Relationship of Yield During Early Lactation and Days Open During Current Lactation with 305-Day Yield

J. K. LEE,*[,1] P. M. VanRADEN,*[,2] H. D. NORMAN,*
G. R. WIGGANS,* and T. R. MEINERT[†,3]
*Animal Improvement Programs Laboratory,
Agricultural Research Service, USDA, Beltsville, MD 20705-2350
[†]National Dairy Herd Improvement Association, Inc., Columbus, OH 43231-4078

ABSTRACT

To measure and to partition the effect of pregnancy on yield, the relationships among milk, fat, and protein yields during early lactation, current days open, and 305-d yields were investigated using sample day records of 247,310 Holstein cows. The model included fixed effects of calving herd-year-season, calving age, and days open; the continuous variable of early cumulative yield to 80, 100, 120, or 140 d; and a random residual effect. As days open during first lactation increased from 30 to 100 d, 305-d milk yield increased by 876 kg; as days open increased from 100 to 200 d, milk yield increased by only 172 kg. The impact of current days open was greater on second lactation than on first; the difference in 305-d milk yield between cows open 40 and 290 d was 1199 kg for first lactation and 1613 kg for second lactation. If early yield to 120 d was included in the model, the corresponding difference was reduced to 860 kg for first lactation and 1001 kg for second lactation. Inclusion of early yield in the model reduced regression coefficients for days open during first lactation by 22% for 80-d yield, 24% for 100-d yield, 27% for 120-d yield, and 30% for 140-d yield and by 31, 35, 38, and 41%, respectively, for second lactation. Statistical models to derive adjustment factors should account for early lactation yield so that those factors can remove effects of pregnancy but not correlations between yield and fertility caused by early yield.
(**Key words**: days open, milk yield, gestation)

Abbreviation key: **DO** = days open, **ECY** = early cumulative yield.

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[1]Current address: Department of Animal Science, Kangwon National University, Chunceon 200-701, Korea.
[2]Reprint requests.
[3]Current address: Central Research Division, Pfizer, Inc., Eastern Point Road, Groton, CT 06340.

INTRODUCTION

Several research reports (17, 20) show the relationship between days open (**DO**) and 305-d yield. Because of the difficulty in collecting complete and accurate breeding dates from field data such as DHI records, other researchers (11, 12, 20) have examined only the relationship between calving interval and lactation yield. Both DO and calving interval have been viewed as environmental factors that need to be considered to obtain more accurate estimates of genetic merit for yield traits (13, 15, 16, 17). A 1992 INTERBULL (International Bull Evaluation Service) summary (8) shows that the genetic evaluation procedures used in 12 of 28 countries adjusted for the relationship between reproduction and yield.

Few of the researchers studying reproductive measures and yield have adequately addressed the issue of cause and effect. Most examined the overall relationship between the reproductive variable of DO (or calving interval) and 305-d yield, suggested that 305-d yield should be corrected for DO, and derived factors from the overall relationships to make such corrections. This approach has been repeated many times but no longer seems justifiable, because some studies also show that cows with high yield during early lactation are not bred as quickly. Reports (1, 2, 7) indicate that cows with higher milk yield during early lactation and cows with higher genetic merit for milk yield also have longer service periods (interval from first breeding to conception) than do cows with mean yield during early lactation. Some cows with high genetic merit are flushed for embryos, and no attempt is made to have those cows maintain a pregnancy during the first 200 d of lactation. High yield during early lactation increases current DO, perhaps because of a biological antagonism between energy balance and reproductive cycling. In addition, some managers deliberately delay breeding of high yielding cows because 1) they want to obtain higher 305-d or 365-d milk records, 2) they think that cows with higher yield will produce more per day of herd life by lactating longer, or 3) they think that less semen will be required if breeding is delayed until after the period of negative energy balance.

