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Effect of dry period length on milk yield over multiple lactations

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ABSTRACT

Shortening or omitting the dry period (DP) can improve the energy balance of dairy cows in early lactation through a decrease in milk yield after calving. Little is known about the effect of a short or no DP on milk yield over multiple lactations. Our objectives were (1) to assess the effect of DP length over multiple lactations on milk yield, and (2) to assess if the prediction of milk yield in response to DP length could be improved by including individual cow characteristics before calving. Lactation data (2007 to 2015) of 16 Dutch dairy farms that apply no or short DP were used to compute cumulative milk yield in the 60 d before calving (additional yield) and in the 305 d after calving (305-d yield), and the mean daily yield over the interval from 60 d before calving to 60 d before next calving (effective lactation yield). The DP categories were no (0 to 2 wk), short (3 to 5 wk), standard (6 to 8 wk), and long (9 to 12 wk). The effect of current DP and previous DP on yields was analyzed with mixed models (n = 1,420 lactations). The highest effective lactation yield of fat- and protein-corrected milk (FPCM) was observed for cows with a standard current DP (27.6 kg per day); a daily decrease was observed of 0.6 kg for a long DP, 1.0 kg for a short DP, and 2.0 kg for no DP. Previous DP did not significantly affect the effective lactation yield. Thus, cows can be managed with short or no DP over consecutive lactations without a change in quantity of milk losses. Cows that received no DP for consecutive lactations had a lower additional yield before calving (−172 kg of FPCM), but a higher 305-d yield (+560 kg of FPCM), compared with cows that received no DP for the first time. This could lessen the improvement of the energy balance in early lactation when no DP is applied a second time compared with the first time. For the second objective, a basic model was explored to predict effective lactation yield based on parity, DP length, and first-parity 305-d yield (n = 2,866 lactations). The basic model was subsequently extended with data about recent yield, days open, and somatic cell count. Extending the model reduced the error of individual predictions by only 6%. Therefore, the basic model seems sufficient to predict the effect of DP length on effective lactation yield. Other individual cow characteristics can still be relevant, however, to make a practical and tailored decision about DP length.
Key words: continuous milking, yield prediction, commercial farms

INTRODUCTION

A dry period (**DP**) of 42 to 60 d is common practice in dairy cow management (Dix Arnold and Becker, 1936). The conventional DP facilitates the replacement of senescent mammary epithelial cells (Capuco et al., 1997) and maximizes milk yield in the next lactation (Kuhn et al., 2005). However, the DP is a challenge for the cow due to the process of drying off and the accompanied transitions in management (Ingvartsen, 2006; Zobel et al., 2015). In addition, the high milk yield with limited feed intake after a conventional DP results in a negative energy balance in early lactation that may last several months (Rastani et al., 2005; van Knegsel et al., 2014). This negative energy balance is associated with metabolic disorders and reduced fertility (Collard et al., 2000; Butler, 2003). To improve the energy balance, health, and fertility, and to ease the transition period, the DP can be shortened or omitted (Andersen et al., 2005; Gümen et al., 2005; Rastani et al., 2005; Chen et al., 2015).

Effects of short or no DP on milk yield in the subsequent lactation have been documented for experimental and commercial farms (Rastani et al., 2005; Santschi et al., 2011a; Steeneveld et al., 2013; van Knegsel et al., 2014). Meta-analyses showed that milk yield after calving (over periods of varying duration) decreased by

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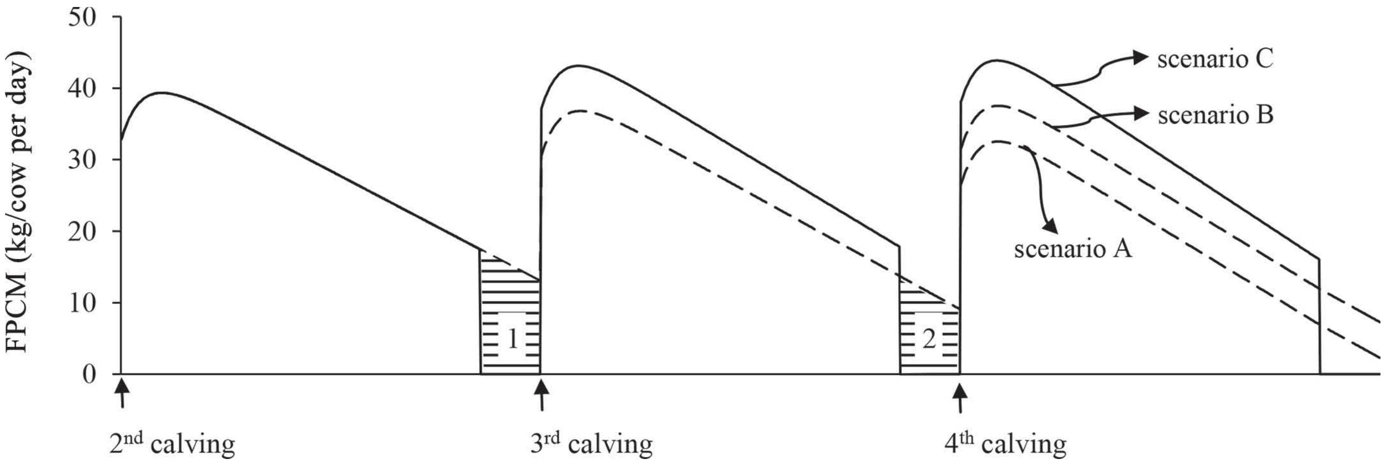

