Estimating Daily Yields of Cows Milked Three Times a Day

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ABSTRACT

Factors to estimate daily yield from one or two sampled milkings of cows milked three times a day were derived with data for 21 mo from seven Pennsylvania herds and data for 1 yr from five Utah herds. Accuracy of estimation increased with number of milkings weighed; standard deviation of error was nearly halved when information was included from two milkings instead of one. Fat yield did not increase as much as milk yield with increased time between milkings (interval); therefore, fat percentage factors increased with interval. If fewer milkings were sampled than weighed, fat yield was estimated by adjusting sample-day fat percentage. Effect of interval on protein yield was nearly the same as on milk yield. Therefore, milk factors are recommended for protein, and no adjustment to protein percentage is necessary if fewer milkings are sampled than weighed. Factors derived for milk were tested on records from 53 California and Oregon herds. Standard deviations of errors were similar to those from Utah and Pennsylvania data.

INTRODUCTION

Approximately 7% of cows enrolled in the National Cooperative Dairy Herd Improvement Program (NCDHIP) are milked three times a day (3X), with the practice most common for large herds. In 1984, average herd size was 70 cow-years for herds with two-times-a-day (2X) milking and 193 cow-years for herds with 3X milking (2). Although NCDHIP is especially useful for large herds, labor requirements and disruption of routine involved with weighing and sampling three milkings on sample day makes production testing particularly difficult for these herds. For 2X herds, a.m.–p.m. sampling plans are available that reduce supervisor visits by weighing and sampling only one milking per month and alternating the sampled milking between a.m. and p.m. Total yield on sample day for cows milked 2X in a.m.–p.m. plans has been estimated from information from a single milking with factors developed by Shook et al. (4), and accuracy of this estimation was demonstrated in field data (5). Recent research by DeLorenzo and Wiggans (1) updated these factors, and the revised factors were adopted by the NCDHIP Policy Board.

For 3X milking, a method to estimate daily yield from yield(s) of one or two milkings had not been available. A resolution for NCDHIP to provide an a.m.–p.m. testing program for 3X herds was approved at the 1980 convention of the National Dairy Herd Improvement Association. This study was undertaken to develop factors to estimate daily yield for cows milked 3X.

MATERIALS AND METHODS

Data

Sample day data from seven Pennsylvania herds with 3X milking were collected from January 1982 through September 1983; for each month of data collection, data from at least five herds were available. Data included 4627 cow sample days with complete milk and component information. Four samples were collected for each cow sample day (one for each milking and a composite). The composite was collected to permit data from these herds to be processed by standard laboratory and computing procedures in preparation of Dairy Herd Improvment reports. Composite percentages were not reported for the first 7 mo of data collection but were obtained from lactation records in progress that are provided

Received April 14, 1986.

routinely to the Animal Improvement Programs Laboratory through NCDHIP. Matches were found for 84% of cow sample days. For the last 14 mo of data collection, composite percentages were included with data for cow sample days.

Sample day data for 12 mo from five Utah herds with 3× milking were collected starting in fall 1982. Samples from each milking were analyzed for fat and protein. Complete information was available for 5553 cow sample days; however, no composite samples were collected.

For Pennsylvania and Utah data, days in milk were added to the cow sample day record. Necessary fresh dates were obtained from records in progress provided routinely to AIPL.

Field data that included 37,315 cow-days from 53 herds with 3× milking from January through March 1984 in California and Oregon were provided by Agri Tech Analytics, Tulare, CA. Component percentages for individual milkings were not available; therefore, only milk yield was analyzed.

For all data sets, individual cow milking sequence was not controlled.

Statistical Analysis

Interval between milkings was computed for each herd. Starting time of milking preceding first sampled milking had been recorded for Utah data, which allowed accurate calculation of length of first interval. For Pennsylvania, California, and Oregon data, first interval was computed by assuming that the milking preceding the first occurred at the same time as the third milking. Information for cows with only two milkings or for cows with a milking of less than 2.27 kg was excluded.

