ADJUSTING MILK PRODUCTION RECORDS FOR AGE AT CALVING IN WESTERN CANADA

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William Esmond Jarvis

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By

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AN ABSTRACT

Submitted to the College of Agriculture
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ABSTRACT WILLIAM ESMOND JARVIS

The milk production records of 10,946 Western Canadian Holstein-Friesian cows were studied with three objectives in mind, the first, to determine the influence of age at calving on milk production, the second, to develop factors which may be used to correct records for the effect of age, and the third, to determine the influence of season of calving on milk production.

The production of the cows in this study increased with increasing age at calving to 61 months of age and maintained a similar production level to 119 months of age after which there was a gradual decline. The milk production averages of the groups of cows calving at various ages were compared with similar averages used by the Canadian Holstein-Friesian Association in calculating B.C.A. milk indexes. The two sets of averages were found to be very similar with the mature production levels being almost identical and the averages being no more than 500 pounds different at any age.

Multiplicative age-correction factors were developed, by the cross-comparison method, from the production averages of the groups of cows calving at the various months of age. The factors developed proved to be very similar to those developed by Kendrick (195[illegible]), the greatest differences appearing at ages beyond maturity when the

Kendrick factors were more generous. These factors were also compared with the present Manitoba age-correction factors and it was found that the present Manitoba factors are much too generous over most of the three year age range in which they are used. A portion of the inaccuracies were shown to be due to correcting records of cows calving within a 12 month range in age by each individual factor.

A study of the records to determine the effect of season of calving on milk production revealed that those cows which calved in November produced the most, a level which was 9.3% higher than that of those cows which calved during July. A division of the year into three seasons showed that those cows calving in the spring season produce significantly less than those calving in the winter and fall, with those calving in the winter giving the highest production.

There was a significant difference between the average age of cows calving in different months of the year, the oldest group calving in May and the youngest in October.

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INTRODUCTION

Factors influencing the production level of a cow are of two basic sources, heredity and environment. The environment includes all aspects of feeding, housing and herd management to which the cow is subjected. Two environmental factors, the effect of age at calving and the effect of season-of-calving, will be considered in this study with the following objectives:

1. to determine the influence of age at calving on milk production of Holstein-Friesian cows in the Prairie Provinces of Canada.

2. to determine the extent to which production of cows in the same part of Canada is influenced by the month or season in which the lactation is initiated.

3. to develop factors which may be used in adjusting records of immature cows in that area to an estimated mature-equivalent.

4. to assess the factors presently used in Manitoba to correct D.H.I.A. production records for age at calving.

DEFINITIONS

Mature-equivalent - when the production record of an immature cow is adjusted to a production level which the cow would have been expected to attain had she been mature during the lactation, the adjusted record is known as the mature-equivalent.

Age-correction factor - a numerical value which when applied to a record of an immature cow adjusts the record to it's mature-equivalent.

Kendrick factors - multiplicative age-correction factors currently used in adjusting U.S.D.A. - D.H.I.A. production records. These factors were developed from 204,330 lactation records and were published by Kendrick (1955).

Manitoba factors - multiplicative age-correction factors currently used in adjusting Manitoba D.H.I.A. production records. The use of these factors assumes two, three, and four year old production records to be 67, 77, and 88%, respectively of mature production.

B.C.A. (Breed Class Average) - the system used by the Canada Department of Agriculture in comparing records of cows of different ages. Under this system the actual production record of a cow is compared to the average production of cows of the same class (age at calving and milking frequency) and of the same breed, and an index number is provided as a measure of this comparison.

R.O.P. (Record of Performance) - a herd testing program offered to owners of registered dairy cattle of all breeds by the Canada Department of Agriculture. This is the only official herd testing program in Canada.

REVIEW OF LITERATURE

The functioning of the mammary gland is dependent first on heredity, second on the effects of environment up to commencement of the lactation, and finally on the environmental influences during the actual lactation, according to Gowen (1920). The literature will be reviewed herein with respect to the effect of two environmental influences, the age of the cow at calving, and the season-of-calving, on the amount of milk and butterfat produced during the ensuing lactation.

Milk Production as Related to Age at Calving

Gowen (1924) studied 2,586 Holstein Advanced Registry records and found a correlation coefficient of milk yield to age of 0.4332 and of butterfat production to age of 0.376. He found that milk production increased with age to a maximum reached at eight years, four months and twenty-nine days with the level being similar in the age range 6.5 to 9.75 years. He noted a decline from the age of maximum production to the end of productive life. Gowen postulated that the relationship of milk production to age is a function of growth and senescence in the life of the cow. He also observed that the percentage butterfat in the milk produced was almost uninfluenced by age.