Figure 1. Scenarios for milk yield over time when a standard (solid line) or no (dashed line) dry period is applied before the third and fourth calving. Additional milk before calving (shaded area) is higher when no dry period is applied for the first time (1) than for the second (2) time. When no dry period is applied a second time, yield after calving could decrease further (scenario A), stabilize (scenario B), or increase up to the level after a standard dry period (scenario C). FPCM = fat- and protein-corrected milk.

4.5% for a short DP (4 to 5 wk) and by 19.1% for no DP, whereas protein content of the milk increased by 0.06% for a short DP and by 0.25% for no DP (van Knegsel et al., 2013). These milk losses after calving, however, were compensated partly, sometimes completely, by the additional milk yield before calving (van Knegsel et al., 2013).

The additional milk yield before calving (when the former lactation is extended) increases with a shorter DP and depends on the parity of the cow (van Knegsel et al., 2014). Moreover, calving interval can be shortened by short and no DP (Gümen et al., 2005; Santschi et al., 2011b), which increases mean daily milk yield after calving, and can further compensate milk losses (Kok et al., 2016). To account for additional yield before calving and for differences in calving interval, the measure "effective lactation yield" was developed to compare milk yield between cows with different DP lengths (Kok et al., 2016). The effective lactation yield was defined as the mean daily yield over the interval from 60 d before calving to 60 d before next calving, and was applied to young cows (parity 2). The 305-d yield of young cows was reduced by 23% after no DP compared with a standard DP, whereas the effective lactation yield was reduced by only 12% (Kok et al., 2016).

Adoption of a short or no DP on commercial farms is currently hindered by uncertainty of the effect on milk yield over multiple lactations and differences in response between cows (Santschi et al., 2011a; van Knegsel et al., 2013). So far, it is unclear how milk yield is affected when the DP is shortened or omitted for multiple consecutive lactations. The first omission or shortening of the DP reduces peak milk yield after calving with no or limited effects on persistency (Schlamberger et al., 2010; Santschi et al., 2011a; Chen et al., 2016a), which likely results in less additional milk at the end of that lactation. When the DP is shortened or omitted a second time, milk yield after calving could be reduced, remain the same, or increase compared with the first time the DP was shortened or omitted (scenarios are visualized in Figure 1). A further reduction of milk yield could result from increased carryover of senescent, less functional, mammary epithelial cells into the next lactation (Capuco et al., 1997; Annen et al., 2007, 2008; Collier et al., 2012). Milk yield could stabilize or increase if cows adapt to continuous milking (Rémond and Bonnefoy, 1997), perhaps through increased renewal of mammary epithelial cells during lactation (Capuco et al., 2001).

Regarding individual responses to short or no DP, cow characteristics, such as milk yield and persistency in late lactation, can improve the prediction of additional milk yield before calving (Steeneveld et al., 2014). It is unknown if such variables improve prediction of effective lactation yield in response to DP length. Individual prediction of overall milk yield could facilitate decisions about DP length at cow level (Grummer and Rastani, 2004).

Our objectives were (1) to assess the effect of DP length over multiple lactations on milk yield on commercial dairy farms, and (2) to assess if the prediction of milk yield for individual cows in response to DP length could be improved by cow characteristics before calving. The effective lactation yield was used for both objectives. In addition, milk yield before and after calving were analyzed separately over multiple lactations, because timing of milk yield can affect the energy balance of the cow.

MATERIALS AND METHODS

Data and Data Processing

This study used data from 16 commercial Dutch dairy farms that recently (mostly in 2010 and 2011) changed their DP management from conventional to short or no DP (Kok et al., 2016). Dry cows were generally housed in a group of nonlactating cows, and fed a DP ration, whereas cows with no DP remained in the lactating herd. Milk yield and composition were recorded every 4 to 6 wk, from January 2007 through September 2015, by the Dutch national milk recording system (CRV, Arnhem, the Netherlands). Test-day milk records were matched with drying off records, provided by the farmers, by cow identity, parity, and calving date. Matched data were validated (described in Kok et al., 2016) and used to compute lactation length and DP length.