Milkings were classified according to starting time: 1 (0200 to 0959 h), 2 (1000 to 1759 h), or 3 (1800 to 0159 h). Three time periods were defined to allow for estimation of effects of time of day milking. Pennsylvania and Utah data did not include cow sample days with more than one milking in a time group. Boundary times were selected so that they would occur when starting times for milkings were least frequent. Starting times for Pennsylvania and Utah data were clustered near midpoints of interval times; therefore, changes between standard and daylight savings times did not affect milking designation. Starting times for California and Oregon field data occurred at all times throughout the day but were somewhat less frequent at the boundaries selected.

Analysis was on proportion of daily yield produced at a particular milking and not its reciprocal, which is the normal factor. Proportion of daily yield was chosen because reciprocals of factors for 2× herds were linear with interval length (1). Model for porportion of daily yield from one milking as a function of interval was:

$$s_{ij}/d_j = \alpha_i + \beta(t_{ij}) + e_{ij}$$

where s_{ij} = yield (milk, fat, or protein) at milking i (1, 2, or 3) for cow sample day j, d_j = daily yield for cow sample day j, α_i = intercept for milking i, β = slope, t_{ij} = interval between milking i and previous milking for cow sample-day j, and e_{ij} = residual effect. A common slope (β) was selected for all three milkings based on results from analysis of 2× data (1) and preliminary analysis of 3× data. The α were adjusted so that $\alpha_1 + \alpha_2 + \alpha_3 = 1 - \beta*24$. This adjustment corrects the α to a 24-hr basis. Pennsylvania and Utah data were combined to estimate coefficients.

Estimated coefficients were tested on data sets individually to assess region, stage of lactation, interval, and herd effects. Each of the three time groups for milkings was analyzed separately. Coefficients also were tested for weighing two milkings of three. The same coefficients were applied by summing α and t over the two milkings included:

$$d = (s_i + s_{i-1})/[\alpha_i + \alpha_{i-1} + \beta(t_i + t_{i-1})]$$

where d = estimated daily yield; s, i, d, β, and t are as defined previously; and i − 1 = milking preceding i. Weighed milkings were consecutive; starting times determined α.

Factors for fat percentage are necessary if fat is sampled for fewer milkings than are weighed (6) and were derived from coefficients for milk and component yields:

$$\begin{aligned}\hat{f}\% &= (\hat{d}_f/\hat{d}_m)\ 100\\ &= (s_{i_f}/p_f)/(s_{i_m}/p_m)\ 100\\ &= (s_{i_f}/s_{i_m})(p_m/p_f)\ 100\\ &= f\%_i\ (p_m/p_f)\end{aligned}$$

where $\hat{f}\%$ = estimated fat percentage, $\hat{d}$ = estimated daily yield for milk (m) or fat (f), s_i =

yield for trait m or f at sampled milking i, p = $\alpha_i + \beta(t_i)$ for yield trait m or f, and $f\%_i$ = fat percentage from sampled milking i. Pennsylvania data allowed comparison of weighted averages for fat percentages with composite sample percentages. Weighting was by milk yield so that daily fat percentage was estimated. If composite sample was not included, sample day records were matched with lactation records in progress to obtain composite percentages. Correlations were computed with the 3010 cow sample days with fat percentages for each milking and a composite percentage.

RESULTS

Coefficients for milk, fat, and protein are in Table 1. As indicated by α, highest yield for a given interval is expected from milking 1 and lowest from milking 3. Effect of time of day was greater for milk and protein than for fat as indicated by greater difference in α among milkings. Effect of interval on yield was similar for milk and protein but was much less for fat. Because of similarity between results for milk and protein, daily protein yield may be estimated with milk factors.

