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Extending Partial Lactation Milk and Fat Records with a Function of Last-Sample Production

G. R. Wiggans
Cornell University

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

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G. R. WIGGANS[1] and L. D. VAN VLECK
Department of Animal Science
Cornell University
Ithaca, NY 14853

ABSTRACT

Holstein production records (364,328) from the Northeast were used to develop a procedure to extend in-progress and terminated records. A function was developed involving last-sample production which accounts for systematic influences in estimating remaining yield, which is yield from day of last sample to day 305. Last-sample production was used because remaining yield is estimated more accurately from last-sample production than from cumulative yield. The function is: estimated 305-day yield = yield in first n days + $[(b_1 + b_2 n)$ last production + $(b_3 + b_4\sqrt{n})$/last production$)] \cdot (305\text{-}n)$. The coefficients (b's) were estimated within three stages (<65, 65 to 245, >245 days in milk), four age at freshening groups (<34, 34 to 48, 49 to 60, and >60 mo, 34 to 36 mo cows were placed in the first group if freshening for the first time), three herd yields (<5900, 5900 to 7000, and >7000 kg), and six 2-mo season-of-freshening groups by least squares for milk and fat yield. Cumulative yield factors were developed from the same data and compared with this function. The last-sample function had smaller error variance.

INTRODUCTION

The measurement of lactation milk production in dairy cattle has been accepted as the production during the first 305 days following freshening. This standard length allows records to be compared without concern for the length of the production period. One difficulty with this measure is that a cow must have an opportunity to complete 305 days in milk before this measure of her productive ability exists. For cows which are sold or die this information is never available; consequently, the 305-day yield must be estimated. This estimation is extending or projecting records. Extending records of cows culled before 305 days in lactation permits records of all daughters to be used in sire evaluation decreasing bias due to differential culling. Extending records-in-progress allows for earlier and more accurate evaluation of young sires and permits comparisons among cows in all stages of lactation for herd management decisions.

Nationally, records are extended by factors which ignore season of freshening developed by McDaniel et al. (9) in 1965. Since these factors were computed, there have been changes in the computation of records, production is now credited from the day of freshening, and the test interval method is used in conjunction with factors developed by Shook (15, 16) which adjust the early and last periods. These changes have changed partial records computed from the same sample-day production values. Powell et al. (12) found that current factors underestimate 305-day milk yield by about 300 kg at midlactation.

Miller et al. (10) showed that records could be extended more accurately if the production on the last-sample-day rather than the cumulative yield was used to predict the unknown remaining yield. The superiority of this approach has been confirmed by several other workers (3, 6, 11). Dommerholt (5) developed last-sample factors for the Netherlands which varied according to herd production. These results suggested that considerable improvement in the accuracy of extended records was possible by considering last-sample production, season, and herd production in extending records, the objective of this study.

EXPERIMENTAL PROCEDURES

Lactation production records (364,325 from the Dairy Records Processing Center at Ithaca,

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[1] Animal Improvement Programs Laboratory, USDA, Beltsville, MD 20705.

NY) which had sample-day yields, normal termination with greater than 180 days in milk, and could be matched with 12-mo rolling herd averages were used. The 305-day yields and cumulative yield to each sample-day were computed with Shook's factors (16). For various combinations of age, parity, month of freshening, herd production, last-sample production, and length of partial record, factors were computed by:

$$\text{Factor}_n = \Sigma RY/\Sigma[LP \cdot (305\text{-}n)]$$

where n = the length of the partial record, RY = is the 305-day yield less the partial record yield (remaining yield), and LP = last-day production. These values then were compared to determine which of the above characteristics had an important influence. Those important characteristics then were used either to define classes or as variables in a prediction equation whose coefficients varied by class. Various functions were compared to determine which variables would give the best fit and require a table of constants of minimum size. Coefficients for the equation were estimated by least squares separately for each class.

Factors using only the cumulative yield also were computed from the same data for use when the last-sample production is unknown and for comparison with the last-sample equation. The factor for a partial record of n days (F_n) was computed for each 10 days during lactation as the ratio of the actual remaining yield to the remaining yield if the average daily yield of the partial record were maintained until day 305. $F_n = \Sigma RY/\Sigma[Y_n/n\ (305\text{-}n)]$. By these factors 305-day yield is estimated as:

$$\hat{Y}_{305} = [1 + F_n(305\text{-}n/n)]\ Y_n$$

where Y_n is the partial record production. The last-sample equation and the cumulative yield factors were evaluated by applying them on a subset of the original data used to compute them. This subset was composed of the first 93,859 records in the file; these are records on cows in New England. This subset was chosen so that the overall factors could be tested on a smaller region. The bias (estimated 305-day record minus actual) and the error variance were computed.

