cows because tremendous variability amongst cows makes it difficult to design experiments with sufficient replication, especially if reproductive measures with bimodal distribution (e.g. conception rate) are examined. Most fresh cow studies are initiated at 3 wk postpartum or later when cow variability is reduced and there is less likelihood of losing a cow from the study. This is unfortunate because one can make a strong argument that nutrition of the cow during the first 3 wk postpartum may be the most important.

The most rapid decrease in EB and negative EB nadir usually occurs during the first 3 wk postpartum. After summarizing 26 studies, Brixy [5] indicated that positive EB was reached by approximately 50 d in milk (DIM) and the minimum EB occurred at about 11 DIM. We collected data from twenty studies published in peer reviewed journal articles [4]. The mean number of DIM until EB was reached was 45 (standard deviation=21 d). The correlation between peak milk yield (r=0.24) or days to peak milk yield (r=0.23) and time to reach positive EB was extremely low indicating that some other factor besides energy output was responsible for variability in the length of time it takes to reach positive EB. The data did not allow us to examine the relationship between energy intake or DMI and time to reach positive EB. However, we were able to examine the relationship between energy density of the diet and days to positive EB. The data indicated that there was a stronger relationship between days to positive EB and energy density of the diet (r=0.57) than peak milk yield.

We also examined individual cow data from a specific research trial that included 24 primi- and 49 multiparous cows from 2 through 21 wk postpartum [4]. Average 4% fat-corrected milk yield was 29.2 kg/d for primiparous cows and 38.4 kg/d for multiparous cows for the first 21 wk postpartum. Energy balance was more closely related to energy intake (r=0.58) than energy output as measured by fat-corrected milk (r= –0.26,). Average time to reach positive EB was the same for multiparous and primiparous cows, 5 ± 2 wk. McGuire *et al*. [20] performed a similar analysis from a trial including 29 multiparous cows averaging 46 kg milk/d for the first 12 wk of lactation. In agreement with our data, the correlation between EB and DMI (r=0.751) was much higher than with milk yield (r=0.051).

Several conclusions can be drawn from this research: 1. Energy status is most compromised during the first 3 wk of lactation. 2. Return to positive EB occurs relatively quickly for most cows if they are fed diets that are nutritionally adequate (as was the case in these research studies). 3. Energy balance is more likely to be related to energy intake than milk yield. 4. Minimizing negative EB is most likely to be accomplished through successful feeding rather than through decreasing milk yield.

We [21, 22] conducted an experiment to examine feeding strategies for transitioning cows from low-energy far-off dry cow diets to high-energy lactation diets. A 2 × 2 factorial arrangement of treatments was used; cows were fed diets containing 1.55 or 1.65 Mcal NEl/kg DM for the last 4 wk prior to calving. Following calving, one half of the cows from each group were fed diets containing 1.67 or 1.74 Mcal NEl/kg DM for the first 3 wk after calving. All cows were fed a diet containing 1.74 Mcal NEl/kg DM after 3 wk postpartum.

There was no effect of prepartum treatment and there was no interaction between prepartum treatment and postpartum treatment on milk yield. Although there was no significant effects of treatment on calculated EB for the first 70 d of lactation, cows on high-energy diet postpartum may have had a more favorable energy status for the first 5 wk postpartum as indicated by higher plasma glucose concentrations (49.2 *vs*. 45.9 mg/dl) and lower BHBA (4.1 *vs*. 6.3 mg/dl). There was no effect of prepartum diet on triglyceride accumulation in the liver at calving; however, cows fed the high-energy diet postpartum had lower liver triglyceride in the liver at the end of the 3 wk treatment period (11.1 *vs*. 15.6 mg triglyceride/mg DNA). Effects on reproductive parameters were not monitored for this trial. Additional research is needed to determine the most appropriate feeding strategies for energy immediately postpartum that may minimize negative energy balance and maximize reproductive efficiency. However, this trial indicated there might be opportunities to improve energy status during the immediate postpartum period.