Factors for estimating daily yield (examples in Table 2) were derived from coefficents and are reciprocals of proportion of daily yield. If one milking was weighed, the factor was approximately 3; if two milkings were weighed, the factor was approximately 1.5.

Factors for estimating fat percentage (examples in Table 3) increased with interval and also were influenced by time of day at milking. Fat percentage was relatively lower at milking 1. Thus, the factor for milking 1 was larger than the factors for the other two milkings, which were similar. This larger factor was related to the milking's smaller milk factor, a result of larger α (Table 1), which indicated that for a given interval, more milk was produced at milking 1 than at milking 2 or 3.

Similar standard deviations of error (estimated minus actual) for estimating daily yield (Table 4) were found for all states. Standard deviations for milk if one milking was weighed were largest for Utah herds and intermediate for California and Oregon herds, which had the largest number of cow sample days. All mean errors were approximately zero and are not reported. Effects of stage of lactation, interval, and herd were minimal and also are not reported.

Correlations among individual and composite determinations and averages for component percentages weighted by milk yield are in Table 5 for fat and Table 6 for protein. Information on last sample day composite percentages was not available for some lactation records in progress.

For fat percentage, individual milkings were related more closely to composite than to each other and more closely to weighted average than to composite, which reflects the part-whole relationship. Substantial differences were found between composite fat percentage and weighted averages of fat percentages for the three milkings. Standard deviation of differences was .36; mean of weighted average exceeded composite mean by .022; the largest difference was 6.32.

The correlation of .83 between weighted average and composite fat percentage raises the

TABLE 1. Slopes (β) and intercepts (α) for estimating daily milk, fat, and protein yields for herds with three-times-a-day milking.[1]

Yield product	β	SE	Milking 1 α	Milking 1 SE	Milking 2 α	Milking 2 SE	Milking 3 α	Milking 3 SE
Milk	.0329	.00040	.077	.0034	.068	.0032	.066	.0031
Fat	.0186	.00058	.186	.0049	.186	.0046	.182	.0045
Protein[2]	.0333	.00041	.072	.0035	.065	.0032	.063	.0032

[1] Milkings numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

[2] Because of the similarity of protein coefficients to milk coefficients, milk factors are recommended for estimating daily protein yield.

TABLE 2. Examples of factors to estimate daily milk yield[1] from one or two weighed milkings for herds milked three times a day for selected milking intervals.

Interval (h)	Factor[2]		
	Milking 1	Milking 2	Milking 3
One weighed milking			
7	3.25	3.35	3.37
8	2.94	3.02	3.04
9	2.68	2.75	2.76
Two weighed milkings[3]			
15	1.57	1.57	1.59
16	1.49	1.49	1.51
17	1.42	1.42	1.44

[1] Daily protein yield can be estimated with milk factors.

[2] Milkings numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

[3] Milking number is for second weighed milking.

question of which is the more appropriate indicator of fat yield. The low correlation between weighted average and composite may explain why Lee and Wardrop (3) found estimates of daily fat yield from a single milking sample to be of low reliability for Canadian data.

For protein percentage, correlations were higher than for fat percentage. Correlations among individual milkings and composite percentage were similar. Individual milkings were related more closely to weighted average than to composite. In contrast to fat percentage, weighted average for protein percentage was related more closely to individual milkings than to composite percentage. However, all correlations were higher for protein than for fat.

CONCLUSIONS

Effect of interval for 3× factors was similar to that for 2× factors. Slope was .0329 for 3× milk yield and .0363 for 2× milk yield (7). Fat yield was affected less by interval than were milk and protein yields. Milk factors were applicable for protein. Although no information on solids-not-fat was available, milk factors are recommended for solids-not-fat because of appropriateness of milk factors for protein.