RESULTS AND DISCUSSION

Investigation of the last-sample factors with respect to age indicated that young cows differ substantially from older cows, but for cows of various ages in first lactation there was little difference. Factors for cows which started their second lactation before 36 mo resembled factors for cows in second lactation so for cows 34 to 36 mo of age the age grouping should be by lactation number. This finding agrees with Lamb et al. (8). The factors are smaller for older cows than for younger cows. This indicates that production declines more steeply after peak production for older cows. Four age groupings (<34, 34 to 48, 49 to 60, and >60 mo, with cows 34 to 36 mo of age freshening for the first time in the first group) were defined to provide different factors according to age.

There is considerable seasonal influence on milk production and a corresponding influence on extension factors (7, 13, 14). A spring stimulus to production as discussed by Wood (20) is especially apparent. This stimulus causes the extension factor for fall freshening cows to be larger since the spring stimulus causes these cows to be more persistent. The effect of season of freshening was accounted for by dividing the year into six periods of two months.

Milk and fat yield required separate factors due to the change in fat test over the lactation. Fat production is more persistent than is milk production.

Herd production was important in determining the appropriate extension factors. Auran (2) showed that herd production accounted for 74 to 89% of the herd effects on yield on the first 8 sample days and that herd production accounted for 5 to 23% of the variation in sample-day yields. Wiggans and Van Vleck (19) also found indications that herd might be important in extending records. Van Vleck and Henderson (17) found regression factors within herds superior to factors which ignored the herd average. When partial records from high-producing herds were extended with factors developed from all records, production was underestimated considerably. Records from higher herds require larger factors which implies that two cows from herds with different production would have different extended

TABLE 1. Coefficients to extend first lactation Holstein milk production records from last-sample production.

Coef- ficient[a]	Herd[b]	Day at end of stage	Season					
			Jan – Feb	Mar – Apr	May – June	July – Aug	Sept – Oct	Nov – Dec
b_1	Low	65	.68	.66	.63	.69	.71	.70
		245	.60	.52	.60	.68	.72	.69
		305	.34	.86	.73	.72	.42	.49
	Medium	65	.68	.67	.65	.68	.73	.70
		245	.63	.56	.62	.67	.70	.68
		305	.67	.76	.79	.77	.39	.55
	High	65	.68	.67	.68	.69	.73	.72
		245	.64	.60	.60	.70	.71	.69
		305	.49	.63	.98	.97	.65	.64
b_2[c]	Low	65	-.41	-.49	.49	.56	.54	.20
		245	.84	1.60	1.38	1.00	.53	.40
		305	2.09	.20	.73	.71	1.66	1.55
	Medium	65	.22	-.31	.73	.76	.18	.27
		245	.75	1.35	1.30	1.02	.66	.55
		305	.92	.63	.56	.60	1.89	1.32
	High	65	.71	.26	.38	1.12	.70	.32
		245	.81	1.23	1.47	.95	.65	.63
		305	1.64	1.21	-.07	-.08	.97	1.08

b_3	Low	65	349	352	333	291	344	396
		245	364	360	312	310	250	332
		305	-72	-394	-373	-86	-293	-311
	Medium	65	618	576	623	554	504	606
		245	472	541	509	529	470	467
		305	-448	-304	-487	11	-555	-210
	High	65	891	858	759	777	755	803
		245	560	593	775	609	613	623
		305	-56	-2	-716	-432	-1043	-856
b_4[d]	Low	65	-25	-26	-28	-23	-30	-35
		245	-25	-26	-23	-23	-17	-22
		305	2	22	20	3	15	17
	Medium	65	-55	-44	-57	-45	-41	-55
		245	-31	-36	-36	-37	-32	-32
		305	23	15	25	-3	29	9
	High	65	-90	-82	-66	-73	-72	-76
		245	-28	-40	-55	-42	-42	-44
		305	-2	-6	36	21	57	46

[a]The four coefficients (b) are used to estimate 305 day yield ($\hat{Y}_{305}$) as follows: $\hat{Y}_{305} = Y_n + (b_1 + b_2 n)\, LP + (b_3 + b_4\sqrt{n})/LP)\,(305-n)$ where Y_n is the production of a partial record of *n* days, and LP is last-sample production.

