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ABSTRACT

Prediction equations were determined to estimate daily milk yield from 306 to 395 d in milk for forecasting herd milk sales from Holstein cows in lactation >305 d. Data were test day milk weights for 65,322 primiparous and 119,220 pluriparous lactations of >305 d from the Southern US. A forecast model was developed using same lactation 305 d milk yield (in classes of 500 kg increments) that gave similar predicted daily yields as models utilizing last sample milk weight information. This model has the advantage of early forecasting of later milk using projected 305-d yields.

Reduced forecast models ignoring days pregnant, yield class, or both accounted for 95, 68, and 59%, and 91, 67, and 56% as much variation in daily milk as the full model for the primiparous and pluriparous cows. Percentage of 305-d milk yielded in mo 11, 12, and 13, depending on 305-d yield class, ranged from 7.1 to 7.0%, 6.2 to 6.0%, and 5.4 to 5.0%, and 5.4 to 5.0%, 4.3 to 3.9%, and 3.3 to 3.0% for first parity and pluriparous cows calving in winter and 125 d open. Cows not calving in winter or with more than 125 d open yielded more milk in extended lactation. These percentages are larger than generally assumed in studies of days open, thus indicating that cost of days open may have been overestimated.

INTRODUCTION

Accurate forecasting of herd milk production and future income from milk sales would aid management decision making. Calving intervals (CI) for Holstein cows enrolled in US DHI programs average 13.5 mo (2), which indicates that most cows should lactate more than 305 d. However, no information is available to predict extended lactation milk yield based on actual records of cows in milk more than 305 d. This lack of information precludes forecasting cash flows from milk sales and hinders economic assessment of culling and breeding management strategies. Information to improve financial planning and herd man-

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agement would enhance the profitability of dairying.

The objective of this study was to develop a method to forecast average milk yield of groups of Holstein cows in the extended lactation period from 306 to 395 d. These forecasts can be combined with projected actual 305-d yields and probable lactation lengths based on reproductive status to estimate future income (e.g., next 12 mo) from herd milk sales. Standardized 305-d projected yields are calculated for cows ⩾50 d in milk in DHI herds. Therefore, most cows can be assigned to projected actual 305-d milk yield classes (MK305) after cancelling mature equivalent (ME) adjustments. Projected actual 305-d milk plus estimated extended lactation milk for cows with expected CI >12 mo would permit forecast of 12 mo rolling herd milk sales by summing value of predicted milk from cows grouped by MK305 and month of year.

MATERIAL AND METHODS

Data and Edits

Original data were 282,339 Holstein lactations exceeding 305 d from Indiana, Kentucky, North Carolina, Tennessee, and Virginia. Lactations terminated from 1979 to 1983. Data were compiled at the University of Kentucky in two parity classes (primiparous and pluriparous). Exclusions at the time of compilation were for missing first test day milk weight, intervals >59 d between each pair of the first four test days (TD), milk yield less than 907 kg for the first 120 d, no recorded breedings, gestation length outside the range of 265 to 295 d based on subsequent date of calving, and missing dates for calving, drying off, or birth. Subsequent criteria to delete data were no TD between 306 to 395 d (76,005 records deleted), calving in midlactation or 0 d dry (resulting in questionable values for days in milk, 14,384 records deleted), and missing or unusual values for calving age, days dry, days open (DO), or cow identification.

Observations included were milk weights on last TD preceding 306 d, TD from 306 to 395 d, and when available, next TD >395 d. Milk weights were deleted if they increased >8 kg for first parity or >10 kg for parities >1 over the preceding observation to avoid cows that may have aborted or calved again. Test days for cows >255 d pregnant (DPREG) were deleted because cows are seldom milked in this stage of pregnancy. Also, observations were dropped if the TD exceeded reported lactation length (LL) or if no TD between 306 and 395 d remained after other edits. Final data were 65,322 primiparous (3853 herds) and 119,220 pluriparous (99,271 cows in 3916 herds) extended lactations consisting of an average of 3 test d each. Parity classes were analyzed separately.

Independent data subsets were constructed for each parity class by separating herds by whether last digit of the herd code was even or odd. Parameters to predict extended lactations were estimated from data from odd-numbered herds (1922 herds for primiparous cows and 1955 herds for pluriparous cows). Data from even-numbered herds (1931 herds for primiparous cows and 1961 herds for pluriparous cows) were used to validate the model.

