May 19, 1971

To the Graduate Council:

I am submitting herewith a dissertation written by A. Vishwanatha Rai entitled "A Comparison of Different Sampling Intervals and Computational Methods for Estimating Lactation Yields." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Don O. Richardson
Major Professor

We have read this dissertation
and recommend its acceptance:

J. T. Miles

M. J. Montgomery

Robert R. Shrode

L. M. Josephson

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

# A COMPARISON OF DIFFERENT SAMPLING INTERVALS AND COMPUTATIONAL METHODS FOR ESTIMATING LACTATION YIELDS

---

A Dissertation

Presented to

The Graduate Council of

The University of Tennessee

---

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

---

by

A. Vishwanatha Rai

June 1971

TO MY PARENTS

975427

ACKNOWLEDGMENTS

The author is grateful to Dr. Don O. Richardson for his friendly sincere guidance in conducting this work. The author expresses his sincere appreciation to Drs. J. T. Miles, M. J. Montgomery and L. M. Josephson for their encouragement, advice and review of the manuscript. High indebtedness is expressed to Dr. R. R. shrode who was a philosopher, guide and friend to the author during his doctoral studies.

Acknowledgment is made to Mrs. Barbara Bridges for her assistance given in computer programming.

Sincere thanks to the staff of U. T. Experiment Stations at Knoxville, Lewisburg, Spring Hill and Jackson for providing records necessary for the work, to the faculty, staff and fellow graduate students of the dairy department who were instrumental in making the stay and study of the author lively at The University of Tennessee, and also to Cole Printing and Thesis Service, Inc. for preparing the manuscript in a presentable form.

Acknowledgment is made to USAID-India program, related agencies and people for the funds and opportunity provided to the author to make the study.

Appreciation to his wife and children is overwhelmingly due, for the encouragement given to him.

## ABSTRACT

A sample of 471 lactation records from four dairy herds of The University of Tennessee were utilized in this study. The experiment was designed to investigate the possibilities of lengthening the DHIA testing interval. The study was limited to 305-day milk yields. Three sampling intervals: (1) 30 days, (2) 60 days and (3) 90 days and three computing methods: (1) unadjusted, (2) first-test-adjusted and (3) first-and-last-test-adjusted were used to estimate the lactation milk yields. Each lactation record provided 30 monthly, 60 bi-monthly and 90 tri-monthly unadjusted estimates. In all, 254,340 lactation estimates (adjusted and unadjusted) were computed.

The deviation of estimate from the actual yield was measured as percent of actual yield. Statistical analysis indicated that herd, age, interval and computational methods produced variation in the percent deviations of estimates. Interactions of these factors also caused variation in percent deviations in most cases. In all the intervals investigated, the average error and the average percent absolute deviation was greater for higher production levels. The average errors of monthly unadjusted, first-test-adjusted and first- and-last-test-adjusted estimates were 0.63, -0.02 and -0.13 percent of actual yields, respectively. The corresponding values for bi-monthly estimates were 0.84, 0.21 and -0.24 percent, respectively. This indicated that in monthly and bi-monthly intervals, the last test correction in addition to the first

test correction was not of any additional value. The conclusion was also supported by similar trends in the average percent absolute deviations, frequency of estimates within a given percent of actual yield and standard deviations of percent deviations. The average errors of tri-monthly (1) unadjusted, (2) first-test-adjusted and (3) first-and-last-test-adjusted estimates were 0.84, 0.87 and -0.14 percent of actual yields, respectively. The corresponding values for absolute deviation were 1.57, 1.75 and 0.85 percent of actual yields. The first test correction by itself was of no value in improving the tri-monthly estimates, but correction of first and last test was essential.

The average errors of bi-monthly first-test-adjusted and tri-monthly first- and-last-test-adjusted estimates were closer to zero than that of monthly adjusted estimates. A study of estimates in three parts of the lactation indicated that as the sampling interval was elongated, the error from the last one-third part of the lactation became more important. The effect of correction of tests was not the same in all herd-age (production) levels. A study of average deviations of estimates by day of first test indicated that delaying testing up to about the tenth day of lactation would decrease the average error as well as variation of percent deviation of tri-monthly estimates.

Hence, if more appropriate factors were periodically evolved on a region-breed-age basis for correcting the estimates, and if the first tests were delayed to about the tenth day of lactation, the tri-monthly first- and-last-test-adjusted estimates could be an alternative to the monthly unadjusted estimates. The savings on tests and computation thus

achieved could be passed on to the farmer which might result in increased participation of the farmers in DHIA testing.

TABLE OF CONTENTS


| CHAPTER | | PAGE |
|---|---|---|
| I. | INTRODUCTION | 1 |
| II. | REVIEW OF LITERATURE | 3 |
| | History | 3 |
| | One-Day Sample Method | 4 |
| | Weekly sampling | 4 |
| | Bi-weekly and tri-weekly sampling | 5 |
| | Monthly sampling | 7 |
| | Sampling at six-week intervals | 10 |
| | Bi-monthly sampling | 11 |
| | Bi-monthly versus actual performance | 11 |
| | Bi-monthly versus monthly sampling | 13 |
| | Sampling at intervals longer than sixty days | 15 |
| | Single-Milking Sample | 17 |
| | Test-Interval Method | 23 |
| | A Potpourri of Testing Methods | 28 |
| | Summary | 31 |
| III. | MATERIALS AND METHODS | 33 |
| | Selection of Records | 33 |
| | Computation | 34 |
| | Measurement of Accuracy of Estimates | 39 |
| IV. | RESULTS AND DISCUSSION | 41 |

CHAPTER PAGE

Monthly Estimates . . . . . 41

First-test-adjusted estimates . . . . . 44

First-and-last-test-adjusted estimates . . . . . 47

Bi-Monthly Estimates . . . . . 56

First-test-adjusted estimates . . . . . 57

First-and-last-test-adjusted estimates . . . . . 60

Tri-Monthly Estimates . . . . . 69

First-test-adjusted estimates . . . . . 73

First-and-last-test-adjusted estimates . . . . . 73

Statistical Analyses . . . . . 82

General . . . . . 86

V. SUMMARY AND CONCLUSIONS . . . . . 89

REFERENCES . . . . . 95

APPENDIX . . . . . 102

VITA . . . . . 113

## LIST OF TABLES


| TABLE | | PAGE |
|---|---|---|
| I. | Distribution of Lactations Selected for Study by Herd and Age | 35 |
| II. | Age Group Equations for Correcting for Length of First Test Period | 37 |
| III. | Details Concerning the 471 Lactations Utilized, Showing Numbers of Lactations and Average 305-Day Actual Milk Yields in Different Age Groups in Individual Herds and in Herds Combined | 42 |
| IV. | Average Percent Error in Monthly Estimates of Actual 305-Day Yields in the Two Breeds | 43 |
| V. | Average Percent Error in Monthly Estimates of Actual 305-Day Yields in the Four Herds | 45 |
| VI. | Average Percent Absolute Deviations of Monthly Estimates of Actual 305-Day Yields in the Two Breeds | 46 |
| VII. | Percentage of Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Breed | 48 |
| VIII. | Limits of Deviations of Lactation Estimates from Actual Yields by Sampling Interval and Computing Method | 51 |
| IX. | Standard Deviations of Percent Deviations of Monthly Estimates by Age, Herd and Computing Method | 52 |
| X. | Contributions of Different Segments of the Lactation to the Average Error in Estimates of the 471 Records | 55 |

TABLE PAGE

XI. Average Percent Errors in Bi-Monthly Estimates of Actual 305-Day Yields in the Two Breeds . . . . . 58

XII. Average Percent Absolute Deviations of Bi-Monthly Estimates from Actual 305-Day Yields in the Two Breeds . . . . . 59

XIII. Percentage of Bi-Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Breed . . . . 61

XIV. Average Percent Errors in Bi-Monthly Estimates of Actual 305-Day Yields in the Four Herds . . . . . 63

XV. Average Percent Absolute Deviations of Bi-Monthly Estimates of Actual 305-Day Yields in the Four Herds . . . . . 64

XVI. Standard Deviations of Percent Deviations of Bi-Monthly Estimates by Age, Herd and Computing Method . . . . . 66

XVII. Average Percent Errors in Tri-Monthly Estimates of Actual 305-Day Yields in the Two Breeds . . . . . 70

XVIII. Average Percent Errors in Tri-Monthly Estimates of Actual 305-Day Yields in the Four Herds . . . . . 71

XIX. Average Percent Absolute Deviations of Tri-Monthly Estimates Estimates of Actual 305-Day Yields in the Two Breeds . . . 72

XX. Percentage of Tri-Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Breed . . . . 74

XXI. Standard Deviations of Percent Deviations of Tri-Monthly Estimates by Age, Herd and Computing Method . . . . . 78

XXII. Statistical Analysis of Deviations (Percent of Actual Yield) of Estimates from Actual Yields . . . . . 84

TABLE PAGE

XXIII. Statistical Analysis of Deviations (Pounds of Milk) of Estimates from Actual Yield . . . . . 85

XXIV. Average Percent Absolute Deviations of Monthly Estimates of Actual 305-Day Yields in the Four Herds . . . . . 103

XXV. Percentage of Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Herd . . . . . 104

XXVI. Contribution of Different Segments of the Lactation to the Average Errors of Estimate in the Breeds Studied . . . . . 106

XXVII. Percentage of Bi-Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Herd . . . . . 108

XXVIII. Average Percent Absolute Deviations of Tri-Monthly Estimates from the Actual 305-Day Yields in the Four Herds . . . . . 110

XXIX. Percentage of Tri-Monthly Estimates Within a Given Percent of Actual Yield by Computing Method, Age and Herd . . . . 111

CRANES CREST

# CHAPTER I

## INTRODUCTION

The human population has increased through the years, while the dairy cow population has decreased. Since milk is an important ingredient in the human diet, to maintain or increase the consumption of milk it is necessary to increase the milk production per cow. This is also desirable for optimum economic returns.

With the decreasing cow population, the one way to meet the challenge of increased milk requirement appears to be in improving the genetic potential of dairy cows. Such improvement is possible by the efficient selection of breeding animals, particularly dairy sires in an age of artificial breeding. Efficient selection of dairy animals leads to the necessity of keeping production records of as many cows as possible.

Organized milk testing started in 1895 in Denmark (3) and in 1905-06 in the United States (15, 34, 36). Nevertheless, the number of dairy cows officially tested in the United States has not exceeded 25 percent of the total number of milking cows (15).

One of the reasons for the comparatively slow acceptance of a testing program seems to be the cost of testing. Since the inception of official testing, several investigations have been made in efforts to make testing cheaper, simpler and more convenient for the testing supervisor and dairy herd owner.

Early investigations in the field were aimed at exploring the possibility of simultaneously estimating lactation milk yield, fat content and fat yield with a certain degree of accuracy. Various studies have indicated that errors in estimates of fat content and fat yield are relatively larger than those in the estimates of milk yield (43). Some recent research deals with estimation of milk yield only, presumably with the belief that the estimation of fat content and fat yield will automatically follow.

With the advent of the computer for calculation, the test-interval method (TIM) has been accepted as the official method of record keeping by the Dairy Herd Improvement Association (DHIA) (9, 60). The TIM procedures allow a certain amount of flexibility in the length of interval between tests which provides convenience for the testing supervisor. Everett and Carter (20) indicated that by adjusting the first- and last-test credits, more accurate lactation estimates could be obtained. Everett and Carter (20), using 403 complete Holstein lactations developed factors for adjusting the first- and last-test credits in lactation estimates.

The purpose of this study was to test the usefulness of factors developed by Everett and Carter (20) in reducing the errors in estimates of 305-day milk yields. The accomplishment of this purpose involved a comparison of actual milk yield with estimated yields made by (1) using factors developed by Everett and Carter (20) and (2) official TIM procedures with different testing intervals.

# CHAPTER II

# REVIEW OF LITERATURE

## I. HISTORY

Gifford (27) indicated that perhaps Pyrrhus, in 300 B. C., was the first to realize the importance of measuring the milk yield of cows. Wing and Anderson (73) reported that record keeping was useful in the long-term improvement of a dairy herd. In 1965, Miller and Meadows (48) reported that testing improved Michigan herds. Milk records are said to be mostly useful for (1) efficient management and improvement of herds; (2) education and research, and (3) sire selection leading to genetic advancement of the dairy cattle population (3, 38, 36). To satisfy all of the three foregoing purposes reasonably, some sort of sampling scheme operated through an organization is the practical procedure for most dairy farmers (43).

The first attempt to organize milk recording on an organizational basis was made in Denmark in 1895 by Emil Konardi (3). The practice spread rapidly to other countries, but world wars and economic depressions were setbacks in its progress (3).

In the United States, the first Dairy Herd Improvement Association (DHIA) was formed during 1905-06 in Michigan (15, 34, 36) in Newaygo County of Helmer Rabilt, who was born in Denmark (34). The number of cows on test throughout the country, however, has never exceeded 25 percent of the total number in the United States (15).

The increasing cost has been considered one of the main causes of the low number of cows being tested (3, 4, 10, 21, 40, 45, 46, 53). Various attempts have been made to lower the cost of testing without losing sight of the purpose of testing.

Early testing procedures involved longer sampling periods at each test, with shorter intervals between tests. Sampling of one day's milk production at monthly intervals with the centering-date method (CDM) was the procedure practiced for the major part of the testing era, particularly in the United States. The test-interval method (TIM) with one day's milk being sampled at each test, had been approved by the Coordinating Committee of the National Dairy Herd Improvement Association in March, 1967 (20). Since July 1, 1969, the TIM has become the only acceptable procedure of estimating DHIA records (9). Currently, investigations are underway in an attempt to restrict the sampling to one milking instead of two consecutive milkings (one-day sample). Investigations are aimed also at an improvement of TIM estimates, preferably with longer intervals between samplings.

## II. ONE-DAY SAMPLE METHOD

### Weekly Sampling

Early studies concentrated on short-interval sampling. Davey and Alexander (12) observed an absolute average deviation of 1.6 percent of actual yields in weekly recorded estimates, while none of the extimates exceeded a deviation of 10 percent. In a study of 400 lactations, Jordao et al. (33) investigated the effects of various sampling intervals

ranging from one to eight weeks and reported the average percent deviation from actual yield to be inversely proportional to the frequency of recording. The range of deviation reported was -5.0 to 6.0 percent, while the absolute average deviation was 1.56 percent. Using 24 lactations, Houston and Hale (29) calculated all the possible weekly estimates, starting from different days of the week, and observed that one of 28 weekly estimates was in error by more than 2.5 percent. Ashton's study (2) cited in his review (3), indicated the maximum deviation of weekly-interval estimates to be less than 4 percent. Ashton's review (3) of early investigations involving shorter sampling intervals, pointed out that the maximum deviations of weekly estimates were 4 percent for milk yield, and 5 percent for fat yield; however, the majority of weekly estimates were within 2 percent error. Dick (13) examined sampling intervals from two to 28 days and concluded that the standard deviations of percentage errors varied linearly with length of sample interval, from about 0.35 for a two-day interval to about 2.32 for a 28-day sample interval. No correlation between percentage error and either the daily or lactation milk yield was observed.

Bi-Weekly and Tri-Weekly Sampling

Davey and Alexander (12) in their study of 89 Jersey lactations, observed fortnightly estimates to have an absolute average error of 2.5 percent while one in 89 estimates had an error of 10 percent. Jordao et al. (33), examining the errors associated with sampling intervals of 1, 2, 3, 4 and 8 weeks, observed that the average percentage deviation for each lactation estimate was inversely proportional to the frequency

of recording. Houston and Hale (29) observed that one of 20 bi-weekly estimates of milk yield differed by 5 percent or more, and that it was twice the amount of variation associated with the weekly estimates which they studied. They examined intervals of 1, 2, 3, 4, 6 and 8 weeks to estimate the fat content and observed that the errors increased with the interval length and concluded that to insure a fat content estimate within 10 percent error, the sampling interval should not exceed one month. The tri-weekly sampling interval has not been used as extensively as others (3). Zorn and Gruhn (75) studied 3-, 4-, 6- and 8-week sampling intervals, and reported an average error of 2.4 percent from the actual milk yield for tri-weekly estimates with a range of -9.0 to +10 percent. The percent of error was greater for fat-yield estimates, and the correlation of tri-weekly milk yield estimates with actual milk yields was 0.994. The range of errors observed by Jordao et al. (33) in tri-weekly estimates of milk yield was -11 to +7 percent. Houston and Hale (29) observed a maximum percentage of error of 6.5 percent in tri-weekly estimates of butterfat. Ashton (3) cited a few investigations where no serious differences were found between 14-day and 21-day sampling intervals. Ashton (3) reviewed other early works and concluded that the accuracy of the 21-day interval was intermediate between 14-day and monthly records. Sere Del Campo (62) found little difference in the accuracy of estimates of milk yields made with sampling intervals of 7, 15, 21, 30 and 42 days.

Monthly Sampling

Monthly-interval sampling with a complete day's milk weight, is the most practiced procedure of estimating the milk production of dairy cows. Reviewing early works, Ashton (3) found the maximum error from monthly recordings, calculated as percentage of the actual milk yield, to vary between 4.69 and 9.95 percent, though some reports revealed errors up to 23 percent. Houston and Hale (29) indicated that to keep the error within 10 percent for fat content, the sampling interval should not exceed one month. Zorn and Gruhn (75) observed an average deviation of 2.60 percent for monthly-tested milk yield estimates. They calculated the estimates in three different ways, with respect to the starting day, and the range of deviations for the poorest estimates of milk yield was from -12.0 to 12.5 percent and from -12 to 11 percent for fat yield, though fat yield was more varied as a whole. Campbell (6) found that with a monthly sampling interval, 86 percent of the milk yield estimates, 76 percent of the fat content estimates and 69 percent of fat yield estimates were within ± 5 percent of actuals. Thompson et al. (65) found average errors of 2.4 percent for milk yield, 2.8 percent for fat content and 3.2 percent for fat yield to be associated with estimates made from monthly sampling. McCarthy and Boyle (42) reported that 95 percent of their milk yield estimates were in an error range of -5.35 to 6.16 percent. With a study of 70 lactations, McDowell (45, 46) observed an average error of 2.91 percent using the centering-date method of monthly-interval estimates, with a maximum error of 8.3 percent. The corresponding average and maximum values for sampling at two-month intervals were

3.8 percent and 12.5 percent, respectively. Also, from this study (45, 46), 16 of 70 monthly estimates and 24 of 70 bi-monthly estimates were in error by more than 5 percent. Ashton's work (2) indicated that estimates from 147 of 154 monthly records were within ± 10 percent of actual milk yields. Davey and Alexander (12) observed an absolute average error of 6.8 percent associated with monthly sampling estimates. Erb et al. (18) reported that an error of 2.4 percent was exceeded by 25 percent of the yield estimates and that the error in fat yield estimates was from 1.2 to 2.5 percent greater than that for milk yield. Copeland (10) found that 49.2 percent of his milk yield estimates from monthly samples were in error by less than 1 percent of the actual yield. He concluded also that there was not much difference between monthly-sample estimates of from "one-day" and "two-day" samples, confirming the findings of Petersen (52).

Jasiorowaski et al. (30) found a correlation of 0.985 between monthly records and actual yields, a slightly greater correlation that that of 0.959 found by Lamb and Young (39), and not much different from the 0.990 correlation between weekly estimates and actual yields, observed by Zorn and Gruhn (75). These values were within the range of correlations between actual yields and monthly estimates calculated by different methods, including those with two to six missing tests, calculated by Everett et al. (21). Based on correlations between estimates and actual yields, Everett et al. (21) did not find any difference between monthly estimates with centering dates on the (1) ninth day, (2) nineteenth day and (3) twenty-ninth day of the month. The correlation was

0.996 between any one of the estimates and actual yields (21). McKellip and Seath (47) found only slight advantage in centering the date of testing in monthly recording. With a small scale study, Jax and Nobl (31) considered monthly testing as a satisfactory method for cows under Alpine grazing conditions. Morrison and Erb (50) compared and found that both the centering-date and calendar-month methods overestimated the actual production, but no conclusion was drawn as to the difference between the methods. Koubek and Stodola (38) observed that the deviation would be less if the cows were tested early in the lactation. Davey and Alexander (12) reduced the error from 6.8 percent to 3.9 percent in monthly testing by adjusting the estimates for dates of calving and cessation of lactation. This appears to be the result of back-crediting from the first test to calving with production at first test and applying the credit of last test up to the cessation of lactation. Such a procedure would overestimate the production (21). Everett and Carter (20) reported that the bias in the estimate at the end of lactation would be two-thirds as large as that in the early part of the lactation.

The standard deviations of percentage differences of monthly-test estimates from actual yields have been studied by several investigators (6, 12, 18, 65). From these studies the average standard deviation values were 2.71, 3.54, and 4.95 percent for milk yield, fat content and fat yield, respectively. Of these three traits milk yield appeared to be estimated most accurately by monthly sampling, with the relative error in appraising fat content being about 30 percent larger than that for milk yield (3.54 percent versus 2.71 percent) and the error for fat yield

being about 80 percent (4.95 percent versus 2.71 percent) larger than that for milk yield. This apparently resulted from a compounding of the inaccuracy in the two component parts. Other investigations (44, 75) indicated also that milk fat percentages computed from monthly samples had greater proportional errors than those of milk yields obtained similarly. The work of McDaniel et al. (44), quoted by McDaniel (43) revealed that 95 percent of DHIA records were within ± 5 percent of true milk yield, 85 percent of them were within ± 3 percent of the actual milk yields and only three of 639 DHIA records differed from actual production by as much as 10 percent. In this study (44), the distribution of absolute deviation in terms of the amount of milk or fat (kilograms) indicated that the errors were lower for younger cows than for mature cows. This age variation, however, was less with regard to fat percentage. With 369 actual lactations, Everett et al. (22) calculated 11,070 monthly estimates with the centering-date method and observed that the deviations increased with the maturity of the cow.

Sampling at Six-Week Intervals

Houston and Hale (29) found that when fat tests were made at six-weeks intervals, most of the errors in fat content estimates were less than 8.5 percent, though some were as high as 12 percent. In contrast, Johansson (32) indicated that recording at six-week intervals would keep the errors of fat content estimates within ± 10 percent, but that this would result in larger errors in milk and fat yield estimates.

In an analysis of 119 lactation records by Zorn and Gruhn (75), it was shown that the error range for milk yield was from -14 to +16 percent,

while it was from -14.3 to +14.4 percent for fat content. McCarthy and Boyle (42) found that 95 percent of milk yield estimates had an error range from -8.17 to 8.9 percent, though two of 350 estimates exceeded the limits recorded by Zorn and Gruhn (75). McCarthy and Boyle (42) concluded that no appreciable biases were introduced in milk yield estimates from monthly, six-weekly or bi-monthly testing. Sere Del Campo (62), examining different testing intervals, found little difference between intervals within 1 - 42 days' range. Jordao et al. (33) studied the influence of 1-, 2-, 3-, 4- and 8-week sampling intervals and observed that the average percentage error of estimate from actual milk yield steadily increased with the length of interval between tests.

