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Milk Production of Dairy Cows Treated With Estrogen at the Onset of a Short Dry Period[1]

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ABSTRACT

The objective was to determine whether the use of estradiol-17β (E_2) at the initiation of short dry periods prevented an anticipated decline in milk production in the subsequent lactation. Lactating Holstein cows (n = 66) were dried at either 60 or 30 d before expected calving. Treatments in a 2 × 2 factorial arrangement included: D60 (n = 19, 60-d dry, no E_2), D60 + E_2 (n = 18, 60-d dry, E_2), D30 (n = 15, 30-d dry, no E_2), and D30 + E_2 (n = 14, 30-d dry, E_2). To accelerate mammary involution, estradiol-17β (15 mg in 4 ml of ethanol) was injected subcutaneously daily for 4 d beginning 30 d before expected calving. Parturitions occurred between November 1995, and March 1996. Actual days dry for respective treatments were 57.3, 60.6, 33.9, and 33.8 ± 1.7 d. Onset of parturition, calving difficulty, and cow health were not affected by E_2. Actual 305-d milk yields for the lactation completed immediately before the experimental dry period were 10,318, 10,635, 10,127, and 10,447 ± 334 kg, respectively; and were 9942, 9887, 9669, and 10,172 ± 387 kg, respectively, for the lactation immediately following treatment. Respective pre- and posttreatment mature equivalent 305-d yields were 9574, 9861, 9812, and 9724 ± 297 kg; 8987, 8843, 9126, and 9008 ± 294 kg. Milk yields did not differ across treatments. Cows with a 34-d dry period were as productive as cows with a 59-d dry period. Estradiol-17β had no effect, but perhaps should be evaluated with dry periods shorter than 34 d.
(**Key words:** dry period, milk yield, estrogen, involution, mammary)

Abbreviation key: D60 = treatment group with 60-d dry, no estradiol-17β; **D60 + E_2** = 60-d dry plus estradiol-17β; **D30** = 30-d dry, no estradiol-17β; and **D30 + E_2** = 30-d dry plus estradiol-17β; **ME** = mature equivalent.

INTRODUCTION

For profitable production of milk, a nonlactating or dry period is established between lactations of the dairy cow. It is anticipated that the quantity of milk that is forfeited during the dry period will be recovered during the ensuing lactation, the milk production of which has been enhanced by inclusion of a preceding dry period (Swanson, 1965; Smith et al., 1966; Keown and Everett, 1986; Sorenson and Enevoldsen, 1991; Remond et al., 1997). Changes that occur in bovine mammary tissue during the dry period that promote increased milk production during the ensuing lactation include replacement of senescent mammary epithelial cells and an increase in the epithelial component of the mammary tissue (Capuco et al., 1997). Based on retrospective analyses of milk yield data, these desired changes apparently occur optimally if dry periods are initiated 60 to 51 d before the expected dates of calving (Schaeffer and Henderson, 1972; Keown and Everett, 1986). In practice, dry periods of < 40 d duration are not recommended (Coppock et al., 1974; Funk et al., 1987) as an earlier-than-expected parturition would result in a dry-period length that is considered to be too short to prepare the cow and mammary gland for the ensuing lactation.

The observation (Athie et al., 1996, 1997) that estradiol-17β (**E_2**) administered at final milk removal accelerated the involution of bovine mammary tissue, suggested the possibility that dry period length could be decreased to <40 d without a loss of milk production during the subsequent lactation. If successful, this elimination of the far-off phase of traditional dry periods should allow management of the dry cow to be modified to thereby improve the transition of the cow back into her full-lactating status (Goff and Horst, 1997).

The objective of this study was to determine whether treatment with E_2 at initiation of a 30-d dry period resulted in milk production during the subse-

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quent lactation that equaled the milk production that followed a 60-d dry period. For comparison, a 30-d dry period without exogenous E_2 was included as a negative control and a 60-d dry period with E_2 administered beginning at 30-d before expected calving was also included. To date, only two other animal trials have been designed specifically to compare bovine milk production following dry period lengths of 30 and 50 to 60 d (Coppock et al., 1974; Sorensen and Enevoldsen, 1991).

