

Effects of Dry Period Length on, Milk Production and Composition, Blood Metabolites and Complete Blood Count in Subsequent Lactation of Holstein Dairy Cows

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Abstract—Twenty - nine Holstein cows were used to evaluate the effects of different dry period (DP) lengths on milk yield and composition, some blood metabolites, and complete blood count (CBC). Cows were assigned to one of 2 treatments: 1) 60-d dry period, 2) 35-d DP. Milk yield, from calving to 60 days, was not different for cows on the treatments ($p=0.130$). Cows in the 35-d DP produced more milk protein and SNF compare with cows in treatment 1 ($p \leq 0.05$). Serum glucose, non-esterified fatty acids (NEFA), beta hydroxyl butyrate acid (BHBA), blood urea nitrogen (BUN), urea, and glutamic oxaloacetic transaminase (GOT) were all similar among the treatments. Body condition score (BCS), body weight (BW), complete blood count (CBC) and health problems were similar between the treatments. The results of this study demonstrated we can reduce the dry period length to 35 days with no problems.

Keywords—complete blood count, dairy cows, dry period, milk yield

I. INTRODUCTION

VARYING the length of the dry period for dairy cows has been an active area of research investigation and field application for the past several years. Assuming that there are no detrimental effects on production or health during the subsequent lactation, the benefits of shortening the dry period for high-producing cows are obvious. Therefore, recently, there has been an interest in shortening the non-income-producing dry period. If the dry period can be reduced sufficiently, the need for a “far-off” dry cow group may be eliminated [13]. This can reduce over-crowding of dry cow facilities that is common on farms.

On many farms, shortening of dry period can eliminate the need to transfer far-off cows to a second farm and hence the cow stress and inconvenience associated with such moves. The traditional dry cow program involves two diet changes within a three-week period. One change occurs when the cow is moved to a “close-up” pen and another occurs when the cow begins lactation. If the dry period could be shortened, it may be possible to feed a more uniform diet throughout the lactation-gestation cycle [12].

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Also reducing the dry period from 60 d has been considered beneficial if additional milk yield from extending the lactation offsets or exceeds any loss in milk yield the following lactation [13]. Milk components must also be considered when determining the economic feasibility of shortening the dry period, especially for countries on quota system [25].

Effects of DP length, metabolic and infectious diseases of cows should also be considered when selecting an optimal DP length.

However, optimal DP length may vary depending on parity, calving interval, level of milk production, etc [13]. Research evaluating the dry period requirement in dairy cows suggests that a 2-month dry period is optimal and that a dry period 40 d results in reduced milk yields in the succeeding lactation [6]-[11]-[28] and [18]. However, much of those data were derived from retrospective analyses of dairy records rather than planned experiments. Subsequent milk yields for unplanned short dry periods likely are less than the yields which follow planned, because with the planned scenario, the dairy farmer manages the cow to best prepare her to transition into a profitable lactating state by monitoring her body condition and providing an appropriate dietary regimen as calving approaches [4]. Even in other studies, a 30-35d dry period did not affect milk production in the next lactation [15]-[23]-[22].

Information relating the effects of DP to subsequent performance and immune system of lactating cows is sparse. Therefore, the objective of this study was to determine whether shortening the dry period would affect the milk production and composition, blood metabolites and immune system in subsequent milk production.

II. MATERIAL AND METHODS

A. Cows, Treatment and Experimental Design

Holstein cows ($n = 29$) were randomly assigned in 1 of 2 treatments: 1) traditional 60 d dry period ($n=14$), 2) 35-d dry period ($n=15$). Holstein cows were blocked by parity (2nd and 3rd to 5th), their previous 305-day milk yield and expected calving dates. All cows were fed by routine ration of farm (total mixed diet) twice a day at 0800 and 1400 h and had at all times free access to water. Cows were housed in stalls during the entire DP and lactation. The Ferdowsi University of Mashhad and Department of Animal Science Animal Care and

Use Committees approved all procedures involving experimental cows.

B. Body Condition Scoring and Body Weight

Body condition score and body weight was recorded every week from entering to experiment to 60 days after parturition. The same assessor assigned BCS to each cow using a 5-point scale (1 = thin to 5 = fat) [9] with 0.25-unit increments.

C. Milk Sampling

Cows were milked 3 times per day at 0100, 0900 and 1700 h and yields were recorded. Milk samples were collected from each milking on 1 d per wk and composited for analysis of milk composition (Micro Scan; FOSS Electric A/s, Denmark).