## Bi-Monthly Sampling

Bi-monthly versus actual performance. The possibility of extending the recording interval to two months was first investigated in North America (3). McDowell (45, 46) found that bi-monthly records showed an average error of 3.8 percent of actual fat yield and a maximum error of 12.5 percent while monthly records showed an average error of 2.91 percent with a maximum error of 8.3 percent. McDowell also considered bi-monthly recording to be satisfactory for all practical purposes. McKellip and Seath (47) indicated that bi-monthly records were as reliable as monthly records. Becker and McGilliard (5) also considered bi-monthly recording to be sufficient, but drew attention to the desirability of preliminary milking. In the investigation by McCarthy and Boyle (42), 95 percent of the bi-monthly milk records were in error by amounts ranging

from -10.10 to +10.11 percent, the maximum error being 19 percent. These investigators believed that the differences in error between monthly, six-weekly and bi-monthly estimates were not appreciable.

Using four different methods, Lamb and Young (39) found high positive correlations between actual and estimated milk and fat yields. These correlations were: (1) 0.959 and 0.977, (2) 0.941 and 0.963 and (3) 0.917 and 0.947 for monthly, bi-monthly and tri-monthly testing intervals, respectively. The study concluded also that longer intervals were quite useful for ranking cows within herds and for sire proving. Zorn and Gruhn (75) found a correlation of 0.981 between actual milk yields and milk yield estimated from bi-monthly recorded milk yields. The average deviation was 4.14 percent for milk yield, and the range of error was from -17 to 18 and -17.3 to 16.4 percent for milk and fat yields, respectively. Erb et al. (18) studied the accuracy of records of different sampling intervals. Twenty-five percent of the bi-monthly records showed an error in excess of 3.4 percent. The corresponding levels of error for intervals of 30, 90, 120 and 150 days were 2.4, 5.6, 7.4 and 8.8 percent, respectively. In a study of 369 Holstein lactations, Everett et al. (22) reported that bi-monthly recording overestimated the milk yield by 80.8 kg. The comparative deviations of 57.3 and 80.8 kg were found for monthly and tri-monthly estimates (22). Jordao et al. (33), in a study of 400 lactations, reported average absolute errors of 4.28 and 2.68 percent for bi-monthly and monthly recorded milk yields, respectively. In this study, 99 and 93 percent of the monthly and bi-monthly estimates, respectively, were found to be within 10 percent of

the actual milk yield. Combining various investigations, McDaniel (43) calculated unweighted average absolute errors of 2.03 and 3.25 percent for monthly and bi-monthly estimates, respectively. Similarly, the standard deviations of errors were 2.50 and 3.83 percent for monthly and bi-monthly estimates, respectively, with all the monthly and 98 percent of the bi-monthly estimates falling within an absolute error of 10 percent. Reviewing the investigation of Erb et al. (17) on variations in daily milk yields of dairy cows, McDaniel (43) concluded that bi-monthly sampling would be expected to give an error of 3.4 percent or more in one out of four milk records, and that only in one case out of 100 should errors exceed 7.6 percent.

Bi-monthly versus monthly sampling. Several studies (1, 4, 8, 10, 27, 38, 42) have compared bi-monthly with monthly testing using data from the same lactations. In the study of Alexander and Yapp (1), only 7.16 percent of 684 bi-monthly fat-corrected milk estimates differed by more than 10 percent from monthly estimates. Bayley et al. (4) found in 1,225 bi-monthly estimates average absolute deviations from monthly estimates of 3 and 4 percent for milk and fat yields, respectively. The frequency of deviations of 10 percent or more was one in 46 and one in 16 for milk and fat yields, respectively. Copeland (10) observed that 49.2 percent of 250 bi-monthly records varied less than 1 percent from "two-days" monthly records. Gifford (27) found mean deviations of $-4.90 \pm 0.346$ and $2.50 \pm 0.375$ pounds of fat for "odd-months" and "even-months" bi-monthly records, respectively, in comparison with "two-days"

monthly records. Correlations between (1) "odd-months" and (2) "even-months" bi-monthly records and "two-days" monthly records were 0.986 and 0.997, respectively.

Castle and Searle (8), in a New Zealand study, compared bi-monthly records started in (1) August and (2) September with monthly records. The study involved 35 herds for a period of four years. When herd averages were calculated, only 5 percent of both types of bi-monthly herd averages differed from the monthly herd averages by 5 percent or more. Two bi-monthly averages, however, differed slightly, which led Castle and Searle to conclude that bi-monthly records were inadequate for between-herd comparison. Dolby (16), working in Australia, calculated "odd-months" and "even-months" bi-monthly estimates, using 5,000 monthly records. The average bi-monthly estimate, based on "odd months" of lactation, was 4 percent lower than the average monthly estimate; the average of estimates, based on "even months" differed by the same amount, but in the opposite direction. With this finding, Dolby confirmed the opinion of Castle and Searle (8), but indicated that a technique to correct the yield according to the stage of lactation might remove the objection to bi-monthly estimates for between-herd comparison, and refine the within-herd comparison.

Castle and Searle (8) computed sire evaluations, based on both monthly and bi-monthly records, using the records of seven natural service bulls. The bulls were ranked about the same under both testing intervals. A similar result was obtained with eleven bulls used for artificial insemination, which were compared under these two recording

intervals. Both monthly and bi-monthly records ranked the cows about the same within each herd-year group. Cunningham and Vial (11) reported that bi-monthly testing was a little less accurate than monthly testing, but indicated that the method could reduce the cost of progeny testing without affecting accuracy. The 305-day means of 5,275 lactations calculated by Poly and Poutous (54), from monthly and bi-monthly records proved to be identical.

Sampling at Intervals Longer than Sixty Days

Only a few investigations have been made using intervals of longer than sixty days. Bayley et al. (4), in comparing quarterly (three-month) sample estimates with bi-monthly and monthly estimates, found that 12.5 percent of the quarterly estimates and 2.2 percent of the bi-monthly estimates differed from the monthly estimates by 10 percent. The average absolute difference was 5 and 3 percent for the quarterly and bi-monthly estimates, respectively. Compared to monthly estimates, the bi-monthly estimates were 2.5 percent more variable, and the corresponding value for quarterly estimates was 8.9 percent. Similar results were found for fat yield estimates. Miller and Meadows (49) studied methods of estimating lactation yields from bi-monthly and tri-monthly interval samples, using 58,840 records. Multiple linear regression estimates were the most accurate. Seventy-four percent of three sets (Set 1: 1st, 4th, 7th and 10th month, Set 2: 2nd, 5th and 8th month, and Set 3: 3rd, 6th, and 9th month) of tri-monthly milk yield estimates had average deviations of 231, 296, and 302 kgs, respectively, from the monthly estimates. The same proportion of bi-monthly estimates had average deviations of 65 and

61 kgs for "odd months" and "even months," respectively. Considering the results of tri-monthly estimates sufficiently accurate, a large-scale tri-monthly testing field trial has been launched in Michigan (40).

Lamb and Young (39) found that lactation totals of milk and fat, estimated from tri-monthly samplings, did not prove to be significantly different when computed by different procedures. Correlations between tri-monthly estimates and actual milk and fat yields were 0.917 and 0.947, respectively.

Alexander and Yapp (1) found that only 7.7 percent of 684 milk yields, estimated from samples taken at the second, sixth and tenth months, differed from monthly records by 10 percent or more. The corresponding frequencies for records from (1) bi-monthly testing, (2) second and tenth month testing, and (3) fourth and eight month testing were 7.2, 12.3 and 16.5 percent, respectively. Erb et al. (18) compared 30-, 60-, 90-, 120-, and 150-day testing intervals. In the order of increasing interval length, 25 percent of the milk yield estimates were in error by 2.4, 3.4, 5.6, 7.4 and 8.8 percent or more of the actual. The comparable error for fat yield estimates was 1.2 to 2.5 percent greater. Based on this, the monthly estimates of milk yield appeared to the investigators to be twice as accurate as tri-monthly ones. They believed also that the accuracy of estimates based on 90-, 120-, and 150-day intervals was grossly influenced by the stage of lactation at which the cow was first tested and indicated the possibility of developing correction factors to minimize the errors arising when cows were tested only three or four times a year.

Everett et al. (22) compared 33,210 calculated tri-monthly estimates from 369 Holstein lactations to actual milk yields. Production was biased upward by an average of 80.8 kg for the tri-monthly intervals, using the centering-date computational methods, compared with a bias of 57.3 kg for monthly intervals. The variance of errors was about six times larger for the tri-monthly than for the monthly sampling. By adjusting for the stage of lactation at the first and last tests the average bias was reduced to -0.5 and -2.9 kgs for monthly and tri-monthly testing, respectively. Reduction in the variance of errors resulting from these two adjustments was more spectacular in the tri-monthly than in the monthly or bi-monthly sampling. When adjustments for production in the first and last test periods were made, the frequency of estimates with less than 4 percent error from the actual was increased from 52 to 62 percent in the tri-monthly estimates. Similar results were obtained with records computed by the test-interval method (20). These results confirm the opinion of Erb et al. (18) that the correction factors were needed.

Increased accuracy in predicting actual production from the yields on a few selected test days should increase the precision in sire and dam selection programs, as well as the confidence and interest of dairy men in the DHIA program (22). The cost of implementing the correction for the first and last tests would be very small, because of the availability of electronic computing (22).

## III. SINGLE-MILKING SAMPLE

In order to test more cows, it has been recommended that one milking sample be used instead of two. Porzio (55) estimated the

lactation milk yields from morning and evening milk samples, made alternatingly every month. Every sample was doubled to represent a day's yield. In the study of 150 lactations, the monthly "A.M.-P.M." milk yield estimates differed from monthly "one-day" estimates by an average of 32.83 kg or 1.05 percent. Porzio recommended this method for mountainous areas where movement of recording personnel would be difficult. Jax and Nobl (31) examined the different methods of milk recording and indicated that methods based either on morning or evening milking alone were unsatisfactory. In the study of Parche (56), the mean milk yield of 52 lactations of Normandy cows, with monthly recording of two milkings each time, was 2,475 kg, while the corresponding estimate for the monthly alternative "A.M.-P.M." recording was (1) 2,451 kg for records beginning with P.M. recording and (2) 2,499 kg for records beginning with A.M. recording. The mean fat content estimate was 4.08 percent in all three cases.

In 1966, Poly and Poutous (53) studied the accuracy of periodic single-milking sampling, by comparing the variance of the difference between records based on one-milking and two-milking samples, both at monthly intervals, and those records based on two-milking samples. In 5,467 lactations, the ratio of these variances (1) did not exceed 1 percent for milk yield and was (2) 3 percent for fat yield and (3) 14 percent for fat content. These authors, in another study (54), compared several recording methods with the official DHI method, using 5,275 lactations. In estimating the 305-day yield, they found that the variances of the difference between monthly DHI-type records and (1)

alternate "A.M.-P.M." monthly records, (2) alternate "A.M.-P.M." bi-monthly records and (3) bi-monthly DHI-type records, were 0.62, 7.98 and 6.62 times as great as variation in monthly DHI-type estimates, respectively.

In 1968, Putnam and Gilmore (57) compared (1) the monthly official DHIA procedure, (2) the alternate monthly "A.M.-P.M." sampling, and (3) the bi-monthly DHIA procedure with actual milk yield in 200 lactations. They found that the standard deviations (SD) of differences from actual 300-day production were 112.5 kg for the monthly official DHIA procedure, 161.4 kg for the alternate monthly "A.M.-P.M." sampling, and 223.0 kg for the bi-monthly DHIA procedure. Putnam and Gilmore found also that 98.8 percent of the official DHIA estimates were within ± 5 percent of actual production, but only 90 percent of the monthly "A.M.-P.M." estimates and only 80.3 percent of the bi-monthly DHIA estimates were within ± 5 percent of actual yields. The two possible alternate "A.M.-P.M." methods were not considered separately. Following these studies, Putnam and Gilmore (58) reported that the alternate "A.M.-P.M." plan has become an optional milk testing program in Pennsylvania, and the fees charged for it, amounted to 80 percent of the charges for the conventional program.

Dickinson and McDaniel (14) estimated 300-day productions factorially by using three test intervals, eight starting days of recording and five sampling plans: (1) 24-hour yield; (2) A.M. yield only; (3) P.M. yield only, (4) alternate "A.M.-P.M." yields, and (5) alternate "P.M.-A.M." yields. Analysis of deviations from actual milk yield indicated that the (2) A.M. yield and (3) P.M. yield plans were extremely

biased with SD twice as great as (1), the 24-hour yield plan; that the (4) alternate "A.M.-P.M." yield plan was about twice as biased as plan (1), with a SD about 40 percent greater; and that plan (5), alternate "P.M.-A.M." yields, was less biased than plan (1), with a SD about 20 percent greater than plan (1). The conclusion was that accurate estimates of lactation production from single milk weights would be possible if adjustments could be made for the few important sources of variation. The problem was further investigated by Dickinson and McDaniel (15). In this second study, 16 time spans from calving to first test, five test intervals and the same five sampling plans employed in their previous work (14) were used. A total of 214,400 different estimates of lactation milk yields were obtained by the test-interval method (TIM) of computation from 536 Holstein lactations. Daily milking intervals were 11 hours (A.M. to P.M.) and 13 hours (P.M. to A.M.). When the estimates were compared with actual yields, the alternate plans were found to be more biased than the conventional DHIA plan. Alternate "A.M.-P.M." estimates were biased significantly above DHIA estimates while the alternate "P.M.-A.M." plan was biased significantly below ($P < .001$). Likewise, all A.M. and all P.M. plans were significantly biased in opposite directions. Time span from calving to first test and the length of sampling interval appeared to have important effects on the biases of alternate plans.

Hardouin (28), working in Tunisia, observed a correlation of 0.963 between lactation yields estimated by (1) monthly conventional recording and (2) alternate "A.M.-P.M." monthly recording in 31 Friesian cows. The

corresponding correlation value for 23 Tarentaise cows was 0.973. With these results, the author concluded that alternate "A.M.-P.M." monthly recordings would be satisfactory under Tunisian conditions. Jasiorowaski et al. (30) analyzed the first lactations of 181 cows. They observed a correlation of 0.949 between morning milk yield and daily total yield.

Campbell (7) reported that more milk and fat were produced per hour during 9-, 12- and 15-hour night intervals than corresponding day intervals, and that the milk increment was, however, greater than the fat increment. Schmidt (61) studied the production of 15 cows averaging 29.2 kg of milk per day and observed that the amount of milk produced per hour was nearly equal until the milking interval exceeded 12 hours, when a decline in production per hour resulted. However, the longer interval would produce more total milk than the shorter interval. In a study of the lactations of identical twins, Koshi and Petersen (37) found that cows produced 44.2 percent of their daily yield instead of the arithmetical 10/24, during a ten-hour interval, and indicated that a higher rate of secretion prevailed during the shorter interval. Spahr and Ormiston (63) found that the amount of an A.M. milking, on a 12-hour interval, exceeded by 2.6 kg the P.M. milking, and that this difference increased to 7.6 kg with 15- and 9-hour intervals preceding A.M. and P.M. milkings, respectively. Ormiston et al. (51), studying 82 cows found that cows with 12.5- and 11.5-hour intervals produced 53.1 and 46.9 percent of their yield in the corresponding milkings and that cows on 14.5- and 9.5-hour intervals, produced 59.8 and 40.2 percent of their yield in the corresponding milkings. A higher rate of secretion was associated with the shorter interval.

Everett and Wadell (23) studied the relationship between milking intervals and individual milk weights in 184,521 test-day records of 19,905 cows of five breeds in 555 herds. They found that the average weight difference of A.M. and P.M. milk was approximately 0.10 kg, with equal interval between milkings for an average of 150 days lactation. The difference between A.M. and P.M. milk was found primarily to be a function of: (1) milking interval, which was found to produce a difference of 1.2 kg for every hour increase in the interval beyond twelve hours and (2) stage of lactation which decreased the difference by about 0.35 kg for each 100 days in milk. In another study, Everett and Wadell (24) found that milking interval and month of lactation, together with interaction between these two factors, were the largest source of variation between morning and evening milk yields. Everett and Wadell (25), in a single-milking testing scheme, indicated that adjustment for the milking interval was the most important correction needed. Putnam and Gilmore (59) observed that with equal milking intervals, the A.M. milk quantity was more by 0.16 pounds, and the difference increased linearly by 0.05 pounds per minute up to an interval difference of 120 minutes. Putnam and Gilmore, in computing lactation records, developed adjustment factors to take care of these differences.

In a testing program the interval between milkings is known to the tester. The milking interval might be well established for a herd, but a farmer might get the test milking delayed and get a longer interval preceding every test milking. Furthermore, in a large herd the sequence of entry of cows into the milking parlor has to be the same in all

milkings in order that milking intervals be uniform for all cows within a herd. This situation may lead the farmer to fraudulent practices. Even if adjustments are possible for milking intervals, how they can best be applied will be a question demanding clarification in view of the possibility of such variation in circumstances. This might cause one to think that the errors associated with estimates made under field conditions would be more than those established by investigations of established records. This point has been well supported by Spike et al. (64), who observed more variation in the fat content of morning and evening milk samples taken on nontest days than obtained from samples on test days, though the milking interval was said to be 12 hours in both cases.

The apparent gains from single-milking sampling over a one-day sampling, for a given testing interval, lie in the shorter time required for obtaining the sample plus possibly, in certain cases, saving the tester a second trip. Unless adjustments are made for each sampling, the single-milking procedures will lead to a poor management guide. The gains from its use might well be offset by the uncertainty concerning accuracy of estimates resulting from possibly fraudulent practices, and such estimates might thus be less valid.

## IV. TEST-INTERVAL METHOD

The test-interval method (TIM), like the centering-date method (CDM), is a procedure of computing the lactation yields from test weights. As per Sargent et al. (60), the basic principle of TIM was proposed by H. Maehrlen in 1880 when he suggested taking the average of the milk

weights of two consecutive tests and multiplying the average weight by the number of days between tests to estimate the production during the interval. Prior to becoming the official DHIA procedure (9), the TIM was used by some of the national breed registry organizations (60) and for computing DHIA records in Ontario, Canada (21). The method was referred to as the Canadian system of testing by Everett et al. (21).

The details of the centering-date method (CDM) were presented by King and Miller (36), and the details of the TIM were given by Sargent et al. (60), as well as by the Coordinating Group for the National Dairy Herd Improvement Program (9). The advantages and disadvantages of the TIM were listed by Sargent et al. (60). Among the advantages of the TIM over the CDM, the most important ones were flexibility of interval and ease of computing when one or few tests were missing (60). The main disadvantage was the difficulty of calculating rolling herd average, for which Sargent et al. (60) pointed out a solution. The TIM was accepted for computing official DHIA records in July, 1969 (9). Voelker and Thomson (72) developed a computer program designed to assign a yearly schedule of random test days for up to 26 herds in a group, in accordance with official DHI rules, July, 1969 (9).

Sargent et al. (60) used 744 (235 Guernsey and 509 Holsteins) Advanced Registry records for comparing the TIM with the CDM. The mean yield of the lactations was 6,751 kg. On the average, both TIM and CDM procedures underestimated the records slightly. Unlike other findings (21, 22), the underestimation was thought to be because of the consistently lower test weights, compared to the rest of the daily milk

weights in Holstein lactations, which constituted more than two-thirds of the total lactations used in the study. It was not clear whether or not the TIM interval was varied in this study (60). The difference between monthly and bi-monthly records was negligible, confirming the findings of McCarthy and Boyle (42). Correlations between actual and estimated records were high both within each breed and over both breeds. The correlation between CDM and TIM milk records was 0.999 with both monthly and bi-monthly intervals in both breeds, indicating no difference between CDM and TIM. The minimum correlation of actual with estimated milk yields was 0.984 (even bi-monthly CDM or TIM estimate with actual yield). The maximum correlation was 0.992 (between actual and CDM monthly estimate), indicating again no difference between monthly and bi-monthly intervals. The correlations obtained by Sargent et al. (60) were identical with those found by Van Vleck and Henderson (69), between actual milk yield and estimates from bi-monthly tests, calculated by using the regression factors developed by them. The results with fat content and fat yield led to similar conclusions (60).

Sargent et al. examined also the distribution of percentage differences of CDM and TIM estimated records compared with actual milk yield. About 50 percent of both CDM and TIM monthly estimated records deviated by 1.5 percent of the actual, whereas only about 40 percent of the bi-monthly records were this close to the actual yield. The frequency of deviations of 5 percent or more was 15 and 25 percent for monthly and bi-monthly records, respectively. Little difference was observed between CDM and TIM estimates (60). Everett and Carter (19)

reported that CDM estimated records would be slightly more accurate and precise than TIM estimated records and indicated also that this difference resulted because the interval was varied in TIM estimation. They further stated that the TIM estimated records adjusted for day of test would be more accurate than the unadjusted CDM estimated records based on the same interval.

Everett et al. (21) compared the TIM (referred to as the Canadian System), with varied numbers of missing tests, but not more than one test being missed in a series, with monthly CDM estimates using different centering dates. In the TIM estimates the intervals were randomly varied from 20 to 45 days. The correlation of the TIM estimates with actual milk production or other estimates was 0.981 or more. Everett et al. (21) studied 357 Holstein lactations and reported that the TIM lead to slightly higher overestimates of production, compared to the CDM, with centering date on ninth, nineteenth or twenty-ninth day. The difference between TIM and CDM estimates was negligible and thought to be the result of variation in the length of intervals used in the TIM. Comparing the biases in lactation milk yield estimates with the biases in first test credits, Everett et al. (21) concluded that most of the bias in the production estimates came from the first test credit. The workers indicated that the large amount of bias in production estimates could be eliminated by adjusting the credits from the first test, based on day of test and age (age related to level of production) of cow at calving.

Everett and Carter (20) used 403 Holstein lactations, which varied in length from 200 to 305 days. From these lactations, mean lactation

curves were developed for different age groups (2, 3, 4, 5 and 6 + years), and from these mean lactations, ratio factors for adjusting the first test credit were developed. The factor was a ratio of actual yield to estimated yield as given by the formula:

$$\sum_{i=1}^{j} Y_i / jY_j$$

where $Y_i$ is the average daily production, j is the lactation day on which the first test was made, $Y_j$ was the test day average production and j was varied from four to 150, thus giving 147 ratio factors for each age group. Factors for second-test interval were similarly developed but discarded because they were too large in number and the benefit derived by using them was negligible. For adjusting the credit beyond the last test, the regression of final 90 days' daily production on days was computed within each age group.

From each lactation 30 monthly, 60 bi-monthly and 90 tri-monthly estimates were calculated. The corresponding number of the first-test adjusted estimates and the first-and-last-test-adjusted estimates also were simulated. The average biases of 57.1, 91.4 and 114.7 kg of milk for monthly, bi-monthly and tri-monthly estimates were changed to 27.9, 85.9 and 117.3 kg by the first-test adjustment alone, and, after adjusting for the first and last tests, the corresponding values were 9.1, 9.0 and -2.0 kg. The last-test adjustment, in addition to the first-test adjustment, was found to be more useful with longer testing intervals. This was demonstrated clearly by the reduction in variance of errors

obtained by the first- and last-test adjustments. By the two adjustments, the variance of errors of monthly, bi-monthly and tri-monthly estimates were reduced to 0.88, 0.83, and 0.78, respectively, of unadjusted estimates. Comparing their results with the findings of Everett et al. (22), the authors (20) concluded that the CDM estimated the production more closely than did the TIM, but with adjustments for the first and last tests, the TIM estimated the production better than the unadjusted CDM.