Statistical Methods

A forecast model utilizing MK305 subclasses to predict milk yield from 306 to 395 d, hereafter called extended lactation yield, was of primary interest. Because 305-d milk is predicted early in lactation, most cows can be assigned to yield classes as early as 9.5 mo before extended lactation milk is sold. Therefore, this model should be capable of early forecasting of herd milk sales. Bias for 305-d milk projected at 45 d is approximately 11 kg (11). The assignment of cows to discrete yield classes of 500 kg increments should make this bias relatively inconsequential. The model to describe milk yield for a particular day in milk (DIM) from the last TD prior to 306 d to the first TD after 395 d was:

$$
\begin{aligned}
Z_{ijklmn} = {} & b_0 + Y_i + H(Y)_{j(i)} + A_k + S_l + (S \times MK305)_{lm} \\
& + b_1 DPREG_n + b_2 DPREG_n^2 + b_{3m} DPREG_n \\
& + b_{4m} DPREG_n^2 + b_5 (DPREG_n DIM_n) \\
& + b_6 (DPREG_n DIM_n^2) + b_7 (DPREG_n^2 DIM_n) \\
& + b_8 (DPREG_n^2 DIM_n^2) + b_{9m} DIM_n \\
& + b_{10m} DIM_n^2 + e_{ijklmn}
\end{aligned}
$$

where:

Z_{ijklmn} = milk weight for the $ijklmn^{th}$ daily observation;

b_0 = intercept:

Y_i = effect of the i^{th} year of calving, with i = 1, 2, 3, and 4;

$H(Y)_{j(i)}$ = effect of the j^{th} herd within the i^{th} year of calving;

A_k = effect of the k^{th} age at calving with k = 1, 2, 3 (<24 mo, 24 to 29 mo, and ⩾30 mo) for primiparous cows and k = 1, 2, 3, 4 for pluriparous cows (<36 mo, 36 to 47 mo, 48 to 59 mo, and ⩾60 mo);

S_l = effect of the l^{th} season of calving with fall/winter (September to February), and spring/summer (March to August) for parity 1; and winter (November to February), spring/fall (March, April, September, October), and summer (May to August) for parity >1;

$MK305_m$ = effect of the m^{th} actual 305-d yield class (MK305) with m = 1,2,. . .,10 for primiparous cows and 1,2,. . ., 11 for pluriparous cows. The initial class for first parity was <4500 kg and increased by 500 kg increments up to ⩾8500 kg. Classes for parity >1 were from <5500 kg to ⩾10,000 kg;

$DPREG_n$ = days pregnant for the ijklmnth observation;

DIM_n = days in milk for the ijklmnth observation;

b_1, b_2 = coefficients for linear and quadratic regressions of Y_{ijklmn} on DPREG;

b_{3m}, b_{4m} = coefficients for linear and quadratic regressions of Y_{ijklmn} on DPREG within MK305 class;

b_5, b_6, b_7, b_8 = coefficients for linear and quadratic regressions of Y_{ijklmn} on DPREG × DIM;

b_{9m}, b_{10m} = coefficients for linear and quadratic regressions of Y_{ijklmn} on DIM within MK305 class; and

e_{ijklmn} = random error.

Initially, a larger number of age classes and six bimonthly season classes were tested. Preliminary analyses indicated that some classes could be grouped together. In our model, the main effects of MK305 class and DIM were subsumed by their interactions with DPREG.

Several studies reported a residual effect of previous days dry (DD) on 305-d milk yield. Originally, 5 DD classes were considered: <40, 40 to 79, 80 to 119, 120 to 149, and ⩾150 d. Main effects of DD and linear and quadratic interactions with DIM were identified but only accounted for .01% of the variance in daily milk yield ($P<.05$) and .018% of the variance explained by the model. These effects were smaller than in previous reports for 305-d milk yield (10, 13), indicating that effects of DD may decrease with advancing lactation. Consequently, DD was omitted from the mathematical model because it explained little variation of daily milk yield in extended lactation.

Last sample milk yields explain much of the variation in 305-d milk yield as partial lactations lengthen (11). Therefore, a comparison was made of the relative accuracy of using last sample milk yield information when available rather than the forecast method. Secondary models included 1) using the last milk weight prior to 306 d, i.e., the first sample (FSMW) of the data set, as an independent variable to predict extended lactation milk; and 2) using the last sample milk weight (LSMW) to predict milk yield on the next test day. The full secondary models, in addition to effects in the forecast model, consisted of FSMW or LSMW and their interactions with MK305 class and either first or last sample test days in milk (linear and quadratic). Consequently, these secondary models were applied to fewer data than the forecast model because milk weights prior to 306 d were not included as dependent variables.