MATERIALS AND METHODS

Holstein cows with previous on-site production records were dried at about 60 d (n = 37) or 30 d (n = 29) before their expected dates of calving. Within each dry period length category, some cows (n = 18 and 14, respectively) at 30 d before their expected parturitions received the estradiol-17β (**E_2**) treatment, which has been shown to accelerate involution of bovine mammary tissue (Athie et al., 1996, 1997). For those cows, four subcutaneous injections of 15 mg of E_2, (Sigma Chemical Co., St. Louis, MO), dissolved in 4 ml of ethanol, were administered over the ribcage once daily. This 2 × 2 factorial arrangement resulted in the following treatment groups: **D60** = cows with 60-d dry, no estradiol-17β, n = 19; **D60** + **E_2** = cows with 60-d dry plus estradiol-17β, n = 18; **D30** = 30-d dry, no estradiol-17β, n = 15; and **D30** + **E_2** = 30-d dry plus estradiol-17β, n = 14.

The weekly protocol used to dry cows during this study was as follows: Tuesday and Wednesday, milked three times daily; Thursday, not milked; Friday, milked once, infused intramammarily with antibiotics, E_2 administered if assigned, and moved to temporary dry cow lot; Saturday, E_2 administered if assigned; Sunday, E_2 administered if assigned; and Monday, E_2 administered if assigned, hooves trimmed, and moved to dry-cow lot. Cows designated to have 60-d dry periods with E_2 administered beginning at 30 d prepartum received their injections in the hospital barn located adjacent to the dry-cow lot. Based on previous results (Athie et al., 1996), the ethanol excipient was not administered to control cows.

Following the injection phase, cows in the study were managed with anonymity within the 3400 cow herd, located in northern Florida, to facilitate collection of unbiased data related to their parturition, health, and production. Production and management events from DHI records, i.e., age at freshening, calving date, calving difficulty, etc., as compiled during complete lactations were used for comparison of treatments. The general linear models procedure of SAS (1996) was used for least squares analysis of variance. The model used to analyze data from this experiment with treatments in a 2 × 2 factorial arrangement included days dry (D60 vs. D30), E_2-treatment status, their interaction, and cow nested within treatment. To account for possible permanent environmental effects and genetic differences in the production potential of cows assigned to the treatments, actual 305-d milk yields for the lactation that preceded the dry-period treatments under study were included as a covariate in the model to adjust the posttreatment milk yields (Makuza and McDaniel, 1996). Age at freshening and percent DIM that cows had exposure to supplementation with bST also were included individually as covariates in the model to adjust the posttreatment milk yields for those possible sources of variation. Posttreatment milk yields evaluated for dry-period treatment effects were actual 168- and 305-d yields. The 168-d milk yields were included because they represented the milk production of the treatment groups before bST exposure. Use of bST was conservative and was not administered until after midlactation in the cooperating herd at the time of the current study.

Table 1. Management information for cows in the dry period study.

	Dry period treatment[1]				
Measure	D60	D60 + E_2	D30	D30 + E_2	SEM
Cows (n)	19	18	15	14	
Days dry					
Actual (d)[2]	57.3	60.6	33.9	33.8	1.7
Expected (d)[2]	58.5	62.9	34.1	32.7	1.4
Calving period (d)[2,3]	43.5	31.8	68.9	58.7	7.3
Lactation no. (parity)[4]	4.00	3.94	3.33	4.00	.35
Age at freshening (mo)[4]	63.0	62.9	54.5	62.6	4.3
Calving difficulty[5]	1.16	1.06	1.13	1.14	.09
Sick herd					
All reasons (d)	16.7	7.4	9.0	11.3	3.8
Reproductive (d)	5.5	1.2	7.0	4.5	2.4

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.

[2]$P < 0.001$ for days dry.

[3]Day 1 = 24 November 1995 and day 116 = 18 March 1996.

[4]After experimental dry period.

[5]1= No problem, 2 = slight problem, 3 = needed assistance, 4 = considerable force; 5 = extreme difficulty.

RESULTS AND DISCUSSION

Complete records available for treatments D60, D60 + E_2, D30, and D30 + E_2 were from 19, 18, 15, and 14 cows, respectively. The respective least-squares means for days dry were 57.3, 60.6, 33.9, and 33.8 ± 1.7 d (D60 vs. D30, $P < 0.001$, Table 1). Comparison of actual days dry with the expected days dry (Table 1) suggested that the E_2 treatment did not hasten or delay parturition.

Table 2. Milk production measures for the lactation that preceded the experimental dry period.

