Multiplicative Factors for Estimating Daily Milk and Component Yields from Single a.m. or p.m. Tests

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ABSTRACT

Prediction of daily yield from single a.m. or p.m. milk samples requires factors that are the reciprocal of the proportion of total yield expected in single milkings given the milking interval. Further adjustments to estimated milk yield will account for DIM. Factors used by the Cornell Dairy Records Processing Lab were estimated from data collected from August 1983 to November 1984. These factors appear to be biased. Inconsistent daily yield estimates were observed from month to month. New factors were developed using recent data. Factors from a.m. milkings for milk and protein yield were smaller than those currently in use. The reverse was true for fat yield. Covariates for DIM were larger than those currently used. Differences were observed when comparing factors obtained using data with known vs. assumed milking intervals. Factors for a.m. milkings with known intervals were smaller than those from p.m. milkings with the same known intervals. Use of covariates for DIM were compared using covariates for single sample milk yield. The latter explained more variation in yield. Factors were tested on independent data. New factors with covariates for single sample milk yield performed best in estimating total daily yield.

(**Key words:** test day, milk yield)

Abbreviation key: **AP** = alternate month a.m.-p.m. sampling; **DRPL** = Dairy Records Processing Lab; **APCS** = alternate a.m.-p.m. component sampling; **MSE** = mean square error.

INTRODUCTION

Alternate strategies for sampling yield traits in the dairy industry have been implemented. Variations in strategies include frequency of testing and whether the sample is obtained by an official tester or by the herd owner. Porzio (10) proposed the use of alternate month a.m.-p.m. sampling (**AP**). McDaniel (9) reviewed sampling strategies and concluded that AP was a promising scheme for the US. The AP method has been shown to be more precise than other single milk sample schemes (e.g., all a.m. or all p.m.) and only slightly less accurate in estimating total lactation yield than using both a.m. and p.m. samples in a 24-h period (2, 11, 13). The history of AP was reviewed by Everett (3) and Lee and Wardrop (8). Everett and Wadell (4) suggested multiplicative factors for estimating daily yield from a single milking were more appropriate than additive factors. Multiplicative factors were estimated by Hargrove and Gilbert (6), Lee and Wardrop (8), and Shook et al. (12). DeLorenzo and Wiggans (1) estimated factors using field data from cows milked from August 1983 through November 1984.

The Cornell Dairy Records Processing Laboratory (**DRPL**) currently uses factors reported by DeLorenzo and Wiggans (1) to estimate daily milk and component yield on AP herds and on alternate a.m.-p.m. component sampling (**APCS**) herds. In APCS herds, milk yields are recorded for both milkings; however, only a single milk sample (a.m. or p.m.) is obtained for estimating fat and protein production. Application of these factors to current data yields estimate that are inconsistent from month to month.

1   The objectives of this study were to re-estimate the factors

2 using the method of DeLorenzo and Wiggans (1) and to examine

3 alternative models of adjustments. Factors from this study along

4 with factors from DeLorenzo and Wiggans were used on an independent

5 data set to test how effectively they predict yield.

MATERIALS AND METHODS

7 **Data**

8   Data were from Cornell DRPL on cows tested between February

9 1991 and May 1992. There were 253,688 Holstein cows in 2,691 herds

10 with two measured milkings per test day (2X herds) and 229,119

11 Holstein cows in 2,604 herds with one measured milking per test day

12 (1X herds). For 1X herds, 23,919 bulk tank sample reports were

13 also available. Records on 16,034 Jersey cows in 195 herds were

14 analyzed separately.

15   Individual cow information included milk yield, fat and

16 protein percentages, DIM, and age of cow. Herd information (bulk

17 tank sample report) included total milk weight sold per day, tank

18 percentage for fat and protein, number of cows milked on sample

19 day, start times of first and last milkings, and type of test (2X

20 or 1X). The 2X programs included regular DHI and APCS for milk

21 yield, and 1X programs included AP data for milk and AP and APCS

22 data for component yield.

23   Data from Cornell DRPL on Holstein cows milked from June 1,

24 1992 to December 31, 1992 were used to compare several sets of

25 factors obtained in this study.

1   For all sampling schemes used by DHI, one observation is

2   obtained for fat and protein per sample day, either from blended

3   a.m.-p.m. samples for 2X herds or single a.m. or p.m. samples in 1X

4   herds. A supplemental data set was from cows from 81 herds milking

5   in 1988 in which a.m. and p.m. component samples from 2X herds were

6   analyzed separately. Cow information in this data set included

7   milk yield, fat and protein percentage, start times for a.m. and

8   p.m. milking, DIM, and cow age.

9   **Procedures for Developing Factors**

10   One set of factors was estimated using the method of DeLorenzo

11   and Wiggans (1). Milk factors were from 2X herds whereas fat and

12   protein factors were from herds with 1X component sampling. In 1X

13   herds, bulk tank weight was used to estimate 24-h yield.

14   Milking interval was defined as the time from the start of one

15   milking to the start of the next. Subsets of data were created

16   based on 15-min intervals and ranged from 600 to 614 min to greater

17   than 899 min. Tables 1 and 2 contain the number of cow tests in 2x

18   herds and herd tests in 1x herds by interval for the current study

19   and for that of DeLorenzo and Wiggans (1).

20   Factors (F_i) for each interval (i) were the inverse of the

21   ratio of total yield from a single milking to the total daily yield

22   of all cows for a test day. This estimator assumed that the

23   subsequent variance of residuals (deviations) was proportional to

24   the level of the single measured yield. This was true for data

25   analyzed by DeLorenzo and Wiggans (1) and data used in the current

1   study. In 2X herds, total yield was the sum of all cows' daily

2   yield; in 1X herds, total yield was estimated from bulk tank data.

3   For milk yield, deviations, defined as observed minus

4   predicted daily milk yield in 2X herds, were analyzed using the

5   model:

6
$$(y_{ij} - \hat{y}_{ij}) = d_{ij} = \alpha + b_i (DIM_{ij}) + e_{ij}$$

7   where

8   y_{ij} = the observed and $\hat{y}_{ij}$ the predicted daily yield of cow

9   test j in interval i,

10   α = the intercept,

11   b_i = the regression of deviations on DIM for the ith interval,

12   DIM_{ij} = DIM for the jth cow test in the ith interval, and

13   e_{ij} = the random residual for the jth cow test in the ith

14   interval.

15   $\hat{y}_{ij}$ was obtained as $\hat{F}_i x_{ij}$, for production level x_{ij}. Similar analyses

16   for fat and protein yield were done using the supplemental data set

17   where separate a.m. and p.m. samples were collected.

18   Several modifications to the analyses proposed by DeLorenzo

19   and Wiggans (1) were tried. First, DIM was replaced with single

20   milk yield in the covariate analysis. Both a linear and a

21   quadratic effect were used. Second, attention was paid to whether

22   the interval prior to the milking of interest was known. Figure 1

23   shows two scenarios for 2X herds. In the first scenario, the

24   interval for p.m. milking was known (situation 2), and the interval

25   for a.m. milking was assumed to be 1440 min minus the known p.m.