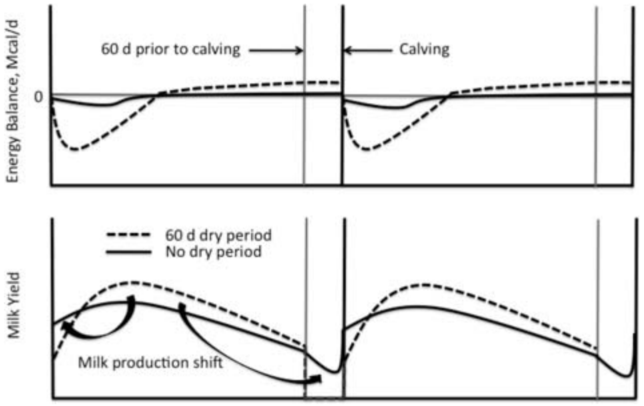

Fig. 1. Theoretical comparison of milk yield and energy balance of cows experiencing a 0 or 60 day dry period.

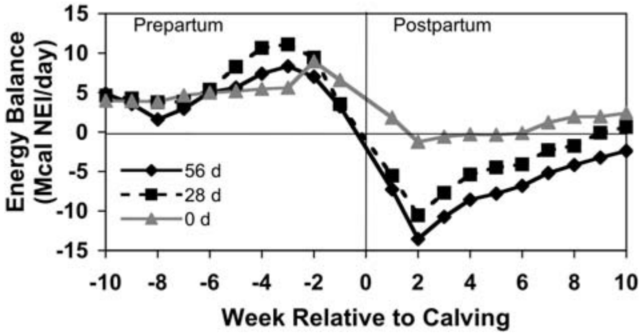

Fig. 2. Energy balance (Mcal/day) of cows with different dry period lengths. Treatments are no planned dry period (▲), 28-day dry period (■), or 56-day dry period (◆). Reprinted with permission from [24].

Table 2. Effects of varying dry period on feed intake, production, and fertility [6, 24]

	0–d (n=19)	28-d (n=21)	56-d (n=18)
DM intake wk 1–10, kg/d	20.7	19.6	19.1
Solids-corrected milk, kg/d	33.5^{a}	37.6^{b}	39.9^{b}
Mean EB wk 1–3, Mcal/d	1.7^{a}	$–6.3^{b}$	$–9.6^{c}$
EB nadir, Mcal/d	–2.0	–9.7	–13.4
Days to first ovulation	13.2^{a}	23.8^{b}	31.9^{b}
Days to first AI	69.4	68.0	75
1st Service conception rate	55^{a}	26^{ab}	20^{b}
Days open	94^{a}	121^{ab}	145^{b}

$^{a–c}$Means within a row having different superscript letters differ ($P<0.05$).

Management of Dry Period Length

Evidence discussed above indicates that it may be very difficult to make dramatic improvements in energy status of early lactation cows through nutritional management of the dry or postfresh transition period. Novel ways to alter management of the gestation-lactation cycle are needed to significantly improve energy status and improve reproductive efficiency of the dairy cow. Our laboratory has examined the effect of shortening or eliminating the dry period as a means to improve postpartum energy status of dairy cows. The extreme measure of eliminating the dry period may have the most potential to improve EB and fertility. Theoretical milk yield and EB responses for cows experiencing a 60 d dry period and no dry period are shown in Fig. 1. First, eliminating the dry period is likely to reduce peak milk production following calving, although this effect is most dramatic for cows entering their second lactation compared to more mature cows [23]. Extending the previous lactation and eliminating the dry period can capture a substantial portion of the "lost" milk production (Fig. 1) [23]. This effectively shifts milk production from a time (postpartum) when the cow cannot consume sufficient energy to support lactation to a time (prepartum) in which cows are in positive EB and are not experiencing energy deficits. Additionally, cows that are continuously milked do not experience as great a decrease in DM intake immediately before and after parturition [24]. Consequently, the magnitude of negative EB postpartum is reduced (Fig. 1) [24] and potential for enhancing reproductive performance is increased. Some of the same benefits may be obtained by shortening the dry period, however, they will likely be of a smaller magnitude than obtained when eliminating the dry period completely [6].