Milk records with missing values for milk yield, fat content, or protein content were excluded, because all were required to compute fat- and protein-corrected milk (**FPCM**). The FPCM was computed as milk (kg) × [0.337 + 0.116 × fat content (%) + 0.06 × protein content (%)] (CVB, 2012). To improve data quality, each lactation was included only when the following 4 criteria were met: a first record before 50 DIM; at least 5 records in total; a maximum period of 90 d between records; and at least 1 record after 215 DIM or less than 90 d before drying off. Lactations after a DP that exceeded 12 wk (about 5%) were excluded from the analyses. The final data set included 2,074 first, 2,176 second, and 3,924 third and higher parity lactations. Standard lactation curves per parity were estimated from test-day records until 600 DIM for kg milk, fat, protein, lactose, and FPCM, using the Wilmink curve (Wilmink, 1987). The full mixed model in SAS (version 9.3, SAS Institute Inc., Cary, NC) to obtain Wilmink curves for yield was

$$\text{Yield (DIM)} = \text{parity} + \text{DIM} + \text{expDIM} + \text{DIM} \times \text{parity} + \text{expDIM} \times \text{parity},$$

with parity classes 1, 2, and ≥3, DIM at the test-day, and expDIM computed as $e^{(-k \times DIM)}$. Moreover, the model included random effects on intercept, DIM, and expDIM for repeated measures per cow lactation (8,174 lactations; 89,400 records), assuming unstructured covariance (type = UN). Parameter k in expDIM was determined with a grid search, in which k was varied between 0.01 and 0.10, with steps of 0.01. We selected the value for k that resulted in the smallest deviance; this is the maximum likelihood estimator for k. Only significant fixed effects based on Kenward-Roger approximate *F*-tests were retained in the model ($P < 0.05$; Kenward and Roger, 1997).

Next, individual yield records were interpolated and extrapolated using the estimated standard lactation curves, and subsequently summed to compute cumulative yields per cow lactation (method described in CRV, 2002; ICAR, 2009; Kok et al., 2016). Per cow lactation, the following yields were computed: yield in the 60 d before calving (additional yield), 305-d yield, and effective lactation yield of fat, protein, lactose, milk, and FPCM. The cumulative effective lactation yield, from 60 d before calving to 60 d before subsequent calving, was subsequently divided by the calving interval and expressed as effective lactation yield in kilograms per day (Kok et al., 2016). To facilitate comparison between 305-d yield and effective lactation yield, 305-d yield was also expressed in kilograms per day.

Analysis 1: Effect of Dry Period Length on Milk Yield Over Multiple Lactations

The analysis was performed using 1,420 lactations with known current DP length, previous DP length, and first lactation production of the cow (Table 1). The DP categories were no (0 to 2 wk; 19%), short (3 to 5 wk; 21%), standard (6 to 8 wk; 47%), and long (9 to 12 wk; 13%). In the no DP category, 89% of the lactations had no DP (0 d), whereas 11% of the lactations had a DP of 1 to 17 d. We assessed the effect of the fixed effects previous DP, current DP, parity class (3, or ≥4 after calving; NB: parity 2 cows have no previous DP), and their interactions on effective lactation yield, additional yield before calving, and 305-d yield after calving, using mixed models and REML. Inclusion of the fixed effects was based on Kenward-Roger approximate *F*-tests, using backward elimination ($P < 0.05$). Moreover, herd was included as a random effect, and first-parity 305-d yield (kg of FPCM) was included as a fixed covariate in the models. Fat, protein, lactose, milk, and FPCM effective lactation yields, additional yields, and 305-d yields were analyzed. Moreover, additional yield was analyzed separately for each DP category, because variances differed between categories (Levene's test on residuals). Pairwise comparisons were performed using Wald tests (Cox and Hinkley, 1974). When the current DP × previous DP interaction was significant ($P < 0.05$), the effect of the previous DP was

Table 1. Sample sizes (no. of lactations) for analyses of effective lactation yields of fat, protein, lactose, milk, and fat- and protein-corrected milk (analysis 1; n per previous dry period) and for the basic model for effective lactation yield (analysis 2; n per parity category)

Current dry period	Analysis 1 (n = 1,420)				Analysis 2 (n = 2,866)	
	No	Short	Standard	Long	Parity 2	Parity ≥3
No	191	39	111	16	292	357
Short	63	89	112	31	357	295
Standard	74	107	371	52	686	604
Long	18	37	74	35	111	164

compared for each current DP length separately. When previous DP affected yield within the current DP category, data were presented separately for each previous DP category. When previous DP did not affect yield within the current DP category, data were clustered per current DP category. Subsequently, comparisons between the different resulting categories were made using the ESTIMATE statement to specify contrasts.

The same model structure and approach were used to assess the effect of previous and current DP on (the natural logarithm of) days open, defined as calving interval minus 280 d (Kok et al., 2016). Mean values (LSMEANS) of the lognormal distribution were transformed back to median days open [median(X) = exp(μ); Johnson et al., 1994].

Analysis 2: Effect of Cow Characteristics on Prediction of Effective Lactation Yield

A mixed model with DP category, parity class (2, or ≥3 after calving), and first-parity 305-d yield (tonnes of FPCM) as fixed effects and a random herd effect was used to explain effective lactation yield (kg FPCM per cow per day) in the subsequent lactation (basic model). Second-parity cows (n = 1,446; see Table 1) were included in this analysis because analysis 1 showed no effect of previous DP length on effective lactation yield of FPCM. Moreover, parity 3 and parity ≥4 cows were clustered because their effective lactation yield of FPCM was not significantly different.