D. Blood Sampling

Using vacutainer tubes, blood samples were collected weekly from entering to experiment to 60 days after calving via venipuncture of coccygeal vessels before the morning feeding to monitor serum metabolites. Serum was separated after collection by centrifugation (15min at 3,000×g) and stored at -20°C until analysis for metabolites. Also to monitor complete blood count (CBC), about 1.5ml from the blood samples poured in vacutainer tubes with EDTA. These samples were kept in room temperature until analyzing for CBC. Complete blood counts were automatically determined with a hematology analyzer (Symex K 1000, TOA Ltd., Tokyo, Japan).

E. Statistical Analyses

Milk yield and composition, BW, BCS and blood metabolites were analyzed by using a mixed model (PROC MIXED, SAS Inst. Inc., Cary, NC)[26] for a completely randomized design with repeated measures using the following model:

$$Y = \mu + T_i + A(i)j + D_k + (T \times D)_{ik} + R_{ijk}$$

Where,

Y = Dependent variable.

μ = Overall mean.

T = Treatment effects.

A = Random effects of animal within treatments.

D = Effects of sampling day or time.

T×D = Interaction effects of treatment and sampling day or time.

R = Residual error associated with the ijk observation

III. RESULTS AND DISCUSSION

A. Milk yield and Composition

The effects of treatment on milk yield and milk composition are shown in Table I. There were no differences in postpartum milk yield between treatments ($p=0.130$).

Similar postpartum milk production between cows on the treatment 1 and 2 is consistent with the finding of [29]-[3]-[22] and [15]. But references [31]-[24] and [34] suggested that managing cows for dry periods of approximately 30 to 35 days resulted in decreased milk yield during the subsequent lactation compared to cows given 60-day dry periods.

In addition, reference [6] reported a decrease in milk production during the subsequent lactation for cows with a DP < 40d. A nonsecretory state, where epithelial cells of the mammary gland do not contain secretory vesicles, is reached by 35 d prepartum with a 60-d DP [5]. Beyond 35 d prepartum, the presence of secretory vesicles in epithelial cells increased as parturition approached in cows with 60- and 0-d DP [5]. However, at 7 d prepartum, only 62% of mammary epithelial cells demonstrated secretory activity in cows with no DP, while 98% of the epithelial cells had secretory activity in cows with a 60-d DP [5].

Milk yield responses to shortened DP is variable, suggesting that there may be interaction between animal characteristics or management and health of the DP. However, some researchers believed that short dry periods reduce milk production in the subsequent lactation in several species, including cattle, rats, and humans [2]; in cattle, this occurs because of reduced mammary epithelial cell turnover and secretory capacity [2].

TABLE I
LEAST SQUARE MEANS OF MILK YIELD AND COMPOSITION

	Dry Periods (Day)		SEM	P-Value		
	60	35		Dry Period	Week	Dry Period × week
Milk yield ¹	36.48	34.90	0.73	0.130	< .0001	0.521
Milk fat, %	3.89	3.84	0.12	0.774	0.139	0.761
Milk Protein, %	3.05 ^a	3.16 ^b	0.03	0.013	< .0001	0.307
Milk lactose, %	4.56 ^a	4.71 ^b	0.05	0.050	< .0001	0.148
Milk SNF, %	8.36 ^a	8.63 ^b	0.09	0.044	< .0001	0.167
Fat yield, kg	1.39	1.17	0.08	0.061	0.063	0.258
Protein yield, kg	1.11	0.94	0.07	0.120	< .0001	0.665
Lactose yield, kg	1.66	1.40	0.11	0.115	< .0001	0.738
SNF yield, kg	3.05	2.58	0.21	0.119	< .0001	0.632

¹ to 60 Days in milk

Based on these data and milk production data from our experiment and that of others [32]-[30]-[25], a DP (at least 35

d) is necessary to achieve maximal milk production in the subsequent lactation.

There was a tendency ($P = 0.01$) for increased milk protein percentage postpartum for cows on the shortened DP=to 35-d compared with cows on the traditional dry period=60d.

However, there were no differences in milk protein yield between treatments. Our data are in agreement with [24]; some researchers believe that there is an inverse relationship between milk protein percentage and milk yield response when altering DP length [13] and also [25] believe that an increase in milk protein percent may be the result of reduced milk yield, improving energy balance and thereby sparing amino acids and energy for protein synthesis.