Many (3, 9, 14) have shown that longer DO supports higher yield during late lactation because delayed conception reduces competition for nutrients from the developing fetus during the 305-d lactation. This reduction in yield during pregnancy might also be caused by endocrinological changes. If differences in yield during early lactation, prior to the difference caused by the influence associated with gestation, can be partitioned from 305-d yields, the true effect of gestation on yield could be estimated more accurately. Early cumulative yield (**ECY**) to a common number of days of lactation can be used to analyze the effect of DO. Only a few reports (17, 20) included partial yield in the model while analyzing the effect of DO on 305-d yield traits.

Lactation records are not influenced linearly by DO. Early lactation yield has little chance to be influenced by pregnancy because few cows conceive prior to 50 d after parturition. In addition, the fetus apparently has little impact on reducing yield until at least 150 d after conception (3, 9, 14). Thus, most of the reduction in 305-d yield occurs during the last third of the lactation and is due to either the hormonal influence or the nutritional demand of the developing fetus.

Some researchers (5, 12, 15) have reported that yields during second and later lactations were influenced by DO during the previous lactation in addition to current DO. Determining how environmental effects influence yield during second and later lactation is more complicated than for first lactation because both the previous DO and current DO, as well as their interaction, may have an influence.

Adjustment factors are designed to remove environmental rather than genetic differences among animals. Heritability estimates of DO and calving interval have been low, generally <8% (1, 4, 5, 6, 11, 12, 16). Nevertheless, genetic effects for DO may be correlated to those for yield (1, 6). If high yield increases DO, then this relationship of cause and effect is opposite to the relation that has been assumed when adjustments are calculated. Yield should be adjusted for DO only if DO affects yield.

The objective of this study was to determine the effect of current DO on 305-d yields by considering early lactation yields. If differences in early lactation yield prior to any influence from gestation can be partitioned from total 305-d lactation yield, the true effect of DO (or pregnancy) on 305-d lactation yield could be estimated more accurately.

MATERIALS AND METHODS

Data were 247,310 records for first lactation and 188,889 records for second lactation of Holstein cows from California, Pennsylvania, and Wisconsin. Data were obtained from USDA master files, which contained records for calving dates between 1989 and 1993 and included data for monthly sample days. Standard USDA edits for sample day yield were used (22) to eliminate records with sample day yields for milk <4.5 kg or those with fat percentages <2.0 or >8.0%. Observations with test intervals >75 d or without fat percentages also were excluded. Completed (or terminated) lactation records with <240 DIM were excluded based on a preliminary analysis, which showed that short records were not affected significantly by DO. Lactation records between 240 and 305 DIM were extended to 305-d yield using last sample day yield (21), as is currently done for USDA-DHIA genetic evaluations. Variables examined were calving age, DO, and yields for milk, fat, and protein.

Determination of DO depends on the availability of accurate information about day of conception, but such information has not always been recorded. The information recorded was verified using the calving date of the subsequent lactation when available. Data were eliminated for lactations with information missing on DO and without information from a subsequent calving from which to derive DO. This edit removed cows that were problem breeders or low producers and that were culled, which could bias the DO analysis. The cows that were retained for analysis were 1) not problem breeders, 2) had adequate yield, and 3) did not represent all cows in the population. Unfortunately, those shortcomings also were present in almost all other reproduction studies because verified data on conception are difficult to acquire for large numbers of cows. If DO (i.e., DO during the lactation) was longer than DIM, indicating a recording error resulted when cows open for an entire 305-d lactation were not tested on d 305, DO was replaced with DIM. This replacement corrected the recording error for those cows and provided a close approximation of the correct DO for others.

Current DO can have virtually no impact on ECY. However, ECY can influence DO. The ECY were calculated from sample day yields by the test interval method (19). The ECY for the first 80, 100, 120, and 140 d after calving were calculated for use as covariables during the examination of the relationship between DO and 305-d yield. Another possibility would be to use late lactation yield as the dependent variable, but this strategy would not completely remove the influence of ECY on DO. Calculation of ECY only for the days the cow is not pregnant for each lactation might also partition more exactly the effects of DO on later yield, but such a calculation was not considered to be practical.