In an earlier study with 1,741 records from the Maine

Agricultural Experiment Station Jersey herd, Cowen (1920) showed a significant correlation between age at test and milk production. He found a distinct rise in the average production of cows with increasing age to seven years after which he noted some decline. He showed that the curve of milk production with age had a logarithmic function.

Dickerson and Chapman (1939), working with 1,374 Holstein records from 41 herds, concluded that the increase in production is essentially linear up to five years of age.

Sanders (1928) concluded that the variation in milk production was due to the age of the cow rather than to the number of lactations she had had.

The major part of the influence of age on yield was exerted during the early part of the lactation, according to the work of Dickerson (1940) and Mahadevan (1951).

Gaines et al (1940, 1947) showed that milk energy yield was related to the body weight of the cow at calving and stated that body weight at calving is a much better criterion for adjusting records than age. They did concede however that, in as much as body weight is correlated with age, age does have some application.

Necessity of Using Age-Correction Factors

In considering the use of Holstein Advanced Registry records in sire analysis, Morton (1952, 1955) noted the difficulty of directly comparing, without adjustment, lactation records made by cows of different ages. He stated, however, that it would be preferable to directly compare a daughter's record at a given age with that of her dam at the same age rather than to adjust for age in making dam-daughter comparisons.

Kendrick (1955) and Hickman (1955) noted the necessity of adjusting records for age in order to make a realistic comparison of the inherent producing ability of many individuals.

Types of Age-Correction Factors

Age-correction factors are most commonly one of four types. Three of these, additive, multiplicative, and regression equation, are designed to adjust the actual production record of an immature animal to an estimated mature-equivalent in pounds of milk or butterfat. The fourth is a comparison of an actual production record with the expected production of cows of the same age and breed with an index number being provided as a measure of this comparison.

Additive Factors

The New Zealand Dairy Board (1938) used additive factors for several years in correcting records for age at calving. For example, 70 and 35 pounds of butterfat were added to the records of two and three year old Jerseys, respectively. They concluded recently that the additive corrections tended to undercorrect records from high producing herds and overcorrect those from low producing herds. This is in agreement with the work of Mahadevan (1951) who showed that additive factors were not entirely accurate and concluded that in order to be accurate, factors must correct the record proportionately.

Multiplicative Factors

Multiplicative factors are used widely. Such a method is used by the United States Department of Agriculture in adjusting D.H.I.A. records. Multiplicative factors have been developed by different methods.

Gross-comparison method

Gowen (1924) developed a method of establishing age-correction factors based on a comparison of the average of all records within an age group with the average of all mature cow records. This is now known as the gross-comparison method, and has been used by Cassell et al (1930) and also by Kendrick (1933) who used it in developing the factors previously referred to as those presently used in adjusting United States D.H.I.A. records.

Sanders (1928) showed a bias in this method which was due to the effect of culling cows from the groups after the first lactation, leading to a relatively select group in the older age groups. Lush and Shrode (1950) showed similar effects of concurrent selection on factors derived by this method and showed that the Kendrick factors tend to overcorrect the records of cows past 10 years of age.

Paired-lactation method

The effect which selection has on the cross-comparison method was first circumvented by Sanders (1929). In developing mature-equivalent factors he compared consecutive lactations of the same cows. This method has become known as the paired-lactation method and has been used by Ward and Campbell (1938), Dickerson (1940), Gaines et al (1947), Lush and Shrode (1950), Mahadevan (1951), the American Jersey Cattle Club (1952), and Hickman and Henderson (1955), in developing factors.

Hickman (1955) and the American Jersey Cattle Club (1952) have shown a weakness in developing mature-equivalent factors by the paired-lactation method in that no records of cows which are culled on their first lactation are included in the calculations. Seath (1940), in studying culling habits of Iowa and Kansas herd owners, showed that considerable culling of two and three year olds was practised. This practice of culling cows before their second lactation, them, may cause a bias in this method.

Lush and Shrode (1950) and Hickman (1955) concluded that the true mature-equivalent factors lie somewhere between those developed by the cross-comparison method and those developed by the paired-lactation method.

Regression Equations

Regression equations have been discussed by Ward and Campbell (1938) and Mahadevan (1951). Ward and Campbell worked with New Zealand Jersey records and developed regression equations. For example, the equation developed for correcting a two year old Jersey record was $X = 167.2 + 0.6073Y$ where X equals the mature-equivalent in pounds of butterfat and Y equals the actual butterfat production. These workers, although recognizing the difficulty of using such factors, compared them with multiplicative factors and found the regression equation to be more accurate. Contrary to this, in comparing types of factors, Mahadevan (1951) concluded that regression equations were unsatisfactory as they included environmental effects.