References [33] and [15] did not report any significant differences between milk protein percentage on 30d dry period and 60d dry period. However, reference [31] reported that milk protein yield was increased when cows were given a traditional DP compared with a shortened dry period (calculated milk protein percentage was 3.4 and 3.5%, respectively).

Milk lactose percentage and milk SNF percentage was greater for cows on the shortened dry period= 35d compared with cows on the dry period =60d ($p=0.05$ and 0.04 , respectively), but no differences in SNF yield, milk fat percentage and yield, milk lactose yield for cows on the treatments. References [19]-[15]-[33] and [22] also reported no difference in milk fat percentage and milk fat yield in the subsequent lactation for cows with 35-d and 60-d DP.

Also, references [31] and [23] reported a decrease in milk fat yield in the subsequent lactation for cows with a 4-wk DP compared with a 7-wk DP. Our data about milk lactose

percentage is not in consistent with [7] and [20] that showed no significant difference between treatments about milk lactose percentage, of course they compared 7-wk or 8-wk dry period with no planned dry periods.

B. Body Weight and BCS changes

Metabolic disorders have been associated with BW or BCS loss. As might be expected, in experiments in which eliminating [32]-[25] or shortening [10] the DP reduced milk production in the subsequent lactation, BW losses were concurrently reduced.

However, based on our data, during the entire course of the study (prepartum and postpartum), cows BW and BCS changes were not affected by treatments (Table II).

The effect of week in body weight ($p<0.001$) and body condition score ($p \leq 0.05$) at postpartum was significant between treatments.

Decreased postcalving body condition score demonstrated that cows experienced negative energy balance.

Unsimilar to our data, reduction in BCS loss after parturition by giving short dry periods is reported by others [32]-[10]-[15].

References [24] and [14] demonstrated that BCS at calving was similar among experimental groups (28-d vs. 56-d and 30-d vs. 70-d dry periods, respectively), but [24] found that postcalving BCS loss for the 56-d dry period group was greater than that of 28-d dry period group.

So our data explained that there is no difference between treatments about negative energy balance.

TABLE II
LEAST SQUARE MEANS OF BODY WEIGHT AND BODY CONDITION SCORE

	Dry Periods (Day)		SEM	P-Value		
	60	35		Dry Period	Week	Dry Period \times Week
Body condition score						
Prepartum ¹	2.86	2.90	0.20	0.915	0.111	0.111
Postpartum ²	2.49	2.53	0.19	0.898	0.053	0.416
Body weight (kg)						
Prepartum	726.93	746.09	20.44	0.904	< .0001	0.821
Postpartum	644.27	646.21	18.82	0.942	< .0001	0.682

¹ -3 week to 0 relative to calving

² 1 week to 7 week relative to calving

C. Serum Metabolites

Serum metabolites are presented in Table III. Although numerically higher concentrations of NEFA were found in cows in 60-d dry period compared with the 35-d dry periods, there was no difference between treatments in postpartum serum NEFA concentration ($p=0.58$); this data is consistent with [19] that reported concentrations of NEFA were similar between cows with 30-d and 60-d dry period. Reference [24] also, reported that postpartum plasma NEFA concentration did not differ when the dry period was reduced from 56 to 28 d. The effect of week in NEFA concentration at postpartum was significant between treatments ($P < 0.001$).

Our data about postpartum serum NEFA concentrations are in opposite with [34] that reported postpartum NEFA concentrations were lower for cows assigned to shortened 34-d dry period compared with 55-d DP.

Also, references [7] and [1] showed that postpartum NEFA concentrations significantly higher in cows with 7 or 8 week dry period than no planned dry period ($p=0.02$).

During the periparturient period, cows undergo dramatic physiological changes associated with parturition and the initiation of lactation and experience numerous changes in feeding and management [13].

Serum NEFA concentration is an indicator of fat mobilization [35]-[17]-[27].

The higher NEFA concentration reflects a higher rate of lipolysis in the adipose tissue [21]. The NEFA are potential substrates for ketogenesis in the liver [16].