Since the factors were tested by applying them to the lactations from which they were developed, the authors (20) indicated that the effectiveness of these factors when applied generally might be less than that observed in their study.

## V. A POTPOURRI OF TESTING METHODS

Experiments had indicated that the amount of milk and fat content in milk could be increased during a two-day test period by leaving milk in the udder on the last milking preceding such a test period, as reported by Petersen (52), who indicated also that it would be much easier to influence two-day test results both in milk weight and fat content than one-day test results. By comparison, Petersen concluded also that the difference in one-day and two-day test records of fat content and milk yield was very small and comparable to possible differences obtained by two individuals conducting the same test. Sere Del Campo (62) indicated that the duration of recording (24 versus 48 hours) produced no significant difference; however, the records with 48-hour recordings were slightly more accurate.

Tyler and Chapman (66) found that the sum of ten monthly milk yields multiplied by 30.5 would give sufficiently accurate estimates of lactation milk yields. The correlation of such simplified estimates and standard CDM estimates was found to be 0.984. It would appear that this method would not provide up-to-date production information within a lactation, and deviations in the length of intervals would have to be strongly restricted. Alexander and Yapp (1) found that testing on (1) second, sixth and tenth months, (2) second and tenth month and (3) fourth and eighth month would all give 305-day production estimates comparable to estimates based on monthly test records. Masuda and Higaki (41) indicated that it would be possible to estimate 305-day milk yields by recording in the eighth, eleventh, twenty-third, thirty-second and thirty-eighth weeks, or in the eighth, twenty-third and thirty-eighth weeks of lactation. Seven-day tests, conducted anytime following the seventh day after calving, were shown by Yapp (74) to be poor indicators of lactation yields, and the correlation between records of the seven-day tests and two-day monthly tests was not high. Later, Gaines (26) showed that seven-day tests conducted after 60 days in lactation, preferably during the fourth month, could be used to estimate the performance of dairy cows. If the freshening of cows is throughout the year, these short-cut methods explored by different scientists (1, 26, 41, 74) lack applicability.

The magnitude of errors in bi-monthly or longer interval estimates has appeared to be dependent on the stage of lactation at the first test (43). Koubek and Stodola (38) developed an equation for predicting the error in a bi-monthly record on the basis of stage of lactation at first

test. Turner (67) found that, for Holsteins and Guernseys, the maximum yield was in the second month of lactation, whereas, the corresponding month for Jerseys was the third month. In twelve-month lactations of these three breeds, each of the first three months yielded more than 10 percent of the total yield, and the yield of the twelfth month was approximately half of the production of the month of maximum yield. Everett et al. (21) studied the daily variability of milk yield in 357 Holstein lactations. The maximum variation in daily milk yields was observed during the first month, followed by a general decrease as the lactation advanced. Van Vleck and Henderson (68) reported that the repeatability and heritability estimates of monthly milk records increased with the stage of lactation until the fifth or sixth month, and then declined indicating more variability early in lactation. Keown and Van Vleck (35) observed lower heritability estimates for both fat content and milk yield in early and late monthly tests than in mid-lactation monthly tests, indicating less variability of yield in the middle of lactation. Studies of the correlations between monthly records and total yields have shown a maximum of 0.85, for fourth, fifth and sixth months (69). Hence, if lactation yield is to be estimated from a single monthly yield, it should be estimated from the yield in the fourth, fifth or sixth month (69). Later, Keown and Van Vleck (35) reported that the genetic and phenotypic correlations between total lactation and monthly-test records were higher for the middle months, both for milk and fat content. Van Vleck and Henderson (69) developed multiple regression factors to estimate the lactation yield from part lactations.

Van Vleck and Henderson (70) indicated that bi-monthly testing would be accurate enough, reporting that approximately the same number of bi-monthly records as ten-month records would be sufficient to prove a bull with equal accuracy for predicting its breeding value for ten-month yield. Relatively high estimates of heritability and repeatibility of bi-monthly records were reported (68). Van Vleck and Henderson (69) observed a correlation of 0.98 between bi-monthly records (for both odd and even months) and 305-day actual yields. Ignoring herd effects, bi-monthly estimates computed by the use of regression factors proved to be slightly less accurate than those computed similarly with herd effects considered, but Van Vleck and Henderson (71) pointed out that such estimates would still be highly correlated with actual milk yields and that the computation of such estimates would be much easier.

The correlation of three sets of tri-monthly estimates with 305-day yields varied between 0.92 and 0.96, indicating the suitability of tri-monthly recording (69). In terms of selection and genetic gain, Keown and Van Vleck (35) observed that selecting on (1) part lactations of six months, (2) bi-monthly records or (3) tri-monthly records would be as effective as selecting on actual 305-day records and that selecting on a quadra-monthly basis would be slightly inferior in terms of genetic gain for milk and fat content.

## VI. SUMMARY

The testing procedures have been investigated extensively since inception. The centering-day method (CDM) was in use for about 30 to

35 years in the United States of America. The TIM replaced the CDM officially in 1969. It has been indicated that by adjusting for the time of first test or for the time of first and last tests, the accuracy of estimates could be improved; and with such adjustments estimates from tests made at longer intervals could be within acceptable accuracy. Everett and Carter (20), using 403 Holstein records, developed adjustment factors and tested the effectiveness of those factors by applying the factors to the records from which they were derived. Investigations examining the effectiveness of these factors in practical application are lacking. Hence, an attempt was made in the present study to assess the effectiveness of the factors developed by Everett and Carter (20) in improving the accuracy of estimates of lactation milk yield and the possibility of lengthening the intervals between tests in practical application.

# CHAPTER III

## MATERIALS AND METHODS

The present study included 471 lactations from University of Tennessee herds. Of these, 232 were from Holstein cows, and 239 were from Jersey cows. Each breed was represented by two herds: Holstein data from herds at Knoxville and Spring Hill and Jersey data from herds at Lewisburg and Jackson. The Lewisburg herd was represented by 123 records and the other three herds by 116 records each. The experimental lactations were restricted to the freshenings of five years (1964 to 1968).

### Selection of Records

The experimental data included only lactations, which had completed at least 305 days in milk, were not affected by any experiment and had the daily weights recorded for 305 days. The available 305-day lactations were stratified into five age groups (2, 3, 4, 5 and 6 or more years), based on the age of the cow at freshening. A random selection of available lactations was obtained from each herd-year-age group, so that the ratio between numbers in the age groups among the experimental lactations would be quite similar to the ratio between numbers in the age groups among all the lactations from which the experimental lactations were selected. This was done to simulate a practical situation. The number of lactations randomly selected varied from 16 to 27 per herd-year group.

The distribution of (A) lactations randomly selected and (B) lactations available, across herds and age groups, is shown in Table I. The average 305-day yields of the selected lactations in a specific herd is noted in the last column. The last two rows of Table I, indicate that the overall ratio between numbers in different age groups, among the available lactations was similar to that ratio among selected lactations.

Computation

The daily milk weights were recorded to the nearest pound, starting from the fourth day after calving (counting the day of calving as the first day). This is in conformity with DHIA procedures (9, 21, 36). The sum of the first 305 days' milk weights provided the actual 305-day yield.

Three sampling intervals of 30-, 60-, and 90-days, hereafter referred to as monthly, bi-monthly, and tri-monthly, respectively, were used. The sampling intervals were of fixed length.

To be in conformity with DHIA procedures (9, 21, 36), no sampling was practiced earlier than the fourth day of lactation (seventh day from calving). Computation of lactation milk yield estimate was by the TIM procedure (9, 60); these are referred to as unadjusted estimates. Thus, from each record 30 monthly, 60 bi-monthly and 90 tri-monthly unadjusted estimates were calculated. The first estimate with a sampling interval of L days (L = 30 or 60 or 90) was made with the first test on the day four of lactation, the second estimate with the first test on the day five of lactation and the Lth estimate with the first test on day L plus three of lactation. In all, 84,780 unadjusted estimates were calculated.

TABLE I

DISTRIBUTION OF LACTATIONS SELECTED FOR STUDY BY HERD AND AGE

| Herd[a] | | Age (Years) 2 | 3 | 4 | 5 | 6+ | Total | Avg. 305-Day Yield (Lbs.) |
|---|---|---|---|---|---|---|---|---|
| KH | A | 40 | 26 | 21 | 12 | 17 | 116 | 15,258 |
| | B | 80 | 54 | 41 | 23 | 33 | 231 | |
| SH | A | 46 | 23 | 16 | 11 | 20 | 116 | 13,831 |
| | B | 103 | 52 | 37 | 27 | 49 | 268 | |
| JJ | A | 44 | 19 | 13 | 12 | 28 | 116 | 9,239 |
| | B | 93 | 45 | 29 | 23 | 54 | 244 | |
| LJ | A | 36 | 22 | 20 | 13 | 32 | 123 | 12,551 |
| | B | 137 | 75 | 64 | 43 | 114 | 433 | |
| All | A | 166 | 90 | 70 | 48 | 97 | 471 | 12,717 |
| | B | 413 | 226 | 171 | 116 | 250 | 1,176 | |
| (All | A)$(\frac{5}{2})$[b] | 415 | 225 | 175 | 120 | 243 | 1,178 | |

[a]KH: Knoxville-Holstein; SH: Spring Hill-Holstein; JJ: Jackson-Jersey; LJ: Lewisburg-Jersey; A: Selected; B: Available.

[b]The numbers in the last row are the products of 2.5 and the numbers of records utilized in each age group, e.g., (2.5)(166) = 415.

For each unadjusted estimate, two adjusted estimates were derived by correcting for the time of first and last test. For the first-test-adjusted estimate, the estimated yield of milk through the first test day was multiplied by the ratio factors developed and generalized into equations by Everett and Carter (20). The equations are given in Table II. Similarly, for each unadjusted estimate a first-and-last-test-adjusted estimate of a record was obtained by correcting for the time of first and last test. The adjustment for the first test was the same as described above. The unadjusted credit beyond the last test was calculated as:

$$Y_k(305 - D_k),$$

while the adjusted credit was calculated by the formula

$$[Y_k + (305 - D_k)\,\frac{b}{2}]\,(305 - D_k).$$

In the formulas $D_k$ and $Y_k$ represent the last test day and last test milk weight, respectively, under the specified sampling interval. The formulas were basically adapted from Everett and Carter (20) and slightly modified to suit specifically 305-day lactations. The following regression values (b) were used: -0.058 pounds for two-, -0.115 for three-, -0.127 for four-, -0.132 for five- and -0.106 pounds for six-year and older age groups. These values were adapted from Everett and Carter (20), except for the unit of weight, which was noted as kilograms in that study.

Back crediting, i.e., giving credit for production before first sampling day, is inherent in the DHIA procedure (9, 21, 60). In this study every series (interval-method combination) of estimates included

TABLE II

AGE GROUP EQUATIONS FOR CORRECTING FOR LENGTH OF FIRST TEST PERIOD

$$(Y = u + b_1 x^k + b_2 x + b_3 (1.0/x^2)$$

(x = length in days)

| Age (Years) | u | $b_1$ | $b_2$ | $b_3$ | k | $R^2$ |
|---|---|---|---|---|---|---|
| 2 | 0.8553 | $0.0000X10^{0}$ | $0.1933X10^{-2}$ | $0.1619X10^{0}$ | 0.00 | 0.983 |
| 3 | 0.8995 | $0.2041X10^{-2}$ | $-0.2478X10^{-2}$ | $0.1090X10^{0}$ | 1.19 | 0.997 |
| 4 | 0.9103 | $0.9057X10^{-2}$ | $-0.1232X10^{-1}$ | $0.1080X10^{0}$ | 1.10 | 0.991 |
| 5 | 0.9018 | $0.2561X10^{-2}$ | $-0.4018X10^{-2}$ | $0.1204X10^{0}$ | 1.19 | 0.988 |
| 6+ | 0.8950 | $0.2793X10^{-2}$ | $-0.4305X10^{-2}$ | $0.1192X10^{0}$ | 1.19 | 0.994 |

Source: R. W. Everett and H. W. Carter. 1968. Accuracy of Test Interval Method of Calculating Dairy Herd Improvement Association Records. J. Dairy Sci., 51:1936.

one case of back crediting for every one of the following periods (in days) in L estimates of "L-days" interval:

$$(3 + 0), (3 + 1), (3 + 2), \ldots, (3 + L - 1).$$

Similarly, every series provided one case of crediting beyond the last test for each of the following periods (in days) in L estimates of "L-days" interval:

$$0, 1, 2, 3, \ldots, (L - 2), (L - 1).$$

In an estimate, the sum of (a) days of back credit from the first test and (b) the days of crediting beyond the last test can be generalized as follows:

$$(a) + (b) = [(0.0 \text{ or } 1.0)\ L + 4] \text{ days},$$

when L = 30 or 60 days. The sum would be equal to four days in two estimates and

in (L - 2) estimates it would be (L + 4) days.

$$(a) + (b) = [(0.0 \text{ or } 1.0)\ L + 34] \text{ days}$$

when L = 90 days. In 32 estimates, the sum would be equal to 34 days and in (L - 32) estimates, it would be equal to (L + 34) days.

With these procedures, a total of 254,340 estimates of 471 lactation records were calculated. The total number of estimates were distributed among the monthly, bi-monthly and tri-monthly intervals in the ratio of 1: 2: 3. They were distributed among the three methods (unadjusted, first-test-adjusted, and first-and-last-test adjusted) of computation equally.

Measurement of Accuracy of Estimates

The accuracy of estimates were measured as deviations from actual yields. To have this standardized between different levels of production, the deviations were converted into percentages of actual yields. These were averaged at different levels.

At this point, it seems preferable to clarify one matter of terminology. Throughout, the term error or residual error will be used to denote average deviations of estimates from actual yields. Undoubtedly, patterns of consistency of direction of these deviations indicate that these errors consist of bias and random error. No plausible statement as to the mechanism of action of any bias has been attempted by previous investigators and the present study has not provided a basis for such a statement. Since no nonrandom influences can be imagined, it seems preferable to refer to average deviation of estimates from actual yields as error rather than bias. Bias, though it may constitute a part of these, cannot be evaluated.

The average percent deviation will not reveal the magnitude of the deviations associated with the system. Hence, the absolute values were studied, also by examining their frequency within certain limits, their percentage of actual yield and their averages at different levels.

Contributions of three lactation segments, day 1 to day 100, day 101 to day 205 and day 206 to day 305, to the deviations of estimates were studied also to ascertain the value of the first and last test period adjustments.

The computation of estimates and their analysis were done with the aid of the IBM 360/65 data processing system of The University of Tennessee Computing Center.

CRANFSE CREST

# CHAPTER IV

## RESULTS AND DISCUSSION

The average of actual 305-day milk yields of 471 lactations utilized in this study was 12,717 pounds. A detailed classification of the 471 lactations according to herd and age group with average 305-day milk yield is shown in Table III. In contrast to the study of Everett and Carter (20), it will be observed that the 6-year and older group showed a higher production than all other groups except in the Jerseys of Jackson.

In any sampling plan, random variation is inherent and bias may contribute to errors of estimates in a particular plan. The objective of a testing program should be to minimize both bias and random variation in yield estimates. However, the reduction of bias and variation (either or both), in estimates in itself is not the purpose of a testing program. Its applicability in terms of testing an unlimited number of herds and the ultimate usefulness of the estimates must be considered.

### Monthly Estimates

Each lactation in this study provided 30 monthly unadjusted, 30 first-test-adjusted and 30 first-and-last-test-adjusted estimates. The average percent residual error of the unadjusted estimates was greater for Holstein records than for Jersey records (Table IV); this was true for every age group. The maximum average residual error of 0.85 percent

TABLE III

DETAILS CONCERNING THE 471 LACTATIONS UTILIZED, SHOWING NUMBERS OF LACTATIONS AND AVERAGE 305-DAY ACTUAL MILK YIELDS IN DIFFERENT AGE GROUPS IN INDIVIDUAL HERDS AND IN HERDS COMBINED

| Age | KH.[a] | | SH. | | JJ. | | LJ. | | Hol. | | Jer. | | All | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (Yrs.) | No. | Yield | No. | Yield | No. | Yield | No. | Yield | No. | Yield | No. | Yield | No. | Yield |
| 2 | 40 | 12796 | 46 | 11725 | 44 | 7809 | 36 | 10958 | 86 | 12223 | 80 | 9226 | 116 | 10779 |
| 3 | 26 | 15099 | 23 | 14491 | 19 | 9107 | 22 | 12536 | 49 | 14813 | 41 | 10947 | 90 | 13052 |
| 4 | 21 | 16976 | 16 | 15051 | 13 | 10695 | 20 | 12930 | 37 | 16144 | 33 | 12049 | 70 | 14214 |
| 5 | 12 | 16465 | 11 | 15438 | 12 | 10479 | 13 | 13375 | 23 | 15974 | 25 | 11985 | 48 | 13896 |
| 6+ | 17 | 18323 | 20 | 16054 | 28 | 10368 | 32 | 13781 | 37 | 17907 | 60 | 12188 | 97 | 14061 |
| All | 116 | 15258 | 116 | 13831 | 116 | 9239 | 123 | 12551 | 232 | 14544 | 239 | 10943 | 471 | 12717 |

[a]Abbreviations in column headings: KH: Knoxville-Holstein; SH: Spring Hill-Holstein; JJ: Jackson-Jersey; LJ: Lewisburg-Jersey. Yield: Average 305-day Yield.

TABLE IV

AVERAGE PERCENT ERROR IN MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.59 | -0.10 | -0.17 | 0.58 | -0.12 | -0.21 | 0.58 | -0.11 | -0.19 |
| 3 | 0.63 | 0.07 | -0.04 | 0.56 | -0.01 | -0.16 | 0.60 | 0.04 | -0.08 |
| 4 | 0.71 | 0.03 | -0.08 | 0.70 | 0.03 | -0.12 | 0.70 | 0.03 | -0.10 |
| 5 | 0.65 | -0.02 | -0.14 | 0.62 | -0.03 | -0.19 | 0.64 | -0.02 | -0.16 |
| 6+ | 0.67 | 0.04 | -0.05 | 0.62 | -0.03 | -0.16 | 0.64 | -0.00 | -0.11 |
| All | 0.64 | -0.01 | -0.10 | 0.61 | -0.04 | -0.17 | 0.63 | -0.02 | -0.13 |

[a]Number of Records.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

of actual yield appeared in the average record of the five-year age group of the Knoxville Holstein herd (Table V). This herd showed also the highest residual error within every age group. Furthermore, the Knoxville Holstein herd showed the highest production level, as shown in Table III.

Tables IV and V show that the average lactation was overestimated by the use of unadjusted monthly sampling. For this method of monthly testing, the average of deviations of 14,130 estimates showed a positive error of 0.63 percent of actual yield (i.e., 80.12 pounds). This agreed with the average of two values observed by Dickinson and McDaniel (15). The average of absolute deviations of the estimates from the actual yields was 0.71 percent (i.e., 90.29 pounds) as revealed in Table VI. When the age groups of the 471 lactations are arranged in an ascending order of yields, an age group ranking by years of age of 2, All, 3, 5, 6+, and 4 is obtained using the data found in Table III. Similarly, when age groups are ranked according to the average error, the rank of age groups by year of age becomes 2, 3, All, 5, 6+, and 4 using the data given in Table IV. The average error or absolute deviation of production estimates, therefore, would appear to be associated with level of production.

First-test-adjusted estimates. The technique of adjusting first test credit changed the average error of estimates from 0.63 to -0.02 percent of the actual records, representing a change in error which is 0.65 percent of the actual yield or a reduction in absolute amount of error of more than 96 percent. Similar changes for different age groups of the 471 records varied from 0.56 to 0.69 (Table IV). The average of

TABLE V

AVERAGE PERCENT ERROR IN MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holsteins | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.64 | -0.05 | -0.11 | 0.54 | -0.15 | -0.22 | 0.59 | -0.12 | -0.23 | 0.57 | -0.12 | -0.20 |
| 3 | 0.73 | 0.16 | 0.05 | 0.51 | -0.03 | -0.14 | 0.51 | -0.09 | -0.27 | 0.59 | 0.04 | -0.09 |
| 4 | 0.82 | 0.12 | 0.01 | 0.54 | -0.10 | -0.22 | 0.67 | -0.03 | -0.20 | 0.72 | 0.06 | -0.08 |
| 5 | 0.85 | 0.16 | 0.04 | 0.42 | -0.23 | -0.35 | 0.53 | -0.10 | -0.28 | 0.68 | 0.02 | -0.12 |
| 6+ | 0.67 | 0.06 | -0.02 | 0.67 | 0.02 | -0.08 | 0.59 | -0.07 | -0.22 | 0.64 | -0.01 | -0.12 |
| All | 0.73 | 0.07 | -0.02 | 0.54 | -0.09 | -0.19 | 0.58 | -0.09 | -0.23 | 0.63 | -0.01 | -0.13 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE VI

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.69 | 0.19 | 0.24 | 0.66 | 0.24 | 0.31 | 0.67 | 0.18 | 0.24 |
| 3 | 0.68 | 0.34 | 0.35 | 0.73 | 0.44 | 0.48 | 0.69 | 0.28 | 0.32 |
| 4 | 0.78 | 0.27 | 0.28 | 0.84 | 0.36 | 0.44 | 0.80 | 0.26 | 0.31 |
| 5 | 0.68 | 0.31 | 0.33 | 0.74 | 0.43 | 0.41 | 0.70 | 0.29 | 0.31 |
| 6+ | 0.72 | 0.20 | 0.19 | 0.70 | 0.29 | 0.34 | 0.70 | 0.20 | 0.22 |
| All | 0.71 | 0.12 | 0.16 | 0.71 | 0.21 | 0.29 | 0.71 | 0.12 | 0.19 |

[a]Number of Records.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

absolute deviations was changed from 0.71 to 0.12 percent of the actual record. The reduction in this value was greater for Holstein herds than for Jersey herds (Table VI).

The frequency distribution of monthly estimates within a given percent of the actual yield for the Holstein and Jersey breeds, separately and combined, is shown in Table VII. The percentages of unadjusted and first-test-adjusted estimates of the 471 records, within ± 1 percent of actual yield were 37 percent and 40 percent, respectively. The corresponding values of estimates within ± 2 percent of actual yield were 65 percent and 70 percent. The first-test-credit adjustment, therefore, showed an increase in the frequency of lactation estimates with a lower amount of deviation.