TABLE 1. Solutions (kilograms) for days open (DO) for milk yield[1] with different lengths of early cumulative yield (ECY) by parity.

	Parity 1 ECY[2]					Parity 2 ECY				
	0	80 d	100 d	120 d	140 d	0	80 d	100 d	120 d	140 d
Coefficient of ECY	. . .	2.865	2.432	2.123	1.886	. . .	2.650	2.250	1.973	1.767
DO Interval										
<30 d	–876	–806	–788	–773	–765	–1201	–749	–719	–698	–680
30 to 59 d	–697	–641	–627	–611	–598	–839	–639	–618	–603	–590
60 to 69 d	–445	–388	–377	–365	–354	–520	–401	–392	–386	–381
70 to 79 d	–236	–226	–217	–207	–199	–338	–267	–258	–252	–247
80 to 89 d	–148	–117	–113	–108	–104	–184	–158	–150	–145	–141
90 to 99 d	–50	–30	–28	–27	–26	–76	–76	–73	–70	–67
100 to 109 d	0	0	0	0	0	0	0	0	0	0
110 to 119 d	42	25	28	29	28	82	47	42	37	36
120 to 139 d	74	40	43	44	41	114	89	89	85	83
140 to 159 d	166	89	90	89	85	206	143	139	134	130
160 to 179 d	191	124	119	115	107	246	177	170	162	154
180 to 209 d	172	129	127	126	121	318	207	195	183	172
210 to 239 d	318	195	186	178	164	398	233	217	201	188
240 to 269 d	268	183	174	165	153	520	318	293	271	251
≥270 d	502	286	265	249	234	774	471	433	398	365
R^2	0.564	0.849	0.875	0.897	0.915	0.487	0.810	0.838	0.863	0.886

[1]Estimated difference from DO subclass of 100 to 109 d obtained from Model [1].

[2]Cumulative yields to 80, 100, 120, and 140 d after parturition, respectively.

The basic model was

$$y_{ijkl} = \mu + HYS_i + A_j + DO_k + b(ECY_l) + e_{ijkl} \quad [1]$$

where y_{ijkl} = actual 305-d yield (milk, fat, or protein) of cow l calving in herd-year-season i of calving age group j and DO group k, μ = population mean, HYS_i = effect of herd-year-season of calving i, A_j = effect of calving age group j, DO_k = effect of DO group k, b = regression coefficient of ECY on 305-d yield, ECY_l = ECY of cow l, and e_{ijkl} = random residual. For comparison, Model [1] was fitted with and without ECY_l using the four alternative DIM (80, 100, 120, and 140 d) for length of ECY.

First and second parities were analyzed separately. All model terms except the residual were assumed to be fixed effects. Because the primary goal was to partition effects within a lactation, random cow effects and relationships among cows were of less concern. Other researchers have used animal models (M. M. Schutz, unpublished data, 1995) or sire models (5, 10, 15) with repeated records to account more fully for selection in the population.

Four 3-mo seasons were February through April, May through July, August through October, and November through January. Calving age was grouped into three classes by parity (<25, 25 to 27, and >27 mo for parity 1; <38, 38 to 40, and >40 mo for parity 2). The DO was grouped into 15 classes (<30, 30 to 59, 60 to 69, 70 to 79, 80 to 89, 90 to 99, 100 to 109, 110 to 119, 120 to 139, 140 to 159, 160 to 179, 180 to 209, 210 to 239, 240 to 269, and ≥270 d). These groupings are identical to those used by Sadek and Freeman (15). Least squares equations were solved by setting the solution for the subclass of cows open 100 to 109 d to 0. M. M. Schutz (unpublished data, 1995) found small regional differences in DO effects; thus, national estimates were obtained in this study.