Analysis was by the SAS General Linear Model procedure. Year and herd effects were absorbed and, therefore, the intercept was not available. Instead, a comparable constant was derived by subtracting Z*. . . from the sample overall mean, where $Z^*_{klmn} = A_k + S_l + (S \times MK305)_{lm} + b_1 DPREG_n + b_2 DPREG_n^2 + b_{3m} DPREG_n\ b_{4m} DPREG_n^2$

$+ b_5(DPREG_n DIM_n) + b_6(DPREG_n DIM_n^2) + b_7(DPREG_n^2 DIM_n) + b_8(DPREG_n^2 DIM_n^2) + b_{9m} DIM_n + b_{10m} DIM_n^2$. The resulting constant contained both the intercept and the weighted average of herd-year effects. Because numerous herds were represented and distributions of observations across herd-years were similar in the independent data sets, the weighted average of herd-year effects was assumed to be appropriate.

An effect of cow was not included in the model. Therefore, no adjustments were made for repeated measures on the same cow. This may underestimate residual variance but will not bias the point estimates unless selection has occurred.

Variances of daily milk yield were heterogeneous for age-season-MK305 subclasses, increasing with test day milk. Therefore, milk yield observations were weighted by reciprocals of the variances of corresponding subclasses to ensure efficient estimation of parameters and valid tests of significance.

Validation of estimates of the parameters for the forecast and FSMW models was quantified by squaring the differences between predicted TD milk yields (calculated from the approximated intercept and parameter estimates for each model) and actual TD milk yields from the independent data from even numbered herds. The squared deviations were summed within age-season-MK305 subclasses and divided by number of observations to approximate residual mean squares within each subclass. Predicted yields for the 11th, 12th, and 13th mo of lactation were calculated by summing together predicted daily yields for 306 to 335 d, 336 to 365 d, and 366 to 395 d.

RESULTS AND DISCUSSION

In both the primiparous and pluriparous data sets, increases were observed for DO (from 174 to 195 d for first parity, 170 to 199 d for parity >1) and LL (from 390 to 418 d for first parity, and 379 to 413 d for parity >1) as 305-d yield class increased. Consequently, if milk yield increases in the future, there may be increased need for extended lactation projection factors as more cows lactate >305 d. Lactation length was slightly less for older cows than for primiparous cows in all MK305 classes.

As days in milk on TD increased from <305 to >395 d, actual 305-d yield increased only slightly (193 kg for first parity cows and 323 kg for older cows). However, DO increased 92 d for each parity subset. Therefore, it appears that if records were adjusted for days carried calf, average producing abilities of cows with lactations extended the most would be similar to those with shorter ones.

Analyses of variance for the forecast model are in Table 1. All main effects and interactions were highly significant ($P<.0001$). When analyses were run separately on segmented portions of extended lactation (<336 d, 336 to 365 d, >365 d) for the pluriparous subset, all effects of DPREG were highly significant ($P<.0001$) in the 11th mo of lactation, whereas only the linear and quadratic interactions with MK305 remained significant ($P<.007$) for the segments from 336 to 365 d and >365 d.

Table 2 shows the relative importance of MK305 and DPREG to predict daily milk yield in extended lactation. Omitting MK305 and its interactions resulted in substantial decreases in the coefficient of determination (R^2). Omitting DPREG and its interactions decreased the R^2 by only 3 to 5% for primiparous and pluriparous cows.

Several workers have reported that pregnancy status influenced milk yield (1, 3, 6, 8, 9, 12). The effect of pregnancy on daily yield appears to increase with advancing lactation (1, 3). Auran (1) and Danell (3) observed a small interaction between pregnancy status and DIM. Oltenacu et al. (6) found that while changes in cumulative 305-d milk yield associated with changes in DO were similar between high and low yielding cows, the effect of DO on cumulative milk beyond 315 d was greater in high than in low yielding cows. The results in Figures 1 and 2 are consistent with their findings. Cows in late pregnancy declined in milk production more rapidly than cows in early pregnancy. Parameter estimates for DPREG × MK305 yield class interactions resulted in a more severe decrease in daily yield due to pregnancy in high than in low yield classes. The effect of these interactions on persistency was similar in both parity subclasses.