Production Indexes

Only limited attention has been given to the use of index factors as a measure of the difference between an actual production record and the expected or average production of cows of the particular age and breed. Such a system is used in comparing records under the Canadian Record of Performance Testing Service. This system is known as B.C.A. (Breed Class Average). For example the B.C.A. for Canadian Holsteins calving at 36 months of age and being milked twice daily is 10,670 pounds of milk. A Holstein calving at this age with a twice a day milking record of 11,000 pounds of milk would be given an index of 103 calculated by $\frac{11,000}{10,670} \times 100$.

Comparison of B.C.A. and multiplicative factors

Berry (1953) stated that B.C.A. was readily applicable in making comparisons of individual records and in sire analysis work. He claimed this system was advantageous over mature-equivalent factors in that it avoided showing, in addition to an actual production record, a mature-equivalent record which the cow did not actually produce and which she perhaps did not produce when mature. He stated that it also circumvented the criticism common of multiplicative factors in that they are inaccurate for very high and very low records. Berry believed that the outstanding characteristic of index factors was the simplicity with which they may be used and the ease of comparing a record of one cow with those of other cows.

Hickman (1955) however stated that this very easy comparison of one cow with another was a weakness of the

D.C.A. system as it could lead to hasty conclusions about the producing ability of a cow when actually the differences were due to environmental influences. He agreed that D.C.A. figures were easier to work with but pointed out that the D.C.A. and multiplicative methods, when the multiplicative factors have been developed by the cross-comparison method, were actually very similar and were subject to the same biases since they were derived from the same age group production averages.

Age Interval Used in Correction Factors

The accuracy of age-correction factors is influenced by the length of age interval which is corrected by each factor. In some cases, the same factor is used to correct records of all cows calving within a 12 month range in age. Lush and Shrode (1950) showed that factors which corrected records of two, three and four year olds in this way were too generous to the senior animals in the two and three year old groups.

The American Jersey Cattle Club (1952), upon reviewing factors which they had used prior to 1952 and which were based on age intervals of six months, concluded that the long intervals resulted in inaccuracies, particularily at the younger ages. A one month interval is now used with most factors for greater accuracy.

Lush and Shrode (1950) suggested that age corrections would be more accurate if different factors were used for first and second calf records during the ages when both are present in appreciable numbers. This age was shown to be about 34 months in the group of Holstein records studied.

Genetic and Environmental Evaluation

Many research workers, including Henderson (1949, 1958), Robertson and Rendel (1950), Berry (1954), Hickman and Henderson (1955), New Zealand Dairy Board (1958), and Searle and Henderson (1959), have been interested in the use of production records in appraising sires, particularly in view of the very rapid expansion of artificial insemination. Some of these workers have attempted to develop methods of eliminating or equalizing environmental effects in order that record differences may reflect differences due to genetic influences. Hickman (1955) stated that the records must be expressed as a deviation from the herd average before anything meaningful results in terms of breeding value.

Searle and Henderson (1959) and the New Zealand Dairy Board (1958) each developed a method of converting an immature record to a mature-equivalent by factors dependent on the level of the age-corrected herd average production.

According to the method proposed by Searle and Henderson (1959) the record of a cow in the youngest age group, 19 to 27 months, would receive an addition of 80 pounds of butterfat if it was in a herd with an average butterfat production of 300 pounds but would receive a 128 pound addition if the herd average was 500 pounds. This is in line with their contention that correction factors should reflect environmental differences from herd to herd and year to year.

Genetic evaluation of animals is not, in all cases, the primary use made of production records. In programs where the records are used as a measure of both genetic and environmental influences on production, a set of age-correction factors are commonly used which correct all records to a similar extent, regardless of the herd production level. The average mature-equivalent production of the cows in the herd may then be used as a measure of the combined effect of genetic and environmental influences present in the herd.

Season-of-Calving Effects on Production

Working with 68,000 Iowa D.H.I.A. records, Cannon (1933) found that cows calving in June had the lowest milk yield. There was a gradual but consistent increase to the highest group in November with a subsequent decline to June. The earlier work of Wylie (1925) on Register of Merit Jersey records showed no such consistent increase and decrease. The Jerseys which calved in July had the highest average production while those calving in August had the lowest. Those calving in November had the second highest production.

Plum (1935) found from D.H.I.A. records that Iowa cows calving in November, December and January produced on the average 13.6% more butterfat than those calving in May, June and July. He concluded however that month-of-calving was a relativ ly minor cause of variance in butterfat production between cows, it being responsible for only 5% of total variance. Mahadevan (1951) found a 10% difference in production among Scottish Ayrshires in favor of cows calving in the winter over those calving during the summer months.

English Red Polls, Lincoln Reds and Holsteins varied similarily, according to the work of Sanders (1927) who found that on the average, lowest records were produced by cows calving in June and highest by those calving in October, November and December.