If two milkings were weighed, standard deviation of error was less than or equal to that for a.m.–p.m. plans for 2× herds (1.7 kg) (5), as expected, because two milkings measure about two-thirds of daily yield, whereas a.m.–p.m. plans for 2× herds measure half. If only one milking was weighed, standard deviations

TABLE 3. Examples of factors to estimate daily fat percentage from one sampled milking for herds milked three times a day for selected milking intervals.

Interval (h)	Factor[1]		
	Milking 1	Milking 2	Milking 3
7	.97	.94	.95
8	1.02	.99	1.00
9	1.06	1.03	1.04

[1] Milkings numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

TABLE 4. Standard deviations of errors for estimating daily milk, fat, and protein yields for herds milked three times a day by region.

Yield product	Number of milkings weighed	Data region	Standard deviation of error[1]		
			Milking 1	Milking 2	Milking 3
Milk	1	Pennsylvania[2]	2.9	3.1	3.1
		Utah[3]	3.4	3.7	3.7
		California/Oregon[4]	3.4	3.6	3.4
	2	Pennsylvania	1.5	1.5	1.5
		Utah	1.7	1.7	2.0
Fat[5]	1	Pennsylvania	.61	.71	.64
		Utah	.60	.62	.62
	2	Pennsylvania	.32	.36	.36
		Utah	.31	.30	.32
Protein[5]	1	Pennsylvania	.37	.48	.40
		Utah	.40	.42	.42
	2	Pennsylvania	.20	.24	.26
		Utah	.20	.20	.22

[1] Milking numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

[2] Number of cow sample days = 4536; average milk yield = 26.9 kg with standard deviation = 9.3 kg.

[3] Number of cow sample days = 5553; average milk yield = 28.0 kg with standard deviation = 9.6 kg.

[4] Number of cow sample days = 37,315; average milk yield = 29.2 kg with standard deviation = 8.9 kg.

[5] Errors for fat and protein divided by mean milk yield and multiplied by 100 to express percentages; protein standard deviations computed with protein coefficients, not milk coefficients.

TABLE 5. Correlations among individual[1] and composite fat percentage determinations and weighted average from 3010 cow sample days in Pennsylvania.

	Milking 2	Milking 3	Composite	Weighted average
Milking 1	.52	.46	.71	.81
Milking 2		.49	.67	.81
Milking 3			.68	.79
Composite				.83

[1] Milkings numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

TABLE 6. Correlations among individual[1] and composite protein percentage determinations and weighted average from 3010 cow sample days in Pennsylvania.

	Milking 2	Milking 3	Composite	Weighted average
Milking 1	.82	.85	.83	.95
Milking 2		.82	.79	.93
Milking 3			.86	.94
Composite				.87

[1] Milkings numbered according to starting time: 1 = 0200 to 0959 h, 2 = 1000 to 1759 h, 3 = 1800 to 0159 h.

of error were substantially larger than those for a.m.–p.m. plans for 2× herds. Weighing one milking of three does not provide information of sufficient accuracy for the a.m.–p.m. plan to be considered official. However, records from such plans might be suitable for sire evaluation if they were weighted less to reflect the lesser accuracy. Increasing the number of sample days per lactation does not appear practical for increasing accuracy adequately within practical limits. Official a.m.–p.m. plans for 3× herds require consecutive weighed milkings and samples from first or second milking. These plans provide information no less accurate than that from a.m.–p.m. plans for 2× herds.

Factors developed in this study were approved by the NCDHIP Policy Board at its December 1984 meeting and have been implemented for calculating NCDHIP lactation records (7). Milk and fat factors currently are calculated with the coefficients in Table 1; protein factors are calculated with the milk coefficients.

ACKNOWLEDGMENTS

Dexter Putnam (deceased), William Heald from Pennsylvania, Wallace Taylor from Utah, and Neil Quesenberry from California participated through cooperative agreements in collecting data necessary for this project. Their interest and hard work in follow up on questionable data were critical to ensure that analyzed information was representative. Suzanne Hubbard's assistance in preparing the manuscript also is acknowledged.

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