Figure 3 shows that daily milk decreased more rapidly as pregnancy advanced for cows 335 DIM compared with those 305 DIM, and

TABLE 1. Estimated mean squares (kg^2) from analyses of variance for extended lactation daily milk yield for parity 1 and parity >1.

Source	Parity 1 df	Parity 1 MS	Parity >1 df	Parity >1 MS
Year	3	Absorbed	3	Absorbed
Herd	5524	Absorbed	6053	Absorbed
Age	2	61.42	3	411.20
Season	1	1133.90	2	302.45
DPREG[1]	1	12.21	1	.05[b]
DPREG²	1	35.34	1	17.95
MK305[1] × Season	18	7.72	30	22.14
DPREG × DIM[1]	1	14.22	1	.34[b]
DPREG × DIM²	1	15.22	1	.87[b]
DPREG² × DIM	1	39.11	1	22.05
DPREG² × DIM²	1	36.90	1	21.56
DPREG × MK305	9	4.54	10	4.78
DPREG² × MK305	9	9.11	10	10.21
TDIM × MK305	10	2.96	11	10.23
TDIM² × MK305	10	1.79[a]	11	5.28
Residual	98,101	.66	180,526	.63
R^2		.63		.57

[a] $P<.005$; all others in this column $P<.0001$.

[b] $P>24$; all others in this column $P<.0001$.

[1] DPREG = Days pregnant; MK305 = 305-d milk yield class; DIM = test days in milk; DPREG × MK305 is equivalent to the effect represented by the term $b_{3m}DPREG_n$ in the forecast model.

for cows 365 DIM compared with those 335 DIM. Susceptibility to the adverse effects of pregnancy on milk yield was apparently similar in mo 12 and 13 of lactation.

Last sample yield is a more accurate predictor of remaining 305-d lactation milk than cumulative yield because it utilizes current performance information (11). Therefore, as expected, the LSMW method, which used the most recent information on daily milk yield, had the highest R^2 (Table 3). The FSMW method, using the last available information

TABLE 2. Estimated residual mean squares (MSE) and coefficients of determination (R^2) for the forecast model and reduced models ignoring the main effects and interactions of days pregnant (DPREG) and 305 d-yield class (MK305) or both for each parity class.

	Parity 1 MSE	Parity 1 R^2	Parity >1 MSE	Parity >1 R^2
	(kg^2)		(kg^2)	
Full model	.66	.63	.63	.57
Reduced model omitting:				
DPREG[1]	.72	.60	.71	.52
MK305[2]	1.03	.43	.90	.38
DPREG + MK305[2]	1.12	.37	1.00	.32

[1] Main effects of MK305 and days in milk (DIM) reinstated in the model.

[2] Main effects of DIM reinstated in the model.

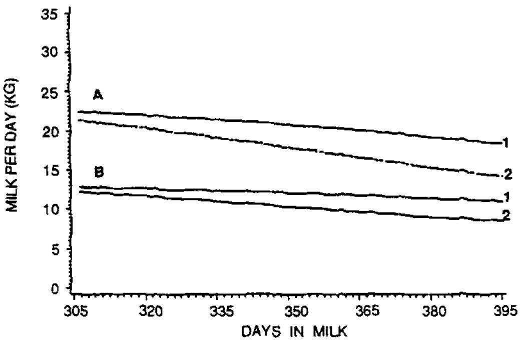

Figure 1. Extended lactation milk yields by the forecast method for first parity cows calving in September to February at 24 to <30 mo of age. A = 305-d milk yield class = 8000 to 8499 kg; B = 305-d milk yield class = 4500 to 4999 kg; 1 = 44 d pregnant at 306 d in milk; and 2 = 154 d pregnant at 306 d in milk.

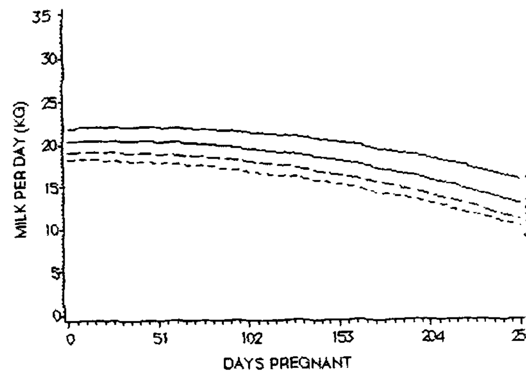

Figure 3. Effect of stage of pregnancy on extended lactation milk yield predictions by the forecast method for pluriparous cows calving in November to February at 36 to <48 mo of age and yielding 9500 to 9999 kg of milk in the first 305 d of lactation. 1 = 305 d in milk; 2 = 335 d in milk; 3 = 365 d in milk; and 4 = 395 d in milk.

previous to 306 d, was intermediate in accuracy of prediction with more variance explained in extended lactation than by the forecast model. Therefore, the cost of early forecasting is a slight increase in error of prediction. In spite of this, Figures 4 and 5 show close agreement between extended lactation predictions based on forecast or first sample methods, especially for primiparous cows. Overestimation of daily milk by the forecast model was slight and mostly in late extended lactation.