First-and-last-test-adjusted estimates. As indicated by the formula, previously presented in Chapter III, the adjustment of last test credit will decrease the positive deviation and increase the negative deviation of an estimate. The first-test-credit correction combined with the correction of last test credit resulted in an improvement in the average error of estimates for the Knoxville Holstein herd, except in the 2-year age group (Table V). This improvement was seen also in the 3-year age group of the Holstein breed (Table IV, page 43). However, with the last test adjustment, the error in the first-test-adjusted lactation estimates was increased from -0.02 to -0.13 percent of actual yield. This trend differed from the findings of Everett and Carter (20). The average percent of deviation (absolute) of first-test-adjusted estimates was 0.12 percent of actual yield. This was increased by last-test-credit correction

TABLE VII

PERCENTAGE OF MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND BREED

| Breed | Age (Yrs.) | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 43 | 72 | 96 | 100 | | | |
| Hol. | 2 | 2 | 45 | 77 | 97 | 100 | | | |
| | | 3 | 45 | 77 | 97 | 100 | | | |
| | | 1 | 42 | 72 | 96 | 100 | | | |
| Hol. | 3 | 2 | 47 | 76 | 97 | 100 | | | |
| | | 3 | 47 | 76 | 97 | 100 | | | |
| | | 1 | 39 | 66 | 92 | 99 | 100 | | |
| Hol. | 4 | 2 | 43 | 72 | 94 | 99 | 100 | | |
| | | 3 | 43 | 73 | 93 | 99 | 100 | | |
| | | 1 | 36 | 65 | 89 | 98 | 100 | | |
| Hol. | 5 | 2 | 42 | 68 | 90 | 98 | 100 | | |
| | | 3 | 40 | 68 | 91 | 98 | 100 | | |
| | | 1 | 39 | 67 | 92 | 99 | 100 | | |
| Hol. | 6+ | 2 | 42 | 72 | 94 | 99 | 100 | | |
| | | 3 | 43 | 72 | 94 | 99 | 100 | | |
| | | 1 | 41 | 69 | 94 | 99 | 100 | | |
| Hol. | All | 2 | 44 | 75 | 95 | 99 | 100 | | |
| | | 3 | 44 | 75 | 95 | 99 | 100 | | |
| | | 1 | 34 | 61 | 92 | 99 | 100 | | |
| Jer. | 2 | 2 | 37 | 68 | 93 | 99 | 100 | | |
| | | 3 | 37 | 67 | 93 | 99 | 100 | | |
| | | 1 | 33 | 63 | 90 | 98 | 100 | | |
| Jer. | 3 | 2 | 35 | 64 | 92 | 99 | 100 | | |
| | | 3 | 35 | 64 | 91 | 99 | 100 | | |
| | | 1 | 33 | 62 | 92 | 99 | 100 | | |
| Jer. | 4 | 2 | 38 | 66 | 94 | 99 | 100 | | |
| | | 3 | 36 | 66 | 94 | 99 | 100 | | |
| | | 1 | 35 | 60 | 92 | 99 | 100 | | |
| Jer. | 5 | 2 | 38 | 66 | 93 | 99 | 100 | | |
| | | 3 | 39 | 66 | 93 | 99 | 100 | | |
| | | 1 | 33 | 59 | 90 | 98 | 100 | | |
| Jer. | 6+ | 2 | 35 | 63 | 91 | 99 | 100 | | |
| | | 3 | 34 | 64 | 91 | 99 | 100 | | |
| | | 1 | 34 | 61 | 91 | 99 | 100 | | |
| Jer. | All | 2 | 36 | 65 | 92 | 99 | 100 | | |
| | | 3 | 36 | 65 | 92 | 99 | 100 | | |
| | | 1 | 39 | 67 | 94 | 99 | 100 | | |
| All | 2 | 2 | 41 | 72 | 95 | 100 | | | |
| | | 3 | 41 | 72 | 95 | 100 | | | |

TABLE VII (continued)

| Breed | Age (Yrs.) | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 38 | 68 | 93 | 99 | 100 | | |
| All | 3 | 2 | 41 | 71 | 94 | 99 | 100 | | |
| | | 3 | 42 | 71 | 94 | 99 | 100 | | |
| | | 1 | 36 | 64 | 92 | 99 | 100 | | |
| All | 4 | 2 | 41 | 69 | 94 | 99 | 100 | | |
| | | 3 | 40 | 70 | 94 | 99 | 100 | | |
| | | 1 | 35 | 62 | 91 | 98 | 100 | | |
| All | 5 | 2 | 40 | 67 | 92 | 99 | 100 | | |
| | | 3 | 40 | 67 | 92 | 99 | 100 | | |
| | | 1 | 36 | 62 | 91 | 98 | 100 | | |
| All | 6+ | 2 | 38 | 66 | 93 | 99 | 100 | | |
| | | 3 | 37 | 67 | 92 | 99 | 100 | | |
| | | 1 | 37 | 65 | 93 | 99 | 100 | | |
| All | All | 2 | 40 | 70 | 94 | 99 | 100 | | |
| | | 3 | 40 | 70 | 94 | 99 | 100 | | |

[a]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

CRANFS CREST

(Table VI, page 46). These two effects appear to indicate that the second adjustment increased the underestimates more than it improved the overestimates. The distribution of estimates within a percent of actual yield (Table VII) would indicate also that the last test adjustment was not of much value when combined with the first test adjustment in monthly sampling.

The details of extreme deviations for the sampling-interval method of computation are presented in Table VIII. The percent deviations of monthly unadjusted estimates varied from 12.36 percent to -13.44 percent, i.e., with a range of 25.80 percent. The first test adjustment reduced the range to 24.89 percent. A similar reduction occurred in terms of pounds of milk. The further reduction in the range due to the last-test correction was negligible. In terms of pounds of milk, the range of deviations was increased slightly due to correction of the last test after correction of the first test. Table IX shows the standard deviations of percent errors of monthly estimates. The overall picture, considered by different age groups, indicates that the standard deviation of estimates was reduced by the first-test correction and that no further reduction was achieved by the last-test correction.

Mean deviations of monthly estimates from actual production, by day of first test, are shown in Figure 1. The unadjusted estimates with the first test on the fourth day showed an average deviation of -0.78 percent of actual production. The corresponding value for the estimates with the first test on the fifth day was -0.40 percent. Adjusting the credit of the first test further reduced these two estimates. The

TABLE VIII

LIMITS OF DEVIATIONS OF LACTATION ESTIMATES FROM ACTUAL YIELDS BY SAMPLING INTERVAL AND COMPUTING METHOD

| Samp. Int. / Comp. Meth. | Monthly 1[a] | Monthly 2 | Monthly 3 | Bi-Monthly 1 | Bi-Monthly 2 | Bi-Monthly 3 | Tri-Monthly 1 | Tri-Monthly 2 | Tri-Monthly 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Percent of Actual | | | | | |
| Over(A) | 12.36 | 11.29 | 11.26 | 14.69 | 13.67 | 13.55 | 24.39 | 24.07 | 22.26 |
| Under(B)[b] | 13.44 | 13.60 | 13.60 | 26.45 | 26.44 | 26.45 | 44.03 | 43.55 | 44.21 |
| Range (A)-(B) | 25.80 | 24.89 | 24.86 | 41.14 | 40.11 | 40.00 | 68.42 | 67.62 | 66.47 |
| | | | | Pounds of Milk | | | | | |
| Over(A) | 1861 | 1767 | 1729 | 3034 | 2808 | 2780 | 3309 | 3586 | 3459 |
| Under(B) | 1678 | 1705 | 1757 | 3684 | 3747 | 3758 | 6672 | 6627 | 6743 |
| Range (A)-(B) | 3539 | 3472 | 3486 | 6718 | 6555 | 6538 | 9981 | 10213 | 10202 |

[a] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

[b] (B): Negative Values.

TABLE IX

STANDARD DEVIATIONS OF PERCENT DEVIATIONS OF MONTHLY ESTIMATES BY AGE, HERD AND COMPUTING METHOD

| Age (Yrs.) | Holsteins | | | | | | Jerseys | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville | | | Spring Hill | | | Jackson | | | Lewisburg | | |
| | 1[a] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.64 | 1.57 | 1.57 | 1.95 | 1.90 | 1.90 | 2.34 | 2.30 | 2.30 | 2.08 | 2.01 | 2.02 |
| 3 | 1.55 | 1.49 | 1.50 | 2.02 | 2.00 | 2.00 | 2.44 | 2.39 | 2.40 | 2.38 | 2.31 | 2.32 |
| 4 | 2.03 | 1.95 | 1.95 | 2.17 | 2.14 | 2.13 | 2.04 | 2.01 | 2.00 | 2.28 | 2.18 | 2.20 |
| 5 | 2.60 | 2.55 | 2.55 | 1.98 | 1.97 | 1.96 | 2.11 | 2.07 | 2.07 | 2.38 | 2.35 | 2.34 |
| 6+ | 1.96 | 1.89 | 1.89 | 2.24 | 2.22 | 2.21 | 2.40 | 2.33 | 2.35 | 2.32 | 2.29 | 2.29 |
| Pooled | 1.86 | 1.80 | 1.80 | 2.05 | 2.02 | 2.02 | 2.32 | 2.27 | 2.27 | 2.26 | 2.20 | 2.21 |

[a] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

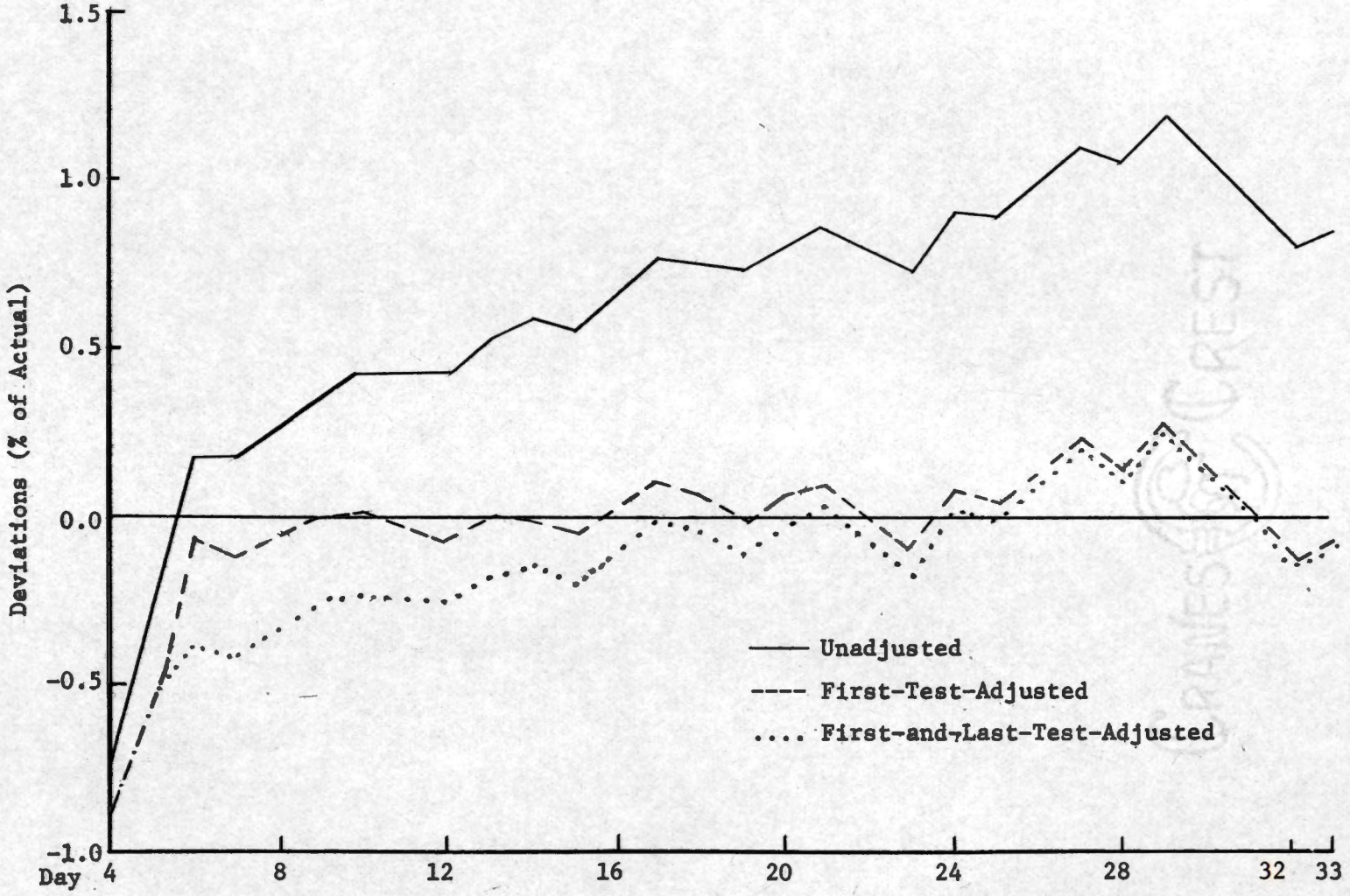



Figure 1. Mean deviations from actual production of monthly estimates by day of first test.

unadjusted estimates with the first test on the twenty-ninth day produced the maximum average deviation of 1.20 percent of actual yield, i.e., 152.60 pounds of milk. A similar finding was reported by Everett and Carter (20) for the five-year age group they examined. By adjusting the first-test credit, by adjusting the first-and-last-test credits, the average deviation of this estimate was changed to 0.27 percent and 0.25 percent, respectively. Figure 1 clearly reveals that the adjustment of the first-test credit brought the deviations closer to zero, when the first test was beyond fifth day. When the first test was later than the twenty-third day, the estimates were further improved by adjusting the last-test credit, but the improvement was slight.

In Table X, the average lactation yield is shown in three segments: (1) days 1 to 100, (2) days 101 to 205 and (3) days 206 to 305. The contributions of these segments to the error of the lactation estimates are shown as percentages of actual 305-day yield. From these the average estimate of any particular segment can be calculated. For example, the unadjusted monthly estimate of the first 100 days of average lactation is about 5,060 pounds of milk (5,002 + 0.46(12717)/100 = 5,060). In each segment, the monthly sampling (unadjusted) overestimated the yield. Agreeing with the popular opinion, more than two-thirds of the error of the monthly unadjusted estimates came from the first 100 days, and the error from the middle third (days 101 to 205) was negligible, while the error from the last one-third (days 206 to 305) was fairly large. These results justify the adjustments of test credits at the extremities of the lactation.

TABLE X

CONTRIBUTIONS OF DIFFERENT SEGMENTS OF THE LACTATION TO THE AVERAGE ERROR IN ESTIMATES OF THE 471 RECORDS

| Part[a] | Yield (lbs.) | Monthly 1[b] | Monthly 2 | Monthly 3 | Bi-Monthly 1 | Bi-Monthly 2 | Bi-Monthly 3 | Tri-Monthly 1 | Tri-Monthly 2 | Tri-Monthly 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 Yrs. - 166 Rec. | | | | | |
| A | 3791 | .46 | -.23 | -.23 | .48 | -.31 | -.31 | .23 | -.21 | -.21 |
| B | 3749 | .03 | .03 | .03 | .04 | .04 | .04 | .07 | ,07 | ,07 |
| C | 3059 | .09 | .09 | .01 | .30 | .30 | -.01 | .56 | .56 | -.16 |
| T | 10779 | .58 | -.11 | -.19 | .82 | .03 | -.28 | .86 | .42 | -.30 |
| | | | | | 3 Yrs. - 90 Rec. | | | | | |
| A | 5307 | .41 | -.15 | -.15 | .29 | -.08 | -.08 | -.28 | .23 | .23 |
| B | 4474 | .06 | .06 | .06 | .08 | .08 | .08 | .14 | .14 | .14 |
| C | 3271 | .13 | .13 | .01 | .42 | .42 | -.10 | .82 | .82 | -.35 |
| T | 13052 | .60 | .04 | -.08 | .79 | .42 | -.10 | .68 | 1.19 | .02 |
| | | | | | 4 Yrs. - 70 Rec. | | | | | |
| A | 5771 | .51 | -.16 | -.16 | .37 | -.33 | -.33 | -.14 | -.12 | -.12 |
| B | 4912 | .04 | .04 | .04 | .06 | .06 | .06 | .11 | .11 | .11 |
| C | 3531 | .15 | .15 | .02 | .44 | .44 | -.08 | .87 | .87 | -.32 |
| T | 14214 | .70 | .03 | -.10 | .87 | .17 | -.35 | .85 | .86 | -.33 |
| | | | | | 5 Yrs. - 48 Rec. | | | | | |
| A | 5721 | .45 | -.21 | -.21 | .28 | -.35 | -.35 | -.28 | -.19 | -.19 |
| B | 4815 | .07 | .07 | .07 | .07 | .07 | .07 | .11 | .11 | .11 |
| C | 3360 | .12 | .12 | -.02 | .45 | .45 | -.11 | .94 | .94 | -.32 |
| T | 13896 | .64 | -.02 | -.16 | .80 | .17 | -.39 | .77 | .86 | -.40 |
| | | | | | 6+ Yrs. - 97 Rec. | | | | | |
| A | 5573 | .47 | -.17 | -.17 | .45 | -.13 | -.13 | .06 | .31 | .31 |
| B | 4919 | .04 | .04 | .04 | .04 | .04 | .04 | .06 | .06 | .06 |
| C | 3569 | .13 | .13 | .03 | .39 | .39 | -.04 | .85 | .85 | -.15 |
| T | 14061 | .64 | -.00 | -.11 | .89 | .31 | -.13 | .97 | 1.22 | .22 |
| | | | | | All - 471 Rec. | | | | | |
| A | 5002 | .46 | -.19 | -.19 | .39 | -.24 | -.24 | -.02 | .01 | .01 |
| B | 4410 | .04 | .04 | .04 | .06 | .06 | .06 | .09 | .09 | .09 |
| C | 3305 | .13 | .13 | .02 | .39 | .39 | -.06 | .77 | .77 | -.24 |
| T | 12717 | .63 | -.02 | -.13 | .84 | .21 | -.24 | .84 | .87 | -.14 |

[a] A: Days 1 to 100; B: Days 101 to 205; C: Days 206 to 305; T: Days 1 to 305.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

Adjusting the first test credit changed the positive deviation of the estimates from the first third of the lactation to a negative deviation offsetting the positive deviation of estimates from the other two-thirds of the lactation, and making the total error in the lactation estimate small.

The last-test-credit adjustment practically nullified the error in estimates from the last one-third of the lactation, indicating that the error in estimates from this segment arose chiefly from the last-test credit. As the error of estimate from the last segment is small in comparison, it is clear from Table X, that the correction of the last-test credit alone cannot improve the lactation estimate significantly. However, if the effect of the first-test-credit correction is reduced so as just to nullify the overestimation from the first third of the lactation, the estimates would be more accurate throughout the lactation, and it, in combination with the last-test adjustment, can improve the estimates of total yield. The change effected by the first-test correction was optimum for the three-year group than for other groups, indicating a relationship with the $R^2$ values of the Everett and Carter age-groups correction factors (20) and the day of first test, $R^2$ being highest for the three-year age group (Table II, page 37), and the ranking of effects of the first-test-credit correction almost followed the ranking of the $R^2$ values for different age groups.

Bi-Monthly Estimates

Each lactation provided 60 bi-monthly unadjusted, 60 bi-monthly first-test-adjusted and 60 bi-monthly first-and-last-test-adjusted estimates.

The average error in unadjusted estimates of average lactations in the Holstein and Jersey breeds were 0.96 and 0.68 percent of the corresponding actual yields, respectively (Table XI). The overestimation was consistently more for Holstein lactations than for Jersey lactations. The bi-monthly unadjusted estimate overestimated the average record by 0.84 percent (106.82 pounds of milk) of actual yield. This agrees almost perfectly with the findings of Dickinson and McDaniel (15). The average of absolute deviations for these 28,260 estimates was 0.97 percent of the record or 123,35 pounds of milk (Table XII). Tables XI and XII indicate that the average error and absolute deviation of unadjusted estimates are positively related to the level of production.

First-test-adjusted estimates. Adjustment of the first-test credit reduced the positive deviation of the estimates considerably. For the estimates of the 471 records, the first-test adjustment reduced the error to one-fourth of the original (21/84 = 1/4). For both Holsteins and Jerseys, the average amount of change in errors of estimate were equal, but the amount of error remaining in the first-test-adjusted estimates basically depends on the amount of error associated with unadjusted estimates. The first-test adjustment nearly nullified the overestimation of the unadjusted estimates of Jersey records (Table XI).

The first-test-credit adjustment reduced considerably the average percent absolute deviation for both Holsteins and Jerseys (Table XII). The reduction was more for Holsteins than for Jerseys. The average absolute deviation of the unadjusted estimates was 0.97 percent of the

TABLE XI

AVERAGE PERCENT ERRORS IN BI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.88 | 0.09 | -0.19 | 0.74 | -0.06 | -0.43 | 0.82 | 0.03 | -0.28 |
| 3 | 0.96 | 0.59 | 0.13 | 0.52 | 0.14 | -0.48 | 0.79 | 0.42 | -0.10 |
| 4 | 0.99 | 0.28 | -0.18 | 0.70 | 0.01 | -0.61 | 0.87 | 0.17 | -0.35 |
| 5 | 0.94 | 0.30 | -0.19 | 0.63 | 0.01 | -0.64 | 0.80 | 0.17 | -0.39 |
| 6+ | 1.07 | 0.50 | 0.13 | 0.73 | 0.14 | -0.37 | 0.89 | 0.31 | -0.13 |
| All | 0.96 | 0.33 | -0.06 | 0.68 | 0.05 | -0.47 | 0.84 | 0.21 | -0.24 |

[a]Number of Records.

[b]1: Unadjusted; 2: First-Test Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XII

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF BI-MONTHLY ESTIMATES FROM ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.01 | 0.32 | 0.33 | 0.94 | 0.37 | 0.60 | 0.96 | 0.29 | 0.38 |
| 3 | 1.08 | 0.74 | 0.72 | 0.82 | 0.68 | 0.73 | 0.91 | 0.55 | 0.59 |
| 4 | 1.14 | 0.64 | 0.45 | 1.08 | 0.63 | 0.81 | 1.05 | 0.54 | 0.52 |
| 5 | 1.12 | 0.61 | 0.52 | 1.08 | 0.62 | 0.81 | 1.06 | 0.50 | 0.52 |
| 6+ | 1.19 | 0.71 | 0.75 | 0.90 | 0.45 | 0.60 | 1.01 | 0.47 | 0.59 |
| All | 1.09 | 0.47 | 0.35 | 0.86 | 0.32 | 0.55 | 0.97 | 0.35 | 0.39 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

actual yield. After the first-test adjustment, this average deviation was reduced to 0.35 percent.

The distribution of bi-monthly estimates within a given percent of actual yield for the two breeds separately and combined is shown in Table XIII. The percentages of unadjusted and first-test-adjusted estimates of all 471 records within ± 1 percent of actual yields were 24 percent and 26 percent, respectively. Wider ranges existed in the 4-, 5-, and 6-year and older age groups of Holsteins, which had a higher level of production. Similarly, 46 and 49 percent of unadjusted and first-test-adjusted estimates were within ± 2 percent of actual yields. This difference was maintained among the estimates within 4 percent of actual yields, indicating that the adjustment of the first-test credit was beneficial in bi-monthly testing. Similar improvement due to first-test adjustment was observed by Everett and Carter (20). However, in their study the percentage of estimates within ± 1 percent of actual yields was comparatively less, possibly because intervals were varied between tests.