	Dry period treatment[1]				
Measure	D60	D60 + E_2	D30	D30 + E_2	SEM
Last test date					
DIM[2]	292.6	284.7	313.7	301.4	5.1
Milk yield (kg)[3]	26.5	26.7	21.9	20.1	1.6
Lactation end (dry)					
DIM[4]	300.6	294.5	313.7	306.7	3.9
305-Day milk yield					
Actual (kg)	10,318	10,635	10,127	10,447	334
Mature equivalent (kg)	9574	9861	9812	9724	297

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.

[2]P < 0.001 for days dry; P = 0.05 for E_2-treatment status.

[3]P < 0.001 for days dry.

[4]P < 0.002 for days dry; P = 0.10 for E_2-treatment status.

Calving period for this study was 116 d long, with the birth of the first calf occurring on November 24, 1995, and the birth of the last calf on March 18, 1996. Designation of these calving dates as d 1 and 116, respectively, allowed the spatial distribution of parturitions to be assessed. The resultant least-squares means for day of calving period differed for D60 vs. D30 (P < 0.001, Table 1) but only by a few weeks and not to the extent that season of calving would be considered an important factor affecting the milk yield responses. Assignment and retention of sufficient cows for the D30 categories took longer because milking parlor pressure periodically dictated the need to dry some cows from the milking herd before they reached the extended portion of their current lactations needed to qualify for use in treatments D30 and D30 + E_2. The average number for the lactation (average parity) that followed the experimental dry period did not differ (P = 0.30, Table 1) nor did age at freshening (P = 0.32) differ. Degree of calving difficulty was low and did not differ among treatments (P = 0.55, Table 1). Total days in the sick herd and the days thereof that were related to reproductive function did not differ (P = 0.14 and 0.71, respectively; Table 1). Thus, neither E_2 treatment nor length of dry period apparently affected parturition or postpartum health of the cow.

Information from DHI for the lactation that preceded the experimental dry period is summarized in Table 2. As expected, on their last test dates, cows assigned to the 30-d dry periods had higher DIM (P < 0.001) and lower daily milk yields (P < 0.001) than cows assigned to the 60-d dry period treatments. Lower daily production would be associated with both the usual decline in the lactation curve with increasing DIM plus the negative effect on milk production attributed to advanced stages of pregnancy (Bachman et al., 1988). At the start of dry periods, DIM differed across days-dry groups (P < 0.002, Table 2). Cows within each days-dry category that were scheduled to receive E_2 tended to have shorter lactations (P = 0.10), but differences were small (6 to 7 d). Probably due to chance, prior pregnancies were established at earlier DIM for cows subsequently assigned to receive E_2, thus resulting in slightly shorter DIM at the end of lactation.

Neither the actual nor the mature equivalent (**ME**) 305-d milk yields for the lactation that preceded the experimental dry period differed among treatments (P = 0.99 and 0.53, respectively, Table 2). Based on that result, the milk producing abilities of cows assigned to each treatment were collectively similar for 305 d of lactation.

Milk production information related to the early portion of the lactation that followed the experimental dry period is presented in Table 3. Treatments did not differ for DIM on the first test date for the lactation (P = 0.78) or for DIM on the test date at which peak milk production (highest test-day yield) occurred (P = 0.14). Importantly, peak milk yields did not differ (P = 0.36); nor did summit milk yields (average of two

Table 3. Characteristics of the peak in milk production during the lactation that followed the experimental dry period.

	Dry period treatment[1]				
Measure	D60	D60 + E_2	D30	D30 + E_2	SEM
Test date (DIM)					
First	21.9	21.6	20.1	21.1	2.4
Peak	61.1	59.0	47.0	59.1	4.8
Milk yield (kg)					
Peak[2]	46.1	45.1	44.2	46.2	1.6
Summit[2]	44.5	43.6	43.3	44.6	1.6

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.

[2]Peak = Highest test-day milk yield; Summit = average of the highest two of first three test-day milk yields.

Table 4. Milk production measures for the lactation that followed the experimental dry period.

Measures	Dry period treatment[1] D60	D60 + E_2	D30	D30 + E_2	SEM
Last test date					
DIM	297.1	292.8	289.9	324.3	14.4
Milk yield (kg)[2]	22.0	21.9	26.1	24.5	1.5
DIM at drying	308.4	306.8	299.9	334.9	13.5
305-Day milk yield					
Actual (kg)	9942	9887	9669	10,172	387
Mature equivalent (kg)	8987	8843	9126	9008	294
305-D Milk yield (adjusted)[3]					
Actual (kg)	9978	9763	9799	10,143	353
Mature equivalent (kg)	9011	8761	9214	8989	274
168-Day milk yield					
Actual (kg)	6825	6569	6541	6640	244