26   interval (situation 1). In the second scenario, the interval for

a.m. milking was known (situation 4), and the interval for p.m. milking was 1440 min minus the known a.m. interval (situation 3). Comparisons between factors obtained for known and assumed intervals were done (situation 1 with 4 and situation 2 with 3). Comparisons were also made between factors for a.m. and p.m. with the same known intervals (comparing situation 2 with situation 4).

Data from June 1, 1992 to December 31, 1992 were used to test the following four sets of factors: Set 1 included factors and DIM covariates reported by Delorenzo and Wiggans (1) and currently used by Cornell DRPL; set 2 included factors and DIM covariates from the current data using the analysis procedure of Delorenzo and Wiggans (1); set 3 included factors from analysis of data with known intervals and DIM covariates; and set 4 included factors from set 3 and single milk weight covariates.

Daily milk yield was estimated as:

$$\hat{y}_{ij} = \hat{F}_i x_{ij} + \hat{b}_i (DIM_{ij} - \overline{DIM}),$$

where $\overline{DIM}$ is the mean of DIM_{ij}, when DIM covariates were used and as:

$$\hat{y}_{ij} = \hat{F}_i x_{ij} + \hat{b}_{0i} + \hat{b}_{1i} x_{ij} + \hat{b}_{2i} x_{ij}^2$$
$$= \hat{b}_{0i} + (\hat{F}_i + \hat{b}_{1i}) x_{ij} + \hat{b}_{2i} x_{ij}^2$$

when single milk yield covariates were used.

RESULTS AND DISCUSSION

Proportions of daily milk yield from a.m. milking from 2X data in both this study and DeLorenzo and Wiggans (1) are shown in Figure 2. Reciprocals of these proportions were the factors. One minus the proportions yielded proportions of daily milk yield from

1   p.m. milkings. Proportions for a.m. milking for milk yield in this

2   study were generally larger for shorter intervals (< 727 min) and

3   smaller for longer intervals ($\geq$ 787 min) than those of DeLorenzo

4   and Wiggans (1).   Proportions for protein yield (not shown)

5   followed the pattern for milk yield.

6   Figure 2 (bottom) demonstrates that proportions of daily fat

7   yield from a.m. milking were generally smaller than those of

8   DeLorenzo and Wiggans (1) for shorter intervals and larger for

9   longer intervals.

10   Within each interval, a covariate analysis on deviations after

11   factor adjustment was used to adjust for DIM.   The mean DIM was

12   151 d. Covariates were significantly different from zero (P < .05)

13   in all intervals except 735 to 749 min. The covariates for each

14   interval by a.m. or p.m. milking are shown in Figure 3 for both

15   this study and that of Delorenzo and Wiggans (1). Covariates for

16   all but one interval were larger in the current study. One reason

17   for the larger estimates can be explained from the fact that high

18   production with recent data makes the deviation variance larger.

19   Although covariates for DIM in the present study were larger,

20   the impact on estimated daily yield was small.   In extreme

21   intervals, the largest difference in adjustments for minimum or

22   maximum lactation lengths (6 or 305 d) was 1.1 kg.

23   Analyses were repeated using data on Jersey cattle. Figure 4

24   shows the comparison of proportion of daily milk yield from a.m.

25   milking by intervals for Jerseys and Holsteins. The proportions

26   were similar in each breed. This was also true for fat and protein

1 yield. Hargrove and Gilbert (6) reported milk yield factors were

2 greater for Holsteins than for Guernseys. No trend was detected in

3 the covariates for DIM across intervals in the Jersey analysis,

4 perhaps due to the small data set.

5 DeLorenzo and Wiggans (1) compared results from 2X herds with

6 those from 1X herds to test the validity of using bulk tank

7 measures to obtain factors. They used a regression analysis of the

8 proportion of milk at a.m. milking on milking interval to make the

9 comparison. Their results from both 2X and 1X analyses were

10 similar in intercept (.0654 vs. .0543) and slope (6.05 x 10^{-4} vs.

11 6.20 x 10^{-4}) for 2X vs. 1X herds (Table 3). In the current study,

12 differences in intercept and slope for 2X and 1X herds were larger

13 (Table 3).

14 Table 3 also contains results from the supplemental data set.

15 The regression of a.m. proportions on milking interval for milk

16 yield was intermediate to those of DeLorenzo and Wiggans (1) and to

17 those in the current study. For milk yield, this may be indicative

18 of a time trend in that the data analyzed by DeLorenzo and Wiggans

19 were from 1984 to 1986, the supplemental data set was from 1988,

20 and data for the current study was from 1991 to 1992. The same

21 trend was observed for protein yield; however, results from

22 analysis of fat yield were not consistent. The R^2 for fit of

23 regression of proportion on interval was smaller (.737) for fat

24 yield from the supplemental data than for any other analysis.

25 Covariate analysis of the deviation of observed total daily

26 yield from predicted yield on DIM for fat and protein was possible

1   in the supplemental data set because of separate collections of

2   a.m. and p.m. samples. Covariates for protein showed a pattern

3   similar to those for milk. Covariates for protein and milk yields

4   multiplied by the average protein percent (.032) for each interval

5   are shown in Figure 5. It appears that protein covariates could be

6   obtained from milk yield covariates. The trend in fat and milk

7   covariates multiplied by .073 was similar, but the association was

8   not as close as that observed for protein and milk covariates

9   (Figure 5).

10   To investigate further the relationship of component yield and

11   milk yield, factors from a.m. milkings were compared. Figure 6

12   shows the ratio of milk factors to factors for each component,

13   which were obtained from analyses of the supplemental data set by

14   interval. Ratio of milk to protein yield proportions was

15   consistent and close to one in all intervals while the ratio of

16   milk to fat proportions decreased dramatically in longer intervals.

17   It appears that protein factors could be derived from milk factors,

18   but fat factors must be obtained separately.

19   **Single Milk Weight Covariate Analysis**

20   Milk yield for the single measured milking was used in place

21   of DIM in the covariate analysis of deviations (actual minus

22   predicted daily yield). Figure 7 (top) shows the relationship of

23   adjustments for predicted daily milk yield to a.m. single milk

24   yield for intervals of 660 to 674, 750 to 764, and 870 to 884 min.

25   It is interesting to note the relationship of these adjustments and

26   interval length for higher producing cows. In the shortest

1 interval, the magnitude of adjustment was highly related to

2 production. Adjustments for higher producing cows were negative,

3 especially in the shortest interval, which implies that predicted

4 yield was overestimated. This result suggests that secretion rate

5 is not linear in time. Secretion rate decreased (at an increasing

6 rate) in response to increased udder pressure starting at

7 approximately 10 h postmilking (7).

8 For factors obtained from short intervals, the influence of

9 nonlinear secretion rates was exerted on production being predicted

10 in the contiguous long interval. For factors from measured

11 milkings with long intervals, the nonlinear secretion rate

12 influenced estimation of factors from those long intervals.

13 Factors were obtained as the inverse of the proportion of single

14 milk yield to total yield. For higher producing cows, the

15 proportion from a long interval was smaller than that observed with

16 lower producing cows because the longer the interval, which

17 contributes to greater milk volume, the greater the influence of

18 nonlinearity in secretion rate. Smaller proportions led to larger

19 factors. Within an interval, the factor obtained as an average

20 across all cows was too small for higher producing cows and too

21 large for lower producing cows. The distribution of production

22 level influenced the level of bias observed.