First-and-last-test-adjusted estimates. The correction of the last-test credit improved the first-test-adjusted estimates on the 3-, and 6-year and older groups of Holsteins (Table XI), an improvement attained in all age groups of the Knoxville Holsteins (Table XIV). In other groups, the effect of this adjustment was apparently excessive, moving the average error of the estimates too much to the negative side.

The adjustment of the last-test credit, in addition to that of the first test, decreased the average absolute deviation for the Knoxville Holstein herd (Table XV). A similar less intense effect occurred also

TABLE XIII

PERCENTAGE OF BI-MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND BREED

| Herd | Age | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 27 | 52 | 83 | 95 | 100 | | |
| Hol. | 2 | 2 | 30 | 56 | 86 | 96 | 100 | | |
| | | 3 | 30 | 56 | 86 | 96 | 100 | | |
| | | 1 | 28 | 52 | 83 | 95 | 100 | | |
| Hol. | 3 | 2 | 30 | 54 | 85 | 96 | 100 | | |
| | | 3 | 30 | 54 | 85 | 96 | 100 | | |
| | | 1 | 22 | 45 | 78 | 98 | 99 | 100 | |
| Hol. | 4 | 2 | 26 | 50 | 81 | 93 | 99 | 100 | |
| | | 3 | 28 | 52 | 82 | 94 | 98 | 100 | |
| | | 1 | 24 | 46 | 76 | 92 | 99 | 100 | |
| Hol. | 5 | 2 | 30 | 51 | 79 | 93 | 99 | 100 | |
| | | 3 | 29 | 53 | 80 | 93 | 99 | 100 | |
| | | 1 | 21 | 42 | 74 | 90 | 98 | 100 | |
| Hol. | 6+ | 2 | 25 | 46 | 76 | 92 | 98 | 100 | |
| | | 3 | 25 | 46 | 77 | 92 | 98 | 100 | |
| | | 1 | 26 | 48 | 80 | 94 | 99 | 100 | |
| Hol. | All | 2 | 29 | 52 | 82 | 95 | 99 | 100 | |
| | | 3 | 29 | 53 | 83 | 95 | 99 | 100 | |
| | | 1 | 23 | 44 | 76 | 92 | 99 | 100 | |
| Jer. | 2 | 2 | 25 | 47 | 78 | 93 | 99 | 100 | |
| | | 3 | 25 | 47 | 78 | 92 | 99 | 100 | |
| | | 1 | 23 | 43 | 75 | 91 | 99 | 100 | |
| Jer. | 3 | 2 | 23 | 44 | 75 | 91 | 99 | 100 | |
| | | 3 | 23 | 43 | 75 | 91 | 99 | 100 | |
| | | 1 | 23 | 44 | 75 | 91 | 99 | 100 | |
| Jer. | 4 | 2 | 24 | 46 | 77 | 92 | 99 | 100 | |
| | | 3 | 24 | 45 | 76 | 91 | 99 | 100 | |
| | | 1 | 22 | 42 | 74 | 90 | 99 | 100 | |
| Jer. | 5 | 2 | 23 | 45 | 76 | 92 | 99 | 100 | |
| | | 3 | 24 | 46 | 76 | 90 | 98 | 100 | |
| | | 1 | 22 | 42 | 73 | 90 | 99 | 100 | |
| Jer. | 6+ | 2 | 23 | 45 | 76 | 91 | 99 | 100 | |
| | | 3 | 24 | 44 | 75 | 90 | 99 | 100 | |
| | | 1 | 23 | 43 | 75 | 91 | 99 | 100 | |
| Jer. | All | 2 | 24 | 46 | 77 | 92 | 99 | 100 | |
| | | 3 | 24 | 45 | 76 | 91 | 99 | 100 | |
| | | 1 | 25 | 48 | 80 | 94 | 99 | 100 | |
| All | 2 | 2 | 27 | 52 | 82 | 95 | 99 | 100 | |
| | | 3 | 28 | 52 | 82 | 94 | 99 | 100 | |

TABLE XIII (continued)

| Herd | Age | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 26 | 48 | 79 | 93 | 99 | 100 | |
| All | 3 | 2 | 27 | 49 | 80 | 94 | 99 | 100 | |
| | | 3 | 27 | 49 | 80 | 93 | 99 | 100 | |
| | | 1 | 23 | 44 | 76 | 92 | 99 | 100 | |
| All | 4 | 2 | 25 | 48 | 79 | 93 | 99 | 100 | |
| | | 3 | 26 | 49 | 79 | 92 | 99 | 100 | |
| | | 1 | 23 | 44 | 75 | 91 | 99 | 100 | |
| All | 5 | 2 | 26 | 48 | 77 | 92 | 99 | 100 | |
| | | 3 | 26 | 49 | 78 | 91 | 99 | 100 | |
| | | 1 | 22 | 42 | 73 | 90 | 99 | 100 | |
| All | 6 | 2 | 24 | 45 | 76 | 91 | 99 | 100 | |
| | | 3 | 24 | 45 | 76 | 91 | 99 | 100 | |
| | | 1 | 24 | 46 | 77 | 92 | 99 | 100 | |
| All | All | 2 | 26 | 49 | 80 | 93 | 99 | 100 | |
| | | 3 | 26 | 49 | 80 | 93 | 99 | 100 | |

[a]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

CRANES CREST

TABLE XIV

AVERAGE PERCENT ERRORS IN BI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holstein | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.04 | 0.24 | -0.02 | 0.73 | -0.05 | -0.34 | 0.75 | -0.07 | -0.50 | 0.74 | -0.05 | -0.36 |
| 3 | 1.18 | 0.79 | 0.35 | 0.70 | 0.34 | -0.12 | 0.40 | -0.01 | -0.74 | 0.59 | 0.23 | -0.31 |
| 4 | 1.12 | 0.39 | -0.05 | 0.79 | 0.13 | -0.36 | 0.45 | -0.26 | -0.95 | 0.83 | 0.15 | -0.42 |
| 5 | 1.28 | 0.61 | 0.14 | 0.55 | -0.07 | -0.57 | 0.57 | -0.04 | -0.78 | 0.67 | 0.04 | -0.53 |
| 6 | 1.30 | 0.74 | 0.40 | 0.85 | 0.26 | -0.12 | 0.59 | 0.00 | -0.59 | 0.82 | 0.23 | -0.22 |
| All | 1.16 | 0.52 | 0.15 | 0.74 | 0.12 | -0.28 | 0.59 | -0.06 | -0.66 | 0.74 | 0.13 | -0.34 |

[a]Number of Records.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XV

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF BI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holstein | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.18 | 0.50 | 0.40 | 0.88 | 0.36 | 0.50 | 0.98 | 0.56 | 0.71 | 0.98 | 0.51 | 0.71 |
| 3 | 1.31 | 0.93 | 0.82 | 0.88 | 0.67 | 0.77 | 0.84 | 0.73 | 1.06 | 0.98 | 0.80 | 0.77 |
| 4 | 1.26 | 0.73 | 0.60 | 1.27 | 0.95 | 0.85 | 1.18 | 0.94 | 1.29 | 1.25 | 0.90 | 0.94 |
| 5 | 1.54 | 1.06 | 0.94 | 0.91 | 0.75 | 0.74 | 1.05 | 0.74 | 1.06 | 1.24 | 0.83 | 0.93 |
| 6+ | 1.50 | 1.05 | 1.06 | 1.03 | 0.63 | 0.60 | 1.15 | 0.72 | 1.01 | 1.01 | 0.65 | 0.59 |
| All | 1.30 | 0.67 | 0.47 | 0.86 | 0.32 | 0.37 | 0.87 | 0.38 | 0.71 | 0.88 | 0.42 | 0.56 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test Adjusted.

for the Holstein breed (Table XII, page 59). In other groups the average absolute deviation of estimates was increased, which suggests that the benefit of the last-test adjustment, over and above the first-test adjustment is realized only at a higher level of production. Also the frequency of estimates within a given percent of actual yields (Table XIII) supports this observation.

In accordance with Table VIII, page 51, the limits of underestimates were not altered by the first-test corrections or by the first-and-last-test corrections. The limits of overestimates were reduced slightly. The range of percent deviation of the unadjusted estimates was 41.04, which was reduced to 40.11 by the first-test correction. Further reduction by the last-test-credit correction was small. In terms of pounds of milk, the magnitude of underestimates was increased by test corrections. The standard deviation of percent deviations was reduced by correcting the first-test credit (Table XVI). On the average, the reduction was more for the Spring Hill Holstein herd.

Mean deviations of the bi-monthly estimates from actual production by day of first tests are shown in Figure 2. The unadjusted estimates with the first test on the fourth day showed an average deviation of -2.24 percent of actual yields. With the change of first test to the fifth day of lactation, the average error was reduced to -1.68 percent of the actual yields. By adjusting the first-test credit alone or together with the last-test credit, the errors in these estimates increased. The unadjusted estimates, with first test after the fifth day of lactation showed a positive average deviation. The unadjusted estimate made with first test on the twenty-seventh day showed the

TABLE XVI

STANDARD DEVIATIONS OF PERCENT DEVIATIONS OF BI-MONTHLY ESTIMATES BY AGE, HERD AND COMPUTING METHOD

| Age | Holsteins | | | | | | Jerseys | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville | | | Spring Hill | | | Jackson | | | Lewisburg | | |
| | 1[a] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 2.64 | 2.59 | 2.57 | 3.18 | 3.13 | 3.14 | 3.57 | 3.51 | 3.53 | 3.13 | 3.01 | 3.11 |
| 3 | 2.57 | 2.56 | 2.63 | 3.12 | 3.12 | 3.16 | 3.63 | 3.62 | 3.65 | 3.63 | 3.56 | 3.56 |
| 4 | 3.56 | 3.30 | 3.28 | 3.51 | 3.43 | 3.38 | 3.34 | 3.23 | 3.32 | 3.64 | 3.57 | 3.59 |
| 5 | 3.82 | 3.78 | 3.78 | 2.92 | 2.91 | 2.82 | 3.62 | 3.55 | 3.58 | 3.90 | 3.82 | 3.84 |
| 6+ | 3.78 | 3.73 | 3.77 | 3.44 | 3.40 | 3.41 | 3.69 | 3.60 | 3.68 | 3.56 | 3.53 | 3.54 |
| Pooled | 3.13 | 3.04 | 3.06 | 3.24 | 3.12 | 3.20 | 3.59 | 3.52 | 3.57 | 3.50 | 3.43 | 3.59 |

[a]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

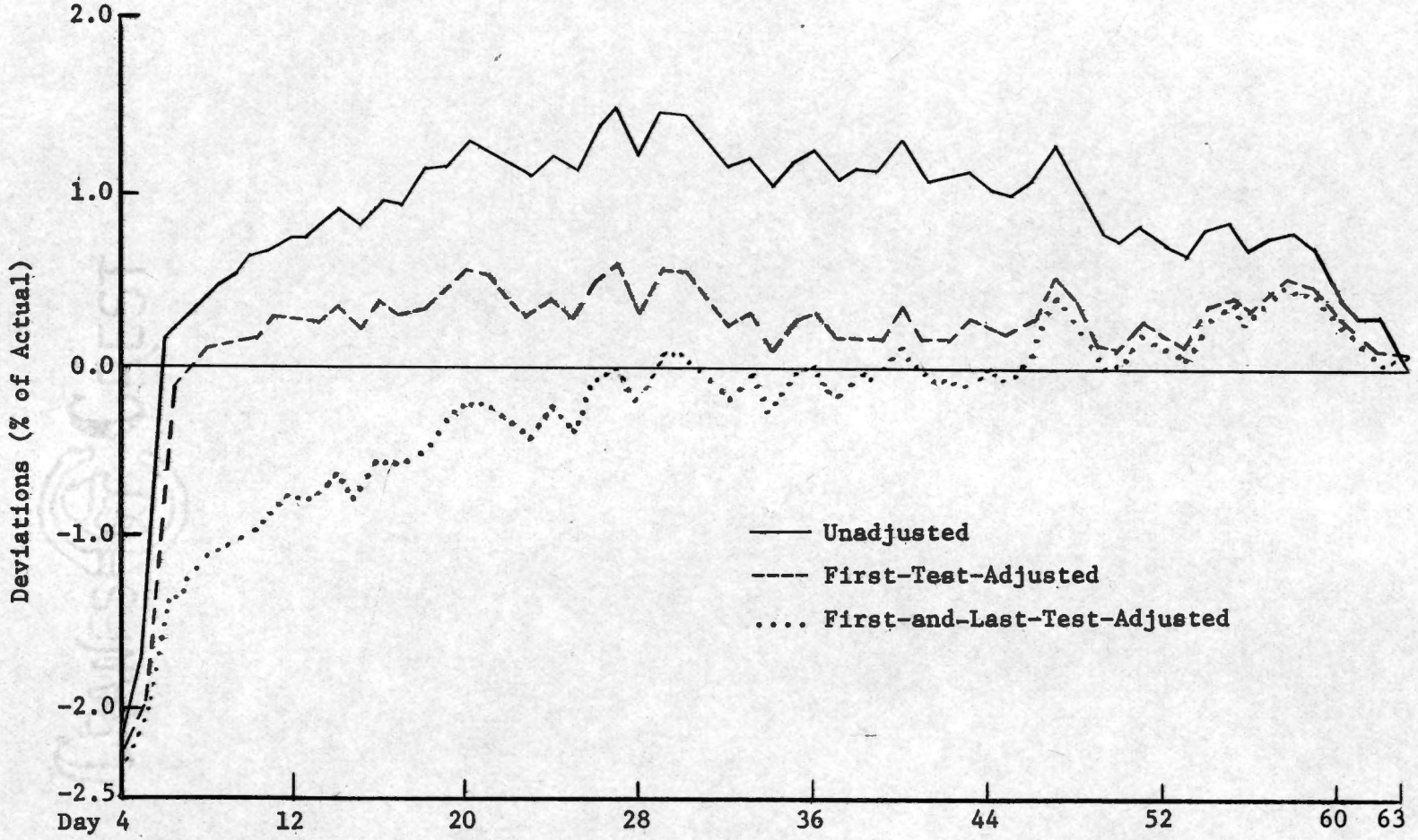



Figure 2. Mean deviations from actual production of bi-monthly estimates by day of first test.

maximum positive average deviation, which was 1.50 percent of the actual yield. By the first-test adjustment, the average positive deviation was reduced except in the case of estimates with the first test on the sixty-third day. For estimates made with the first test on any day prior to the twentieth day, the figure reveals the adjustment of last-test credit increased the errors of estimate. This was apparently caused by the longer period, for which the last-test credit was adjusted in these cases.

In Table X, page 55, the average lactation in yield and mean deviation of estimates are shown for three parts of the lactation. The deviations, for each part are expressed also as percentages of the total yield. Bi-monthly sampling estimates overestimated the lactation yield from each of the three parts. The average lactation was overestimated by 0.84 percent of the actual yield, but the overestimation from the middle third of the lactation was minimum. Compared to monthly sampling, the overestimation is strikingly increased from the final one-third part of the lactation for all age groups, a factor which seemed to account for the major share of difference in the estimates of monthly and bi-monthly sampling. As the values obtained indicate, the adjustments of first-test credit overcorrects the estimate from the first one-third of the lactation except for the 3-, and 6-year and older groups. As stated previously, the $R^2$ values for the factors and the day of first test calculated by Everett and Carter (20), are higher for these two age groups (Table II, page 37). This overcorrection combines with the overestimates of the other two-thirds of the lactation and leads to a better estimate of total lactation yield.

The adjustment of last-test credit actually removes the overestimation of the last third of the lactation, but when both the first and last tests are adjusted (because of the overcorrection made in the first one-third), the lactation estimate becomes an underestimate and for age groups other than 3-, and 6-year and older groups, the errors of the lactation estimates were increased as compared to those in the first-test-adjusted estimates. If more appropriate factors were developed for the first-test-credit adjustment, the estimates should be more accurate in each of the three parts of the lactation, and the two adjustments should make the lactation estimate still more accurate.

Tri-Monthly Estimates

For each lactation, 90 tri-monthly unadjusted, 90 tri-monthly first-test-adjusted and 90 tri-monthly first-and-last-test-adjusted estimates were calculated. In this study unadjusted tri-monthly estimates overestimated the total lactation yields. The average error in unadjusted estimates of Holstein lactations was 1.03 percent of actual yield, while it was only 0.59 percent for Jersey lactations (Table XVII). Within the two breeds, the average error was greater for herds with a higher level of production (Table XVIII).

The average error in 42,390 tri-monthly unadjusted estimates of all 471 records was 0.84 percent of the actual yield. The average of absolute deviation of the 42,390 unadjusted estimates of all 471 records was 1.57 percent of the actual yield. As Table XIX indicates, the average percent absolute deviation also was greater with Holsteins than with

TABLE XVII

AVERAGE PERCENT ERRORS IN TRI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.99 | 0.55 | -0.08 | 0.68 | 0.23 | -0.61 | 0.86 | 0.42 | -0.30 |
| 3 | 0.89 | 1.42 | 0.39 | 0.33 | 0.82 | -0.57 | 0.68 | 1.19 | 0.02 |
| 4 | 1.07 | 1.09 | 0.04 | 0.51 | 0.52 | -0.88 | 0.85 | 0.86 | -0.03 |
| 5 | 0.89 | 0.98 | -0.12 | 0.61 | 0.71 | -0.75 | 0.77 | 0.86 | -0.40 |
| 6+ | 1.29 | 1.57 | 0.75 | 0.68 | 0.92 | -0.23 | 0.97 | 1.22 | 0.22 |
| All | 1.03 | 1.07 | 0.20 | 0.59 | 0.62 | -0.56 | 0.84 | 0.87 | -0.14 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XVIII

AVERAGE PERCENT ERRORS IN TRI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holstein | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.32 | 0.88 | 0.28 | 0.69 | 0.25 | -0.41 | 0.72 | 0.26 | -0.73 | 0.64 | 0.20 | -0.50 |
| 3 | 1.21 | 1.76 | 0.75 | 0.53 | 1.03 | -0.02 | -0.09 | 0.38 | -1.29 | 0.59 | 1.10 | -0.12 |
| 4 | 1.25 | 1.27 | 0.28 | 0.79 | 0.81 | -0.31 | 0.03 | 0.01 | -1.57 | 0.77 | 0.79 | -0.51 |
| 5 | 1.18 | 1.27 | 0.20 | 0.56 | 0.65 | -0.48 | 0.71 | 0.83 | -0.84 | 0.53 | 0.62 | -0.69 |
| 6+ | 1.85 | 2.16 | 1.35 | 0.76 | 0.99 | 0.12 | 0.53 | 0.77 | -0.59 | 0.78 | 1.03 | 0.00 |
| All | 1.36 | 1.42 | 0.57 | 0.67 | 0.69 | -0.22 | 0.45 | 0.45 | -0.90 | 0.68 | 0.74 | -0.31 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XIX

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF TRI-MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE TWO BREEDS

| Age | Holstein (232)[a] | | | Jersey (239)[a] | | | All (471)[a] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.56 | 1.53 | 0.96 | 1.21 | 1.06 | 0.80 | 1.38 | 1.33 | 0.75 |
| 3 | 2.10 | 2.60 | 1.66 | 1.53 | 1.46 | 1.04 | 1.79 | 2.10 | 1.08 |
| 4 | 2.10 | 2.25 | 1.32 | 1.34 | 1.04 | 1.11 | 1.68 | 1.73 | 0.87 |
| 5 | 2.66 | 2.39 | 1.54 | 1.49 | 1.29 | 1.07 | 1.96 | 1.79 | 0.88 |
| 6+ | 2.28 | 2.88 | 2.13 | 1.32 | 1.39 | 0.79 | 1.67 | 2.06 | 1.15 |
| All | 1.92 | 2.22 | 1.42 | 1.22 | 1.16 | 0.74 | 1.57 | 1.75 | 0.85 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

Jerseys. The amount of percent deviation of lactation estimates seems to be related to levels of production.

First-test-adjusted estimates. When the first-test credit was adjusted, the average percent error in the lactation estimates of all 471 records changed from 0.84 to 0.87 percent of actual yield (Table XVII). This is similar to the findings of Everett and Carter (20). However, in the 2-year group the trend appeared to be opposite in all herds. Table XIX reveals that the average percent absolute deviation of the estimates of all 471 records changed from 1.57 to 1.75 percent of the actual record after adjustment of the first-test credit. The correction of first-test credit, therefore, was apparently of no utility in improving the lactation estimates. This was supported also by the frequency of estimates within a given percent of the actual yield, shown in Table XX. The first-test adjustment did not increase the frequency of estimates within ± 1 percent of the actual yield. In certain age groups, the frequency of estimates with a low amount of deviation was actually lowered. This finding agreed with that of Everett and Carter (20). The average errors in the tri-monthly estimates observed in this study, however, were of lesser magnitude than those observed by Everett and Carter (20).