A second or alternative model was

$$y_{ijl} = \mu + HYS_i + A_j + b_1DO_l + b_2ECY_l + e_{ijl} \quad [2]$$

where y_{ijl} = actual 305-d yield (milk, fat, or protein); μ, HYS_i, and A_j are defined as for Model [1]; b_1 = regression coefficient of DO on 305-d yield; DO_l = current DO for cow l; b_2 = regression coefficient of ECY on actual 305-d yield; ECY_l = ECY of cow l, and e_{ijl} = random residual. For Model [2], DO was treated as a continuous variable instead of as a discrete variable, and a regression coefficient was added to document the mean change of DO solution when ECY was also included in the model. Model [2] also was fit with the four alternative DIM lengths for ECY_l and without ECY_l.

RESULTS AND DISCUSSIONS

Solutions showing the relationship between DO and 305-d milk yield by parity without considering differences in early lactation yield are in Table 1. These solutions illustrate the inhibitory effect of early conception on milk yield. The differences in actual

TABLE 2. Solutions (kilograms) for days open (DO) for fat yield[1] with different lengths of early cumulative yield (ECY) by parity.

	Parity 1 ECY[2]					Parity 2 ECY				
	0	80 d	100 d	120 d	140 d	0	80 d	100 d	120 d	140 d
Coefficient of ECY	. . .	2.390	2.117	1.911	1.742	. . .	2.278	2.012	1.820	1.670
DO Interval										
<30 d	–31.3	–27.6	–27.2	–26.8	–26.7	–43.0	–28.6	–26.9	–25.7	–24.9
30 to 59 d	–24.8	–21.5	–20.8	–20.3	–20.0	–29.3	–22.7	–21.7	–20.9	–20.5
60 to 69 d	–16.2	–12.9	–12.2	–11.6	–11.2	–18.1	–14.1	–13.4	–12.9	–12.7
70 to 79 d	–7.8	–6.6	–6.1	–5.7	–5.5	–11.3	–9.2	–8.6	–8.1	–7.8
80 to 89 d	–4.3	–3.2	–3.0	–2.8	–2.6	–6.4	–5.5	–5.1	–4.7	–4.4
90 to 99 d	–2.5	–0.4	–0.3	–0.1	–0.1	–2.4	–2.4	–2.3	–2.1	–1.9
100 to 109 d	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
110 to 119 d	0.6	1.1	1.1	1.0	0.9	2.3	1.2	1.1	1.0	0.9
120 to 139 d	1.0	0.9	1.0	0.9	0.6	4.0	3.2	3.2	2.9	2.6
140 to 159 d	4.5	2.9	2.8	2.6	2.2	6.5	4.5	4.4	4.3	3.9
160 to 179 d	4.9	3.0	2.8	2.6	2.1	8.1	6.0	5.8	5.3	4.7
180 to 209 d	5.2	4.5	4.4	4.1	3.5	10.4	7.4	7.0	6.4	5.7
210 to 239 d	8.4	5.4	5.3	4.9	4.3	14.0	8.5	7.9	7.2	6.4
240 to 269 d	8.5	6.3	5.9	5.4	4.7	19.6	12.8	11.9	10.9	9.7
≥270 d	16.2	10.6	9.8	9.0	8.2	27.9	18.5	17.1	15.7	14.2
R^2	0.585	0.834	0.861	0.884	0.904	0.477	0.785	0.817	0.845	0.871

[1]Estimated difference from DO subclass of 100 to 109 d obtained from Model [1].

[2]Cumulative yields to 80, 100, 120, and 140 d after parturition, respectively.

305-d milk yield between cows with DO of 40 and 290 d were 1199 and 1613 kg for first and second parities. These differences are similar to results from some studies (5, 13, 16) but larger than the differences obtained by others (15).