To assess whether the precision of prediction of individual effective lactation yield (kg of FPCM per cow per day) could be improved, 6 variables that would be available at the moment of the DP decision in practice were extracted from test-day records. Three of these variables, to reflect each cow's actual yield and udder health, were extracted from the last test-day record before 70 d before calving (i.e., available before the DP decision is made): kg of FPCM, natural logarithm of SCC (transformation to normalize data), and a binary value that reflected SCC ≤250,000 or >250,000 cells per mL on the test day. The fourth variable, to reflect persistency, was the change in yield between the last (before 70 d before calving) and the before-last test-day (kg of FPCM per day). The final 2 variables, as indicators of yield level and fertility, were the 305-d yield (kg of FPCM per day) and (natural logarithm of) days open of the lactation preceding the lactation of interest.

The 6 variables were added as fixed effects to the basic mixed model, including interaction effects with DP and parity class (extended model). Potential explanatory variables and their interactions were tested for their predictive value with approximate *F*-tests (Kenward and Roger, 1997). The *F*-tests were constructed based on leave-one-out (similar to the use of type II sums of squares in conventional ANOVA), but also on backward and forward elimination ($P < 0.05$). Results of these different approaches were basically the same. The final extended model that was selected using backward elimination is shown in the results.

To assess the precision of prediction of effective lactation yield for individual cows, residuals of the basic and extended models were assessed. Residuals consisted of the random herd effect and the individual error because, in practice, herd effects are unknown when a decision to shorten DP length is first made. To facilitate interpretation of the mixed model analyses, Pearson correlations were calculated between variables in the final model.

RESULTS AND DISCUSSION

Analysis 1: Effect of Dry Period Length on Milk Yield Over Multiple Lactations

Effective Lactation Yield. The highest effective lactation yield of FPCM was observed for cows with a standard current DP (27.6 kg per cow per day); a daily decrease was observed of 0.6 kg for a long DP, 1.0 kg for a short DP, and 2.0 kg for no DP (Table 2). These yields were achieved over an overall median calving interval of 383 d. Median calving interval, analyzed

Table 2. Effect of current dry period[1] on effective lactation yield[2] (least squares means and standard errors) of fat, protein, lactose, milk, and fat- and protein-corrected milk (FPCM)

	Fat		Protein		Lactose		Milk		FPCM	
Dry period	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
No	1,082[a]	28	871[a]	25	1,031[a]	30	23.2[a]	0.6	25.6[a]	0.7
Short	1,115[b]	28	895[b]	25	1,102[b]	30	24.5[b]	0.6	26.6[b]	0.7
Standard	1,159[c]	27	911[c]	24	1,157[c]	30	25.7[c]	0.6	27.6[c]	0.6
Long	1,132[b]	29	886[ab]	25	1,143[c]	31	25.4[c]	0.6	27.0[b]	0.7

[a–c]Different letters within the same column indicate different means ($P < 0.05$; n = 1,420 lactations).

[1]Previous dry period did not affect the effective lactation yield of fat, protein, lactose, milk, or FPCM.

[2]Fat, protein, and lactose in grams per cow per day; milk and FPCM in kilograms per cow per day.

as days open, was 8 to 18 d shorter for cows with no DP than for cows with a short, standard, or long DP (Table 3; parity ≥3). We found no effect of previous DP or parity on effective lactation yield for FPCM, fat, protein, lactose, and milk ($P \geq 0.05$), except that third-parity cows produced 16 g of fat per day less than older cows ($P < 0.05$). The effective lactation yield reflects the average milk yield per day and corrects for differences in calving interval (Kok et al., 2016). Therefore, the maximum average daily milk yield per lactation was obtained with a standard DP, despite a longer average calving interval. Further research is necessary to assess the overall effect of DP length on farm performance. For example, applying a short or no DP might lower involuntary culling through improved fertility, thus increasing the average age and reducing replacement costs.

Additional Yield. No DP resulted in the highest additional yield over the 60 d before calving, with 857 kg of FPCM (SE: 48.5) for third parity cows and 791 kg of FPCM (SE: 48.2) for older cows. Additional yields for cows with a short DP (501 kg of FPCM; SE: 34.9) or standard DP (187 kg of FPCM; SE: 10.2) did not differ between parities. Other studies reported similar additional yields (over the 56 d before calving) for multiparous cows (Annen et al., 2004; Schlamberger et al., 2010; van Knegsel et al., 2014). The different quantities of additional yield can be explained by an increased number of days in lactation in case of fewer days dry, and by a higher lactation persistency in younger cows (second parity before calving) than older cows (Wood, 1969). Additional yield was lower for cows that previously had no DP than for cows that previously had a short, standard, or long DP. Compared with a standard previous DP, no previous DP reduced additional yield by 172 kg of FPCM in case of no DP, 85 kg of FPCM in case of a short DP, and 51 kg of FPCM in case of a standard DP (Figure 2A). This reduction could be expected: omitting the DP was previously found to reduce peak milk yield with limited effects on persistency (Schlamberger et al., 2010), which results in a lower daily milk yield after calving, and consequently, a lower additional yield in the current DP (Figure 1).