Hickman and Henderson (1955) and Branton _et al_ (1958), the first using New York D.H.I.A. records and the second using Louisiana Holstein records, both found season-of-calving a significant influence on level of production.

Michigan D.H.I.A. cows, according to the Annual Herd Summary (1958), showed a marked difference in milk yield with month-of-calving. Among the junior two year olds, those calving in January averaged 9,332 pounds of milk while those calving in May averaged 9,283 pounds. The mature cows showed a similar trend with those cows calving in January producing an average of 11,730 pounds of milk while those that calved in August produced an average of 10,473 pounds.

Studying the lactation curves of Quebec Ayrshires calving at various months of the year, Mercier and Bernard (1934) concluded that the shape of the lactation curve is associated with the changes in length of daylight period.

Fritz (1933), in considering environmental influences on regression factors for estimating 305-day production from part lactations, found that season-of-calving was not an important influence on the relationship of the part to the whole lactation.

A study of Florida Experiment Station Jerseys, by Becker and Arnold (1935), indicated that higher butterfat tests were associated with November, December and January and lower tests with the hotter months of June, July and August. This they showed to be true also on analysis of records from Missouri, Iowa, Tennessee, and Sweden. However, when the average butterfat percentage for the whole lactation was considered, Cannon (1933) found that Iowa D.H.I.A. cows showed only a slight variation with the high being among cows calving in June and the low for those calving in November. Wylie (1925), considering Register of Merit Jerseys, found those calving in July had the highest average butterfat percentage for the lactation while those calving in January had the lowest.

How Season-of-Calving Effects Production

Sanders (1927) found that cows calving in the winter months remained open longer and had longer dry periods than those calving in the summer months. He concluded, as did Dickerson (1940), that the effect of month-of-calving on milk production is associated with periods of poor summer feeding conditions. Sanders suggested that overcoming the poor feeding conditions of middle and late summer would alleviate greatly the seasonal effects on production.

There was a significant correlation between age of cow and month-of-calving in twelve herds of Scottish Ayrshires studied by Mahadevan (1951). He found that a larger proportion of heifers calved in the autumn and winter than in the spring and summer, while calving in the spring seemed to predominate among the older cows.

Sanders (1927) investigated the effect of season-of-calving on high and low producers, and although he noted that high yielding cows drop off more in production proportionately than low yielding cows, he concluded that the same adjustment factors could satisfactorily correct both groups.

As might be expected, Dickerson (1940) showed that persistent producers were less affected by season-of-calving than less persistent producers.

SOURCE OF DATA

The material used in this study was obtained from official R.O.P. (Record of Performance) lactation records on Holstein-Friesian cows from Manitoba, Saskatchewan and Alberta, the three prairie provinces of Canada. The I.B.M. (International Business Machine) cards bearing the information were obtained from the I.B.M. recording center at the Ontario Agricultural College, Guelph, Ontario, through the assistance of the Animal Husbandry Department of that institution. The 11,655 records in the group represented all lactation records from the prairie provinces found in volumes 49, 50, and 51 of the Canadian Record of Performance for Purebred Dairy Cattle, Holstein-Friesian. These three volumes contain all records that were reported during the three year period, May 1, 1955 to April 30, 1958.

The R.O.P. program is operated by the Canada Department of Agriculture through a staff of herd testers. The records used were recorded under two testing procedures, plan A and plan B. Under plan A, the dairyman records the daily weight of milk produced by each cow in the herd and, in addition, an R.O.P. inspector visits the farm one day each month to weigh the milk from each cow and to test a sample for butterfat. Under plan B, the milk is weighed and tested only when the inspector makes the monthly visit and the record is calculated by using the production of this one day.

The I.B.M. cards, which were duplicates of the originals, carried the following information: Record of Performance volume number, herd identification, provincial code number, sire, dam and individual registration numbers, testing plan, age at calving, date of calving before test, times milked per day, days in milk, milk and butterfat production, butterfat percentage and B.C.A. milk and butterfat indexes.

Cards from volume 51 included production totals for both 305-day and complete lactations on all cows that were milked more than 305 days. Records from volumes 49 and 50 included only total production for lactations of up to 365 days in length.

Breed Class Average milk and butterfat indexes were provided on all records, up to 365 days in length, in volumes 49 and 50 but only on lactations of 240 or more days in volume 51. In this latter volume, the indexes had been calculated on the 305-day production rather than on the complete lactation production for records longer than 305 days.

METHOD

There were 312 records among the total of 11,533 that were from cows milked three times a day. They were not used in the study due to the small number involved and the difficulty of converting them to a two-time equivalent, particularily when the actual number of days that they were milked three times per day was not known.