First-and-last-test-adjusted estimates. The correction of the last test, in addition to that of the first test, lowered the error of estimates from 1.07 to 0.20 percent of actual yield for the Holstein breed, whereas, for the Jersey breed, the average error was almost unchanged, although having a negative value after the correction

TABLE XX

PERCENTAGE OF TRI-MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND BREED

| Herd | Age (Yrs.) | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 19 | 37 | 67 | 86 | 98 | 100 | |
| Hol. | 2 | 2 | 20 | 39 | 69 | 87 | 98 | 100 | |
| | | 3 | 21 | 42 | 72 | 89 | 98 | 100 | |
| | | 1 | 18 | 35 | 62 | 80 | 96 | 100 | |
| Hol. | 3 | 2 | 15 | 31 | 58 | 78 | 96 | 100 | |
| | | 3 | 18 | 35 | 65 | 84 | 97 | 100 | |
| | | 1 | 17 | 33 | 60 | 80 | 96 | 99 | 100 |
| Hol. | 4 | 2 | 16 | 32 | 59 | 80 | 96 | 99 | 100 |
| | | 3 | 19 | 36 | 65 | 84 | 97 | 99 | 100 |
| | | 1 | 16 | 34 | 58 | 76 | 93 | 98 | 99 |
| Hol. | 5 | 2 | 17 | 33 | 59 | 77 | 93 | 98 | 99 |
| | | 3 | 19 | 36 | 64 | 82 | 95 | 98 | 99 |
| | | 1 | 16 | 31 | 58 | 76 | 95 | 99 | 100 |
| Hol. | 6+ | 2 | 14 | 27 | 54 | 74 | 94 | 99 | 100 |
| | | 3 | 16 | 31 | 58 | 79 | 96 | 99 | 100 |
| | | 1 | 18 | 35 | 63 | 81 | 96 | 99 | 100 |
| Hol. | All | 2 | 17 | 34 | 62 | 81 | 96 | 99 | 100 |
| | | 3 | 19 | 37 | 67 | 85 | 97 | 99 | 100 |
| | | 1 | 18 | 35 | 63 | 81 | 96 | 100 | |
| Jer. | 2 | 2 | 18 | 36 | 65 | 82 | 96 | 100 | |
| | | 3 | 19 | 36 | 65 | 82 | 96 | 100 | |
| | | 1 | 16 | 31 | 59 | 78 | 94 | 99 | 100 |
| Jer. | 3 | 2 | 16 | 33 | 59 | 78 | 95 | 99 | 100 |
| | | 3 | 17 | 34 | 59 | 79 | 95 | 99 | 100 |
| | | 1 | 18 | 34 | 62 | 82 | 97 | 100 | |
| Jer. | 4 | 2 | 18 | 36 | 65 | 83 | 97 | 100 | |
| | | 3 | 17 | 35 | 63 | 82 | 97 | 100 | |
| | | 1 | 17 | 32 | 59 | 76 | 94 | 99 | 100 |
| Jer. | 5 | 2 | 17 | 32 | 58 | 78 | 94 | 99 | 100 |
| | | 3 | 17 | 31 | 59 | 77 | 95 | 99 | 100 |
| | | 1 | 17 | 32 | 59 | 78 | 95 | 99 | 100 |
| Jer. | 6+ | 2 | 17 | 33 | 60 | 78 | 95 | 99 | 100 |
| | | 3 | 17 | 34 | 63 | 79 | 95 | 99 | 100 |
| | | 1 | 17 | 33 | 61 | 79 | 95 | 99 | 100 |
| Jer. | All | 2 | 17 | 34 | 62 | 80 | 96 | 99 | 100 |
| | | 3 | 18 | 35 | 63 | 80 | 96 | 99 | 100 |
| | | 1 | 19 | 36 | 65 | 83 | 97 | 100 | |
| All | 2 | 2 | 19 | 37 | 67 | 85 | 97 | 100 | |
| | | 3 | 20 | 39 | 69 | 85 | 97 | 100 | |

TABLE XX (continued)

| Herd | Age (Yrs.) | Meth.[a] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 17 | 33 | 61 | 79 | 95 | 99 | 100 |
| All | 3 | 2 | 16 | 32 | 58 | 78 | 96 | 99 | 100 |
| | | 3 | 17 | 34 | 62 | 82 | 96 | 99 | 100 |
| | | 1 | 18 | 34 | 61 | 81 | 96 | 99 | 100 |
| All | 4 | 2 | 17 | 34 | 62 | 81 | 97 | 100 | |
| | | 3 | 18 | 35 | 64 | 83 | 97 | 99 | 100 |
| | | 1 | 16 | 33 | 58 | 76 | 93 | 99 | 100 |
| All | 5 | 2 | 17 | 32 | 58 | 77 | 94 | 98 | 100 |
| | | 3 | 18 | 34 | 62 | 80 | 95 | 98 | 100 |
| | | 1 | 16 | 32 | 59 | 78 | 95 | 99 | 100 |
| All | 6+ | 2 | 16 | 31 | 58 | 77 | 95 | 99 | 100 |
| | | 3 | 17 | 33 | 61 | 79 | 95 | 99 | 100 |
| | | 1 | 18 | 34 | 62 | 80 | 96 | 99 | 100 |
| All | All | 2 | 17 | 34 | 62 | 80 | 96 | 99 | 100 |
| | | 3 | 18 | 36 | 65 | 83 | 96 | 99 | 100 |

[a] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

CRANES CREST

(Table XVII, page 70). According to the data of Table XVIII, page 71, the rank in ascending order of the average effect of the last-test correction, after the first-test correction would be: (1) Knoxville Holstein, (2) Spring Hill Holstein, (3) Lewsiburg Jersey and (4) Jackson Jersey. The same rank is shown in Tables I and II, pages 35 and 37, with regard to production in a decreasing order. The regression factors used in this study seem to be better suited to herds of higher production. This would be particularly true with longer sampling intervals since the credit with the last test weight is given for a larger number of days beyond the last test.

The average of the absolute percent deviation of first-test-adjusted estimates was 1.75. As shown in Table XIX, page 72, this was reduced to 0.85 percent when the estimates were adjusted for the last test also. This beneficial effect was observed also for the two breeds considered separately.

The frequency distribution of the tri-monthly estimates, presented in Table XX, indicates that 100 percent of the estimates were within 20 percent of actual yields. There were estimates exceeding this deviation. Because of their small number, they did not appear in the frequency table. The first-test adjustment did not increase the percentage of estimates with a lower amount of deviation; and in certain groups, it lowered the percentage. When the last-test correction was made, percentages of estimates with a lower amount of deviation increased, particularly with deviations having a range of ± 2 percent to ± 6 percent.

As presented in Table VIII, page 51, the limits of percent of negative deviations of unadjusted, first-test-adjusted and first-and-last-test-adjusted tri-monthly estimates were 44.03, 43.55 and 44.21 percent, respectively. The corresponding values for overestimates were 24.39, 24.07 and 22.26 percent, respectively. However, the range of these deviations was reduced slightly by each correction. The range in terms of pounds of milk was maximum (10,213 pounds) for first-test-adjusted estimates and minimum (9,981 pounds) for the unadjusted estimates.

The standard deviations of percent deviations increased as a result of the first-test correction for the Knoxville Holsteins and Lewisburg Jerseys, which, for each breed, were the herds with higher production levels (Table XXI). The standard deviations of first-and-last-test-corrected estimates were lower than those of the unadjusted estimates. The effect of the first-test correction varied from herd to herd, which appears to indicate the necessity of different first-test correction factors for different herd levels of production.

Mean deviations of tri-monthly estimates from actual yields by day of first test are shown in Figure 3. The unadjusted estimates, with the first test on the fourth day, showed an average deviation of -3.28 percent. This negative average deviation decreased as the day of the first test was delayed, and the average deviation became zero when the first test was made on the twenty-third day of the lactation. As Figure 3 indicates, the average positive deviation of the estimates was maximum when the first test occurred at about the thirty-eighth day of the lactation. As explained in Chapter III, with the first test at this point

TABLE XXI

STANDARD DEVIATIONS OF PERCENT DEVIATIONS OF TRI-MONTHLY ESTIMATES BY AGE, HERD AND COMPUTING METHOD

| | Holsteins | | | | | | Jerseys | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville | | | Spring Hill | | | Jackson | | | Lewisburg | | |
| Age | 1[a] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 4.05 | 4.04 | 3.88 | 4.22 | 4.16 | 4.06 | 4.92 | 4.86 | 4.82 | 4.33 | 4.29 | 4.21 |
| 3 | 4.85 | 4.94 | 4.53 | 4.49 | 4.45 | 4.29 | 5.51 | 5.16 | 5.07 | 4.82 | 4.93 | 4.90 |
| 4 | 5.24 | 5.22 | 4.92 | 4.52 | 4.48 | 4.35 | 4.39 | 4.06 | 4.13 | 4.61 | 4.58 | 4.55 |
| 5 | 7.05 | 6.92 | 6.53 | 4.22 | 4.11 | 3.89 | 5.13 | 5.23 | 5.27 | 5.38 | 5.12 | 5.00 |
| 6+ | 5.06 | 5.32 | 5.03 | 5.06 | 5.04 | 4.86 | 5.23 | 5.21 | 5.30 | 4.98 | 4.92 | 4.77 |
| Pooled | 4.92 | 5.01 | 4.74 | 4.47 | 4.42 | 4.28 | 5.06 | 4.95 | 4.96 | 4.90 | 4.85 | 4.76 |

[a] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

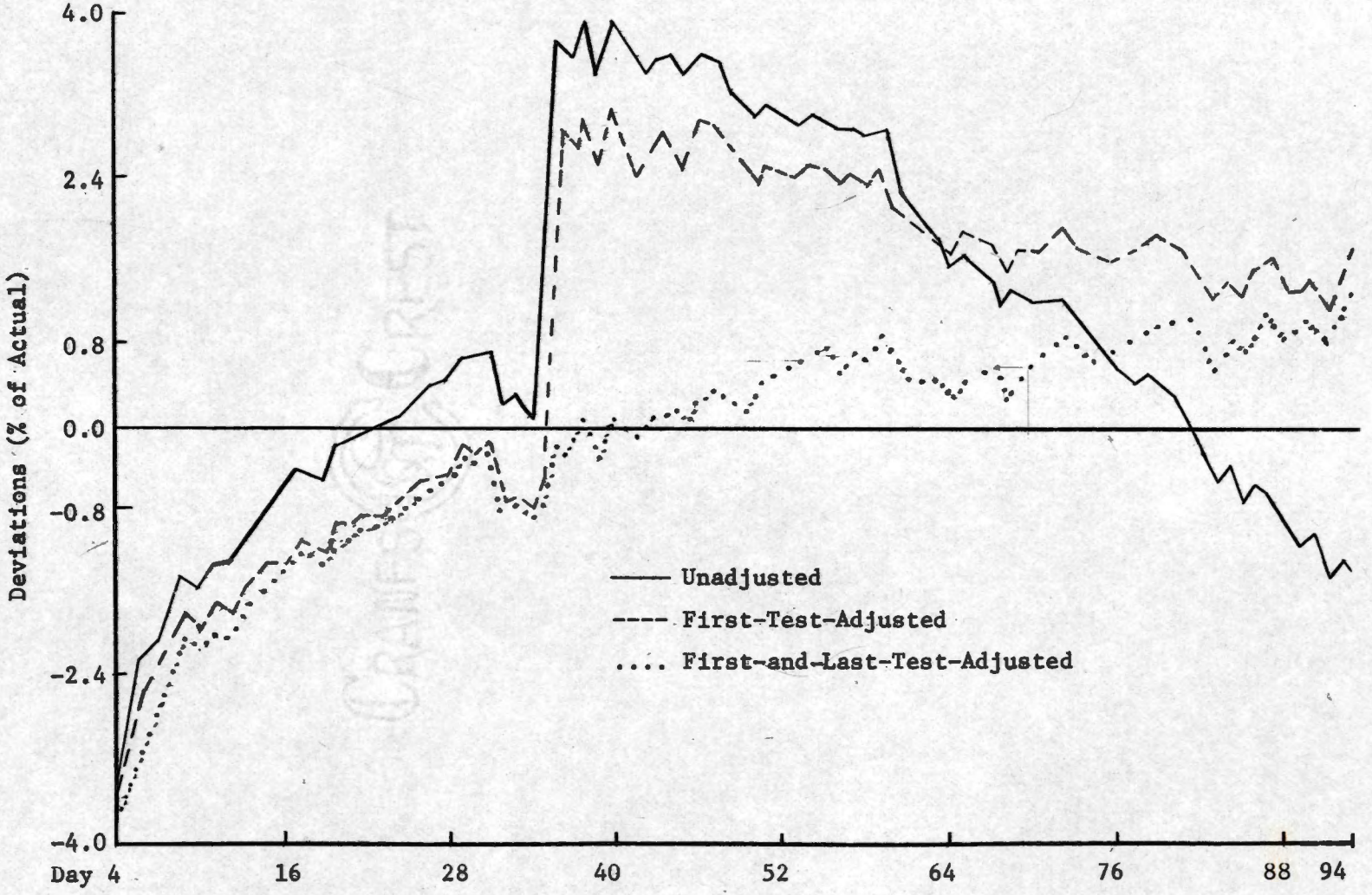



Figure 3. Mean deviations from actual production of tri-monthly estimates by day of first test.

in the lactation, the number of days for which credit was given with last test weight would be maximum. Thus, the last-test correction would have maximum effect on those estimates. The average positive deviation of the unadjusted estimates was minimum when the first test was on the eighty-first day. Thereafter, the average deviation became negative and increasingly so as the first test was delayed. By the first-test correction, the estimates, with the first test occurring between the thirty-sixth and sixty-second days of the lactation, were improved, i.e., the amount of the average positive deviation was reduced. With the correction of the first and last tests, the average deviation with the first test on or after the thirty-sixth day of the lactation, were minimized.

The average lactation and the average estimates were divided into three parts in Table X, page 55. The deviations, of estimates from each part from the corresponding actual yields, are presented as percentages of the actual total yield. Within each age group, the average deviation of the tri-monthly unadjusted estimates was not much different from that of bi-monthly unadjusted estimates. For all three intervals examined, the unadjusted estimates overestimated the lactation yields. Table X shows that the amount of positive deviation arising in the first third of the lactation was less for the tri-monthly sampling than for the monthly or bi-monthly sampling. It was true also for each age group of the two breeds separately.

Unlike monthly and bi-monthly sampling, the tri-monthly sampling more frequently showed a negative average deviation in the first third of

the lactation. The major portion of the error, exceeding 88 percent (77/84) of the total deviation came from the final one-third of the lactation. In the five-year age group, deviation of estimates from the final one-third of the lactation was actually more than that of the lactation estimate. The magnitude of this overestimation, however, in combination with the underestimation arising in the first third of the lactation was actually hidden. The deviation arising from the middle third of the lactation was comparatively low. The effect of first-test correction on the average deviation from the first third of the lactation was not uniform for different age groups. However, the average deviation of -0.02 percent of total yield arising from the first third of the lactation changed to 0.01 percent as a result of first-test correction. In other words, the first-test correction seemed to counteract the error of estimate arising from the first third of the lactation. As the error from the first third was comparatively low, the first-test correction did not improve the lactation estimates. By the first-test correction, the average errors of estimate (Tables XVII and XVIII, pages 70 and 71), the average absolute percent deviation (Table XIX, page 72) and the standard deviation of percent deviations (Table XXI, page 78) did not change greatly. The effectiveness of the first-test correction in improving lactation estimates from tri-monthly sampling is seriously questioned. The average error from the final third of the lactation was 0.77 percent of the total actual yield, for the lactation estimates, made without test corrections. This error was reduced to -0.24 percent by the last-test correction, indicating overcorrection. In this regard, the last-test

correction appeared to be optimum in the monthly and bi-monthly sampling. Possibly the regression values employed were too large for correcting the last-test credit for longer periods. However, from the data presented in Table X, page 55, it is clear that the last-test correction is quite important, while the first-test correction is not of much consequence in reducing the errors in lactation estimates. This view is contrary to popular opinion (20, 43).

The overcorrection effect of the last-test correction was higher for Jerseys than for Holsteins, indicating that the use of different regression factors for different breeds or different levels of production can improve production estimates.

Statistical Analyses

The deviations of estimates were statistically analyzed, using the following mathematica model:

$$D_{ijklm} = \mu + H_i + A_j + 1_k + M_l + HA_{ij}$$
$$+ Hl_{jk} + HM_{il} + Al_{jk} + AM_{jl} + lM_{kl}$$
$$+ HAl_{ijk} + HAM_{ijl} + HlM_{ikl} + AlM_{jkl}$$
$$+ HAlM_{ijkl} + E_{ijklm}$$

where $D_{ijklm}$ is ijklm-th deviation,

$\mu$ = an overall mean of deviation

$H_i$ = effect of i-th herd, i = 1,2,3,4

$A_j$ = effect of j-th age, j = 1,2,...,5

$l_k$ = effect of k-th interval, k = 1,2,3

$M_l$ = effect of l-th method of computation, l = 1,2,3

$E_{ijklm}$ = random error associated with the individual observation, m = 1,2,3,...,4,140

and other terms refer to various interaction effects.

The deviations were considered in two forms: (1) percent of actual yield, and (2) pounds of milk.

Statistical analysis of (1) percent deviations and (2) pounds of milk are presented in Tables XXII and XXIII, respectively. In these two tables, the source of variation, degrees of freedom associated with each source and the corresponding F values are shown. The error mean square is shown as a footnote. Other values, such as mean squares and sum of squares of different sources can be calculated easily. In this analysis all effects are fixed. In both analyses, the main effects: (1) herds, (2) ages, (3) intervals and (4) computational methods were significant ($P < 0.01$). In other words, the amount of deviation of estimates was influenced by the difference in levels of these four main effects. Likewise, all interaction effects, except (1) herd x computing method, (2) herd x age x computing method, (3) herd x interval x computing method and (4) herd x age x interval x computing method were significant ($P < 0.01$). In addition, in the analysis of deviations as percentages of actual yield, herd x computing method interaction also was significant

TABLE XXII

STATISTICAL ANALYSIS OF DEVIATIONS (PERCENT OF ACTUAL YIELD) OF ESTIMATES FROM ACTUAL YIELDS

| Source | DF | F |
|---|---|---|
| Herds (H) | 3 | 449.251[a] |
| Ages (A) | 4 | 55.958[a] |
| Intervals (I) | 2 | 114.964[a] |
| Comput. Methods (M) | 2 | 1447.919[a] |
| HXA | 12 | 17.299[a] |
| HXI | 6 | 41.847[a] |
| HXM | 6 | 11.267[a] |
| AXI | 8 | 9.921[a] |
| AXM | 8 | 23.168[a] |
| IXM | 4 | 113.946[a] |
| HXAXI | 24 | 3.829[a] |
| HXAXM | 24 | 0.187 |
| HXIXM | 12 | 1.542 |
| AXIXM | 16 | 3.477[a] |
| HXAXIXM | 48 | 0.027 |
| Error | 254161 | -- |

[a] $P < 0.01$; Error Mean Square = 15.704.

TABLE XXIII

STATISTICAL ANALYSIS OF DEVIATIONS (POUNDS OF MILK) OF ESTIMATES FROM ACTUAL YIELD

| Source | DF | F |
|---|---|---|
| Herds (H) | 3 | 622.501[a] |
| Ages (A) | 4 | 106.933[a] |
| Intervals (I) | 2 | 172.179[a] |
| Comput. Methods (M) | 2 | 1221.639[a] |
| HXA | 12 | 29.997[a] |
| HXI | 6 | 56.805[a] |
| HXM | 6 | 1.249 |
| AXI | 8 | 15.055[a] |
| AXM | 8 | 23.092[a] |
| IXM | 4 | 104.264[a] |
| HXAXI | 24 | 5.473[a] |
| HXAXM | 24 | 0.234 |
| HXIXM | 12 | 1.119 |
| AXIXM | 16 | 4.533[a] |
| HXAXIXM | 48 | 0.089 |
| Error | 254161 | -- |

[a] $P < 0.01$; Error Mean Square = 275854.875.

($P < 0.01$). This discrepancy could be explained largely as follows. The differences in pounds of milk between the first-test-adjusted and the corresponding first-and-last-test-adjusted estimates were simply a function of the day of the last test and the regression value used. Thus, for estimates of different lactations with the same first test day within an interval-age combination, the difference was same and it would be:

$$(305 - D_K)^2 \frac{b}{2}$$

where $D_K$ was the last test day and b was the regression value. Herd or actual production did not affect this value (pounds of milk), but when it was converted into percentages of actual yield, it was affected by level of yield and thus was varied.

General

It might be beneficial to compare the monthly alternate "A.M.-P.M." sampling suggested by other investigators (28, 53, 57, 58) with bi-monthly and tri-monthly testing as a substitute for the conventional DHIA sampling procedure.

The variance of deviations of estimates from actual yields was more with alternate monthly sampling than with monthly sampling (15, 57). The fees charged for alternate testing amounted to 80 percent of the charges of conventional monthly testing (58).

Number of tests or work of computing will not be reduced by alternate sampling. Thus, the cost cannot be reduced much, and this may be a factor in not increasing the number of herds tested. However, as

discussed in Chapter II, alternate sampling might give rise to fraudulent practices by farmers.

The average errors of monthly unadjusted, bi-monthly first test adjusted and tri-monthly first-and-last-test-adjusted estimates were 0.84, 0.27 and -0.14 percent of actual yields, respectively. The corresponding averages of absolute deviations were 0.71, 0.35 and 0.85 percent of actual yields. These figures indicate that bi-monthly first-test-adjusted or tri-monthly first-and-last-test-adjusted estimates could satisfactorily be substituted for the monthly unadjusted estimates. By changing to tri-monthly testing, the number of tests, the amount of work and the computation involved could be reduced to one-third of those involved in monthly sampling. This means that the number of herds tested by a supervisor can be at least doubled, and more flexibility in scheduling the tests would result. Even after reducing the cost of testing to 50 percent of current charges, the supervisor can earn more because the cost of trips, computations etc. would be reduced to one-third.

The variation in tri-monthly first-and-last-test-adjusted estimates was more than that of monthly unadjusted estimates (Tables VIII, IX and XXI, pages 51, 52 and 78). Pronounced decrease in daily milk yields due to illness or other reasons can be expected in a lactation. With long sampling intervals these variations can give rise to certain nonrandom underestimates, and they can thus increase the variation of estimates. This is clearly shown in Table VIII. In practical situations, certain lactations would provide a test beyond day 305 of lactation, and this would lower the contribution of the last third of the

lactation to the possible deviation, which appeared to be maximum in tri-monthly sampling (Table X, page 55).

The effect of test-credit adjustment was not uniform at all levels of production. If more appropriate factors, periodically developed and revised on region-breed-age basis, were used, the adjusted estimates should be much more accurate in estimating the lactations in part and as a whole than evidenced by this study.

The study of deviations by day of first test indicated that it would be better to delay testing for about 10 days of lactation in tri-monthly testing to reduce the error involved in the testing and variation of the estimates.

Hence, with appropriate test-credit adjustment and by delaying the testing up to about 10 days, the tri-monthly first-and-last-test-adjusted estimates might be favored as an alternative to the monthly unadjusted method to enhance the popularity of DHIA testing.

# CHAPTER V

## SUMMARY AND CONCLUSIONS

A sample of 471 lactation records from the University of Tennessee dairy herds was used for this study. The lactation records were from two Jersey herds and two Holstein herds. One Jersey herd supplied 123 records, and the other three herds supplied 116 records each. The records used were from those in which the calvings initiating the lactations occurred in the five-year period (1964 to 1968), and the study was limited to 305-day yields.

Three sampling intervals were used: (1) 30 days, (2) 60 days and (3) 90 days. The first estimate was made by having the first test on the fourth day of lactation, while the second estimate was made with the first test on the fifth day of lactation and so on in this manner. Each lactation records, thus provided 30 monthly, 60 bi-monthly and 90 tri-monthly unadjusted estimates, the calculation of which was done by current DHIA procedures (TIM).

From each unadjusted estimate, two adjusted estimates were developed: (1) a first-test-adjusted estimate and (2) a first-and-last-adjusted estimate. In all, 254,340 lactation estimates were calculated. For the first-test adjustment, the factors developed by Everett and Carter in 1968 (20) were used. For the last-test correction, the regression values employed by the same workers were used, but the units of weight were changed from kilograms to pounds.

The accuracy of the estimates was measured in terms of deviations from actual yields in percent of actual yield. The percent deviations were averaged for each combination of interval and computation method in different herd-age groups and called a residual error, known to consist partly of random error and probably partly of bias. The average of absolute deviations in different herd-age groups and the frequency of estimates within a given percent of actual yield at different herd age levels also were studied. Furthermore, standard deviations of percent deviations of estimates in different herd-age groups were studied. The extreme values and the range of percent deviations within each combination of interval and computation method were investigated. The average of percent deviations by day of the first test was studied as a measure of accuracy of estimates. In addition, to determine how the testing procedures actually operated throughout the lactation length, the average lactations with their corresponding estimates were examined in three segments: the first, middle and last third of the total lactation period.

Statistical analyses indicated that herd, age, interval and computation method were factors which produced variation in the percent deviations of yield estimates. Also, interactions of these factors caused variations in percent deviations in most cases.