TABLE III
LEAST SQUARE MEANS OF NEFA¹, BHBA², GLUCOSE, BUN³, UREA AND GOT⁴

	Dry Periods (Day)		SEM ⁵	P-Value		
	60	35		Dry Period	Week	Dry Period × Week
NEFA (mmol/L) ⁶	0.793	0.743	0.06	0.588	<0.001	0.254
BHBA (mmol/L) ⁶	0.726	0.740	0.10	0.924	0.008	0.551
Glucose (mg/dL)						
-3 wk to 0 wk ⁶	54.34	56.95	2.02	0.370	<0.001	0.121
1 wk to 7 wk	45.91	47.34	1.48	0.498	0.001	0.974
BUN (mg/dL) ⁶	14.928	13.833	0.91	0.411	0.079	0.670
Urea (mg/dL) ⁶	31.947	29.603	1.95	0.411	0.079	0.670
GOT (U/l) ⁶	87.629	82.028	6.38	0.546	0.007	0.649

¹ NEFA= Non-Esterified Fatty Acid EM

² BHBA = Beta Hydroxy Butyrate Acid

³ BUN = Blood Urea Nitrogen

⁴ GOT = Glutamic oxaloacetic transaminase

⁵ SEM = Standard Error of Mean

⁶ Postpartum = from 1 wk to 7 wk

⁷ wk = Week relative to calving

These data suggested that cows with a 7 or 8-week dry period were in a greater negative energy balance in the early postpartum period, most likely due to higher milk yields. But in our study, we showed milk yields and NEFA concentrations have no different between treatments.

Postpartum serum BHBA concentrations like NEFA were similar between treatments ($p=0.92$). The effect of week in BHBA concentrations at postpartum was significant between treatments ($P=0.008$).

Reference [24] also reported that there are no treatment effects on postpartum plasma BHBA. Reference [7] compared standard 8 week for dry period and no planned dry period and reported that there were no differences in plasma BHBA concentrations between the dry period treatments from week -3 to 3 and from week 4 to 12 relative parturition.

Reference [20] reported that the same results about plasma BHBA concentrations when cows assigned in 7-week dry period and no planned dry period treatments.

However, reference [1] reported that the significant difference between treatments (7-wk dry period vs. no planned dry period) about postpartum plasma BHBA concentrations ($p=0.04$).

There were no prepartum and postpartum differences in serum glucose concentrations for cows in treatments ($p=0.37$ and $p=0.49$, respectively).

Nevertheless, the effect of week in serum glucose concentrations was significant ($p < 0.001$) at prepartum and postpartum ($p=0.001$) between treatments.

Our data are in agreement with the observations [22] who reported no difference in prepartum and postpartum serum glucose between 56-d, 42-d and 35-d dry period lengths. Reference [24] also showed no difference in prepartum serum glucose between 28-d and 56-d dry period lengths.

We also observed no differences in postpartum BUN, urea and GOT concentrations between treatments. Reference [1] reported no difference in prepartum and postpartum plasma urea nitrogen between treatments (49-d vs. omission of the dry period).

D. Complete Blood Count and Immunology Responses

Effect of dry period lengths on complete blood count are summarized in Table IV.

Dry period lengths have no effect on complete blood count and immunology factors. There is no research on effect of dry period lengths on immune system.

The high incidence of health problems during the transition period contributes to the variation in DMI, milk yield, and responses to imposed treatments [8].

However, our data showed that imposed treatments in this study (dry period lengths) had no effect on health problems and metabolic disorders.

TABLE IV
LEAST SQUARE MEANS OF COMPLETE BLOOD COUNT¹

	Dry Periods (Day)		SEM	P-Value		
	60	35		Dry Period	Week	Dry Period × Week
WBC ² , /μL	12277	13468	1991.31	0.729	0.700	0.803
RBC ³ , /μL	5283037	5363237	102438	0.582	0.001	0.922
HGB ⁴ , g/dL	8.08	8.11	0.14	0.914	<.0001	0.605
HCT ⁵ , %	27.97	28.24	0.49	0.699	<.0001	0.782
PLT ⁶ , /μL	250271	286354	16517.5	0.128	0.0006	0.848
Neutrophils, no	3445.30	3622.66	193.47	0.519	0.587	0.196
Lymphocytes, no	7703.88	8920.23	1578.58	0.589	0.861	0.651
Monocytes, no	68.61	716.54	98.57	0.825	0.706	0.761
Eosinophils, no	173.77	152.77	22.68	0.515	0.804	0.520

¹ from -1 wk to 7 wk relative to calving

² WBC = White Blood Cell

³ RBC = Red Blood Cell

⁴ HGB = Hemoglobin

⁵ HCT = Hematocrit

⁶ PLT = Platelet

The effect of week was significant between treatments for Red Blood Cells ($p=0.001$), Hemoglobin, Hematocrit and platelets ($p < 0.001$).