305-d Yield. After calving, the lowest mean daily 305-d yield of FPCM was observed for cows with no DP (28.8 kg), and it was lower for cows with a short DP (30.9 kg) than for cows with standard (32.7 kg) or long (33.1 kg) DP (Table 4; Figure 2B). A short DP reduced 305-d yield by 1.8 kg of FPCM per day compared with a standard DP. Similar milk yield reductions of 1.1 kg per day (until 17 wk postcalving) and 1.9 kg per day (until 210 DIM) have been reported after a short DP of 28 and 30 d, respectively (Annen et al., 2004; Pezeshki et al., 2008).

Table 3. Effect of dry period length on days open (DO) of parity 2 (included in analysis 2 only; n = 1,446) and parity ≥3 cows (n = 1,420)[1]

Dry period (wk)	Parity 2			Parity ≥3		
	Median DO	P1	P99	Median DO	P1	P99
0–2	86[a]	25	305	94[a]	29	347
3–5	90[a]	31	353	102[b]	30	376
6–8	100[b]	32	338	105[b]	41	331
9–12	114[c]	41	394	112[b]	38	375

[a–c]Different letters within the same column indicate different means ($P < 0.05$).

[1]Data are presented as median DO [backtransformed from LSM of ln(DO)], and 0.01 percentile (P1) and 0.99 percentile (P99) of the data.