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.
[2]$P = 0.03$ for days dry.
[3]Actual 305-d milk yields for the lactation that preceded the experimental dry period were included as a covariate.

highest of first three test-day yields) differ ($P = 0.53$). Peak and summit milk yields were achieved without exogenous bST. Apparently, the combined effect of mammogenesis and lactogenesis on the rate of milk synthesis was similar among treatments. Therefore, similar milk yields for the complete lactations should be anticipated given the comparable management received. That mammary tissue remodeling equal to that achieved during the 59-d dry periods could have occurred within the 34-d dry periods experienced in this study is supported by the observation that mammary growth was initiated within the first 25 d of 60-d dry periods (Capuco et al., 1997).

On the last test date for the lactation that followed the experimental dry period, DIM did not differ for D60 vs. D30 ($P = 0.41$) nor for E_2-treatment status ($P = 0.30$, Table 4). Although DIM were similar, milk yields on the last test date differed ($P = 0.03$) for days dry, in that cows which had 34-d dry periods produced more milk. This unexplained difference persisted when pretreatment actual milk yield, age at freshening, and percentage DIM with bST exposure were included individually as covariates in the model. Subsequent DIM at dry-off did not differ ($P = 0.18$). Thus, relative to cows that had 59-d dry periods, galactopoiesis was sustained to a similar extent throughout the lactations of cows that had 34-d dry periods.

Neither the actual nor the ME 305-d milk yields for the lactation that followed the experimental dry period differed among treatments ($P = 0.48$ and 0.96, respectively; Table 4). Adjustment of these yield measures by including the actual 305-d milk yields for the lactation completed before the experimental dry period in the model as a covariate did not change that conclusion ($P = 0.44$ and 0.96, respectively, Table 4). Therefore, irrespective of E_2 treatment, cows that had 34-d dry periods produced the same amount of milk during 305 d of lactation as the cows that had 59-d dry periods. The individual inclusion of age at freshening (Table 1) and percentage DIM with bST exposure (Table 5) as covariates in the model did not change this conclusion (Table 4).

In addition to the 305-d milk yields, milk yields through 168 DIM were compared (Table 4). Milk production through 168 DIM was achieved without bST. Again, no differences between treatments were observed before ($P = 0.48$) and after ($P = 0.32$) inclusion of the above-mentioned covariates in the model.

That the milk production of the cows assigned 30-d dry periods without E_2 did not differ from the milk production of cows assigned 60-d dry periods was unexpected. It was anticipated, based on the accepted industry recommendation, that the cows with 30-d dry periods and no E_2 would be an appropriate negative control to determine whether inclusion of E_2 with the 30-d dry periods resulted in an increase in milk yield during the subsequent lactation such that the en-

Table 5. Summary of the use of bovine somatotropin during lactations completed before and after the experimental dry period.

Lactation	Dry period treatment[1] D60	D60 + E_2	D30	D30 + E_2	SEM
Before dry period					
Days with bST (%)[2]	27.0	18.0	12.2	14.3	4.6
After dry period					
Days with bST (%)[3]	25.5	27.9	34.3	41.5	3.6

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.
[2]$P = 0.05$ for days dry.
[3]$P = 0.003$ for days dry; $P = 0.11$ for days dry × E_2-treatment status.

Table 6. Summary of dairy herd milk production during experimental period.

Test (mo)	Cows (n)	In milk (%)	Milk (kg)	150-d milk (kg)	Herd average (kg)
NOV 95	3408	86	26.8	33.2	10,147
OCT 96	3467	81	23.9	32.0	9794

hanced production would approach the milk production of the cows given 60-d dry periods. If an increase in milk production had occurred with the inclusion of E_2, it would have suggested that dry periods of dairy cows can be shortened profitably if mammary involution is accelerated by E_2 administered at the onset of the dry period (Athie et al., 1996, 1997). However, based on the results obtained with the cow numbers used in this experiment, the appropriate negative control needed to evaluate E_2 might be a dry period shorter than 34 d.