The remaining cards were separated into groups which contained lactation records of various lengths. There were 395 records from lactations of less than 180 days in length, 775 from those of 180 to 239 days, 5,841 from those of 240 to 305 days, and 4,330 from lactations longer than 305 days. Those records which were from lactations of less than 180 days in length were not included in the study in view of the liklihood that many of these records were from incomplete lactations. The actual production records of lactations 180 to 239 days in length were used in the study since, although no doubt some of these records were from incomplete lactations, it was likely that the majority were from lactations which were completed naturally.

There were a total of 10,946 records used throughout the study. Records in volumes 49 and 50 included total production for lactations up to 365 days in length. Those lactations longer than 305 days were adjusted to an estimated 305-day equivalent. This was accomplished by using the factors given in table 1. These factors are the same as those published by the Holstein-Friesian Association of America (1955) with the exception that those published provided a conversion factor of 0.99 to adjust the records of lactations of 306 to 319 days in length.

TABLE 1

FACTORS USED TO CONVERT RECORDS TO 305-DAY EQUIVALENT

Days in Milk	Conversion Factor	Days in Milk	Conversion Factor
306-309	0.99	340-349	0.95
310-319	0.98	350-359	0.94
320-329	0.97	360-364	0.92
330-339	0.96	365	0.90

New B.C.A. milk indexes were calculated on the 305-day equivalents using the class production averages currently used by the Holstein-Friesian Association of Canada (1960). These indexes were also calculated for all records of 100 to 239 days duration in volume 51 as they had not been determined previously.

Therefore, all records used in this study were from cows milked twice a day and, with the exception of those that were adjusted to a 305-day equivalent, were actual production records of lactations of 100 to 305 days in length.

Development of Age-Correction Factors

The lactation records were subdivided into groups according to the age in months of the cow at calving, each group containing records of all of the cows which calved while at one particular month of age.

The milk production records for each group were averaged and the averages were plotted on a graph (figure 1). The resulting curve was smoothed, first by using a moving nine year weighted average and, finally, by sight beyond the 33 month age group. The moving nine year average was weighted on a scale of 1-2-3-4-5-4-3-2-1. The moving average was used in a similar manner by Lush and Shrode (1950). Sight smoothing was used for the same purpose over the total age range by Kendrick (1955) in developing age-correction factors.

The age at which the mature level of production was reached was determined by using a ratio of the production average at a given immature age with that of the average production of the group that calved when they were 12 months older. For example, the production of those that calved at 30 months of age was divided by that of those that calved at 18 months of age with the procedure being repeated for each succeeding month. The assumption was made that the mature level was reached when the ratio reduced to a value of 1.00. The actual point of mature production was taken as the age half way between the two ages which provided the ratio equal to 1.00.

This procedure was followed in determining the mature level of production on the curve after smoothing with the moving average. Age-correction factors were calculated by dividing the mature production average by the average production of the group calving at each month of age. For instance, the correction factor calculated from this curve for records of cows calving at 30 months of age was 1.23, determined by dividing the average production of mature cows, 12,038 pounds of milk, by the average production of those calving at 30 months of age, 9,778 pounds.

The mature production level was also determined on the curve developed by sight smoothing, and a second and final set of age-correction factors was developed using the procedure outlined above.

The final set of correction factors was compared with the Kendrick (1955) factors and the Manitoba (1960) factors. In the first comparison, the three sets of factors were plotted on a graph (figure II). In the second, the three sets of factors were used to calculate the mature-equivalent production from the actual production average for the group calving at each month of age. This comparison is shown in figure III.

In order to have a comparison of the average milk production of cows calving at each month of age as determined in this study with those presently used by the Canadian Holstein-Friesian Association (1960) in determining D.C.A. milk indexes, the two sets of averages were compared as shown in figure IV.

Effect of Season of Calving on Production

The records were divided into 12 groups, each group containing the records of all cows that calved in a particular month of the year. For each group, averages were determined for age at calving, milk production, lactation butterfat percentage, and D.C.A. milk index. The significance of the difference in the average age of cows calving in various months was determined by an analysis of variance and F test.

There were differences in lactation milk production between cows calving in different months. In order to determine whether these differences were significant and whether they followed a similar pattern for various ages of cows, all those cows calving in each month were subdivided into seven groups, according to age at calving, as follows: those that calved at or before 36 months of age, and those that calved between 37 and 48, 49 and 60, 61 and 72, 73 and 84, 85 and 96, and 97 months and older. The average milk production was then calculated for each of the seven age groups calving in each month of the year.

An analysis of variance was performed on the above 84 averages using the unweighted average method to find whether the differences in production with month of calving were significant and to determine whether cows of

different ages responded in a similar manner to season of calving. A further analysis by the same method was made to determine whether there were significant differences between the average production of cows calving in three seasons of the year. For this purpose the months were grouped into three seasons, December to March, April to July, and August to November, three seasons which might be considered to represent winter calving, spring calving, and fall calving,respectively.