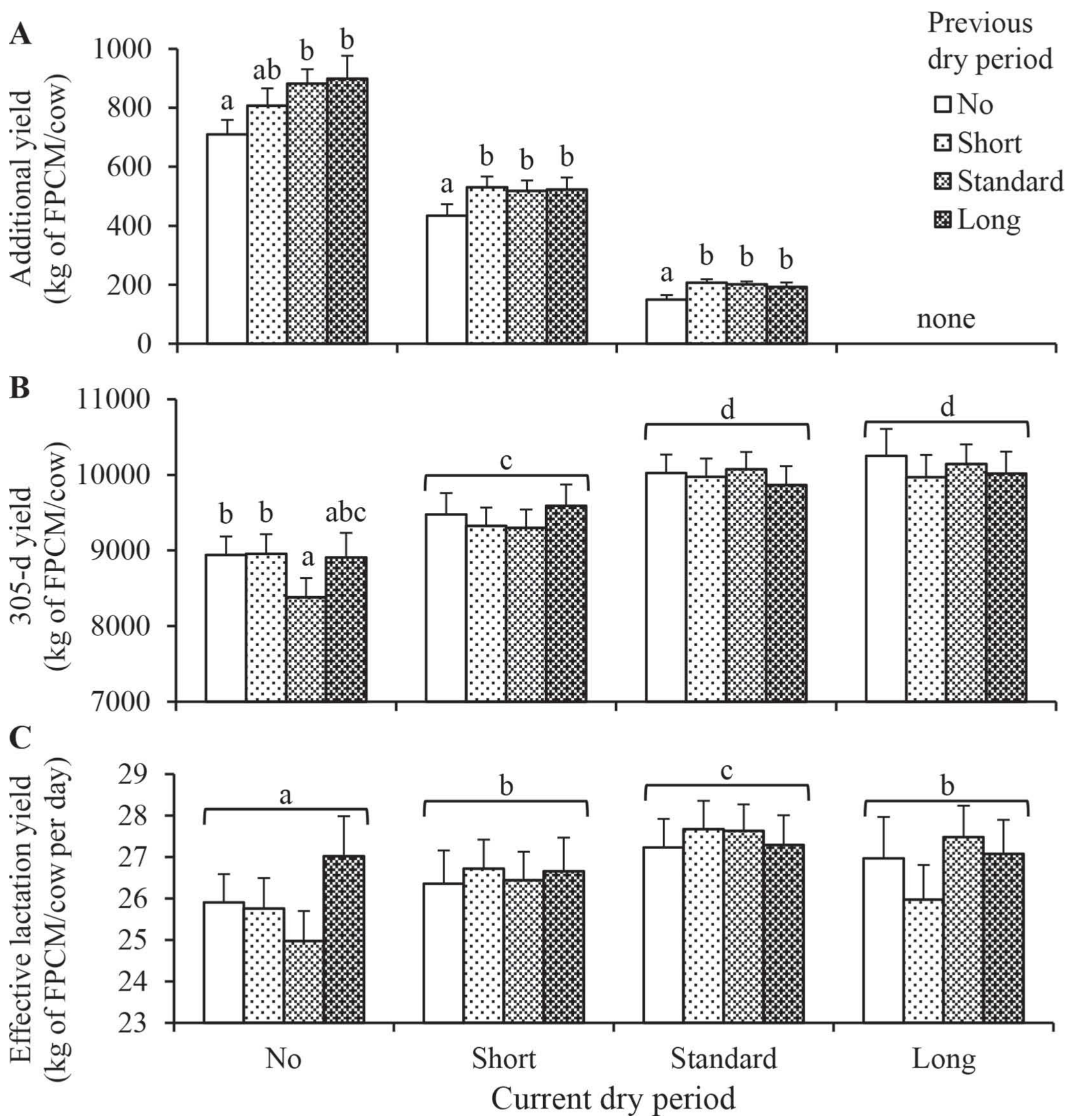

Figure 2. Effect of previous dry period (legend) on additional yield in the 60 d before calving (A; n = 2,010 lactations), 305-d yield (B; n = 2,010 lactations), and effective lactation yield (C; n = 1,420 lactations) for cows with no, a short, a standard, or a long dry period. Data are presented as LSM and SE. In A, different letters within the same current dry period category indicate differences between means; in B and C, different letters indicate differences between means. FPCM = fat- and protein-corrected milk.

Table 4. Effect of dry period length and previous dry period length on 305-d yields[1] of fat, protein, lactose, milk, and fat- and protein-corrected milk (FPCM), presented as LSM and SE

Dry period	Previous dry period	Fat		Protein		Lactose		Milk		FPCM	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
No	All	366[a]	10								
	No			298[b]	9	366[b]	12	26.9[b]	0.8	29.3[b]	0.8
	Short			302[b]	10	371[b]	14	27.3[b]	0.9	29.4[b]	0.9
	Standard			284[a]	9	339[a]	12	25.0[a]	0.8	27.5[a]	0.8
	Long			299[abc]	12	362[ab]	18	26.6[ab]	1.2	29.2[abc]	1.2
Short	All	391[b]	10	317[c]	9	395[c]	11	28.9[c]	0.8	30.9[c]	0.8
Standard	All	422[c]	9	327[d]	9	420[d]	11	30.6[d]	0.7	32.7[d]	0.8
Long	All	424[c]	10	328[d]	9	428[d]	12	31.2[d]	0.8	33.1[d]	0.8

[a–d]Different letters within the same column indicate different means ($P < 0.05$; n = 2,010 lactations).

[1]Fat, protein, and lactose in total 305-d yield (kg); milk and FPCM in kilograms per day.

The length of the previous DP affected only FPCM yield of cows that had no current DP (Figure 2B): cows that previously had a standard DP produced 560 kg less than cows that previously had no DP, and 572 kg of FPCM less than cows that previously had a short DP. The 305-d milk yield after one omission of the DP (after a standard previous DP), was 5.6 kg of milk per day lower than after a standard current DP (25.0 vs. 30.6 kg of milk per day, see Table 4), similar to yield reductions of 5.0 and 7.7 kg of milk per day reported in literature (Mantovani et al., 2010; Schlamberger et al., 2010). The reduction in milk yield likely results from reduced renewal of mammary epithelial cells when the DP is omitted, which results in an increased carryover of senescent, less functional cells into the next lactation (Capuco et al., 1997; Annen et al., 2007, 2008; Collier et al., 2012). The 305-d milk yield after a second omission of the DP was higher than after the first omission of the DP (intermediate between scenario B and C in Figure 1; 26.9 kg of milk per day), which compensated the reduction in additional yield before calving compared with the first omission of the DP (Figure 2C). It can be hypothesized that the lower milk yield and improved energy balance after one omission of the DP (Gümen et al., 2005; van Knegsel et al., 2014) facilitate more renewal of mammary epithelial cells throughout lactation (Capuco et al., 2001). More renewal of mammary epithelial cells throughout lactation can be expected to result in a higher secretory activity after a second omission of the DP, despite the absence of the DP. Because the current study is based on commercial milk records only, these physiological questions could not be addressed. Higher yields after a second omission of the DP might also be due to a selection effect: farmers could give a DP to cows with lower yields after a first omission of the DP and omit the DP multiple times for cows with higher yields. However, a lower additional yield and an increased 305-d yield after the second omission of the DP were also reported in an experimental study (n = 17 cows with no DP; Chen et al., 2016a). Cows with a long previous DP and no current DP had yields similar to cows after multiple omitted DP, but this result is based on few lactations (n = 16; Table 1).

Protein, lactose, and milk yields after no current DP were also found to be lower after a standard previous DP, as compared with no or a short previous DP (Table 4). No such interaction between current and previous DP was found for 305-d fat yield. There was an effect of previous DP length on fat yield: omission of the previous DP increased fat yield in the current lactation compared with a short or a standard previous DP, irrespective of current DP length. Fat yield after omission of the previous DP was 12 kg (SE: 4 kg) higher compared with a standard previous DP, and 10 kg (SE: 4 kg) higher compared with a short previous DP.

Parity did not influence protein and lactose yields ($P \geq 0.05$), whereas third-parity cows produced 7.1 kg (SE: 2.5) less fat, 0.6 kg per day (SE: 0.19) less milk, and 0.5 kg per day (SE: 0.18) less FPCM than older cows ($P < 0.05$).