Present results, albeit with a small number of cows per treatment group, also suggest that the industry recommendation of a 51- to 60-d dry period should be evaluated via animal experiments designed to compare dry period lengths. Of no apparent benefit, in terms of a positive effect on subsequent milk production, were the additional 25 d that cows were dry, not producing income among those with 59-d dry periods. Only one US study (Coppock et al., 1974) used an animal trial, conducted with 65 herds, to determine the optimum length of the dry period. It was concluded that, on average, < 40 d dry will result in a substantial loss in milk production. That 1974 study has been criticized (Sorensen and Enevoldsen, 1991; Sorensen et al., 1993) for the execution of its design and a lack of statistical analysis. The only other animal trial (Sorensen and Enevoldsen, 1991) used dual-purpose cows of mixed breeding managed in eight Danish herds. Milk production after a planned 4-wk dry period was decreased relative to the production that followed the recommended 7-wk dry period. Most studies (Klein and Woodward, 1943; Schaeffer and Henderson, 1972; Dias and Allaire, 1982; Keown and Everett, 1986; Funk et al., 1987; Makuza and McDaniel, 1996) have used retrospective analysis of nonexperimental production data to estimate optimum dry period length. The limitations of this approach include the nonrandom assignment of cows to dry period lengths, which can result in interactions between milk producing ability and dry period length (Coppock et al., 1974; Sorensen and Enevoldsen, 1991; Sorensen et al., 1993).

Considerable milk income is potentially being forfeited by dairy farmers if the modern dairy cow under modern management can retain her milk producing ability with much shorter dry periods than currently recommended and practiced. Using, for purposes of illustration, the milk yields for the last test date that preceded the experimental dry period (Table 2), the milk production forfeited during the additional 25 d of dry status needed to achieve 59 d dry was at least 24 kg per day or a total of 600 kg of milk for each cow. Based on the small number of cows that had 59-d dry periods in our study (n = 37), this forfeited milk was not recovered during the next lactation because no benefit in terms of enhanced milk production was attributable to the additional 25 d dry, i.e., 9911 versus 9918 kg of milk for cows that had 59- and 34-d dry periods, respectively (Table 4, $P = 0.99$). The respective values were 9951 and 9873 kg milk ($P = 0.85$) when percentage DIM with bST exposure was the covariate.

Based on the evaluation of milk production records, the negative impact of a 31- to 40-d versus a 51- to 60-d dry period on actual 305-d milk production has been estimated to be about a 4% decrease in subse-

Table 7. Summary of cow removals from herd.

	Dry period treatment[1]			
Cow removal	D60	D60 + E_2	D30	D30 + E_2
Number	4	3	3	2
Percentage	21.0	16.7	20.0	14.3
Reason [dim (d)/my (kg)][2]				
Reproduction	270/15.0	303/16.8	270/18.1	300/19.5 312/18.6
Production	243/17.2 266/18.1		213/18.1	
Mastitis		249/27.2	190/38.6[3]	
Digestion	212/33.6[3]	287/32.6		

[1]Days dry; E_2 indicates estradiol-17β treatment at 30-d prepartum.

[2]Days in milk/milk yield at time of removal.

[3]Died.

quent milk yield (Keown and Everett, 1986; Makuza and McDaniel, 1996). Assuming that a 4% decrease is correct for a present-day cow and management scenario that supports 10,000 kg of milk production, the total milk production for two consecutive lactations would be unchanged if cows were kept in milk for an additional 20 d to obtain the 400 kg of saleable milk that would be lost in the ensuing lactation as a result of decreasing the preceding dry period by 20 d. Either with or without the use of bST, this level of production in late lactation, i.e., 20 kg/d, is achievable by cows that produce 10,000 kg of milk during a 305-d lactation. Therefore, when parlor pressure does not exist, shorter dry periods can be profitable if milk income per day of continued milking exceeds the difference in the daily variable costs assigned to a cow when she is being managed in the lactating herd instead of the nonlactating herd.

The point at which the additional profit from milk recovered during a lactation extended by a shorter, postponed dry period starts to be exceeded by the loss in milk production and income in the ensuing lactation due to a shorter dry period should determine dry period length (Klein and Woodward, 1943; Dias and Allaire, 1982). In the current study, albeit based on a small number of cows, extension of established lactations by 25 d to have 34-d instead of 59-d dry periods did not reach that point. In contrast, additional milk gained from continuous milking throughout pregnancy with no dry period apparently is more than offset by milk loss in the subsequent lactation (Swanson, 1965; Smith et al., 1966; Capuco et al., 1997; Remond et al., 1997).

Within treatments, milk yields for the lactations that followed (Table 4) the experimental dry period were lower than the yields for the lactations that preceded it (Table 2). These declines in milk yield reflect what occurred for the entire herd (Table 6). Lower quality (data not available) of the corn silage fed likely contributed to this herd-wide decline in production.