23 If this hypothesis of the relationship of factors to

24 production level is applied to the trend in factors observed over

25 time in the three data sets, the pattern of results is intuitive.

26 The higher yield generally achieved in the current data would tend

1   to produce larger factors in longer intervals and smaller factors

2   in shorter intervals. This would lead to a smaller regression of

3   proportion on intervals in recent data (Table 3).

4   Adjustments from milk weight were larger than the minimum and

5   maximum adjustments for DIM, especially for higher producing cows

6   in shorter intervals. Days in milk account, in part, for single

7   milk yield because of the relationship of DIM to the shape of the

8   lactation curve. Both regressions of DIM and of single measured

9   milk yield were used in the test data sets.

10   The relationship of adjustments to predicted yield and

11   production by interval was also examined in the p.m. milkings

12   (bottom, Figure 7). The relationship was different in this subset

13   of data. This discrepancy in results from using a.m. or p.m.

14   milkings will be addressed when the analyses are confined to data

15   with known milking intervals.

16   **Known Versus Assumed Milking Intervals**

17   Proportions of daily milk yield observed from milkings with

18   known intervals were compared with proportions obtained from

19   milkings with assumed intervals. In 2X herds, milkings with known

20   intervals were from the second measured milking, and those with

21   assumed intervals were from the first measured milking (Figure 1).

22   The frequency of a.m. milking being the last measured milking was

23   higher than the frequency of p.m. milking (approximately 6.5 to 1).

24   Previous studies (1, 6, 8, 12) did not consider known and assumed

25   intervals in calculating factors.

1   Figure 8 shows the proportions by interval for a.m.

2 milkings with known and assumed intervals. Proportions from data

3 with known intervals were smaller for shorter intervals and larger

4 for longer intervals. Regression of proportion on milking

5 intervals for a.m. last milking was more similar to the regression

6 obtained for all milkings (Figure 2) than regression for p.m. last

7 milking because of the higher frequency of a.m. last milkings in

8 these data. Comparisons of factors from different studies could be

9 influenced by frequencies of a.m. and p.m. last milkings

10 represented in the different data sets.

11   Proportions using bulk tank measures of total daily yield were

12 compared with those from actual production for both a.m. and p.m.

13 last milking with known intervals in 2X herds (Figure 9). For all

14 intervals, the proportions from bulk tank measures were larger than

15 those from actual milk measurements. This brings into question the

16 accuracy of using bulk tank measures to estimate factors.

17   Figure 10 shows the relationship of adjustments to predicted

18 daily yield with single milk yield covariates for both a.m. and

19 p.m. last milkings with known intervals. Results for both a.m. and

20 p.m. milkings were similar. When all data were used (Figure 7),

21 p.m. milking adjustments were far different from a.m. adjustments.

22 In those data, most p.m. samples were from unknown intervals.

23   It is also interesting to note that the proportion of milk

24 produced from p.m. to a.m. was larger than that produced from a.m.

25 to p.m. for cows with the same milking intervals of 660 min or more

26 in length (Figure 11). Gilbert et al. (5), Hargrove and Gilbert

1   (6), and Shook et al. (12) also reported that cows produced more

2   milk at night for the same interval lengths from comparing their

3   results for 12-h intervals. However, differences between

4   production during day and night were not found in the estimates of

5   DeLorenzo and Wiggans (1) (Figure 2).

6   <u>Evaluation</u>

7   Four sets of factors were used to predict daily yield from

8   single samples in the test data set. In 2X herds, mean square

9   error (**MSE**) was calculated for each set of factors (Table 4).

10   Prediction from a.m. samples was better than from p.m. samples,

11   perhaps due to the difference in amount of data used to estimate

12   factors and covariates. Reduction in MSE was observed in both a.m.

13   and p.m. samples when comparing factors obtained in this study to

14   those currently used by Cornell DRPL. The MSE from set 4 was .936

15   as large as the MSE from set 1 in a.m. data and .755 as large with

16   p.m. data.

17   Figure 12 shows average deviations from using each set of

18   factors by month of freshenings in APCS herds (a.m. milkings in odd

19   months; p.m. milkings in even months). The smallest deviations

20   were for sets of factors estimated from data with known intervals

21   (sets 3 and 4). Using single milk weight covariates as opposed to

22   covariates for DIM improved prediction of total daily milk yield.

23   All factors tended to overpredict total daily yield.

24   Figures 13 and 14 show deviations for protein and fat yield in

25   the APCS herds. The "true" total daily yield for each component

1 was estimated as percent observed in the bulk tank measure times

2 daily milk yield of each cow. Average deviations were small for

3 all sets of factors. It is interesting that milk factors with

4 single milk weight covariates perform well for protein yield.

5 Fat deviations for factors from Delorenzo and Wiggans (1) and

6 factors from the current data using their method were quite small.

7 Using fat factors from bulk tank data with known intervals did not

8 do well. In these data, the association of fat yield to milk yield

9 shown in Figure 6 caused problems in prediction of daily fat yield.

10 **CONCLUSIONS**

11 Factors currently used by Cornell DRPL to predict daily milk

12 yield from single a.m. or p.m. milk yield appear to be biased.

13 New factors were estimated from current data. These factors were

14 estimated from data with known intervals between milkings with

15 attention paid to which milking was the last (a.m. or p.m.), and

16 regressions on daily milk yield were considered in place of DIM.

17 The use of these factors resulted in smaller MSE of predicting

18 daily yield than using the current factors, especially where the

19 p.m. was the last milking. It appears that a single set of

20 factors could be used for milk and protein yield while separate

21 factors are necessary for fat yield.

22 **ACKNOWLEDGMENTS**

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Table 1.   Number of cow tests by interval from 2X herds

Interval[1] (min)	Current study			DeLorenzo and Wiggans
	a.m. last	p.m. last	Total	
600-614	128	454	582	6,568
615-629	103	185	288	6,883
630-644	1,048	302	1,350	10,123
645-659	1,140	1,440	2,580	10,859
660-674	2,787	918	3,705	20,035
675-689	5,254	2,585	7,839	17,924
690-704	12,766	5,469	18,235	24,843
705-719	49,972	14,534	64,506	43,004
720-734	185,533	42,242	227,775	93,530
735-749	121,821	19,493	141,314	72,156
750-764	177,025	24,894	201,919	104,550
765-779	207,735	32,174	239,909	149,898
780-794	346,380	43,356	389,736	233,210
795-809	162,656	20,431	183,087	156,239
810-824	145,611	22,189	167,800	142,534
825-839	101,377	10,861	112,238	91,636
840-854	88,953	12,437	101,390	92,547
855-869	44,946	3,806	48,752	38,497
870-884	33,475	4,002	37,477	26,433
885-899	11,407	1,742	13,149	9,092
900-914[2]	8,736	1,058	9,794	9,528
Total	1,708,853	264,572	1,973,425	1,360,089

[1]   Time from start of p.m. milking to start of a.m. milking.

[2]   Greater than 899-min interval for DeLorenzo and Wiggans (1).