RESULTS AND DISCUSSION

Development of Age-Correction Factors

The production records used in the study represented cows which had ranged from 16 to 214 months of age at the time of calving. There were consistently over 100 records for cows calving at each month of age from 24 to 66 months with the highest number of records, 253, being from the group that calved at 28 months of age. There were from 20 to 100 records for cows calving at each month of age from 67 to 115 months while those beyond age 120 months at calving all had less than 20 records and those beyond age 144 months at calving all had less than 10 records. There were 3 records for cows that calved at 16 months of age and this number increased to 97 records for cows that calved at 23 months of age.

The curve developed, in figure 1, from the average actual milk production of the cows that calved at each month of age indicated a consistent trend to increasing milk production with increasing age to approximately 80 months of age. The curve then followed a relatively level plane to 125 months of age after which a gradual decline with age was observed. This general form of curve agreed with the findings of Gowen (1924) who worked with Advanced Registry Holstein-Friesian records. It did, however, indicate later maturity among the cows in this study than

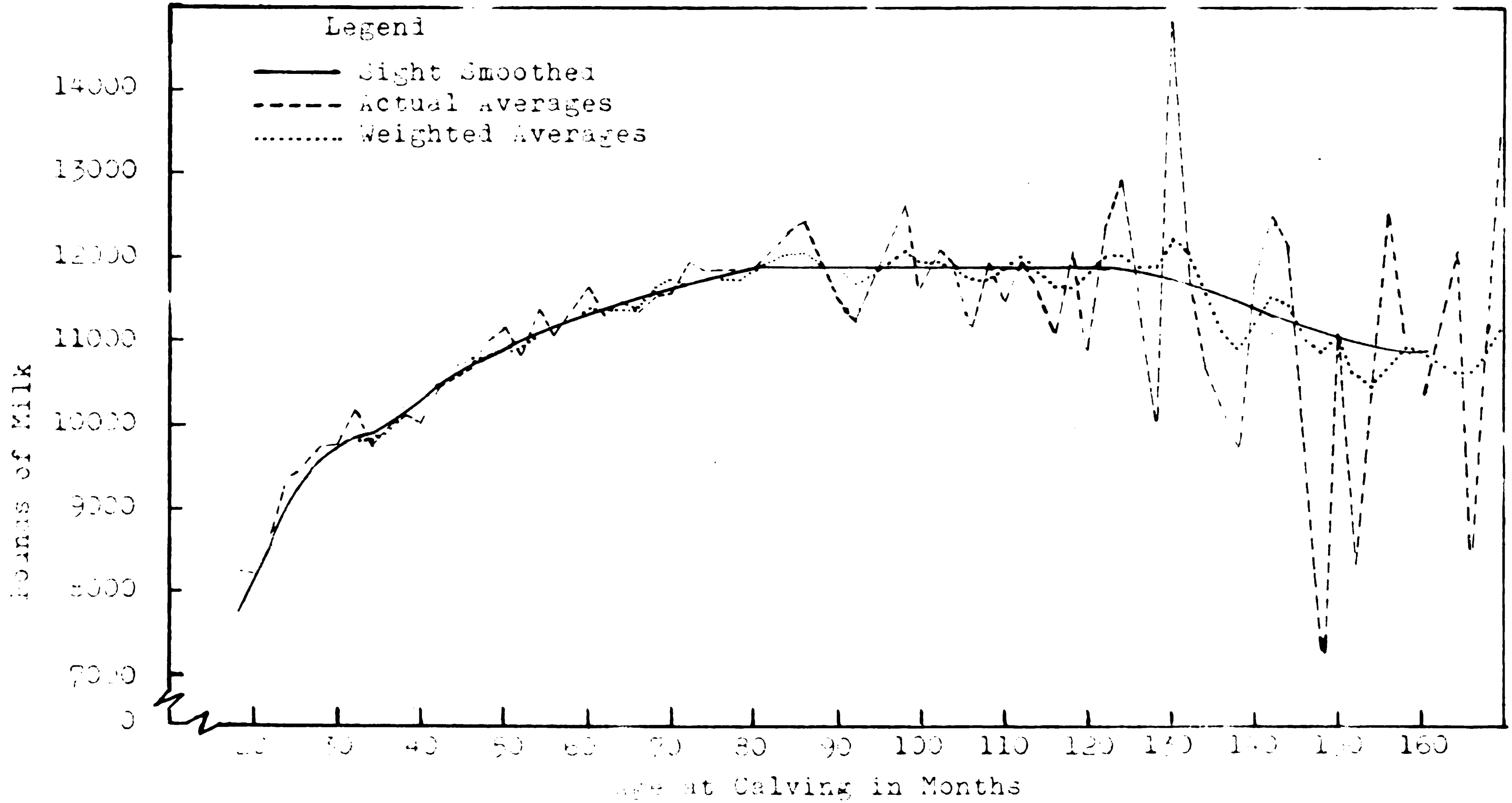

Figure 1 - Three curves of milk production with varying age at calving showing actual average production, weighted average production, and the sight smoothed curve.

the work of Hendrick (1933) who found Holstein-Friesians to be at a mature level of production from 72 to 101 months of age.