Cumulative yield (MK305) in the forecast model appears to behave as an effective proxy for the relatively unavailable late lactation milk information. When this information is available, as in the FSMW and LSMW models, inclusion of MK305 is redundant (Table 3). However, use of MK305 rather than FSMW or LSMW information results in similar predictions of daily milk yield in extended lactation.

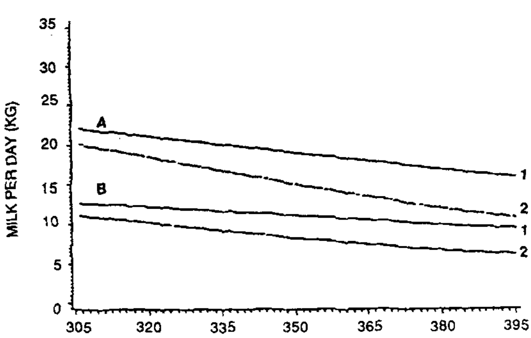

Figure 2. Extended lactation milk yields by the forecast method for pluriparous cows calving in November to February at 36 to <48 mo of age. A = 305-d milk yield class = 9500 to 9999 kg; B = 305-d milk yield class = 5500 to 5999 kg; 1 = 44 d pregnant at 306 d in milk; and 2 = 154 d pregnant at 306 d in milk.

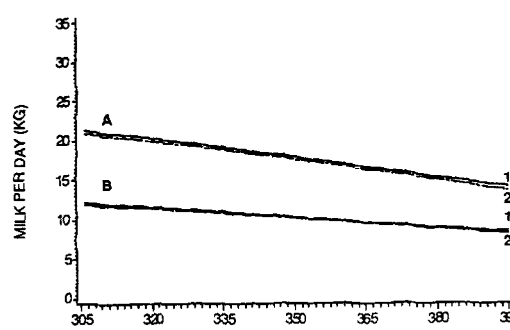

Figure 4. Predicted extended lactation milk yields by the forecast and first sample methods for primiparous cows calving in September to February at 24 to <30 mo of age and 154 d pregnant on d 306 in milk. A = 305-d milk yield class = 8000 to 8499 kg; B = 305-d milk yield class = 4500 to 4999 kg; 1 = forecast method; and 2 = first sample method.

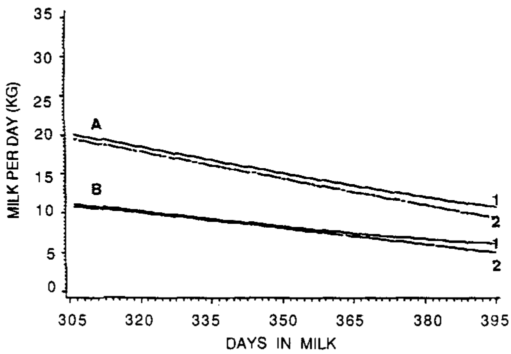

Figure 5. Predicted extended lactation milk yield by the forecast and first sample methods for pluriparous cows calving in November to February at 36 to <48 mo of age and 154 d pregnant on d 306 in milk. A = 305-d milk yield class = 9500 to 9999 kg; B = 305-d milk yield class = 5500 to 5999 kg; 1 = forecast method; and 2 = first sample method.

Validation of the Models

Means and standard deviations in the even-numbered herds for 305-d milk yield, LL, DO, and DPREG agreed closely with those for the odd-numbered herds. Calculated error mean squares were similar for the independent even and odd-numbered data sets for both the forecast and first sample models (Table 4). This result shows that estimated coefficients obtained from the odd-numbered herds were consistent predictors of milk yield for a different set of herds in the same geographical region. Calculated error mean squares for even-numbered herds from the forecast model were largest, especially for the pluriparous subsets, and tended to increase as MK305 yield class increased, which was also found in analysis of the odd-numbered herds. Calculated error mean squares for the odd-numbered herds were larger than actual residual mean squares because they were unweighted, and the intercepts and absorbed herd and year effects were approximated.