Table 2. Number of herd tests by interval from 1X herds

Interval[1] (min)	Current study			DeLorenzo and Wiggans		
	a.m.	p.m.	Total	a.m.	p.m.	Total
600-614	11	7	18	7	1	8
615-629	15	5	20	7	2	9
630-644	21	7	28	18	2	20
645-659	45	18	63	19	23	42
660-674	85	49	134	47	38	85
675-689	107	72	179	52	44	96
690-704	266	240	506	197	169	366
705-719	631	695	1326	359	382	741
720-734	1736	1612	3348	1042	777	1819
735-749	1197	1097	2294	819	642	1461
750-764	1251	1213	2464	824	641	1465
765-779	1227	1384	2611	888	723	1611
780-794	1742	1695	3437	1075	913	1988
795-809	871	910	1781	659	596	1255
810-824	619	680	1299	497	455	952
825-839	373	385	758	287	345	632
840-854	262	247	509	246	258	504
855-869	138	118	256	94	109	203
870-884	82	87	169	52	73	125
885-899	35	62	97	17	12	29
900-914[2]	43	47	90	15	28	43
Total	10757	10630	21387	7224	6236	13460

[1]   Time from start of p.m. milking to start of a.m. milking.

[2]   Greater than 899-min interval for DeLorenzo and Wiggans (1).

Table 3. Linear regression of milk and component proportion at a.m. milking on preceding interval[1]

Yield trait	Type of test	Data[2]	Intercept	Intercept SE (10^{-2})	Slope (10^{-4})	Slope SE (10^{-5})	Value of R-squared
Milk	2X	A	.0654	.57	6.05	.73	.997
	2X	B	.0745	3.06	5.99	3.92	.951
	2X	C	.1299	.79	5.20	1.01	.993
	1X	A	.0543	1.07	6.20	1.39	.989
	1X	C	.0714	0.91	6.02	1.18	.993
Fat	1X	A	.1960	1.21	4.24	1.57	.971
	2X	B	.2997	3.72	2.76	4.77	.737
	1X	C	.0557	1.81	6.16	2.36	.973
Protein	1X	A	.0437	.98	6.35	1.27	.991
	2X	B	.0582	3.28	6.14	4.21	.947
	1X	C	.0959	1.50	5.68	1.95	.978

[1]   Milking interval taken as midpoint of each interval range.

[2]   Data set A--1984 to 1986 data processed at Cornell DRPL and analyzed by DeLorenzo and Wiggans (1); data set B--1988 data collected by Tom Wiswall; and data set C-- 1991 to 1992 data processed at Cornell DRPL).

Table 4. Mean square error(kg^2) in predicting daily milk yield by four methods: 1) current estimates in Cornell DRPL: 2) factors & DIM covariates obtained from current data; 3) factors for known intervals & DIM covariates; and 4) factors for known intervals & single milk weight covariates.

Last Milking	a.m.[1]	p.m.[2]
Method 1	4.7	10.6
Method 2	4.6	10.3
Method 3	4.5	9.5
Method 4	4.4	8.0

[1]   810,583 records

[2]   127,533 records

1   Figure 1.   Four possible situations from two scenarios in

2   2X data.
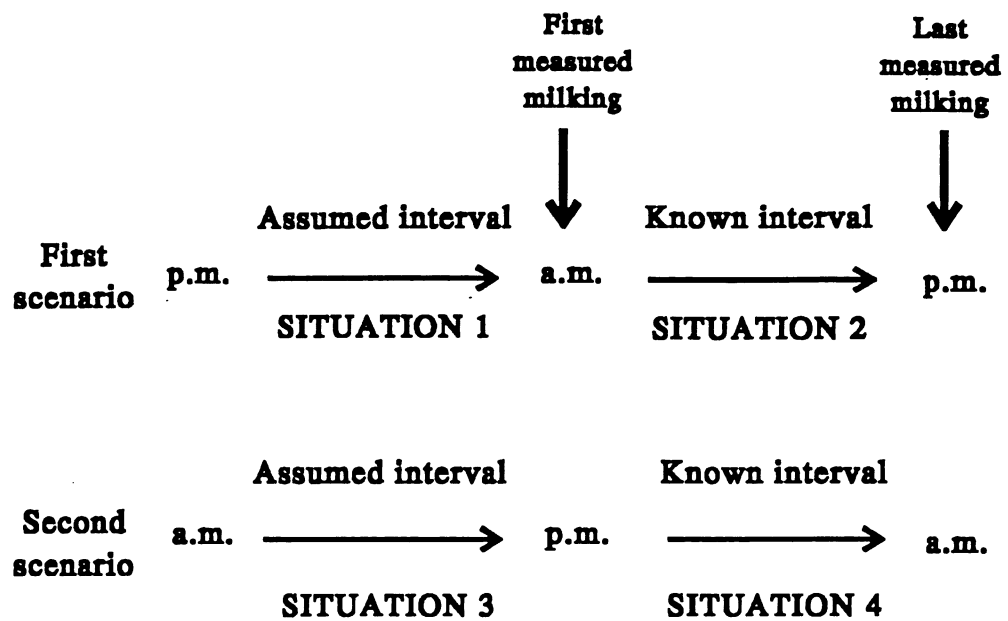
1 Figure 2. Proportion of daily milk yield from a.m. milking

2 estimated by Lee (■) and by DeLorenzo and Wiggans (1) (□)

3 using 2X data for milk and 1X data for fat by milking

4 intervals.
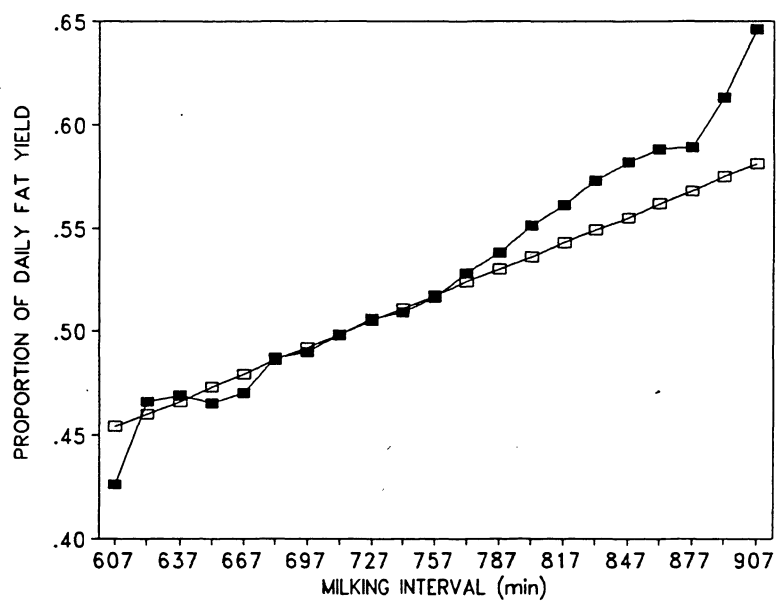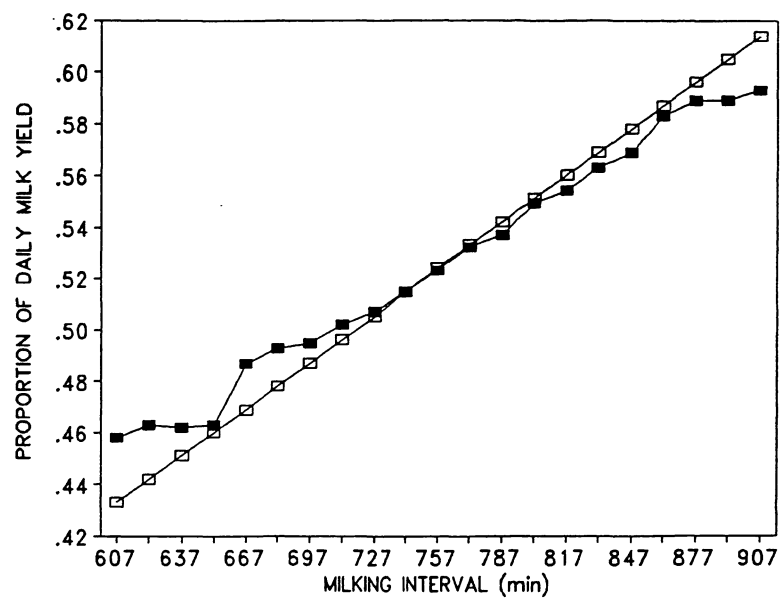
1   Figure 3.   Covariate coefficients for DIM for a.m. milking

2   estimated by Lee (■) and by DeLorenzo (1) (+) and for p.m.