Brody (1945) in speaking in general terms of the age-production relationship in dairy cattle stated that "the age curve of milk production (up to seven years) reflects the increase in size of the biological plant which produces the milk. Following age eight years, the decline in milk production reflects the aging process uncomplicated by increase in size in the milk forming plant."

The increase in the size of the "biological plant" to which Brody refers no doubt has reference to the increase in feed and digestive capacity of the cow and the increase in size of the udder and productive capacity of the mammary tissues. These changes are most rapid at younger ages with the result that greater increases in production are observed from first to second than between subsequent lactations. Both body size and milk production increase steadily at a declining rate to maturity. The declining production observed beyond maturing when the "aging process" is taking place is no doubt due to a decreasing metabollic rate and to an increasing susceptibility to low-grade infections and to other ailments.

There were large fluctuations within the curve, particularily at the older ages. The highest average production of all age groups, 14,370 pounds of milk, was found at 150 months, with the lowest, 4,695 pounds, being observed at 136 months of age. It is probable that these large fluctuations among the average production of the older groups of cows were due mainly to sampling effects and to the small number of individuals represented in the group averages. The fact that the group that calved at 150 months of age included only seven records while only one cow calved at 136 months of age supports this statement. A larger population resulting in more records in each age group would probably remove these extreme fluctuations from the curve.

The validity of using the average production of groups beyond 120 months of age to calculate age-correction factors might be questioned in view of the small number of records represented by the averages. They were used however, as a matter of interest, to determine the trend in the age-production relationship at these older ages. The factors from these ages would require further verification before being used.

The age-production curve, in figure 1, was smoothed in order to obtain a curve less subject to the effects of sampling. The moving averages, weighted on the scale of 1-2-3-4-5-4-3-2-1, removed the extreme variations from the curve. The curve developed from the weighted averages did, as shown in figure 1, show a pronounced leveling off at approximately 50 months through to 55 months of age. A similar effect was observed by Lush and Shrode (1950) when studying Holstein-Friesian records.

The reason for this leveling at 30 to 35 months of age is obscure. The age represented by this part of the curve is, however, an age when occurrence of some cows calving with a first calf and others calving with the second calf might be expected. Those calving the second time at this age would be those that calved young the first time and might not have had sufficient time to complete growth and completely regain condition with the result that they would not produce at a level equal to heifers calving for the first time at this age. Such a phenomenon would cause the curve to level off.

The records could not be studied to determine whether this situation did actually exist since the records were not identified as to lactation number. Johansson and Hansson (1940) did conduct such a study on records of Swedish Red and White cows and concluded that cows that calved the second time between three and four years of age yielded less than cows which calved the first time at that age.

There was some tendency also for the curve to continue to show a cyclical effect with some leveling being observed at 46 to 50 months of age and again at 60 to 64 months of age. The former could perhaps be due to a similar effect from a combination of cows calving with second and third calves, and the latter, although less likely, to a combination of third and fourth lactations.

The age-correction factors developed from the weighted averages provided a factor of 1.56 for correcting records of heifers calving at 19 months of age, with subsequent factors decreasing steadily with increasing age to six years. From this age on, however, the factors fluctuated considerably. The records of those cows calving at 96 and 122 months of age would receive no correction, according to these factors, while those of some cows calving between these ages would be corrected by 1.05. Similarly records of cows calving at 137 months of age would be corrected by 1.09 while those of older cows calving at 142 months of age would be corrected by only 1.04.

According to the work of Castell (1930) and Kendrick (1955), a range of two to two and one-half years at mature ages during which time no adjustment would be made on the records, might be expected. This period is usually followed by a consistent decline in production with a simultaneous increasing in the size of age-correction factors.

Further smoothing of the weighted average curve was considered necessary due to the cyclical effect at immature ages and to the irregular fluctuations of the curve at mature and older ages. Consideration was given to fitting polynomials or developing an equation for the curve. The conclusion was reached that sight smoothing, similar to that used by Kendrick (1955) and Lush and Shrode (1950), would be equally accurate and more readily applied. The curve was smoothed only beyond the 55 month age group as the nature of the curve to this age was so pronounced there appeared to be little justification for altering it.