[b]The herd production groups are defined by the 12 mo rolling herd average with low, <5900 kg; medium, 5900 kg to 7000 kg; and high, above 7000 kg of milk.

[c]Table value is $b_2 \times 1000$.

[d]If production is expressed in kg b_3 and b_4 should be divided by 4.86.

TABLE 2. Coefficients to extend first lactation Holstein fat production records from last-sample production.

Coef-ficient[a]	Herd[b]	Day at end of stage	Season					
			Jan – Feb	Mar – Apr	May – June	July – Aug	Sept – Oct	Nov – Dec
b_1	Low	65	.57	.57	.54	.61	.60	.60
		245	.57	.49	.63	.69	.71	.67
		305	.35	.73	.72	.76	.21	.51
	Medium	65	.57	.56	.57	.62	.63	.59
		245	.56	.53	.70	.67	.67	.65
		305	.67	.66	.73	.72	.10	.61
	High	65	.57	.57	.59	.63	.61	.60
		245	.57	.55	.62	.68	.68	.64
		305	.54	.59	.82	.83	.43	.60
b_2[c]	Low	65	1.26	.69	2.29	1.87	2.07	1.27
		245	1.14	1.89	1.30	.94	.65	.51
		305	2.02	.72	.75	.50	2.40	1.47
	Medium	65	1.33	1.06	1.90	1.40	1.19	1.34
		245	1.25	1.66	.83	.95	.74	.64
		305	.89	.98	.72	.73	2.88	1.13
	High	65	1.88	.80	1.65	1.41	1.92	1.67
		245	1.29	1.52	1.22	.99	.73	.72
		305	1.42	1.18	.44	.36	1.70	1.26

b_3[d]	Low	65	.57	.50	.57	.48	.59	.57
		245	.62	.72	.59	.56	.50	.55
		305	.35	-.04	-.24	.15	.38	.10
	Medium	65	.86	.86	.81	.77	.75	.89
		245	.93	1.07	.68	.93	.87	.78
		305	.13	.43	.12	.74	.94	.44
	High	65	1.17	1.02	1.03	.97	1.12	1.16
		245	1.15	1.36	1.28	1.20	1.16	1.11
		305	.88	1.18	.76	.83	.65	.33
b_4[d,e]	Low	65	-.34	-.24	-.38	-.29	-.40	-.33
		245	-.40	-.50	-.41	-.38	-.32	-.33
		305	-.24	-.00	-.12	-.11	-.26	-.08
	Medium	65	-.53	-.47	-.46	-.35	-.36	-.57
		245	-.58	-.69	-.41	-.59	-.53	-.46
		305	-.13	-.30	-.12	-.47	-.61	-.31
	High	65	-.83	-.38	-.53	-.46	-.71	-.78
		245	-.71	-.84	-.79	-.75	-.71	-.66
		305	-.59	-.79	-.53	-.54	-.45	-.27

[a]The four coefficients (b) are used to estimate 305 day yield ($\hat{Y}_{305}$) as follows: $\hat{Y}_{305} = Y_n + (b_1 + b_2 n)\ LP + (b_3 + b_4\sqrt{n}/LP)\ (305-n)$ where Y_n is the production of a partial record of n days, and LP is last-sample production.

[b]The herd production groups are defined by the 12 mo rolling herd average with low, <5900 kg; medium, 5900 kg to 7000 kg; and high, above 7000 kg of milk.

[c]Tabled value is $b_2 \times 1000$.

[d]If production is expressed in kg b_3 and b_4 should be divided by 4.86.

[e]Tabled value is $b_4 \times 10$.

records even if the cows had the same partial record and last-sample production. This result is appropriate since some of the production superiority of higher producing herds comes from their greater persistency. This influence was accounted for by defining three herd groups with dividing points of 5900 and 7000 kg milk. The three groups included approximately 25%, 50%, and 25% of the records.