3   (▲, x, respectively).
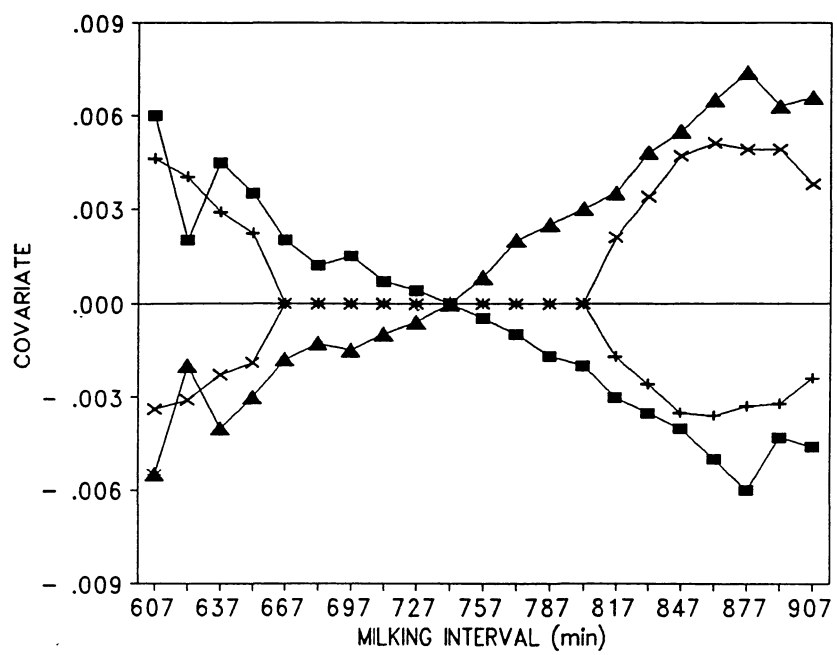
1   **Figure 4.** Proportion of daily milk yield from a.m. milking

2   by intervals for Jerseys (■) and Holsteins (□).
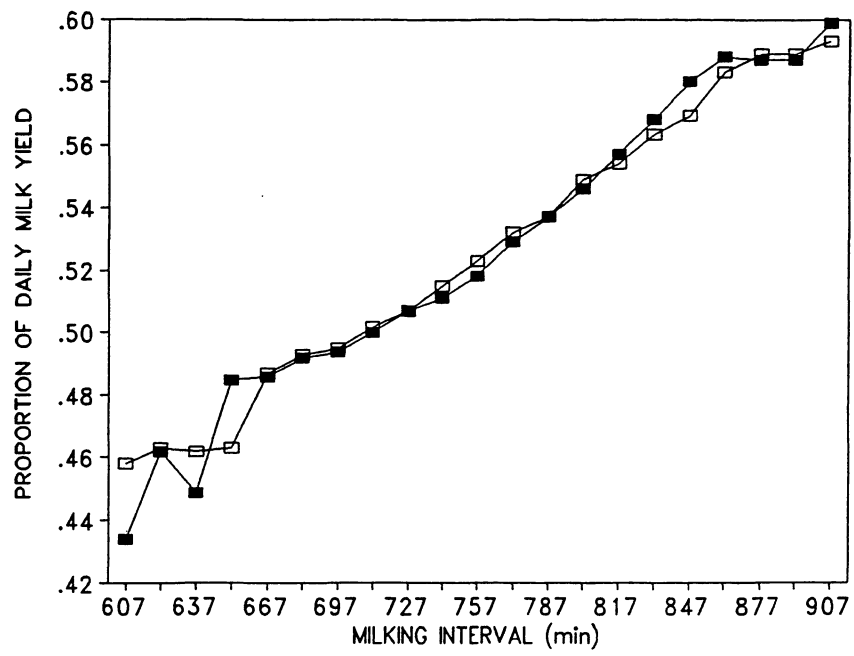
1   Figure 5.   Covariate coefficients for DIM using a.m.

2   component (top, protein; bottom, fat) weight (■) and

3   predicted component weight from a.m. milk covariate × .032

4   (□) by intervals.
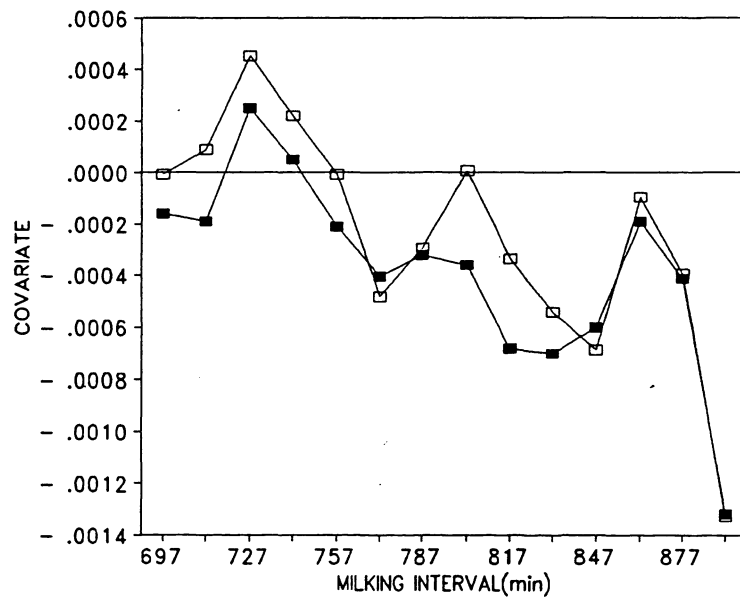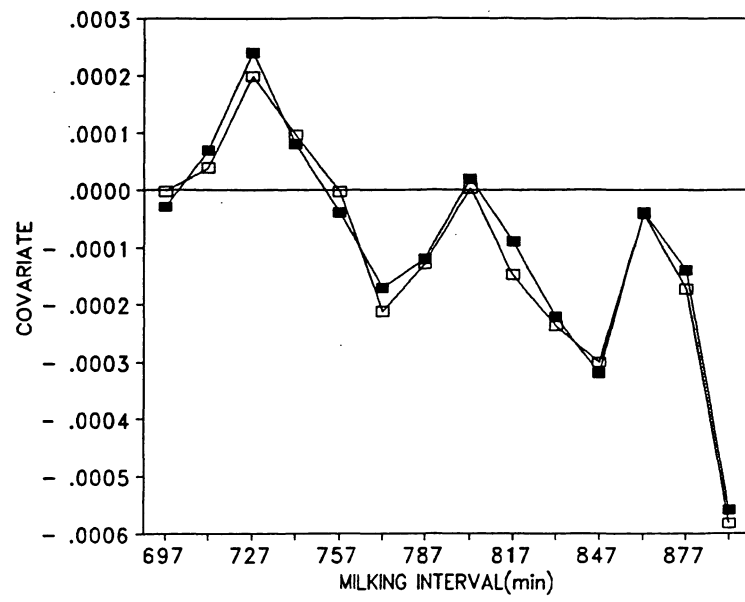
1   Figure 6. Ratio of the proportion for protein (■) and fat