Milk Production in Extended Lactation

More milk was produced in extended lactation when expressed as percentage of 305-d yield than was assumed in earlier studies that evaluated costs of days open (4, 7). Depending on MK305 yield class, pluriparous cows calving from November to February and 125 DO yielded from 5.4 to 5.0%, 4.3 to 3.9%, and 3.3 to 3.0% of their 305-d milk yield in the 11th, 12th, and 13th mo of lactation. Primiparous cows calving in the same season and with the same DO declined in daily milk less rapidly, yielding from 7.1 to 7.0%, 6.2 to 6.0%, and 5.4 to 5.0% of their 305-d milk for the 3 mo of extended lactation. Therefore, milk production and sales in extended lactation for fall and winter calving cows were probably underestimated in previous studies of days open. Consequently, cost of days open would be even

TABLE 3. Influence of omitting the effects of days pregnant (DPREG) and 305-d milk yield class (MK305) on residual mean squares (kg^2) for the forecast, first sample (FSMW), and last sample (LSMW) models for each parity class.

	Parity 1			Parity >1		
Model	Full	DPREG Omitted	MK305 Omitted	Full	DPREG Omitted	MK305 Omitted
			Residual mean squares			
Forecast						
Residual MS	.66	.72	1.03	.63	.71	.90
R^2	.63	.60	.43	.57	.52	.38
FSMW						
Residual MS	.57	.64	.59	.50	.58	.51
R^2	.68	.64	.66	.65	.60	.64
LSMW						
Residul MS	.49	.53	.50	.40	.45	.41
R^2	.72	.70	.71	.72	.69	.72

TABLE 4. Comparisons of calculated error mean squares (kg^2) from the odd and even-numbered herds for the forecast and first sample models.

Yield class[1]	Parity 1				Parity >1			
	Forecast		First sample		Forecast		First sample	
	Odd	Even	Odd	Even	Odd	Even	Odd	Even
1	6.82	7.48	5.45	6.23	10.01	10.11	6.41	6.31
2	7.46	7.24	6.32	7.80	10.89	11.24	7.64	7.46
3	7.82	7.69	6.71	7.69	11.71	11.35	8.15	8.20
4	8.52	8.50	7.25	8.74	12.39	12.86	8.75	8.84
5	9.52	9.18	7.99	9.02	13.84	13.99	9.89	10.10
6	10.18	9.54	8.59	9.45	14.85	14.56	10.65	10.60
7	11.18	10.64	9.55	11.37	16.04	16.15	11.69	11.68
8	11.69	11.65	10.24	12.13	17.24	17.25	13.12	12.76
9	13.14	12.95	11.95	12.79	18.52	18.54	13.53	13.67
10	17.66	16.46	13.74	13.75	19.80	19.63	14.34	14.61
11	...	...	...	...	25.25	24.77	18.18	17.49
Overall means								
RMILK[2]	16.14	16.14	15.41[4]	15.06[4]	15.05	15.04	13.87[4]	13.86[4]
PMILK[3]	16.14	16.10	15.41	15.00	15.05	14.99	13.87	13.84
MSE	9.91	9.62	8.43	9.68	15.20	15.16	11.00	10.93

[1] The 305-d milk yield classes increased by 500 kg increments from <4500 kg to >8500 kg for parity 1, and from <5500 kg to >10,000 kg for parity >1. Odd herds were used to establish the model equations.

[2] RMILK = Means for actual milk yield on day of observation (kg).

[3] PMILK = Means for predicted milk yield on day of observation (kg).

[4] Actual milk yield means were smaller for the first sample model than for the forecast model, because observations prior to 306 d were excluded as dependent variables in the first sample data set.

less than estimated by assumptions by Holmann et al. (4).

However, March to August and May to August were the seasons with greatest frequencies of calving for primiparous and pluriparous cows in the data set, which may have been due to antagonism between summer calving and days to conception. Extended lactation yields were predicted to be greatest for these calving seasons (see Appendix). Predicted percentages of 305-d yield for pluriparous cows calving in May to August at 125 DO ranged from 6.3 to 5.7%, 5.2 to 4.6%, and 4.2 to 3.8% for the 11th, 12th, and 13th mo of lactation, or approximately 1% more per month than for their winter calving counterparts. Keown et al. (5) also found that although peak yield was generally lowest in summer calving cows, persistency was greatest, probably because of cooler temperatures in the latter half of lactation. Extended lactation yield was adversely affected by increased age in both parity subsets (see Appendix).