For our first study [6, 24], cows were assigned to treatments at –56 d prepartum. The 3 treatments were 1) 56 d dry: cows fed a low-energy far off diet from –56 to –29 d prepartum and a moderate-energy transition diet from –28 d to parturition; 2) 28 d dry: cows fed lactation diet throughout the dry period; and 3) 0 d dry: cows fed lactation diet until calving. After calving, all animals were fed the same lactation diet. Actual days dry for the 56, 28 and 0 d treatments were 54, 29 and 5. Some cows on the 0 d treatment spontaneously dried up. One of the most striking observations was that cows on the 0 d dry treatment essentially did not enter into negative EB (Fig. 2, Table 2) after calving. This reflected lower solids-corrected milk production and greater DM intake for cows that were continuously milked (Table 2). Although mean DM intake for the first 10 wk postpartum did not differ, cows on 0 d dry treatment consumed significantly more feed during the first three wk postpartum. Ovarian dynamics were monitored by ultrasound three times per week [6]. Reducing the dry period resulted in a more rapid resumption of ovarian activity (Table 2). Although this trial

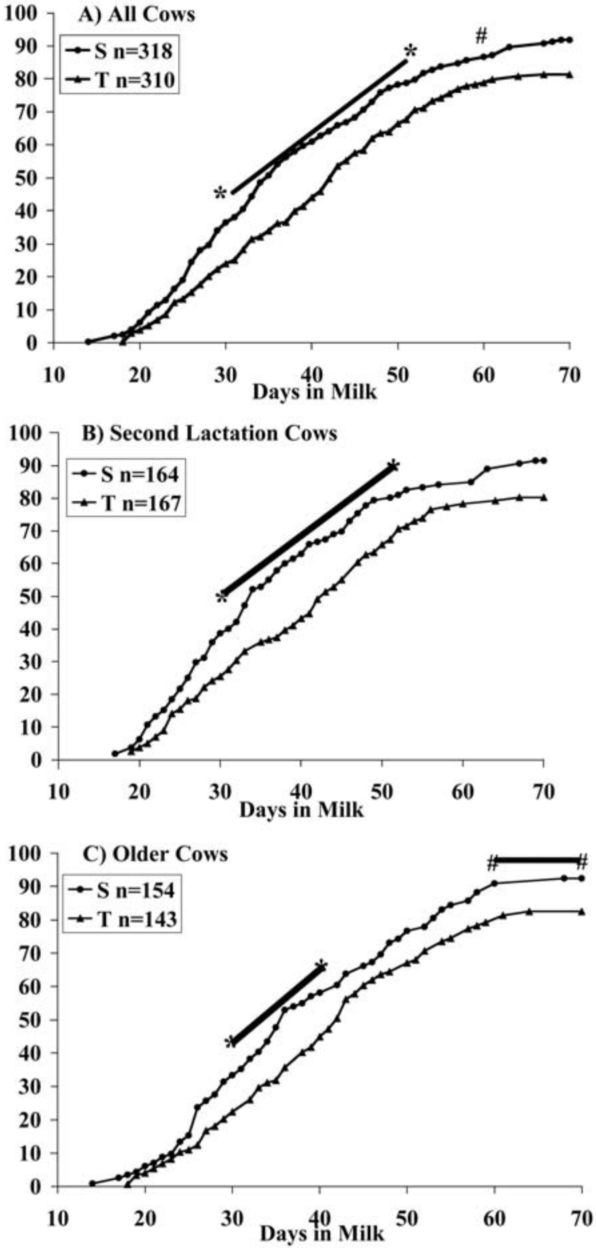

Fig. 3. Survival curves for days to first ovulation for cows managed for S (●) shortened 34 d dry period or T (▲) traditional 55 d dry period shown for: A) All cows; B) Younger cows (dry period between first and second lactation and reproduction during second lactation); and C) Older cows in their third or greater lactation. Differences between treatment groups were analyzed at 10 d intervals by Chi Square analysis and significant differences are shown directly on the Kaplan-Meier curves with an asterisk (* indicates $P<0.05$) or a pound sign (# indicates $0.05 \leq P < 0.1$) with lines connecting points with similar statistical differences. Reprinted with permission of Elsevier from [25].