In all sampling intervals investigated, the average error and the average absolute deviation were greater in herds with higher levels of production, indicating a direct relationship between the variation in percent deviations of estimates and level of production. This relationship might occur because of the greater variation in daily milk yields among high producers.

The means of percent deviations (average errors) of monthly unadjusted, monthly first-test-adjusted and monthly first-and-last-test-adjusted estimates were 0.63, -0.02 and -0.13 percent, respectively. The last-test correction after the first-test correction was made did not appear to be useful. This conclusion was supported by similar trends in the average of deviations (absolute) and the frequency of estimates within a given percent of actual yields.

The means of percent deviations (average errors) of bi-monthly unadjusted, bi-monthly first-test-adjusted and bi-monthly first-and-last-test-adjusted estimates were 0.84, 0.21 and -0.24 percent of actual yields, respectively. The corresponding values for absolute deviations were 0.97, 0.35 and 0.39 percent, respectively. No change in the overall frequency distribution of estimates within a given percent of actual yields was observed as a result of the last-test correction after the first-test correction was made. This conclusion was supported also by the fact that the pooled within-herd-age standard deviations of percent deviations were not reduced by the last-test correction after the first-test correction was made.

The means of deviations (average errors) of tri-monthly unadjusted, tri-monthly first-test-adjusted and tri-monthly first-and-last-test-adjusted estimates were 0.84, 0.87 and -0.14 percent of actual yields, respectively. The corresponding values for absolute deviations were 1.57, 1.75 and 0.85 percent of actual yields. By itself, the first-test correction proved to be of no value in tri-monthly sampling. The first- plus the last-test corrections improved the estimates, a conclusion

supported also by similar trends in the standard deviations of percent deviations and the frequency distribution of estimates.

The mean of percent deviations (average errors) was closer to zero in the case of bi-monthly first-test-adjusted estimates than for monthly unadjusted estimates, and, furthermore, it was closer to zero for the tri-monthly first-and-last-test-adjusted estimates. The average of deviations (absolute) for monthly unadjusted, bi-monthly first-test-adjusted and tri-monthly first-and-last-test-adjusted estimates were 0.71, 0.35 and 0.85 percent, respectively, of actual yields. The standard deviations of monthly unadjusted, bi-monthly first-test-adjusted and tri-monthly first-and-last-test-adjusted estimates revealed an increasing order of difference. Therefore, based on the means of deviations, the bi-monthly first-test-adjusted and the tri-monthly first-and-last-test-adjusted estimates could apparently be substituted satisfactorily for the monthly unadjusted estimates of lactation records.

Unadjusted estimates overestimated the lactation yields in all the three testing intervals. Study of the lactation in three segments indicated that with monthly sampling the major portion of the deviation came from the first third of the lactation, a small portion from the middle third and a large portion from the final third. The contribution of the middle third to the deviations was smallest in all three sampling intervals. As the sampling interval increased, the third part of the lactation contributed more to the deviation of estimates, which was greatest in the tri-monthly sampling. Hence, the correction of the last test was more important in tri-monthly sampling. In actual practice,

however, the contribution to the average error by the last third of the lactation and the average error of the lactation yield estimate may be less because many lactations would provide the opportunity for a sampling beyond 305 days of lactation to estimate 305-day yield.

Since the effect of the corrections varied between herds and age groups, more appropriate first-test correction factors and regression values, which probably can be derived periodically on a region-breed-age basis, might further improve the corrected estimates. Because sudden decreases in daily milk yields can result from illness, weather or feed changes; with longer sampling intervals, a few extreme underestimates must be anticipated, and the number of such underestimates would be greater in poorly managed herds.

The study of average deviations of estimates by day of first test revealed that the number of underestimates and variation between the corrected estimates from bi-monthly or tri-monthly sampling intervals could be reduced by delaying the first test until about the tenth day of lactation for tri-monthly first-and-last-test-corrected estimates.

Therefore, in practice, with more appropriate first-test correction factors, more appropriate regression values for correcting last-test credit and first test being made on or after the thirteenth day after calving, the tri-monthly first-and-last-test-adjusted estimates would lead to estimates of lactations, both part and whole, as reliable as monthly unadjusted estimates. However, variation of estimates may still be slightly greater. Similarly, certain extreme

deviations, particularly negative, might be found, which would be resulted from tripling the testing interval.

CRANES CREST

# REFERENCES

## REFERENCES


1. Alexander, M. H., and W. W. Yapp. 1949. Comparison of methods of estimating milk and fat production in dairy cows. J. Dairy Sci., 32:621.

2. Ashton, E. D. 1948. Frequency distribution of percentage errors in milk yields calculated from 154 lactation records. (Quoted in Milk and Butterfat Recording (1956), p. 49).

3. Ashton, E. D. 1956. Milk and Butterfat Recording. A World Survey. Tech. Commun. 3, Commonwealth Bur. of Dairy Sci. and Technol., Farnham Royal, Bucks, England.

4. Bayley, N. D., R. M. Liss, and J. E. Stallard. 1952. A comparison of bi-monthly and quarterly testing with monthly testing for estimating dairy cattle production. J. Dairy Sci., 35:350.

5. Becker, R. B., and P. C. McGilliard. 1929. A suggested simplification of the present system of official testing with the dairy breeds of cattle. J. Dairy Sci., 12:337.

6. Campbell, I. L. 1948. The accuracy of various methods of estimating a dairy cow's production of milk and butterfat. Dairy Sci. Abstr., 4:258.

7. Campbell, K. W. D. 1932. The effect of nine-, twelve-, fifteen-hour intervals during the day and night on milk production. J. Dairy Res., 4:28.

8. Castle, O. M., and S. R. Searle. 1961. Use of bi-monthly records in herd testing. J. Dairy Sci., 44:1335.

9. Coordinating Group for the National Dairy Herd Improvement Program. July 1969. Official DHI Rules.

10. Copeland, L. 1928. Monthly and bi-monthly tests. Jersey Bull., 47:731.

11. Cunningham, E. P., and V. E. Vial. 1968. Relative accuracy of different sampling intervals and methods of estimation for lactation milk yields. Ir. J. Agric. Res., 7:49.

12. Davey, G. P., and G. I. Alexander. 1954. The accuracy of estimation of a dairy cow's production of milk and butterfat. Queensland J. Agr. Sci., 11:75.

13. Dick, I. D. 1951. Some results on the accuracy of milk sampling over a complete lactation and the daily variability in milk yields. Dairy Sci. Abstr., 13:413.

14. Dickinson, F. N., and B. T. McDaniel. 1968. Single-milking yield vs 24-hour yield at three intervals for estimating lactation milk production by test interval method. (Abstr.) J. Dairy Sci., 51:985.

15. Dickinson, F. N., and B. T. McDaniel. 1970. Single-milking yields versus 24-hour yields for estimating lactation milk production by test interval method. J. Dairy Sci., 53:200.

16. Dolby, G. R. 1969. A comparison of monthly and bi-monthly production records of Queensland dairy cows. Aus. J. Exp. Agric. Anim. Husb., 9:490.

17. Erb, R. E., M. M. Goodwin, R. A. Morrison, and A. O. Shaw. 1952. Lactation studies. III. Variations in daily yields of dairy cows. J. Dairy Sci., 35:967.

18. Erb, R. E., M. M. Goodwin, R. A. Morrison, and A. O. Shaw. 1952. Lactation studies. IV. Accuracy of different methods of estimating lactation yields. J. Dairy Sci., 35:977.

19. Everett, R. W., and H. W. Carter. 1968. Relative accuracy of test interval method and centering date method of calculating Dairy Herd Improvement records. (Abstr.) J. Dairy Sci., 51:985.

20. Everett, R. W., and H. W. Carter. 1968. Accuracy of test interval method of calculating Dairy Herd Improvement records. J. Dairy Sci., 51:1936.

21. Everett, R. W., H. W. Carter, and J. D. Burke. 1968. Evaluation of Dairy Herd Improvement Association record system. J. Dairy Sci., 51:153.

22. Everett, R. W., B. T. McDaniel and H. W. Carter. 1968. Accuracy of monthly, bi-monthly, and tri-monthly Dairy Herd Improvement Association records. J. Dairy Sci., 51:1051.

23. Everett, R. W., and L. H. Wadell. 1970. Relationship between milking intervals and individual milk weights. J. Dairy Sci., 53:548.

24. Everett, R. W., and L. H. Wadell. 1970. Source of variation affecting the difference between morning and evening daily milk production. J. Dairy Sci., 53:1424.

25. Everett, R. W., and L. H. Wadell. 1970. Source of variation affecting ratio factors for estimating total daily milk yield from individual milkings. J. Dairy Sci., 53:1430.

26. Gaines, W. L. 1927. Deferred short-time test as a measure of the performance of dairy cows. J. Agric. Res., 35:237.

27. Gifford, W. 1930. The reliability of bi-monthly tests. J. Dairy Sci., 13:81.

28. Hardouin, J. 1967. Results obtained by a simplified method of alternate milk recording. Anim. Breed. Abstr. 35:1147.

29. Houston, J., and R. H. Hale. 1932. The errors involved in certain methods of estimating the lactation yield of milk and butterfat. J. Dairy Res., 4:37.

30. Jasiorowaski, H., J. Kossakowaski, and M. Kurowaska. 1966. Studies on the accuracy and the possibility of simplifying milk recording. Anim. Breed. Abstr., 34:2864.

31. Jax, P., and E. Nobl. 1954. On the most suitable method of milk recording of cattle grazed in the Alps. Dairy Sci. Abstr., 16:362.

32. Johanson, I. 1943. Investigations on methods of milk recording. Anim. Breed. Abstr., 11:156.

33. Jordao, L. P., P. Assis, F. De. P. Medina, and R. N. Guranga. 1948. Effect of the frequency of milk recording on the milk yield. Dairy Sci. Abstr., 10:90.

34. Kendrick, J. F. 1953. The Dairy Herd Improvement Association Program. USDA, Farmers' Bull. No. 1974.

35. Keown, J. E., and L. D. Van Vleck. 1971. Selection on test-day fat percentage and milk production. J. Dairy Sci., 54:199.

36. King, G. J., and R. H. Miller. 1965. The National Cooperative Dairy Herd Improvement Program Handbook No. 278. USDA, Washington, D. C.

37. Koshi, J. H., and W. E. Petersen. 1954. The effect of the length of intervals between milking on the milk and butterfat production. (Abstr.) J. Dairy Sci., 37:673.

38. Koubek, K., and J. Stodola. 1967. The effect of the length of the first recording period on the milk production during the normal lactation as calculated by KHT method. Anim. Breed. Abstr., 35:1160.

39. Lamb, R. C., and R. M. Young. 1968. Relative accuracy of estimating production as affected by length of testing interval and method of estimating. (Abstr.) J. Dairy Sci., 51:977.

40. Marks, J. 1966. Test milk every 90 days. Hoard's Dairyman, July, p. 853.

41. Masuda, S., and S. Higaki. 1953. A simplified method of estimating milk yield in Holstein cows. Dairy Sci. Abstr., 15:694.

42. McCarthy, M. D., and C. Boyle. 1948. The accuracy of monthly, six-weekly and two-monthly weighing in estimating milk yields. Dairy Sci. Abstr., 9:258.

43. McDaniel, B. T. 1969. Accuracy of sampling procedures for estimating lactation yields: A review. J. Dairy Sci., 52:1742.

44. McDaniel, B. T., N. W. Hooven, Jr., and R. D. Plowman. 1968. Factors related to errors in DHIA records on the Beltsville herd. (Quoted by B. T. McDaniel. 1969. (43)).

45. McDowell, J. C. 1927. Testing cows for production every other month. USDA Circ. 1.

46. McDowell, J. C. 1927. Testing cows for production every other month. Holstein-Fresian World, 24:1970.

47. McKellip, I., and D. Seath. 1941. A comparison of the different methods of calculating yearly milk and butterfat records. J. Dairy Sci., 24:181.

48. Miller, C. C., and C. E. Meadows. 1965. Production increases of continuous testing Michigan herds compared to increases in non-tested herds. (Abstr.) J. Dairy Sci., 48:796.

49. Miller, C. C., and C. E. Meadows. 1966. Estimating 305-day yield from bi-monthly and tri-monthly data. (Abstr.) J. Dairy Sci., 49:743.

50. Morrison, R. A., and R. E. Erb. 1953. Centering date versus calendar month for computing dairy cow production records. Dairy Sci. Abstr., 13:117.

51. Ormiston, E. E., S. L. Sphar, R. W. Touchberry, and J. L. Albright. 1967. Effect of milking at unequal intervals for a complete lactation on milk yield and composition. J. Dairy Sci., 50:1597.

52. Petersen, W. E. 1925. Accuracy of one-day and two-day test. Jersey Bull., 44:2044.

53. Poly, J., and M. Poutous. 1966. The accuracy of alternative milk recording. Anim. Breed. Abstr., 34:2872.

54. Poly, J., and M. Poutous. 1968. Alternate monthly milk recording. I. Accuracy of recording monthly and every other month for 305-day milk yield. Dairy Sci. Abstr., 30:454.

55. Porzio, G. 1953. A new method of milk recording. Anim. Breed Abstr., 21:1659.

56. Prache, M. 1968. Study of milk recording on alternate milking. Dairy Sci. Abstr., 30:779.

57. Putnam, D. N., and H. C. Gilmore. 1968. Evaluation of AM and PM monthly testing plan and its application for use in the Dairy Herd Improvement Association programs. (Abstr.) J. Dairy Sci., 51:985.

58. Putnam, D. N., and H. C. Gilmore. 1969. Alternate AM-PM testing for Dairy Herd Improvement Association programs - operational procedures. (Abstr.) J. Dairy Sci., 52:945.

59. Putnam, D. N., and H. C. Gilmore. 1970. Adjusting single milk weights from unequal milking intervals for use in the AM-PM testing plan. Paper E-9. ADSA, June 1970.

60. Sargent, F. D., V. H. Lytton, and O. G. Wall, Jr. 1968. Test interval method of calculating Dairy Herd Improvement Association records. J. Dairy Sci., 51:170.

61. Schmidt, G. H. 1960. Effect of milking intervals on rate of milk and fat secretion. J. Dairy Sci., 43:213.

62. Sere Del Campo, J. 1950. The efficiency of various methods of milk recording. Anim. Breed. Abstr., 18:270.

63. Spahr, S. L., and E. E. Ormiston. 1966. Effect of 9-15 hour milking intervals on the yield of high-producing cows. (Abstr.) J. Dairy Sci., 49:729.

64. Spike, P. W., P. L. Spike, and C. E. Meadows. 1970. Variation in PM-AM milk fat sampling. (Abstr.) J. Dairy Sci., 53:685.

65. Thompson, N. R., W. K. Stone, G. C. Graf, C. Y. Karmer, and R. J. Freund. 1960. Errors in estimation of lactational yields of milk, fat and solids-not-fat from individual cows. J. Dairy Sci., 43:951.

66. Tyler, W. J., and A. B. Chapman. 1944. A simplified method of estimating 305-day lactation production. J. Dairy Sci., 27:463.

67. Turner, C. W. 1923. Seasonal variations in milk and fat production. J. Dairy Sci., 6:198.

68. Van Vleck, L. D., and C. R. Henderson. 1961. Estimates of genetic parameters of some functions of part lactation milk records. J. Dairy Sci., 44:1073.

69. Van Vleck, L. D., and C. R. Henderson. 1961. Regression factors for extending part lactation milk records. J. Dairy Sci., 44: 1085.

70. Van Vleck, L. D., and C. R. Henderson. 1961. Use of part lactation records in sire evaluation. J. Dairy Sci., 44:1511.

71. Van Vleck, L. D., and C. R. Henderson. 1961. Extending part lactation milk records by regression ignoring herd effects. J. Dairy Sci., 44:1519.

72. Voelker, D. E., and G. M. Thomson. 1970. Computer scheduling of random test dates. Paper E-7, ADSA, June 1970.

73. Wing, H. H., and L. Anderson. 1899. Studies in milk secretion. Cornell Agric. Expt. Sta. Bull. 169.

74. Yapp, W. W. 1919. A study of the relative reliability of official tests of dairy cow. Ill. Agric. Expt. Sta. Bull. 215.

75. Zorn, W., and R. Gruhn. 1945. Milk yields and fat contents. Comparison of milk yields calculated from records made at intervals of 3, 4, 6 or 8 weeks. Dairy Sci. Abstr., 6:156.

# APPENDIX

TABLE XXIV

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF MONTHLY ESTIMATES OF ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holstein | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 0.73 | 0.23 | 0.25 | 0.66 | 0.24 | 0.28 | 0.67 | 0.38 | 0.40 | 0.69 | 0.31 | 0.36 |
| 3 | 0.77 | 0.36 | 0.36 | 0.60 | 0.40 | 0.41 | 0.78 | 0.50 | 0.54 | 0.88 | 0.57 | 0.59 |
| 4 | 0.91 | 0.44 | 0.47 | 0.67 | 0.42 | 0.40 | 0.79 | 0.39 | 0.42 | 0.99 | 0.61 | 0.66 |
| 5 | 0.94 | 0.44 | 0.42 | 0.48 | 0.43 | 0.46 | 0.72 | 0.53 | 0.59 | 0.85 | 0.53 | 0.53 |
| 6+ | 0.74 | 0.27 | 0.29 | 0.75 | 0.36 | 0.33 | 0.73 | 0.37 | 0.45 | 0.73 | 0.44 | 0.43 |
| All | 0.79 | 0.20 | 0.22 | 0.62 | 0.19 | 0.20 | 0.68 | 0.18 | 0.29 | 0.74 | 0.30 | 0.34 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XXV

PERCENTAGE OF MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND HERD

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 45 | 75 | 97 | 100 | | | |
| KH | 2 | 2 | 49 | 83 | 98 | 100 | | | |
| | | 3 | 49 | 82 | 98 | 100 | | | |
| | | 1 | 45 | 75 | 98 | 100 | | | |
| KH | 3 | 2 | 52 | 81 | 99 | 100 | | | |
| | | 3 | 52 | 81 | 99 | 100 | | | |
| | | 1 | 40 | 69 | 91 | 99 | 100 | | |
| KH | 4 | 2 | 46 | 76 | 94 | 99 | 100 | | |
| | | 3 | 46 | 77 | 94 | 99 | 100 | | |
| | | 1 | 31 | 57 | 85 | 97 | 100 | | |
| KH | 5 | 2 | 38 | 63 | 87 | 97 | 100 | | |
| | | 3 | 36 | 64 | 87 | 97 | 100 | | |
| | | 1 | 39 | 67 | 96 | 100 | | | |
| KH | 6+ | 2 | 45 | 75 | 96 | 100 | | | |
| | | 3 | 46 | 75 | 95 | 100 | | | |
| | | 1 | 42 | 71 | 95 | 99 | 100 | | |
| KH | All | 2 | 47 | 78 | 96 | 99 | 100 | | |
| | | 3 | 47 | 78 | 96 | 99 | 100 | | |
| | | 1 | 41 | 69 | 95 | 99 | 100 | | |
| SH | 2 | 2 | 41 | 73 | 97 | 100 | | | |
| | | 3 | 41 | 73 | 97 | 100 | | | |
| | | 1 | 39 | 68 | 94 | 99 | 100 | | |
| SH | 3 | 2 | 40 | 71 | 94 | 100 | | | |
| | | 3 | 41 | 71 | 94 | 100 | | | |
| | | 1 | 37 | 62 | 93 | 99 | 100 | | |
| SH | 4 | 2 | 39 | 66 | 94 | 99 | 100 | | |
| | | 3 | 39 | 68 | 93 | 99 | 100 | | |
| | | 1 | 40 | 74 | 94 | 99 | 100 | | |
| SH | 5 | 2 | 46 | 72 | 95 | 99 | 100 | | |
| | | 3 | 45 | 72 | 95 | 99 | 100 | | |
| | | 1 | 39 | 67 | 90 | 98 | 100 | | |
| SH | 6+ | 2 | 40 | 70 | 93 | 98 | 100 | | |
| | | 3 | 41 | 70 | 93 | 98 | 100 | | |
| | | 1 | 40 | 68 | 94 | 99 | 100 | | |
| SH | All | 2 | 41 | 71 | 95 | 99 | 100 | | |
| | | 3 | 41 | 71 | 95 | 99 | 100 | | |
| | | 1 | 33 | 60 | 89 | 99 | 100 | | |
| JJ | 2 | 2 | 37 | 65 | 91 | 99 | 100 | | |
| | | 3 | 37 | 65 | 91 | 99 | 100 | | |

TABLE XXV (continued)

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 32 | 60 | 89 | 98 | 100 | | |
| JJ | 3 | 2 | 31 | 61 | 90 | 99 | 100 | | |
| | | 3 | 32 | 61 | 89 | 99 | 100 | | |
| | | 1 | 34 | 65 | 93 | 99 | 100 | | |
| JJ | 4 | 2 | 39 | 67 | 95 | 100 | | | |
| | | 3 | 37 | 68 | 96 | 100 | | | |
| | | 1 | 36 | 63 | 93 | 99 | 100 | | |
| JJ | 5 | 2 | 39 | 68 | 94 | 100 | | | |
| | | 3 | 41 | 69 | 94 | 100 | | | |
| | | 1 | 31 | 59 | 90 | 98 | 100 | | |
| JJ | 6+ | 2 | 34 | 61 | 92 | 99 | 100 | | |
| | | 3 | 33 | 62 | 92 | 98 | 100 | | |
| | | 1 | 34 | 61 | 91 | 99 | 100 | | |
| JJ | All | 2 | 33 | 61 | 91 | 99 | 100 | | |
| | | 3 | 36 | 64 | 92 | 99 | 100 | | |
| | | 1 | 36 | 64 | 92 | 99 | 100 | | |
| LJ | 2 | 2 | 37 | 69 | 94 | 100 | | | |
| | | 3 | 37 | 69 | 95 | 100 | | | |
| | | 1 | 35 | 65 | 91 | 99 | 99 | 100 | |
| LJ | 3 | 2 | 39 | 67 | 93 | 99 | 99 | 100 | |
| | | 3 | 39 | 67 | 93 | 99 | 99 | 100 | |
| | | 1 | 32 | 60 | 91 | 98 | 100 | | |
| LJ | 4 | 2 | 37 | 66 | 94 | 98 | 100 | | |
| | | 3 | 36 | 66 | 93 | 99 | 100 | | |
| | | 1 | 34 | 57 | 91 | 98 | 100 | | |
| LJ | 5 | 2 | 38 | 63 | 92 | 98 | 100 | | |
| | | 3 | 37 | 63 | 92 | 98 | 100 | | |
| | | 1 | 35 | 59 | 91 | 98 | 100 | | |
| LJ | 6+ | 2 | 35 | 64 | 91 | 99 | 100 | | |
| | | 3 | 35 | 65 | 91 | 99 | 100 | | |
| | | 1 | 35 | 61 | 92 | 99 | 100 | | |
| LJ | All | 2 | 37 | 66 | 93 | 99 | 100 | | |
| | | 3 | 37 | 66 | 93 | 99 | 100 | | |

[a]KH: Knoxville-Holstein; SH: Spring Hill-Holstein; JJ: Jackson-Jersey; LJ: Lewisburg-Jersey.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XXVI