A main reason to apply short and no DP strategies is to improve the energy balance, and related metabolic health and fertility, of dairy cows in early lactation (Collier et al., 2004; Grummer et al., 2010). Energy balance in early lactation was greater for cows with no DP than for cows with a short DP, and greater for cows with a short DP than for cows with a conventional DP (Rastani et al., 2005; van Knegsel et al., 2014). A reduction in yield precalving and an increase in yield postcalving, when no DP is applied multiple times, is expected to lessen the improvement of the energy balance in early lactation. Chen et al. (2016b) indeed reported a more negative energy balance in the 9 wk after the second short or omitted DP than after the first short or omitted DP. No DP likely results in the least negative energy balance in early lactation, even over multiple lactations, because this strategy results in the greatest reduction in milk yield (Table 4), combined with a similar or increased feed intake compared with a standard DP (Rastani et al., 2005; van Knegsel et al., 2014). A short DP can also be applied without changes in ration and thereby ease the transition period (Rastani et al., 2005). A short DP results in smaller milk losses than no DP. It can be questioned whether these smaller milk losses sufficiently improve the energy balance, metabolic health, and fertility of cows. Further research is needed to elucidate the effect of short and no DP on health, disease incidences, and longevity (van Knegsel et al., 2013) and to assess the overall effect of DP length on farm performance.

Analysis 2: Effect of Cow Characteristics on Prediction of Effective Lactation Yield

The basic model to predict effective lactation yield (kg of FPCM per cow per day) consisted of a random herd effect, the covariate first-parity 305-d yield, parity, DP, and a DP × parity interaction (Table 5). Compared with a standard DP, the FPCM effective lactation yield of parity ≥3 cows was reduced by 2.2 kg per day in case of no DP (2.0 kg in analysis 1) and 1.1 kg in case of a short DP (1.0 kg in analysis 1). Second parity cows, despite fewer days open (Table 3), had lower effective lactation yields than older cows, and a greater FPCM loss (2.8 kg per day) when no DP was applied

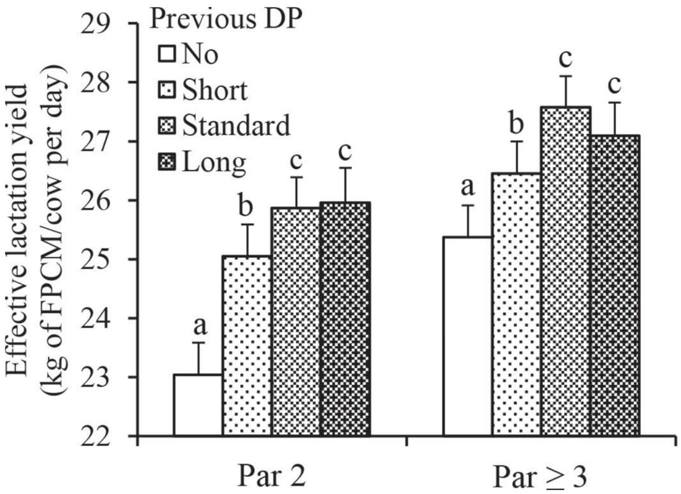

Figure 3. Effect of dry period (legend) and parity (par) category on effective lactation yield (n = 2,866 lactations). Data are presented as LSM and SE. Different letters within the same parity category indicate differences between means. FPCM = fat- and protein-corrected milk.

as compared with a standard DP ($P < 0.05$; Figure 3). van Knegsel et al. (2014) also reported a greater reduction in milk yield for second-parity cows than for older cows when the DP was omitted. One explanation could be that continued mammary development between the first and second lactation is impaired when the DP is omitted, resulting in a greater reduction in milk yield for second-parity cows than for older cows (Collier et al., 2012).

The main question in analysis 2 was whether the prediction of individual cows' effective lactation yield after different DP lengths could be improved by including individual cow characteristics into the model. If variation between cows in response to DP length could be predicted more precisely, this could be used for tailored decisions about DP length (Grummer and Rastani, 2004).

The 2 test-day records before the DP decision, which provided individual cow characteristics for the extended model, occurred at 88 (SD: 12) d and 121

Table 5. Final basic model[1] and extended model[2] for effective lactation yield [kg of fat- and protein-corrected milk (FPCM) per cow per day; coefficient and SE]; and the SD of the residuals for predictions per lactation for each model