IV. CONCLUSION

The results indicate that shortening the dry period from 60 to 35 d does not have appreciable effects on milk production. However, reducing targeted dry period length to 35-d increased milk SNF and milk protein and lactose percentage. In addition shortening DP length to 35 d had no negative influences on BW, BCS, some serum metabolites, complete blood count and finally immune system. However, follow-up research should be done to study the effect of short dry periods on long-term health and longevity in the herd.

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REFERENCES

- [1] J. B. Andersen, T. G. Madsen, T. Larsen, K. L. Ingvarsen, and M. O. Nielsen. The effects of dry period versus continuous lactation on metabolic status and performance in periparturient cows. *J. Dairy Sci.* 88:3530–3541. 2005.
- [2] E. L. Annen, R. J. Collier, M. A. McGuire, J. L. Vicini, J. M. Ballam, and M. J. Lormore. Effect of modified dry period lengths and bovine somatotropin on yield and composition of milk from dairy cows. *J. Dairy Sci.* 87:3746–3761. 2004.
- [3] K. C. Bachman. Milk production of dairy cows treated with estrogen at the onset of a short dry period. *J. Dairy Sci.* 85:797–803. 2002.
- [4] K. C. Bachman and M. L. Schairer. Invited review: Bovine studies on optimal lengths of dry periods. *J. Dairy Sci.* 86:3027–3037. 2003.
- [5] A. V. Capuco, R. M. Akers, and J. J. Smith. Mammary growth in Holstein cows during the dry period: Quantification of nucleic acids and histology. *J. Dairy Sci.* 80:477–487. 1997.
- [6] C. E. Coppock, R. W. Everett, R. P. Natzke, and H. R. Ainslie. Effect of dry period length on Holstein milk production and selected disorders at parturition. *J. Dairy Sci.* 57:712–718. 1974.
- [7] M. A. De Feu, A. C. O. Evans, p. Lonergan, and S. t. Butler. The effect of dry period duration and dietary energy density on milk production, bioenergetic status, and postpartum ovarian function in Holstein-Friesian dairy cows. *J. Dairy Sci.* 92: 6011–6022. 2009.
- [8] J. K. Drackley. Biology of dairy cows during the transition period: The final frontier. *J. Dairy Sci.* 82:2259–2273. 1999.
- [9] A. J. Edmonson, I. J. Lean, L. D. Weaver, T. Farver, and G. Webster. A body condition scoring chart for Holstein Dairy Cows. *J. Dairy Sci.* 72:68–78. 1989.
- [10] E. Farries and S. Hoheisel. The influence of reduced dry periods on some performance and metabolism traits in dairy cows. *J. Dairy Sci.* 72(Suppl.1):565. (Abstr.) 1989.
- [11] D. A. Funk, A. E. Freeman, and P. J. Berger. Effects of previous days open, previous days dry and present days open on lactation yield. *J. Dairy Sci.* 70:2366–2373. 1987.
- [12] R. R. Grummer. Strategies to improve fertility of high yielding dairy farms: Management of the dry period. *Theriogenology* 68s: s281–s288. 2007.
- [13] R. R. Grummer and R. R. Rastani. Why reevaluate dry period length? *J. Dairy Sci.* 87(E-Suppl.):E77–E85. 2004.
- [14] M. S. Gulay, M. J. Hayen, H. H. Head, C. J. Wilcox, and K. C. Bachman. Milk production from Holstein half udders after concurrent thirty- and seventy-day dry periods. *J. Dairy Sci.* 88: 3953–3962. 2005.
- [15] M. S. Gulay, M. J. Hayen, K. C. Bachman, T. Belloso, M. Liboni, and H. H. Head. Milk production and feed intake of Holstein cows