2   (□) yield to the proportion for milk yield by intervals

3   using supplemental data.
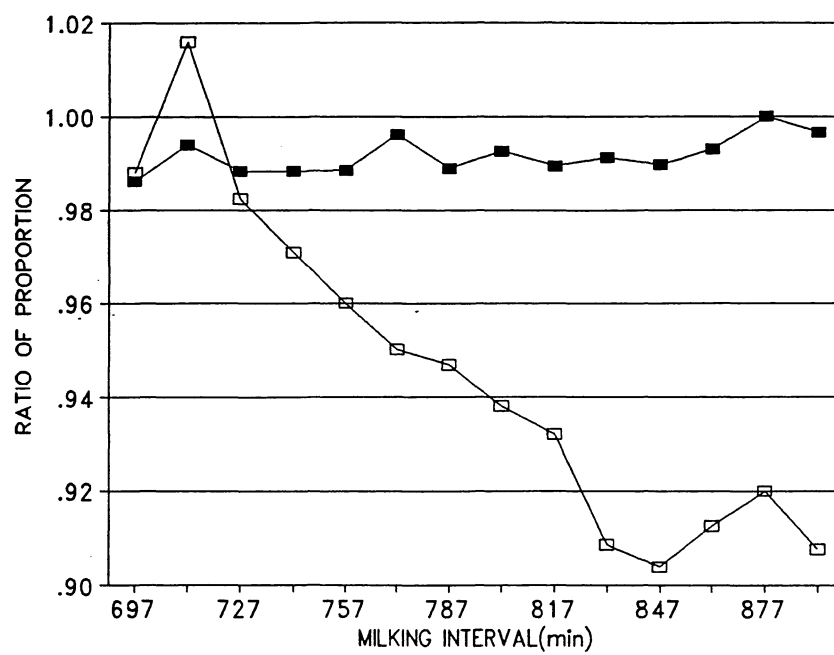
1   Figure 7. Covariate adjustment to milk yield for single

2   milk weight in intervals of 660-674 (+), 750-764 (□), and

3   870-884 (x) min; a.m. milk yield (top) and p.m. milk yield

4   (bottom).
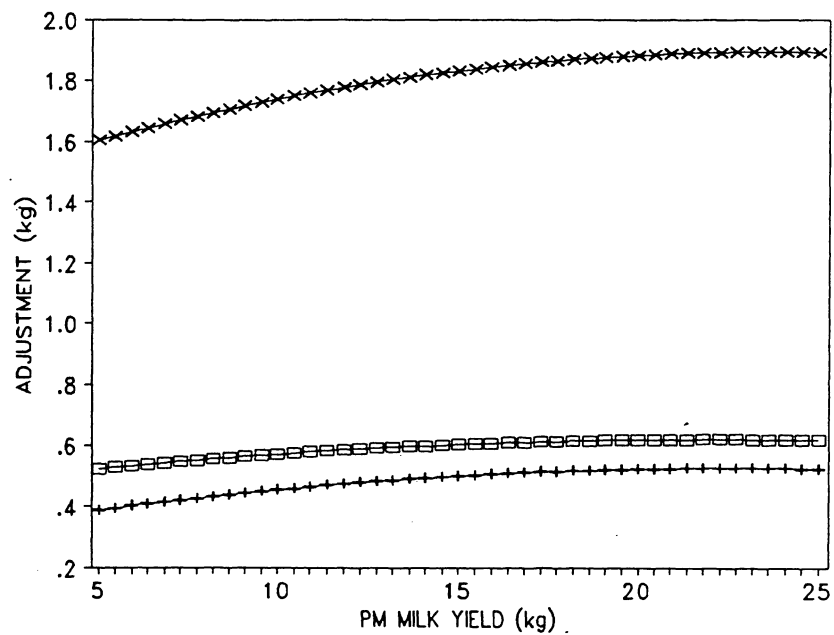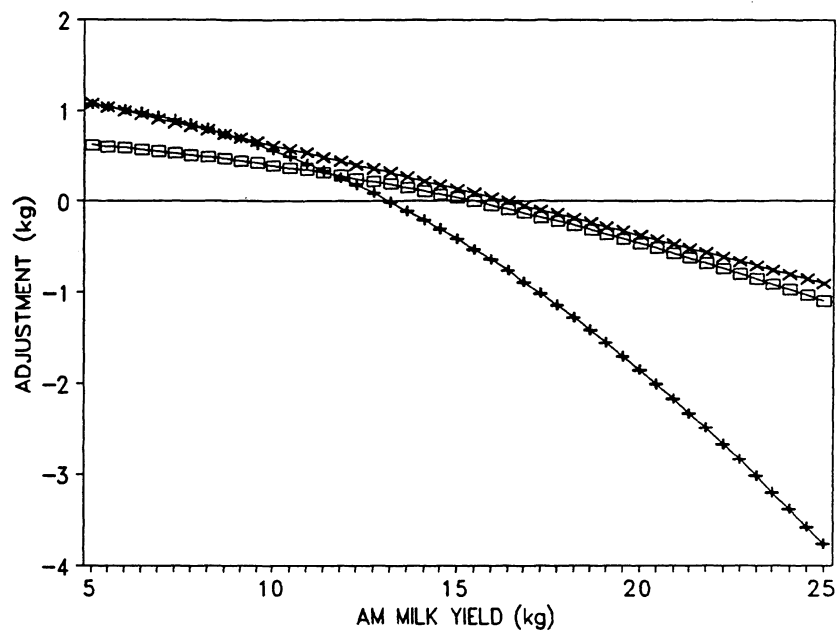
1   Figure 8.   Proportion of daily milk yield from a.m. milking