Lactation yield increased rapidly as DO increased up to 100 d and then increased more slowly for longer DO. For example, a change from 20 to 100 d for DO increased yield by 876 kg, but a change from 100 to 200 d for DO increased yield only an additional 172 kg. Current DO had more impact on second lactation than on first lactation, which is similar to the results obtained by others (10). The parity differences may be explained in part by the higher milk yield of second lactation cows.

Effects of pregnancy during late lactation were isolated by removing ECY. Because early and 305-d yields have a part-whole relationship, R^2 increased from near 50% to over 80% when ECY was included in the model. As expected, R^2 was higher with longer intervals of ECY because the overlapping portion of lactation increased. The relative differences of each DO class from 100 d decreased as the interval of ECY increased. When the interval of ECY was 120 d, the differences in lactation milk yield between cows with DO of 40 and 290 d were 860 and 1001 kg for first and second parities, respectively. These estimates were considerably less than the 1199 and 1613 kg that were derived when differences in yield during early lactation were ignored.

Solutions of DO for second lactation were reduced more than for first lactation with the addition of ECY as a covariable in the model. This result suggests that early yield during second lactation had a greater effect on current DO, or that pregnancy had a smaller effect on yield, or both. Wiggans and Ernst (20), using a similar model, determined that inclusion of ECY to 100 d caused effects of previous days dry to be nonsignificant and that 100-d yield group had no interaction with effect of DO.

Effects of DO on fat and protein yields were essentially the same as on milk yield (Tables 2 and 3). Regressions of 305-d yield on ECY were slightly lower for fat and protein, and R^2 for those models were slightly lower than the corresponding models for milk.

Table 4 shows the change in regression coefficients for DO on yield traits when ECY was added as a covariable. Inclusion of ECY in the model greatly reduced solutions for DO on yield. When the intervals of ECY were 80, 100, 120, and 140 d, the estimates of DO on milk yield decreased by 22, 24, 27, and 30%, respectively, for parity 1 and decreased by 31, 35, 38, and 41%, respectively, for parity 2. If early lactation yield was ignored while factors were being derived, those factors that were estimated would be too large by as much as 28 to 70%. For example, a reduction of 22% in the factors would mean that the factors would be 28% too large; that is, $[1/(1 - 0.22)] - 1 = 0.28$. The percentage of reduction was much more difficult to quantify for Model [1] when DO was fitted as a number of discrete classes.

The true effect of DO on 305-d yield can be estimated more accurately when early lactation milk

TABLE 3. Solutions (kilograms) for days open (DO) for protein yield[1] with different lengths of early cumulative yield (ECY) by parity.

	Parity 1 ECY[2]					Parity 2 ECY				
	0	80 d	100 d	120 d	140 d	0	80 d	100 d	120 d	140 d
Coefficient of ECY	. . .	2.701	2.347	2.085	1.874	. . .	2.631	2.268	2.008	1.809
DO Interval										
<30 d	–30.5	–27.9	–27.3	–26.9	–26.5	–39.0	–26.6	–25.4	–24.5	–23.6
30 to 59 d	–22.4	–21.7	–21.3	–20.8	–20.3	–26.3	–21.9	–21.2	–20.6	–20.1
60 to 69 d	–13.9	–12.7	–12.4	–12.0	–11.7	–16.1	–13.6	13.3	–13.1	–12.8
70 to 79 d	–7.8	–7.6	–7.3	–7.0	–6.7	–10.5	–9.1	–8.8	–8.6	–8.4
80 to 89 d	–5.1	–4.0	–3.8	–3.6	–3.5	–5.4	–5.1	–4.9	–4.8	–4.6
90 to 99 d	–2.5	–1.3	–1.2	–1.1	–1.1	–2.4	–2.3	2.2	–2.2	–2.0
100 to 109 d	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
110 to 119 d	0.5	0.7	0.9	1.0	1.0	2.3	1.6	1.4	1.2	1.2
120 to 139 d	1.4	0.9	1.1	1.2	1.1	3.6	3.0	2.9	2.8	2.6
140 to 159 d	3.8	2.6	2.7	2.8	2.7	5.8	4.8	4.7	4.5	4.4
160 to 179 d	4.5	3.8	3.8	3.8	3.6	6.9	5.9	5.6	5.3	5.0
180 to 209 d	4.3	3.8	3.9	4.0	3.8	9.2	7.0	6.6	6.3	5.8
210 to 239 d	7.6	5.8	5.7	5.5	5.1	11.5	8.1	7.7	7.2	6.6
240 to 269 d	7.0	6.1	5.8	5.6	5.3	15.4	10.9	10.3	9.5	8.8
≥270 d	14.0	9.6	9.2	8.8	8.4	22.9	16.2	15.2	14.2	13.1
R^2	0.626	0.842	0.866	0.888	0.907	0.507	0.797	0.825	0.850	0.874