To be profitable, short dry periods and E_2 treatment must not predispose cows to early removal from the herd. Based on cow removal information gleaned from DHI records (Table 7), no differences in cow removals among treatments were apparent. Obviously, more records are needed to evaluate the lifetime profitability of cows that have experienced short dry-period protocols within which the efficacy of E_2 treatments is assessed.

CONCLUSIONS

Cows that had 34-d dry periods, irrespective of the use of estradiol-17β, produced amounts of milk during their ensuing 305-d lactations similar to cows that had 59-d dry periods. Dry period lengths of < 34 d should be used, within expanded cow trials, to evaluate the efficacy of the estradiol-17β treatment. Estradiol-17β, when administered about 30 d from expected calving, had no apparent negative effects on the physiology and health status of the cows. Efficacy of dry period lengths < 60 d should be reevaluated via experiments that involve cows from the present genetic pool and that use current nutritional management practices. Shorter dry periods, if proven effective with or without the use of estradiol-17β, could improve the profit margins of dairy farm enterprises, in large part, by reducing the incidence of disorders associated with transition cows as they initiate new lactations.

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REFERENCES

Athie, F., K. C. Bachman, H. H. Head, M. J. Hayen, and C. J. Wilcox. 1996. Estrogen administered at final milk removal accelerates involution of bovine mammary gland. J. Dairy Sci. 79:220–226.

Athie, F., K. C. Bachman, H. H. Head, M. J. Hayen, and C. J. Wilcox. 1997. Milk plasmin during bovine mammary involution that has been accelerated by estrogen. J. Dairy Sci. 80:1561–1568.

Bachman, K. C., M. J. Hayen, D. Morse, and C. J. Wilcox. 1988. Effect of pregnancy, milk yield, and somatic cell count on bovine milk fat hydrolysis. J. Dairy Sci. 71:925–931.

Capuco, A. V., R. M. Akers, and J. J. Smith. 1997. Mammary growth in Holstein cows during the dry period: Quantification of nucleic acids and histology. J. Dairy Sci. 80:477–487.

Coppock, C. E., R. W. Everett, R. P. Natzke, and H. R. Ainslie. 1974. Effect of dry period length on Holstein milk production and selected disorders at parturition. J. Dairy Sci. 57:712–718.

Dias, F. M., and F. R. Allaire. 1982. Dry period to maximize milk production over two consecutive lactations. J. Dairy Sci. 65:136–145.

Funk, D. A., A. E. Freeman, and P. J. Berger. 1987. Effects of previous days open, previous days dry, and present days open on lactation yield. J. Dairy Sci. 70:2366–2373.

Goff, J. P., and R. L. Horst. 1997. Physiological changes at parturition and their relationship to metabolic disorders. J. Dairy Sci. 80:1260–1268.

Keown, J. F., and R. W. Everett. 1986. Effects of days carried calf, days dry, and weight of first calf heifers on yield. J. Dairy Sci. 69:1891–1896.

Klein, J. W., and T. E. Woodward. 1943. Influence of length of dry period upon the quantity of milk produced in the subsequent lactation. J. Dairy Sci. 26:705–713.

Makuza, S. M., and B. T. McDaniel. 1996. Effects of days dry, previous days open, and current days open on milk yields of cows in Zimbabwe and North Carolina. J. Dairy Sci. 79:702–709.

Remond, B., J. Rouel, N. Pinson, and S. Jabet. 1997. An attempt to omit the dry period over three consecutive lactations in dairy cows. Ann. Zootech. 46:399–408.

SAS/STAT Software: Changes and Enhancements Through Release 6.11. 1996. SAS Inst., Inc., Cary, NC.

Schaeffer, L. R., and C. R. Henderson. 1972. Effects of days dry and days open on Holstein milk production. J. Dairy Sci. 55:107–112.

Smith, A., J. V. Wheelock, and A. F. Dodd. 1966. Effect of milking throughout pregnancy on milk yield in the succeeding lactation. J. Dairy Sci. 49:895–896.

Sorensen, J. T., and C. Enevoldsen. 1991. Effect of dry period length on milk production in subsequent lactation. J. Dairy Sci. 74:1277–1283.

Sorensen, J. T., C. Enevoldsen, and T. Kristensen. 1993. Effects of different dry period lengths on production and economy in the dairy herd estimated by stochastic simulation. Livest. Prod. Sci. 33:77–90.

Swanson, E. W. 1965. Comparing continuous milking with sixty-day dry periods in successive lactations. J. Dairy Sci. 48:1205–1209.