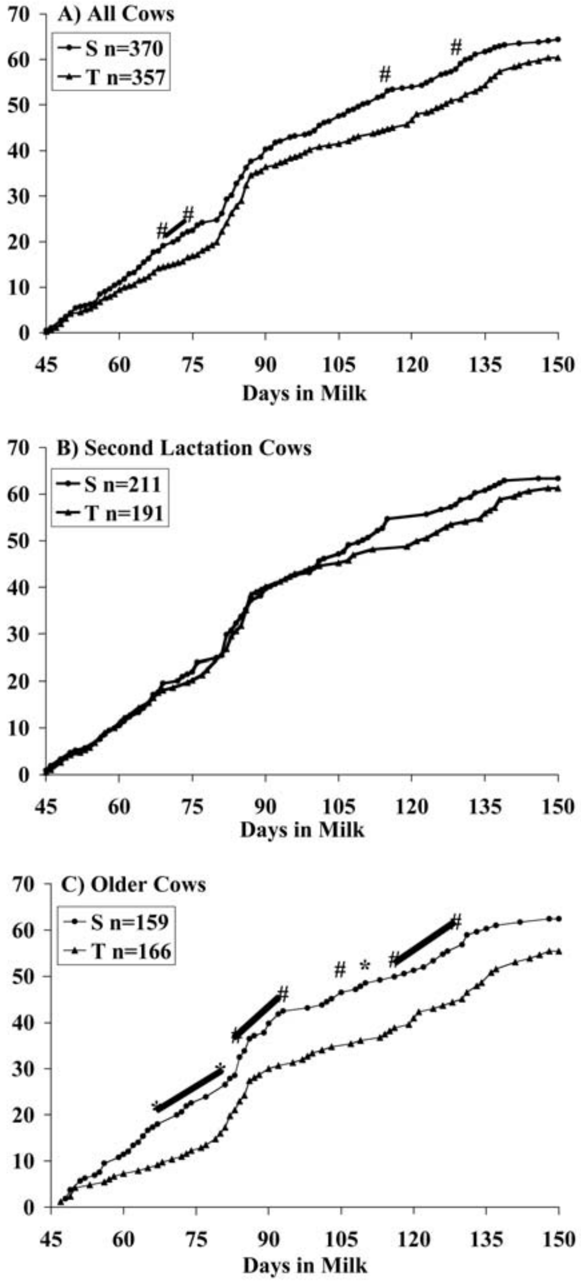

Fig. 4. Survival curve for days to pregnancy with data truncated at 150 DIM for cows managed for S (●) shortened 34 d dry period or T (▲) traditional 55 d dry period shown for: A) All cows; B) Younger cows (second lactation); and C) Older cows in their third or greater lactation. Differences between treatment groups were analyzed at 5 d intervals by Chi Square analysis and significant differences are shown directly on the Kaplan-Meier curves with an asterisk (* indicates $P<0.05$) or a pound sign (# indicates $0.05 \leq P < 0.1$) with lines connecting points with similar statistical differences. Reprinted with permission of Elsevier from [25].

ended at 70 d postpartum, reproductive performance of cows was monitored beyond 70 d. Cows that were on the 0 d dry treatment had fewer days to first AI, higher first service conception rate, fewer services per conception, and fewer days open. We suspect that these benefits were due to differences in EB. However, because there were limited cows numbers in this trial and cows were not on experiment beyond 70 d, these results were interpreted with caution.