- given short (30-d) or normal (60-d) dry periods. *J. Dairy Sci.* 86:2030–2038. 2003.
- [16] R. N. Heitmann and J. M. Fernandez. Autoregulation of Alimentary and Hepatic Ketogenesis in Sheep. *J. Dairy Sci.* 69:1270–1281. 1986.
- [17] K. L. Ingvarsen and J. B. Andersen. Integration of metabolism and intake regulation: A review focusing on periparturient animals. *J. Dairy Sci.* 83:1573–1597. 2000.
- [18] J. W. Klein and T. E. Woodward. Influence of length of dry period upon the quantity of milk produced in the subsequent lactation. *J. Dairy Sci.* 26:705–713. 1943.
- [19] E. Lotan and J. H. Adler. Observations on the effect of shortening the dry period on milk yield, body weight, and circulating glucose and FFA levels in dairy cows. *Tijdsch. Diergeneeskd.* 101:77–82. 1976.
- [20] T. G. Madsen, M. O. Nielsen, J. B. Andersen, and K. L. Ingvarsen. Continuous lactation in dairy cows: Effect on milk production and mammary nutrient supply and extraction *J. Dairy Sci.* 91:1791–1801. 2008.
- [21] D. Mashek, K. L. Ingvarsen, J. B. Andersen, M. Vestergaard, and T. Larsen. Effects of a four-day hyperinsulinemic-euglycemic clamp in early and mid-lactation dairy cows on plasma concentrations of metabolites, hormones, and binding proteins. *Domest. Anim. Endocrinol.* 21:169–185. 2001.
- [22] A. Pezeshki, J. Mehrzad, G. R. Ghorbani, H. R. Rahmani, R. J. Collier, and C. Burvenich. Effect of short dry periods on performance and metabolic status in Holstein dairy cows. *J. Dairy Sci.* 90:5531–5541. 2007.
- [23] R. R. Rastani, R. R. Grummer, S. J. Bertics, A. Gumen, M. C. Wiltbank, D. G. Mashek, and M. C. Rich. Effects of varying dry period length and prepartum diet on metabolic profiles and lactation of periparturient dairy cattle. *J. Dairy Sci.* 86(Suppl. 1):154. (Abstr.) 2003.
- [24] R. R. Rastani, R. R. Grummer, S. J. Bertics, A. Gumen, M. C. Wiltbank, D. G. Mashek, and M. C. Schwab. Reducing dry period length to simplify feeding transition cows: Milk production, energy balance, and metabolic profiles. *J. Dairy Sci.* 88:1004–1014. 2005.
- [25] B. Remond, J. Kerouanton, and V. Brocard. The effect of reducing or omitting the dry period on the performance of dairy cows. *Prod. Anim.* 10:301–315. 1997.
- [26] SAS Institute. User's Guide: Statistics. Version 8 ed. SAS Institute, Cary, NC. 1999.
- [27] H. Seifi, M. Gorji-Dooz, M. Mohri, B. Dalir-Naghadeh, and N. Farzaneh. Variations of energy-related biochemical metabolites during transition period in dairy cows. *Comp. Clin. Pathol.* 16:253–258. 2007.
- [28] L. R. Schaeffer and C. R. Henderson. Effects of days dry and days open on Holstein milk production. *J. Dairy Sci.* 55:107–112. 1972.
- [29] M. L. Schairer. Estrogen treatments for the initiation of dry off in dairy cows. M.S. Thesis. Univ. Florida, Gainesville. 2001.
- [30] A. Smith, J. V. Wheelock, and F. H. Dodd. Effect of milking throughout pregnancy on milk secretion in the succeeding lactation. *J. Dairy Res.* 34:145–150. 1967.
- [31] J. T. Sorensen and C. Enevoldsen. Effect of dry period length on milk production in subsequent lactation. *J. Dairy Sci.* 74:1277–1283. 1991.
- [32] E. W. Swanson. Comparing continuous milking with sixty-day dry periods in successive lactations. *J. Dairy Sci.* 48:1205–1209. 1965.
- [33] R. D. Watters, J. N. Guenther, A. E. Brickner, R. R. Rastani, P. M. Crump, P. W. Clark, and R. R. Grummer. Effects of Dry Period Length on Milk Production and Health of Dairy Cattle. *J. Dairy Sci.* 91:2595–2603. 2008.
- [34] J. W. Wilton, E. B. Burnside, and J. C. Rennie. The effects of days dry and days open on the milk and butterfat production of Holstein-Friesian cattle. *Can. J. Anim. Sci.* 47:85–90. 1967.
- [35] D. A. Whitaker, W. J. Goodger, M. Garcia, B. Perera, and F. Wittwer. Use of metabolic profiles in dairy cattle in tropical and subtropical countries on smallholder dairy farms. *Prev. Vet. Med.* 38:119–131. 1999.