CONCLUSION

The forecast model provides a practical way to predict extended lactation milk yield and future herd milk sales. Information about 305-d milk and DPREG is easily obtained from DHI data. The MK305 yield class is a useful proxy for first or last sample milk yield information. Predicted values for daily milk yield in extended lactation obtained from either the forecast or FSMW model were similar despite the lower statistical accuracy of the forecast model. Unlike the first and last sample models, the forecast model can be used to predict extended milk yield for a set of cows within a herd by grouping them by 305-d yield class. Since MK305 projections are available as early as 50 DIM, cows can be first grouped by producing ability and predictions obtained several months before the extended lactation period with later revisions based on reproductive status and more accurate milk projections. Therefore, variables utilized in the forecast

method are preferred for forecasting future herd income to those from the first and last sample methods. Suitability of these models in other regions of the US needs to be explored.

Extended lactation milk yield, as a percentage of 305-d yield, was greater than previously assumed, especially in first lactations and summer calvings. Underestimating extended lactation milk yield corresponds to an overvaluation of the cost of DO.

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APPENDIX

TABLE 1A. Regression coefficients and class effects (kg) for milk yield on a given day in milk (DIM) and a specified day of pregnancy (DPREG) for primiparous cows.

Parameter	Estimate	SE
Intercept	48.36580460	
Age class		
<24 mo	.51048306	.04086168
24 – <30 mo	.26834203	.02511342
⩾30 mo	0	. . .
Season of calving		
Sep to Feb (A)	−1.61237481	.12523583
Mar to Aug (B)	0	. . .
DPREG	−.15637529	.03788009
DPREG²	.00106877	.00015386
MK305[1] × Season		
1 × A	−24.92749063	4.48717452
1 × B	−25.85931266	4.49068437
2 × A	−20.56123805	4.39918219
2 × B	−21.39737233	4.40281069
3 × A	−23.39115394	4.22383789
3 × B	−24.19566849	4.22751496
4 × A	−22.71909142	4.17825724
4 × B	−23.36821968	4.18199137
5 × A	−16.84224027	4.17281926
5 × B	−17.50780825	4.17666822
6 × A	−14.44367170	4.23153185
6 × B	−14.98231316	4.23530815
7 × A	−13.53489716	4.35279177

(continued)

TABLE 1A. (continued) Regression coefficients and class effects (kg) for milk yield on a given day in milk (DIM) and a specified day of pregnancy (DPREG) for primiparous cows.

Parameter	Estimate	SE
7 × B	−14.16812481	4.35669116
8 × A	−5.34371220	4.61924754
8 × B	−5.81751788	4.62311272
9 × A	−8.42207631	5.17575766
9 × B	−8.28827298	5.18078181
10 × A	0	...
10 × B	0	...
DPREG × DIM	.00104730	.00022524
DPREG × DIM^2	−1.6010E−06	.00003328
DPREG^2 × DIM	−6.9847E−06	.00009057
DPREG^2 × DIM^2	9.93E−09	.00001326
DPREG × MK305		
1	−.01793118	.00394942
2	−.00881413	.00389948
3	−.00941359	.00371428
4	−.01103210	.00364971
5	−.00518160	.00363179
6	−.00509390	.00368404
7	−.00345115	.00378609
8	.00025246	.00401947
9	−.00204338	.00451328
10	0	...
DPREG^2 × MK305		
1	.00011810	.00001608
2	.0000845	.00001586
3	.0000729	.00001518
4	.0000771	.00001496
5	.0000539	.00001492
6	.0000511	.00001512
7	.0000472	.00001554
8	.0000229	.00001645
9	.0000251	.00001835
10	0	...
DIM × MK305		
1	−.05991749	.01849692
2	−.07527913	.01774465
3	−.04622871	.01618521
4	−.04078080	.01572250
5	−.06666278	.01551135
6	−.06952342	.01612329
7	−.06399519	.01714571
8	−.10124819	.01943342
9	−.07362102	.02371444
10	−.10552595	.02596610
DIM^2 × MK305		
1	.0000832	.00002743
2	.0000991	.00002630
3	.0000528	.00002401
4	.0000415	.00002334
5	.0000749	.00002301
6	.0000738	.00002389
7	.0000591	.00002536
8	.00010809	.00002865
9	.0000651	.00003482
10	.00010742	.00003799

[1] The 305-d milk yield classes (MK305) began at <4500 kg and increased by 500 kg increments to >8500 kg.