There is a practical limit as to how extensive a system of extension factors can be. The need to have a different set of factors for different ages, seasons, herds, and products (milk and fat) required that consideration be given to possible simplifications in expressing the effect of length of partial record on a set of factors. The length of the partial record had regular influence on the factors indicating that a mathematical function might represent a set of factors. The last-sample production as suggested by Appleman et al. (1) and Auran (4) also affected the factors.

Various functions of last-sample production and days in the partial record were examined to determine which form would give adequate fit. The result was an equation with four coeffi-

TABLE 3. Cumulative milk yield factors[a] for first lactation Holsteins.

Day at start of stage	Season					
	Jan – Feb	Mar – Apr	May – Jun	July – Aug	Sept – Oct	Nov – Dec
5	1.24	1.20	1.18	1.23	1.28	1.29
15	1.05	1.03	1.02	1.08	1.11	1.10
25	.95	.93	.93	.99	1.02	1.00
35	.89	.86	.86	.92	.94	.92
45	.86	.84	.84	.89	.92	.90
55	.84	.82	.83	.88	.90	.88
65	.82	.78	.81	.86	.88	.85
75	.80	.78	.79	.85	.87	.84
85	.79	.76	.79	.85	.86	.83
95	.78	.75	.78	.84	.85	.82
105	.76	.74	.78	.84	.84	.81
115	.75	.74	.78	.84	.84	.81
125	.75	.73	.78	.83	.83	.80
135	.74	.73	.76	.83	.82	.78
145	.73	.73	.77	.83	.82	.78
155	.72	.72	.77	.82	.81	.77
165	.71	.71	.76	.82	.80	.76
175	.70	.71	.76	.81	.80	.75
185	.69	.71	.76	.80	.79	.73
195	.68	.69	.75	.80	.78	.72
205	.67	.70	.74	.80	.77	.71
215	.66	.69	.74	.78	.76	.69
225	.65	.67	.73	.77	.73	.67
235	.64	.67	.72	.77	.73	.66
245	.63	.66	.72	.75	.70	.64
255	.61	.65	.70	.74	.68	.62
265	.60	.64	.70	.74	.66	.61
275	.61	.65	.69	.72	.64	.62
285	.62	.66	.70	.74	.65	.62
295	.65	.69	.73	.76	.66	.65

[a]Yield is estimated by $\hat{Y}_{305} = [1 + \text{factor}\ (305\text{-}n)/n]\ Y_n$.

cients shown below:

$$\hat{Y}_{305} = Y_n + [(b_1 + b_2 n) LP + (b_3 + b_4\sqrt{n})/LP] (305\text{-}n)$$

where n is the length of the partial record, $\hat{Y}_{305}$ is the estimated 305-day production, and Y_n is the cumulative yield to day n. The first 65 days and last 60 days of lactation were not fit adequately by this equation, so separate equations were fitted for those stages. For each of four age of freshening groups, six seasons of freshening, three herd production levels, three stages, and two products (milk and fat), the four coefficients (b's) were estimated by least squares.

The coefficients for first lactation milk and fat records are in Tables 1 and 2. The values for milk in Table 1 are difficult to interpret because of the high correlations among the variables in the equation. For example, differences in one coefficient between herd groups may be offset by differences in another coefficient. The differences in the coefficients by stage of lactation are clear; the last stage differs especial-

TABLE 4. Cumulative fat yield factors[a] for first lactation Holsteins.

Day at start of stage	Season: Jan – Feb	May – Apr	May – Jun	July – Aug	Sept – Oct	Nov – Dec
5	.80	.80	.82	.89	.88	.84
15	.74	.73	.76	.82	.81	.78
25	.71	.69	.73	.78	.77	.73
35	.68	.68	.71	.76	.76	.71
45	.67	.67	.70	.75	.75	.71
55	.67	.66	.71	.76	.75	.70
65	.66	.66	.70	.75	.74	.70
75	.66	.65	.71	.75	.74	.69
85	.66	.65	.71	.75	.74	.69
95	.65	.65	.70	.75	.74	.69
105	.65	.65	.71	.74	.73	.69
115	.65	.65	.70	.75	.73	.68
125	.63	.65	.70	.74	.73	.68
135	.63	.65	.70	.74	.73	.67
145	.63	.65	.70	.74	.72	.67
155	.62	.64	.69	.73	.72	.66
165	.61	.64	.69	.73	.71	.65
175	.61	.63	.68	.72	.70	.64
185	.60	.62	.68	.71	.70	.63
195	.59	.62	.67	.70	.69	.62
205	.59	.61	.65	.70	.67	.60
215	.57	.59	.66	.69	.66	.59
225	.56	.59	.65	.67	.64	.57
235	.55	.58	.62	.67	.62	.56
245	.53	.57	.62	.65	.60	.55
255	.52	.56	.62	.64	.59	.54
265	.52	.56	.61	.64	.57	.52
275	.52	.56	.61	.64	.57	.53
285	.53	.58	.63	.65	.57	.55
295	.57	.61	.66	.67	.58	.57