2   for known (■) and estimated (□) intervals using 2X data.
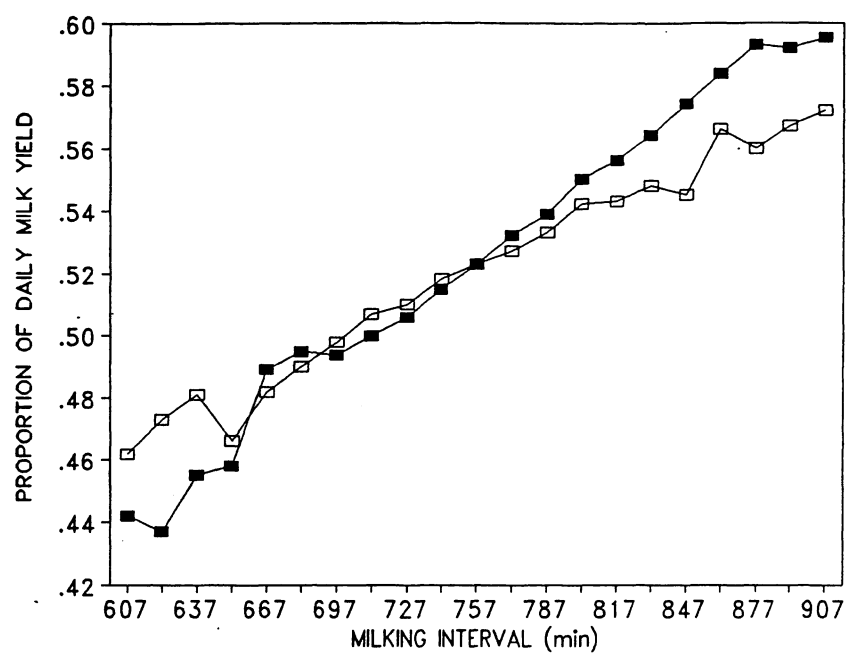
1   Figure 9. Proportion of daily milk yield at a.m. (top) and

2   p.m. (bottom) last milking by intervals in 2X herds using

3   real weights (□) and bulk tank weights (+).
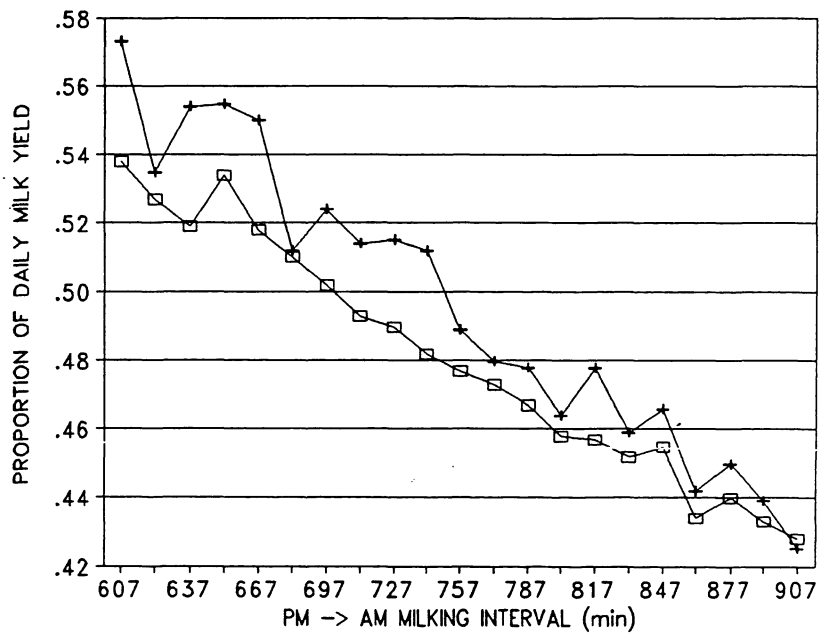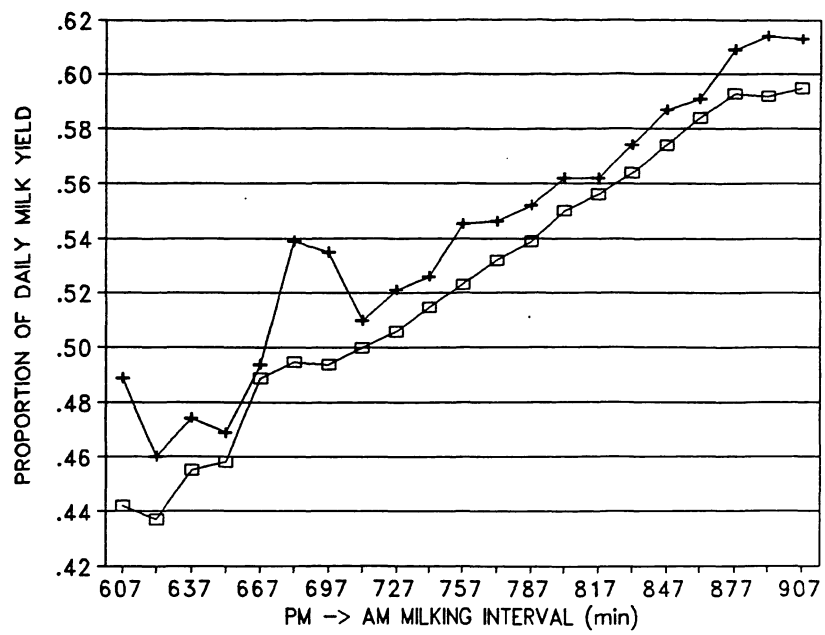
1   Figure 10.   Covariate adjustment to milk yield for a.m.