TABLE 2A. Regression coefficients and class effects (kg) for milk yield on a given day in milk (DIM) and a specified day of pregnancy (DPREG) from the forecast model for pluriparous cows.

Parameter	Estimate	SE
Intercept	65.59522595	...
Age class		
<36 mo	1.13149477	.05257771
36 – <48 mo	.89504535	.02148229
48 – <60 mo	.26653641	.02239966
⩾60 mo	0	...
Season of calving		
Nov to Feb (A)	−3.22317407	.12158060
Mar, Apr, Sep, Oct (B)	−2.01067350	.12496074
May to Aug (C)	0	...
DPREG	−.00491366	.03670641
$DPREG^2$	.00074496	.00014926
MK305[1] × Season		
1 × A	−44.64948036	3.67373031
1 × B	−45.40632474	3.67292166
1 × C	−46.96435373	3.67486785
2 × A	−38.67855379	3.71609611
2 × B	−39.06870124	3.71516124
2 × C	−40.42036507	3.71727743
3 × A	−37.22011594	3.55440703
3 × B	−37.94289218	3.55369145
3 × C	−38.96276055	3.55543017
4 × A	−30.75115754	3.47767099
4 × B	−31.10762309	3.47703357
4 × C	−32.19827030	3.47880490
5 × A	−30.21760214	3.44805812
5 × B	−30.35099478	3.44753898
5 × C	−31.39434432	3.44932318
6 × A	−26.19262345	3.47616694
6 × B	−26.36845822	3.47562589
6 × C	−27.19981452	3.47738577
7 × A	−21.97243290	3.53944277
7 × B	−22.26318992	3.53892271
7 × C	−22.85719015	3.54068309
8 × A	−16.69637651	3.69094116
8 × B	−16.75097576	3.69059720
8 × C	−17.34321556	3.69256097
9 × A	−11.17695737	3.92503392
9 × B	−10.91869207	3.92384955
9 × C	−11.49317427	3.92612392
10 × A	−8.18407335	4.37665832
10 × B	−8.21010140	4.37615563
10 × C	−8.63056027	4.37788632
11 × A	0	...
11 × B	0	...
11 × C	0	...
DPREG × DIM	.00016044	.00021992
DPREG × DIM^2	−3.83E−07	.00003272
$DPREG^2$ × DIM	−5.2282E−06	.00008851
$DPREG^2$ × DIM^2	7.62E−09	.00001305
DPREG × MK305		
1	−.01722604	.00327730
2	−.01139154	.00330045
3	−.00804463	.00313359
4	−.00671226	.00301952
5	−.00753520	.00298708

(continued)

TABLE 2A. (continued) Regression coefficients and class effects (kg) for milk yield on a given day in milk (DIM) and a specified day of pregnancy (DPREG) from the forecast model for pluriparous cows.

Parameter	Estimate	SE
6	−.00219261	.00300183
7	−.00358096	.00306588
8	.00014066	.00320301
9	−.00009860	.00337539
10	−.00115597	.00379278
11	0	. . .
DPREG² X MK305		
1	.00010994	.00001324
2	.0000858	.00001338
3	.0000709	.00001279
4	.0000640	.00001241
5	.0000646	.00001230
6	.0000409	.00001238
7	.0000421	.00001265
8	.0000210	.00001320
9	.0000221	.00001397
10	.0000157	.00001568
11	0	. . .
DIM X MK305		
1	−.03408100	.01746899
2	−.05889909	.01760322
3	−.05966213	.01652230
4	−.08856385	.01582712
5	−.08320492	.01562332
6	−.09680768	.01577697
7	−.11118719	.01618621
8	−.13378335	.01731971
9	−.15694469	.01898337
10	−.16007408	.02206171
11	−.18824561	.02196701
DIM² X MK305		
1	.0000408	.00002611
2	.0000684	.00002627
3	.0000654	.00002466
4	.00010066	.00002363
5	.0000887	.00002333
6	.00010123	.00002354
7	.00011701	.00002414
8	.00014555	.00002576
9	.00017284	.00002815
10	.00016953	.00003257
11	.00020254	.00003239

[1]The 305-d milk yield classes began at <5500 kg and increased by 500-kg increments to >10,000 kg.