A second study [23, 25] was conducted utilizing a large commercial dairy herd to facilitate greater replication and examine effects of shorter dry periods on metabolic disorders and reproduction. The drawback of doing this type of trial is the inability to monitor feed intake and EB. Animals were assigned to the trial if they met the following criteria: 1) milk production greater than or equal to 18 kg milk/d at 180 d carried calf, 2) less then 300 DIM at 180 d carried calf. Cows (n=772) were assigned to either a 55 (traditional dry period, T) or 34 d dry period (shortened dry period, S). Dry cows on C were fed a low-energy diet until 34 d before their expected calving date and then all cows (C and S) were fed a moderate-energy transition diet until calving. All cows were fed the same lactation diet after calving. Cows were milked 4 times/d for the first 28 DIM and 3 times/d thereafter.

Cows were observed for days to first ovulation, days to first AI, first service conception rate, days open, and percentage of cows pregnant at 150 DIM. Blood samples were taken weekly starting at 14 DIM for progesterone, which was used to determine days to first ovulation (circulating progesterone > 1 ng/ml). Breeding to observed estrus, after removal of tail chalk, began at 45 DIM and continued until 70 DIM when the Ovsynch protocol was initiated. Cows that had not ovulated by 70 DIM were considered anovular. The timed AI after Ovsynch took place at 80–86 DIM and a total of 37% of the first breedings were by timed AI. Body condition score was recorded once weekly for each animal starting at 4 wk prior to expected calving and was terminated at 9 wk after calving. For statistical analysis, cows were categorized as young (second lactation following calving) or old (third or greater lactation after calving).

Average days dry for T and S were 55.5 and 34.0. For treatment T, 90% of the cows had a dry period that ranged from 44 to 65 d, while for treatment S, 90% of the cows had a dry period that ranged from 20 to 45 d.

For the first 100 d postpartum, cows assigned to T produced more milk (43.6 *vs*. 41.5 kg/d) and tended to produce more solids-corrected milk (SCM; 38.6 *vs*. 37.4 kg/d) than cows on S. It is important to note that there was a treatment x parity interaction: younger cows accounted for treatment differences in milk and SCM yield. There was no effect of dry period length on production by older cows. Milk fat percentage did not differ between treatments, but milk protein percentage was greater for cows assigned to S (2.83 *vs*. 2.68%)

Median days until first postpartum ovulation occurred sooner for S compared to T (35 *vs*. 43 d; Fig. 3). This confirmed results from our earlier study with fewer cows [6]. The percentage of cows that were classified anovular by 70 DIM was more than two-fold greater for cows on T than S (18% *vs*. 8%). Although we were unable to measure EB in this study, we speculate that a reduction in negative EB after a shorter dry period is likely to account for the earlier postpartum ovulation and reduction in anovular cows by 70 DIM. Body condition score was lower for cows on T than although the difference was small (3.07 *vs*. 3.01). The postpartum NEFA concentrations were lower for cows assigned to S compared with T (337 *vs*. 428 μEq/l).

There was a reduction in days to pregnancy when cows had a shorter dry period length (Fig. 4), but only for older cows (third lactation or greater). There was a 20 d reduction in days open for older cows that had a shorter dry period compared to a traditional dry period length (113 *vs*. 133). At 300 DIM, 85% of cows in both treatments were pregnant. There was some evidence that the improvement in days to pregnancy found in our study might be related to earlier post-partum AI and to improvements in conception rate. Cows with a shorter dry period had, at least numerically, an earlier time to first detected estrus/AI and more cows were bred prior to the timed AI than for cows with a longer dry period. For example, a total of 54% of S cows received AI prior to 69 DIM (when Ovsynch began) compared to only 45% of T cows. Conception rate tended to be greater in older cows on S than T combining data from first and second service (32% vs. 24%). Thus, shortening the dry period appeared to increase reproductive efficiency in older cows perhaps by shortening time to first ovulation, reducing numbers of anovular cows, and improving fertility.

Conclusion

Obtaining substantial reductions in negative energy balance of early postpartum cows will be difficult to do through nutritional modification of dry or transition period diets. Shortening or eliminating the dry period is a management tool that can fundamentally alter the gestation-lactation cycle to create a more favorable energy status for early lactation cows and improve reproductive efficiency. This can be accomplished with minimal losses in milk production, particularly for cows that are entering their third or greater lactation.

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