[1]Estimated difference from DO subclass of 100 to 109 d obtained from Model [1].

[2]Cumulative yields to 80, 100, 120, and 140 d after parturition, respectively.

yield is considered as a covariable. An exact definition of "early" was not essential, because estimates of DO effects varied little for ECY ranging from 80 to 140 d.

The change in the regression coefficients of DO on fat yield from inclusion of ECY was similar to that for milk yield, and the change in coefficients of DO on protein yield was less than for milk and fat yields. The reasons for this difference are unknown.

The USDA began to standardize 305-d yield for previous DO for January 1995 genetic evaluations (18) using factors by M. M. Schutz (1994, unpublished data). Preliminary research (USDA, 1994, unpublished results) had shown that the effects of previous and current DO on lactation yield were independent of each other. Because previous DO can nearly always be verified through calving dates from previous and current lactations and thus previous DO for individual cows are likely to be accurate, adjustment for previous DO was implemented. An adjustment for current DO was not implemented because additional results are needed to determine whether breeding information recorded in DHI programs is

TABLE 4. Regression coefficients for days open (DO) from Model [2] by parity and relative change in coefficient when early cumulative yield (ECY) was included in the model.

		Milk yield		Fat yield		Protein yield	
Parity	ECY[1]	Regression coefficient	Coefficient change from including ECY	Regression coefficient	Coefficient change from including ECY	Regression coefficient	Coefficient change from including ECY
	(d)	(kg/d)	(%)	(kg/d)	(%)	(kg/d)	(%)
1	0	9.884	. . .	0.325	. . .	0.287	. . .
	80	7.753	–22	0.252	–23	0.251	–13
	100	7.500	–24	0.240	–26	0.245	–15
	120	7.240	–27	0.228	–30	0.238	–17
	140	6.963	–30	0.216	–34	0.229	–20
2	0	12.154	. . .	0.427	. . .	0.364	. . .
	80	8.358	–31	0.306	–28	0.284	–22
	100	7.922	–35	0.288	–33	0.271	–26
	120	7.545	–38	0.269	–37	0.259	–29
	140	7.207	–41	0.252	–41	0.247	–32

[1]Cumulative yields to 80, 100, 120, and 140 d after parturition, respectively.

sufficient to realize an increase in accuracy for most herds. Inclusion of ECY as a covariable in the model can avoid assigning undue influence of DO on lactation yields. The resulting adjustment factors for standardizing lactation yield for current DO will be more accurate.

CONCLUSIONS

This study confirms that cows with higher yield during early lactation have longer DO and that longer DO increases subsequent yield. Factors derived to standardize 305-d yield for current DO should be based on methods that consider and remove the effect of early yield to prevent overcorrection (by 28 to 70%) for this environmental effect. The correlation between current DO and yield during early lactation should not be included in adjustment factors if the direction of causation is actually the reverse. By including a covariable in the model to partition the effect of ECY, factors were developed that measure only the effects of pregnancy on yield.

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