[a]Yield is estimated by $\hat{Y}_{305} = [1 + \text{factor } (305\text{-}n)/n]\ Y_n$.

TABLE 5. Comparison of mean and variance of differences between estimated and actual lactation milk yield for two procedures, (A) using the last-sample production, and (B) using only the cumulative yield.

Day at start of 10 day period[a]	Bias $(\hat{Y}_{305} - Y_{305})$ kg		Variance of error kg^2		No. of records in period
	A	B	A	B	
5	-65.9	5.7	907,000	1,379,000	23,471
25	55.9	1.8	702,000	887,000	29,657
45	11.1	-1.3	562,000	715,000	29,801
65	-4.9	1.4	469,000	593,000	28,307
85	4.4	.2	385,000	487,000	27,640
105	4.5	1.0	316,000	403,000	27,279
125	9.1	6.2	262,000	344,000	25,478
145	13.3	6.8	212,000	284,000	24,851
165	19.5	2.3	167,000	237,000	23,985
185	19.8	6.3	126,000	195,000	22,820
205	11.5	6.6	87,000	151,000	21,707
225	-4.7	5.0	55,000	111,000	21,080
245	-.6	3.6	26,000	68,000	19,206
265	5.6	1.7	9,000	30,000	17,385
285	-4.4	-1.2	1,000	6,000	14,364

[a]Results for the 10 day period following each listed period are omitted.

ly from the other two. A trend due to season of freshening is usually apparent especially in the first coefficient. The second coefficient, b_2 can be thought of as how much adjustment there is to b_1 with an additional day in the partial record. It is usually positive indicating an increasing weight on the last-sample production as the partial record increases in length. The last two coefficients effectively change the weight on last-sample production depending on the amount of production on that day. As shown in the equivalent representation:

$$\hat{Y}_{305} = Y_n + [b_1 + b_2 n + (b_3/LP^2) + (b_4\sqrt{n}/LP^2)]\ LP\,(305\text{-}n)$$

A greater LP yields a smaller $1/LP^2$ and since the b_3 coefficient is positive for the first two stages of lactation, it causes a reduction in weight on LP with increasing production. The last coefficient b_4 is an adjustment to b_3 for length of partial record. It is often negative which causes a reduction in the influence of b_3 with increasing length of partial record.

Table 5 compares the last-sample equation with the cumulative yield factors showing the reduction in error variance by using the production on the last-sample. The bias (estimated minus actual) for the last-sample procedure was greater than for the cumulative yield procedure because the last-sample procedure was developed considering fewer stages of lactation than the cumulative yield factors. This bias could be reduced by increasing the number of stages; however, the possible improvement did not seem to justify the increase in the number of factors required. The relatively smaller variance of the error of the last-sample procedure became more pronounced with increasing length of partial record as expected since the advantage of the last-sample procedure results from using the most current information. The cumulative yield could also be included in the last-sample procedure as an additional variable used in estimating the remaining yield, however this augmented equation reduced the variance of the error little so the cumulative yield was not used in this way. The number of observations declined with increasing length of partial record due to cows going dry. A total of 93,857 lactation records were used for the comparison shown in Table 5. The number in any 10 days represents only those cows that were sampled in that period of lactation.

In application it may be necessary to maintain cumulative yield factors which ignore herd to use in situations when the last-sample production or the herd production is unknown. The cumulative yield factors are appropriate for this purpose and do not require interpolation of the type described earlier (18). Production trends may cause both sets of factors to become gradually less accurate, requiring a periodic updating. However, the last-sample production will continue to be the most important single indication of yield during the remainder of lactation. Additional work may result in some simplification of this system making it easier to use; however, factors described here represent the first proposed implementation of last-sample factors in the U.S.

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