2   (p.m.) last milking in intervals of 660 to 674 (▲), 690 to

3   704 (+), 720 to 734 (x), and 750 to 764 (□) min.
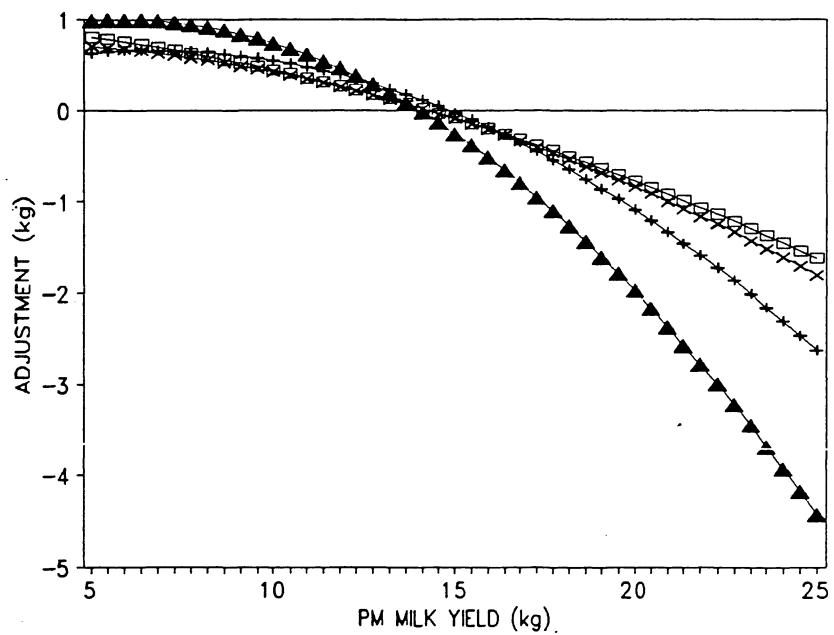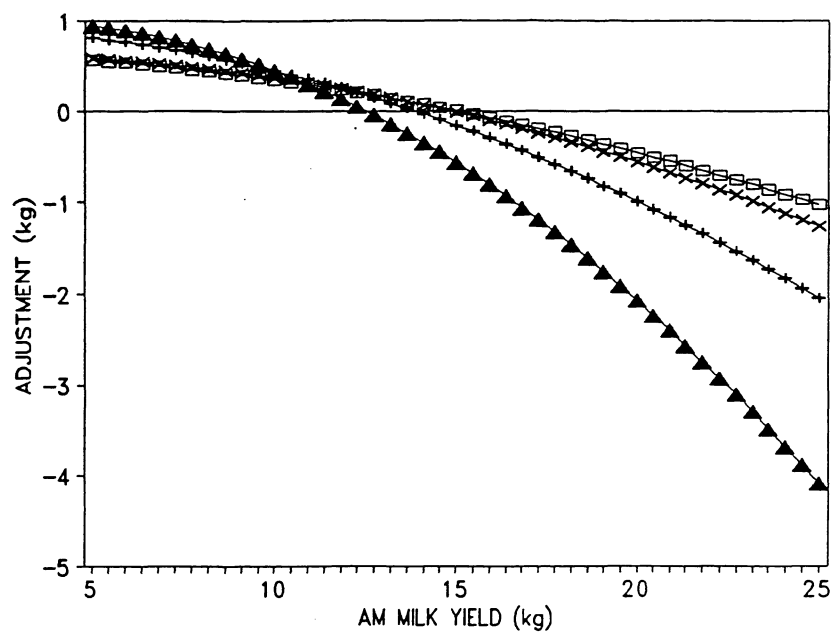
1   Figure 11. Proportion of daily milk yield at a.m. (■) and
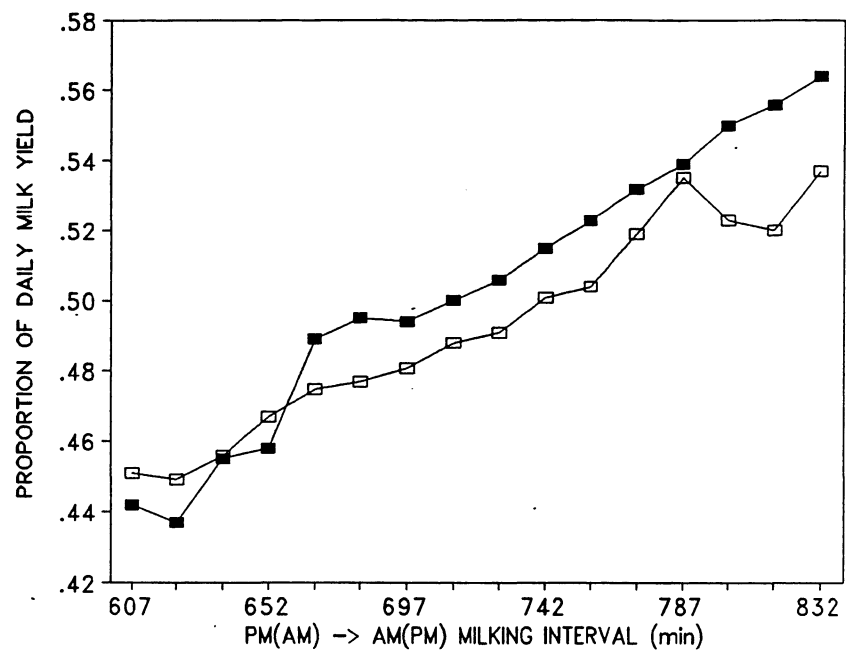
2   p.m. (□) last milking by intervals using 2X herds.

1   Figure 12. Average milk yield deviations using 1) current

2   estimates in NE DRPL (■), 2) factors and DIM covariates

3   obtained from current data (▲), 3) factors for known

4   intervals and DIM covariates (+), and 4) factors for known

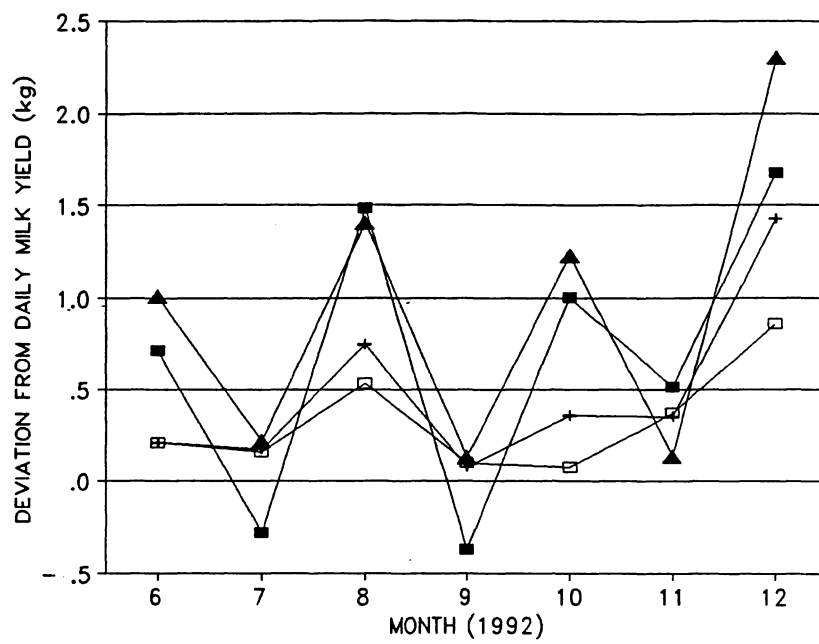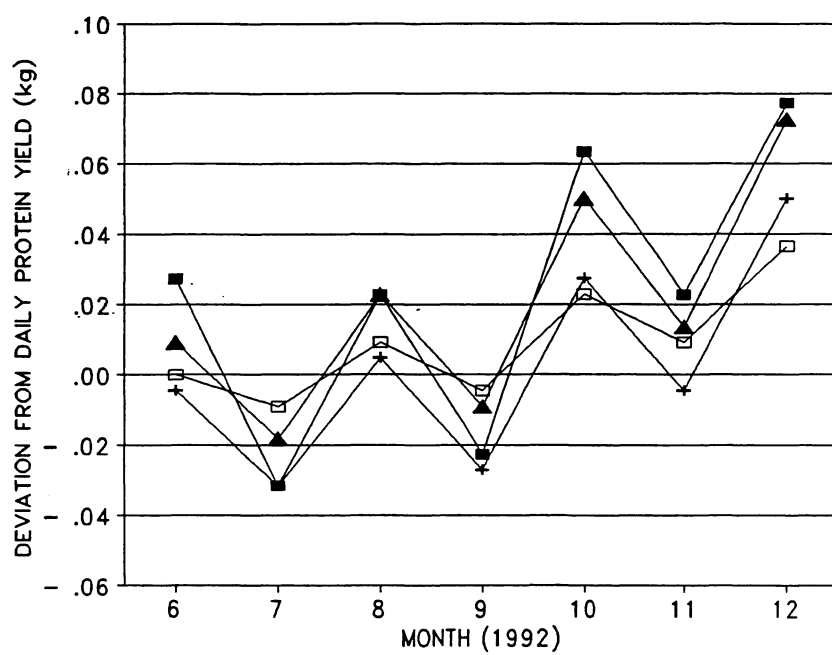5   intervals and single-weight covariates (□).

1   Figure 13.   Average protein yield deviations using 1)
2   estimates in NE DRPL (■), 2) factors for combined intervals
3   (▲), 3) factors for known intervals (+), and 4) milk factors
4   for known intervals and single milk weight covariates (□).

1   Figure 14. Average fat yield deviations using 1) estimates

2   in NE DRPL (■), 2) factors for combined intervals (▲), and

3   3) factors for known intervals (+).