CONTRIBUTION OF DIFFERENT SEGMENTS OF THE LACTATION TO THE AVERAGE ERRORS OF ESTIMATE IN THE BREEDS STUDIED

| Part[a] | Yield (Lbs.) | Monthly 1[b] | Monthly 2 | Monthly 3 | Bi-Monthly 1 | Bi-Monthly 2 | Bi-Monthly 3 | Tri-Monthly 1 | Tri-Monthly 2 | Tri-Monthly 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Hol. - 2 Yrs. - 86 Rec. | | | | | |
| A | 4483 | .45 | -.24 | -.24 | .50 | -.29 | -.29 | .30 | -.14 | -.14 |
| B | 4321 | .02 | .02 | .02 | .01 | .01 | .01 | -.01 | -.01 | -.01 |
| C | 3419 | .12 | .12 | .05 | .37 | .37 | .10 | .70 | .70 | .07 |
| T | 12223 | .59 | -.10 | -.17 | .88 | .09 | -.19 | .99 | .55 | -.08 |
| | | | | | Hol. 3 Yrs. - 49 Rec. | | | | | |
| A | 6069 | .42 | -.14 | -.14 | .40 | .02 | .02 | -.17 | .36 | .36 |
| B | 5117 | .07 | .07 | .07 | .09 | .09 | .09 | .14 | .14 | .14 |
| C | 3627 | .14 | .14 | .03 | .47 | .47 | .02 | .92 | .92 | -.10 |
| T | 14813 | .63 | .07 | -.04 | .96 | .59 | .13 | .89 | 1.42 | .39 |
| | | | | | Hol. - 4 Yrs. - 37 Rec. | | | | | |
| A | 6651 | .50 | -.18 | -.18 | .41 | -.30 | -.30 | -.05 | -.03 | -.03 |
| B | 5684 | .03 | .03 | .03 | .03 | .03 | .03 | .04 | .04 | .04 |
| C | 3809 | .18 | .18 | .06 | .55 | .55 | .09 | 1.08 | 1.08 | .03 |
| T | 16144 | .71 | .03 | -.08 | .99 | .28 | -.18 | 1.07 | 1.09 | .04 |
| | | | | | Hol. - 5 Yrs. - 23 Rec. | | | | | |
| A | 6679 | .43 | -.23 | -.23 | .31 | -.34 | -.34 | -.32 | -.23 | -.23 |
| B | 5538 | .09 | .09 | .09 | .10 | .10 | .10 | .14 | .14 | .14 |
| C | 3757 | .12 | .12 | .01 | .53 | .53 | .05 | 1.06 | 1.06 | -.03 |
| T | 15974 | .65 | -.02 | -.14 | .94 | .30 | -.19 | .89 | .98 | -.12 |
| | | | | | Hol. - 6+ Yrs. - 37 Rec. | | | | | |
| A | 6826 | .46 | -.17 | -.17 | .56 | -.02 | -.02 | .26 | .54 | .54 |
| B | 6065 | .04 | .04 | .04 | .04 | .04 | .04 | .05 | .05 | .05 |
| C | 4206 | .17 | .17 | .08 | .47 | .47 | .11 | .98 | .98 | .16 |
| T | 17097 | .67 | .04 | -.05 | 1.07 | .50 | .13 | 1.29 | 1.57 | .75 |
| | | | | | Hol. - All - 232 Rec. | | | | | |
| A | 5755 | .45 | -.19 | -.19 | .45 | -.18 | -.18 | .06 | .10 | .10 |
| B | 5105 | .05 | .05 | .05 | .05 | .05 | .05 | .06 | .06 | .06 |
| C | 3684 | .13 | .13 | .05 | .46 | .46 | .07 | .91 | .91 | .03 |
| T | 14544 | .64 | -.01 | -.10 | .96 | .33 | -.06 | 1.03 | 1.07 | .20 |
| | | | | | Jer. - 2 Yrs. - 80 Rec. | | | | | |
| A | 3420 | .49 | -.22 | -.22 | .47 | -.34 | -.34 | .13 | -.31 | -.31 |
| B | 3134 | .04 | .04 | .04 | .10 | .10 | .10 | .18 | .18 | .18 |
| C | 2672 | .05 | .05 | -.03 | .17 | .17 | -.18 | .36 | .36 | -.48 |
| T | 9226 | .58 | -.12 | -.21 | .74 | -.06 | -.43 | .68 | .23 | -.61 |

TABLE XXVI (continued)

| Part[a] | Yield (Lbs.) | Monthly 1[b] | Monthly 2 | Monthly 3 | Bi-Monthly 1 | Bi-Monthly 2 | Bi-Monthly 3 | Tri-Monthly 1 | Tri-Monthly 2 | Tri-Monthly 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Jer. - 3 Yrs. - 41 Rec. | | | | | |
| A | 4397 | .40 | -.17 | -.17 | .12 | -.26 | -.26 | -.47 | .02 | .02 |
| B | 3704 | .04 | .04 | .04 | .07 | .07 | .07 | .15 | .15 | .15 |
| C | 2846 | .12 | .12 | -.03 | .33 | .33 | -.29 | .65 | .65 | -.74 |
| T | 10947 | .56 | -.01 | -.16 | .52 | .14 | -.48 | .33 | .82 | -.57 |
| | | | | | Jer. - 4 Yrs. - 33 Rec. | | | | | |
| A | 4784 | .53 | -.14 | -.14 | .32 | -.37 | -.37 | -.27 | -.27 | -.27 |
| B | 4046 | .05 | .05 | .05 | .12 | .12 | .12 | .22 | .22 | .22 |
| C | 3219 | .12 | .12 | -.03 | .26 | .26 | -.36 | .56 | .56 | -.83 |
| T | 12049 | .70 | .03 | -.12 | .70 | .01 | -.61 | .51 | .52 | -.88 |
| | | | | | Jer. - 5 Yrs. - 25 Rec. | | | | | |
| A | 4840 | .47 | -.18 | -.18 | .25 | -.38 | -.38 | -.23 | -.13 | -.13 |
| B | 4149 | .03 | .03 | .03 | .05 | .05 | .05 | .06 | .06 | .06 |
| C | 2995 | .12 | .12 | -.04 | .33 | .33 | -.31 | .78 | .78 | -.68 |
| T | 11984 | .62 | -.03 | -.19 | .63 | .01 | -.64 | .61 | .71 | -.75 |
| | | | | | Jer. - 6 Yrs. - 60 Rec. | | | | | |
| A | 4801 | .47 | -.18 | -.18 | .34 | -.25 | -.25 | -.12 | .12 | .12 |
| B | 4211 | .04 | .04 | .04 | .05 | .05 | .05 | .08 | .08 | .08 |
| C | 3176 | .11 | .11 | -.02 | .34 | .34 | -.17 | .72 | .72 | -.43 |
| T | 12188 | .62 | -.03 | -.16 | .73 | .14 | -.37 | .68 | .92 | -.23 |
| | | | | | Jer. - All - 239 Rec. | | | | | |
| A | 4271 | .47 | -.18 | -.18 | .33 | -.30 | -.30 | -.14 | -.11 | -.11 |
| B | 3735 | .04 | .04 | .04 | .07 | .07 | .07 | .14 | .14 | .14 |
| C | 2937 | .10 | .10 | -.03 | .28 | .28 | -.24 | .59 | .59 | -.58 |
| T | 10943 | .61 | -.04 | -.17 | .68 | .05 | -.47 | .59 | .62 | .56 |

[a] A: Days 1 to 100; B: Days 101 to 205; C: Days 206 to 305; T: Days 1 to 305.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

Cranes Crest

TABLE XXVII

PERCENTAGE OF BI-MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND HERD

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 29 | 54 | 85 | 96 | 100 | | |
| KH | 2 | 2 | 33 | 59 | 88 | 97 | 100 | | |
| | | 3 | 33 | 61 | 89 | 97 | 100 | | |
| | | 1 | 30 | 54 | 85 | 97 | 100 | | |
| KH | 3 | 2 | 33 | 57 | 87 | 97 | 100 | | |
| | | 3 | 31 | 59 | 88 | 97 | 100 | | |
| | | 1 | 23 | 46 | 79 | 92 | 98 | 100 | |
| KH | 4 | 2 | 28 | 52 | 83 | 94 | 98 | 100 | |
| | | 3 | 30 | 54 | 84 | 94 | 98 | 100 | |
| | | 1 | 22 | 40 | 69 | 87 | 98 | 100 | |
| KH | 5 | 2 | 27 | 48 | 74 | 89 | 98 | 99 | 100 |
| | | 3 | 27 | 49 | 76 | 90 | 98 | 99 | 100 |
| | | 1 | 19 | 38 | 70 | 88 | 98 | 100 | |
| KH | 6+ | 2 | 22 | 42 | 73 | 90 | 98 | 100 | |
| | | 3 | 23 | 42 | 74 | 90 | 98 | 100 | |
| | | 1 | 26 | 49 | 80 | 94 | 99 | 100 | |
| KH | All | 2 | 30 | 54 | 83 | 95 | 99 | 100 | |
| | | 3 | 30 | 55 | 84 | 95 | 99 | 100 | |
| | | 1 | 27 | 50 | 82 | 94 | 99 | 100 | |
| SH | 2 | 2 | 27 | 52 | 83 | 96 | 99 | 100 | |
| | | 3 | 27 | 52 | 84 | 95 | 99 | 100 | |
| | | 1 | 25 | 49 | 81 | 93 | 99 | 100 | |
| SH | 3 | 2 | 28 | 49 | 82 | 94 | 100 | | |
| | | 3 | 28 | 49 | 81 | 94 | 100 | | |
| | | 1 | 22 | 43 | 77 | 92 | 99 | 100 | |
| SH | 4 | 2 | 23 | 47 | 80 | 92 | 99 | 100 | |
| | | 3 | 26 | 50 | 80 | 92 | 99 | 100 | |
| | | 1 | 27 | 51 | 83 | 96 | 100 | | |
| SH | 5 | 2 | 33 | 55 | 84 | 96 | 100 | | |
| | | 3 | 31 | 57 | 84 | 96 | 100 | | |
| | | 1 | 23 | 45 | 77 | 92 | 99 | 100 | |
| SH | 6+ | 2 | 27 | 50 | 79 | 93 | 99 | 100 | |
| | | 3 | 26 | 50 | 80 | 94 | 99 | 100 | |
| | | 1 | 25 | 48 | 80 | 94 | 99 | 100 | |
| SH | All | 2 | 27 | 51 | 82 | 95 | 99 | 100 | |
| | | 3 | 27 | 51 | 82 | 95 | 99 | 100 | |
| | | 1 | 22 | 43 | 73 | 93 | 99 | 100 | |
| JJ | 2 | 2 | 25 | 46 | 76 | 92 | 99 | 100 | |
| | | 3 | 25 | 47 | 75 | 91 | 99 | 100 | |

TABLE XXVII (continued)

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 23 | 42 | 73 | 90 | 100 | | |
| JJ | 3 | 2 | 22 | 42 | 73 | 91 | 99 | 100 | |
| | | 3 | 22 | 40 | 72 | 89 | 99 | 100 | |
| | | 1 | 23 | 45 | 77 | 93 | 100 | | |
| JJ | 4 | 2 | 25 | 46 | 80 | 93 | 100 | | |
| | | 3 | 22 | 45 | 77 | 91 | 100 | | |
| | | 1 | 21 | 41 | 73 | 90 | 99 | 100 | |
| JJ | 5 | 2 | 22 | 44 | 75 | 92 | 99 | 100 | |
| | | 3 | 23 | 46 | 75 | 90 | 99 | 100 | |
| | | 1 | 22 | 41 | 72 | 90 | 99 | 100 | |
| JJ | 6+ | 2 | 23 | 45 | 75 | 90 | 99 | 100 | |
| | | 3 | 23 | 43 | 74 | 89 | 99 | 100 | |
| | | 1 | 22 | 43 | 73 | 90 | 99 | 100 | |
| JJ | All | 2 | 24 | 45 | 75 | 91 | 99 | 100 | |
| | | 3 | 24 | 45 | 74 | 90 | 99 | 100 | |
| | | 1 | 24 | 45 | 80 | 94 | 100 | | |
| LJ | 2 | 2 | 24 | 49 | 82 | 95 | 100 | | |
| | | 3 | 24 | 48 | 81 | 94 | 100 | | |
| | | 1 | 23 | 44 | 77 | 92 | 99 | 100 | |
| LJ | 3 | 2 | 23 | 46 | 77 | 92 | 99 | 100 | |
| | | 3 | 23 | 46 | 77 | 92 | 99 | 100 | |
| | | 1 | 23 | 43 | 73 | 90 | 99 | 100 | |
| LJ | 4 | 2 | 24 | 45 | 75 | 91 | 99 | 100 | |
| | | 3 | 25 | 45 | 75 | 90 | 99 | 100 | |
| | | 1 | 23 | 43 | 75 | 90 | 98 | 99 | 100 |
| LJ | 5 | 2 | 24 | 45 | 77 | 91 | 99 | 100 | |
| | | 3 | 24 | 46 | 77 | 91 | 98 | 99 | 100 |
| | | 1 | 22 | 42 | 74 | 90 | 99 | 100 | |
| LJ | 6+ | 2 | 23 | 44 | 76 | 92 | 99 | 100 | |
| | | 3 | 24 | 45 | 75 | 91 | 99 | 100 | |
| | | 1 | 23 | 43 | 76 | 91 | 99 | 100 | |
| LJ | All | 2 | 24 | 46 | 78 | 92 | 99 | 100 | |
| | | 3 | 24 | 46 | 78 | 92 | 99 | 100 | |

[a]KH: Knoxville-Holstein; SH: Spring Hill-Holstein; JJ: Jackson-Jersey; LJ: Lewisburg-Jersey.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XXVIII

AVERAGE PERCENT ABSOLUTE DEVIATIONS OF TRI-MONTHLY ESTIMATES FROM THE ACTUAL 305-DAY YIELDS IN THE FOUR HERDS

| | Holstein | | | | | | Jersey | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Knoxville (116)[a] | | | Spring Hill (116)[a] | | | Jackson (116)[a] | | | Lewisburg (123)[a] | | |
| Age | 1[b] | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 2 | 1.98 | 1.99 | 1.44 | 1.24 | 1.12 | 0.70 | 1.23 | 1.06 | 0.90 | 1.30 | 1.15 | 0.88 |
| 3 | 2.75 | 3.39 | 2.46 | 1.66 | 1.76 | 0.99 | 2.07 | 1.41 | 1.53 | 1.43 | 1.87 | 1.41 |
| 4 | 2.64 | 2.74 | 1.86 | 1.51 | 1.56 | 0.96 | 1.73 | 1.07 | 1.75 | 1.44 | 1.47 | 1.16 |
| 5 | 3.67 | 3.38 | 2.58 | 1.58 | 1.52 | 0.89 | 1.39 | 1.62 | 1.88 | 2.02 | 1.62 | 1.24 |
| 6+ | 3.19 | 3.94 | 3.24 | 1.90 | 1.94 | 1.23 | 1.22 | 1.16 | 1.28 | 1.66 | 1.76 | 1.00 |
| All | 2.52 | 2.90 | 2.12 | 1.41 | 1.47 | 0.71 | 1.14 | 0.83 | 0.99 | 1.38 | 1.43 | 0.78 |

[a] Number of Records.

[b] 1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

TABLE XXIX

PERCENTAGE OF TRI-MONTHLY ESTIMATES WITHIN A GIVEN PERCENT OF ACTUAL YIELD BY COMPUTING METHOD, AGE AND HERD

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 19 | 37 | 68 | 86 | 98 | 100 | |
| KH | 2 | 2 | 20 | 38 | 69 | 88 | 98 | 100 | |
| | | 3 | 22 | 43 | 73 | 90 | 98 | 100 | |
| | | 1 | 16 | 33 | 59 | 78 | 95 | 99 | 100 |
| KH | 3 | 2 | 13 | 27 | 53 | 74 | 93 | 99 | 100 |
| | | 3 | 16 | 34 | 63 | 82 | 97 | 100 | |
| | | 1 | 16 | 31 | 57 | 78 | 95 | 99 | 99 |
| KH | 4 | 2 | 14 | 29 | 55 | 77 | 95 | 99 | 99 |
| | | 3 | 17 | 34 | 64 | 83 | 97 | 99 | 100 |
| | | 1 | 15 | 31 | 50 | 67 | 88 | 96 | 99 |
| KH | 5 | 2 | 15 | 28 | 49 | 68 | 89 | 96 | 99 |
| | | 3 | 17 | 32 | 57 | 77 | 92 | 96 | 99 |
| | | 1 | 14 | 27 | 52 | 72 | 95 | 100 | |
| KH | 6+ | 2 | 11 | 22 | 46 | 68 | 93 | 100 | |
| | | 3 | 14 | 27 | 52 | 75 | 96 | 100 | |
| | | 1 | 17 | 33 | 60 | 79 | 95 | 99 | 100 |
| KH | All | 2 | 15 | 31 | 57 | 78 | 95 | 99 | 100 |
| | | 3 | 18 | 36 | 65 | 84 | 97 | 99 | 100 |
| | | 1 | 19 | 37 | 67 | 85 | 98 | 100 | |
| SH | 2 | 2 | 20 | 39 | 69 | 87 | 98 | 100 | |
| | | 3 | 21 | 41 | 71 | 88 | 98 | 100 | |
| | | 1 | 20 | 38 | 65 | 82 | 97 | 100 | |
| SH | 3 | 2 | 18 | 36 | 64 | 82 | 97 | 100 | |
| | | 3 | 20 | 37 | 68 | 86 | 98 | 100 | |
| | | 1 | 19 | 36 | 65 | 82 | 97 | 100 | |
| SH | 4 | 2 | 18 | 37 | 64 | 83 | 97 | 100 | |
| | | 3 | 21 | 38 | 67 | 85 | 97 | 100 | |
| | | 1 | 18 | 37 | 67 | 86 | 98 | 100 | |
| SH | 5 | 2 | 19 | 38 | 70 | 86 | 98 | 100 | |
| | | 3 | 21 | 40 | 72 | 88 | 99 | 100 | |
| | | 1 | 17 | 35 | 64 | 80 | 95 | 99 | 100 |
| SH | 6+ | 2 | 17 | 32 | 60 | 79 | 96 | 99 | 100 |
| | | 3 | 18 | 35 | 62 | 82 | 97 | 99 | 99 |
| | | 1 | 25 | 48 | 80 | 94 | 99 | 100 | |
| SH | All | 2 | 27 | 51 | 82 | 95 | 99 | 100 | |
| | | 3 | 27 | 51 | 82 | 95 | 99 | 100 | |
| | | 1 | 17 | 33 | 61 | 79 | 95 | 99 | 100 |
| JJ | 2 | 2 | 18 | 35 | 62 | 80 | 95 | 99 | 100 |
| | | 3 | 19 | 35 | 63 | 80 | 95 | 99 | 100 |

TABLE XXIX (continued)

| Herd[a] | Age (Yrs.) | Meth.[b] | Percent Error 1 | 2 | 4 | 6 | 10 | 15 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 15 | 29 | 60 | 75 | 93 | 99 | 100 |
| JJ | 3 | 2 | 16 | 31 | 58 | 77 | 95 | 99 | 100 |
| | | 3 | 17 | 32 | 58 | 77 | 94 | 99 | 100 |
| | | 1 | 19 | 34 | 63 | 84 | 98 | 100 | |
| JJ | 4 | 2 | 20 | 40 | 71 | 86 | 99 | 100 | |
| | | 3 | 17 | 35 | 65 | 83 | 97 | 100 | |
| | | 1 | 18 | 34 | 59 | 77 | 94 | 99 | 100 |
| JJ | 5 | 2 | 17 | 32 | 58 | 77 | 93 | 99 | 100 |
| | | 3 | 15 | 28 | 56 | 74 | 95 | 99 | 100 |
| | | 1 | 16 | 32 | 59 | 78 | 94 | 99 | 100 |
| JJ | 6+ | 2 | 17 | 33 | 61 | 78 | 94 | 99 | 99 |
| | | 3 | 17 | 34 | 63 | 78 | 94 | 99 | 99 |
| | | 1 | 17 | 32 | 60 | 78 | 95 | 99 | 100 |
| JJ | All | 2 | 17 | 34 | 62 | 79 | 95 | 99 | 100 |
| | | 3 | 18 | 34 | 61 | 79 | 95 | 99 | 100 |
| | | 1 | 19 | 36 | 66 | 84 | 97 | 100 | |
| LJ | 2 | 2 | 19 | 37 | 67 | 84 | 97 | 100 | |
| | | 3 | 18 | 38 | 67 | 84 | 98 | 100 | |
| | | 1 | 18 | 33 | 62 | 81 | 95 | 99 | 100 |
| LJ | 3 | 2 | 16 | 34 | 59 | 78 | 95 | 99 | 100 |
| | | 3 | 17 | 35 | 60 | 80 | 96 | 99 | 100 |
| | | 1 | 17 | 34 | 62 | 81 | 96 | 100 | |
| LJ | 4 | 2 | 17 | 33 | 62 | 81 | 97 | 100 | |
| | | 3 | 18 | 34 | 63 | 81 | 97 | 100 | |
| | | 1 | 16 | 30 | 58 | 76 | 94 | 99 | 100 |
| LJ | 5 | 2 | 16 | 32 | 58 | 79 | 95 | 99 | 100 |
| | | 3 | 19 | 35 | 62 | 81 | 95 | 99 | 100 |
| | | 1 | 18 | 33 | 59 | 79 | 95 | 99 | 100 |
| LJ | 6+ | 2 | 16 | 32 | 59 | 79 | 95 | 99 | 100 |
| | | 3 | 17 | 34 | 63 | 80 | 96 | 100 | |
| | | 1 | 18 | 34 | 62 | 81 | 96 | 100 | |
| LJ | All | 2 | 17 | 34 | 62 | 81 | 96 | 100 | |
| | | 3 | 18 | 35 | 64 | 82 | 96 | 100 | |

[a]KH: Knoxville-Holstein; SH: Spring Hill-Holstein; JJ: Jackson-Jersey; LJ: Lewisburg-Jersey.

[b]1: Unadjusted; 2: First-Test-Adjusted; 3: First-and-Last-Test-Adjusted.

# VITA

Amai Vishwanatha Rai (A. V. Rai) was born on January 8, 1931, in Kadeshwallya Village, South Kanara Dt. of Mysore State, India. He received his Bachelor of Veterinary Science (B. V. Sc.) degree from The University of Madras in June, 1954.

After graduation he entered government service. He was selected as a USAID participant for higher studies. He obtained his M. S. in Dairying with emphasis on reproductive physiology from The University of Tennessee in December, 1965 under the direction of Dr. Don O. Richardson for his M. S. degree.

On return to his country, he joined the staff of The Mysore University of Agricultural Sciences, Bangalore. In January, 1969, he returned to The University of Tennessee, as a USAID participant for his Doctoral studies.

He is a member of The American Dairy Science Association and Gamma Sigma Delta.

T. Kusuma Rai and he were married in 1960. They are the proud parents of three girls, Amritha, Anitha and Mamatha.