	Basic model			Extended model		
Effect	β	SE	*P*-value	β	SE	*P*-value
Constant[3]	17.1	0.68	<0.01	8.8	0.97	<0.01
Level[4]	1.4	0.06	<0.01	0.8	0.08	<0.01
Parity						
2 versus ≥3	−1.7	0.17	<0.01	−0.6	0.69	0.35
Dry period			<0.01			0.89
No versus standard	−2.2	0.23	<0.01	0.1	0.58	0.84
Short versus standard	−1.1	0.22	<0.01	−0.2	0.58	0.74
Long versus standard	−0.5	0.27	0.07	0.1	0.60	0.83
Dry period × parity[5]			0.02			0.01
No × parity 2	−0.6	0.30	0.04	−0.8	0.29	<0.01
Short × parity 2	0.3	0.29	0.30	0.1	0.29	0.67
Long × parity 2	0.6	0.41	0.16	0.2	0.41	0.65
Extra cow characteristics						
Persistency before last test-day[6]				−2.8	0.71	<0.01
Yield at last test-day				0.16	0.02	<0.01
Previous 305-d yield				0.10	0.02	<0.01
Previous ln(days open)				1.25	0.14	<0.01
Yield at last test-day × parity						
2 versus ≥3				0.07	0.03	0.02
Previous 305-d yield × parity						
2 versus ≥3				−0.07	0.03	0.03
Yield at last test-day × dry period						<0.01
Yield at last test-day × no				−0.11	0.03	<0.01
Yield at last test-day × short				−0.04	0.03	0.10
Yield at last test-day × long				−0.01	0.03	0.63
SD of residual (n lactations)	3.56	(2,866)		3.33	(2,803)	

[1]Basic model: based on dry period, parity, and first-parity 305-d yield.

[2]Extended model: based on variables of the basic model and individual cow characteristics before calving.

[3]Population mean of cows in parity 3 and older, with a standard dry period.

[4]First-parity 305-d yield in tonnes of FPCM.

[5]Compared with cows in parity 3 and older, with a standard dry period.

[6]Last test-day before 70 d before calving.

(SD: 15) d before calving. The variables for SCC at the last test-day (as binary and continuous variable) did not improve predictions and were eliminated from the final extended model ($P \geq 0.05$). The final extended model did include calving interval and yield variables (Table 5). A lower persistency between the last 2 test-days, higher 305-d and last test-day yields, and more days open in the previous lactation were all related to a higher effective lactation yield in the subsequent lactation. These relations were irrespective of DP length, except that a higher yield at last test-day resulted in a smaller increase in effective lactation yield for cows with no DP than for cows with a standard DP.

The positive relations of recent yield with effective lactation yield may be expected because cows with a high yield at the last test-day and a high 305-d yield before calving are likely high-yielding cows in an extended lactation and after calving. The correlation of yield level across lactations was our motivation to include first-parity 305-d yield in the basic model as a covariate of lactation yield potential. First-parity 305-d yield was less important in the extended model than in the basic model, implying that the inclusion of other variables made this variable partially redundant. Indeed, previous 305-d yield was identical to, or highly correlated with, first-parity 305-d yield (identical for parity 2 and r: 0.61 for parity ≥3), and yield at the last test-day also correlated with first-parity 305-d yield (r: 0.67 for parity 2 and r: 0.33 for parity ≥3).

The negative relation between persistency before calving and effective lactation yield seems to be in contrast with the positive relation between yield before calving and effective lactation yield. Although there was no interaction between persistency and parity (2 vs. ≥3) to explain effective lactation yield, this relation may be explained partly by younger cows being more persistent and at the same time having lower (effective lactation) yields than older cows (Santschi et al., 2011a). Moreover, the positive relation between days open and effective lactation yield may be caused by a weak positive correlation (r: 0.18) of (the natural logarithm of) days open with first-parity 305-d yield, which could be explained by impaired fertility in cows with higher yield levels (Butler, 2003).

Compared with the basic model, the SD of the residuals of the extended model was reduced by only 6%. The extended model did not add much insight, and therefore, the basic model seems sufficient to predict the effect of DP length on effective lactation yield. The correlations between different yield variables may explain why additional yield variables barely improved the fit of the basic model.

Although additional information on cow characteristics did not improve predictions of effective lactation yield, variables such as SCC, milk yield, and persistency around 3 mo before calving can be relevant in a tool to select the best DP strategy for a dairy cow for other reasons than effective lactation yield. For example, high yield and high persistency before calving can pose a risk for cow welfare when drying off (Rajala-Schultz et al., 2005; Zobel et al., 2015), and at the same time indicate that the cow would be capable of a continuous lactation. In contrast, high yield levels and low persistency at 3 mo before expected calving could indicate that drying off at a month before calving, when yield is likely much lower, is suitable, whereas no DP is not feasible. Finally, high SCC could be indicative of an intramammary infection, which could require a DP to facilitate treatment with an intramammary antibiotic.

CONCLUSIONS

Shortening or omitting the DP can improve the energy balance of dairy cows in early lactation through a decrease in milk yield after calving. Cows submitted to short DP produced less milk than cows submitted to standard DP, but the quantity of this loss did not change when a short DP was applied over consecutive lactations. Consecutive omissions of the DP also decreased milk production as compared with a standard DP. Consecutive omission of the DP reduced the additional milk produced before calving and increased the milk production after calving, compared with the first omission of the DP. Individual cow characteristics did not improve the prediction of individual response of yield to DP length based on parity and first lactation 305-d yield, but may be relevant to make a practical decision about DP length. Further study is needed to assess the effect of short or no DP on farm performance; the reduced milk yield may be compensated by improved health and fertility, which could increase cow longevity.

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