The final age-correction factors, given in table 11, decrease consistently with age to 76 months. No correction is made on records from cows calving between 77 and 123 months of age while, beyond 123 months of age, the size of the factors increases steadily with increasing age at calving.

Determining Mature Production Level

The ratio which was used to indicate the age at which the cows reached maturity was that of the average milk production at a given immature age with the average production of the group of cows 12 months older. This technique is similar to that used by Lush and Shrode (1950) for the same purpose. This ratio was used on the assumption that the calving interval of the cows was approximately 12 months and that the ratio was, in part at least, a comparison of the production of the same group of cows in two successive lactations. This comparison would not, seemingly, be handicapped by the inclusion of records of many cows which did not have records in both groups since it would still be primarily a comparison of the production of cows of different ages, one group being 12 months older than the other.

Since the ratio provided such a comparison, the age

TABLE 11

AGE-CORRECTION FACTORS DEVELOPED FROM THE SIGHT SMOOTHED CURVE

Age	Factor	Age	Factor	Age	Factor
18	1.54	54	1.07	133	1.02
19	1.51	55	1.07	134	1.02
20	1.47	56	1.07	135	1.03
21	1.43	57	1.06	136	1.03
22	1.39	58	1.06	137	1.03
23	1.36	59	1.06	138	1.04
24	1.32	60	1.05	139	1.04
				140	1.04
25	1.29	61	1.05	141	1.05
26	1.27	62	1.05	142	1.05
27	1.25	63	1.04	143	1.05
28	1.24	64	1.04	144	1.06
29	1.23	65	1.04		
30	1.22	66	1.03	145	1.06
31	1.21	67	1.03	146	1.07
32	1.21	68	1.03	147	1.07
33	1.20	69	1.02	148	1.07
34	1.20	70	1.02	149	1.08
35	1.19	71	1.02	150	1.08
36	1.19	72	1.02	151	1.08
				152	1.08
37	1.18	73	1.01	153	1.08
38	1.17	74	1.01	154	1.09
39	1.17	75	1.01	155	1.09
40	1.16	76	1.01	156	1.09
41	1.15				
42	1.14	77 to		157	1.09
43	1.13	123	1.00	158	1.09
44	1.12			159	1.10
45	1.12	124	1.01	160	1.10
46	1.11	125	1.01	161	1.10
47	1.11	126	1.01	162	1.10
48	1.10	127	1.01	163	1.10
		128	1.01	164	1.11
49	1.10	129	1.01	165	1.11
50	1.09	130	1.02	166	1.11
51	1.08	131	1.02	167	1.11
52	1.08	132	1.02	168	1.11
53	1.08				

of mature production was reached when the ratio decreased to 1.00 which would mean that the level of production in the lactation of the younger group became equal to or greater than the production of the group 12 months older. The actual point of mature production was considered to be at the age half way between the two ages involved in the comparison which gave the ratio equal to 1.00.

The ratio decreased to a value of 1.00 on the weighted average curve at 78 months of age and on the eight smoothed curve at 77 months of age. The actual level of mature production was considered to be 84 months, or 12,030 pounds of milk, for the first and 83 months, or 11,900 pounds of milk, for the final curve.

The ratio values were recalculated using a 14 month interval in view of the possibility that the average calving interval of the cows in the study was more than 12 months. This longer interval made no difference on the final smoothed curve but the ratio did decrease to a value of 1.00 one month earlier on the weighted average curve. The point of mature production level remained the same, however, since the point half way between the two points in the ratio, 77 and 91 months, was still 84 months as with the 12 month interval.

The age-correction factors developed in this study were developed by the cross-comparison method. The objective of this study was to develop factors which could be used to correct D.H.I.A. records for age and, while making this adjustment, to provide mature-equivalent production records which may be used as a measure of the total influences on production, both genetic and environmental. One alternative method of developing such factors is the paired-lactation method in which consecutive records of the same cows are compared in order to determine the increase in production with increasing age. This method would have been preferred but it could not be used in this study since the records used did not reveal the lactation number which the record represented and further, because no cow had more than three records included in the study and the majority had only one or two. The biases and weaknesses inherent in each of these methods have been discussed in an earlier section.

A Comparison of Age-Correction Factors

A comparison of the Kendrick age-correction factors, the Manitoba correction factors and the final factors developed in this study is shown in figure 11.

The factors developed in this study are very similar to those developed by Kendrick (1953) from 284,538 Holstein-Friesian records. The two sets of factors are not more than 0.04 different at any age. They are very close to being the same at the younger ages with differences being not more than 0.02 at any calving age up to 48 months. These younger ages are the most critical so far as correction for age is concerned in view of the large proportion

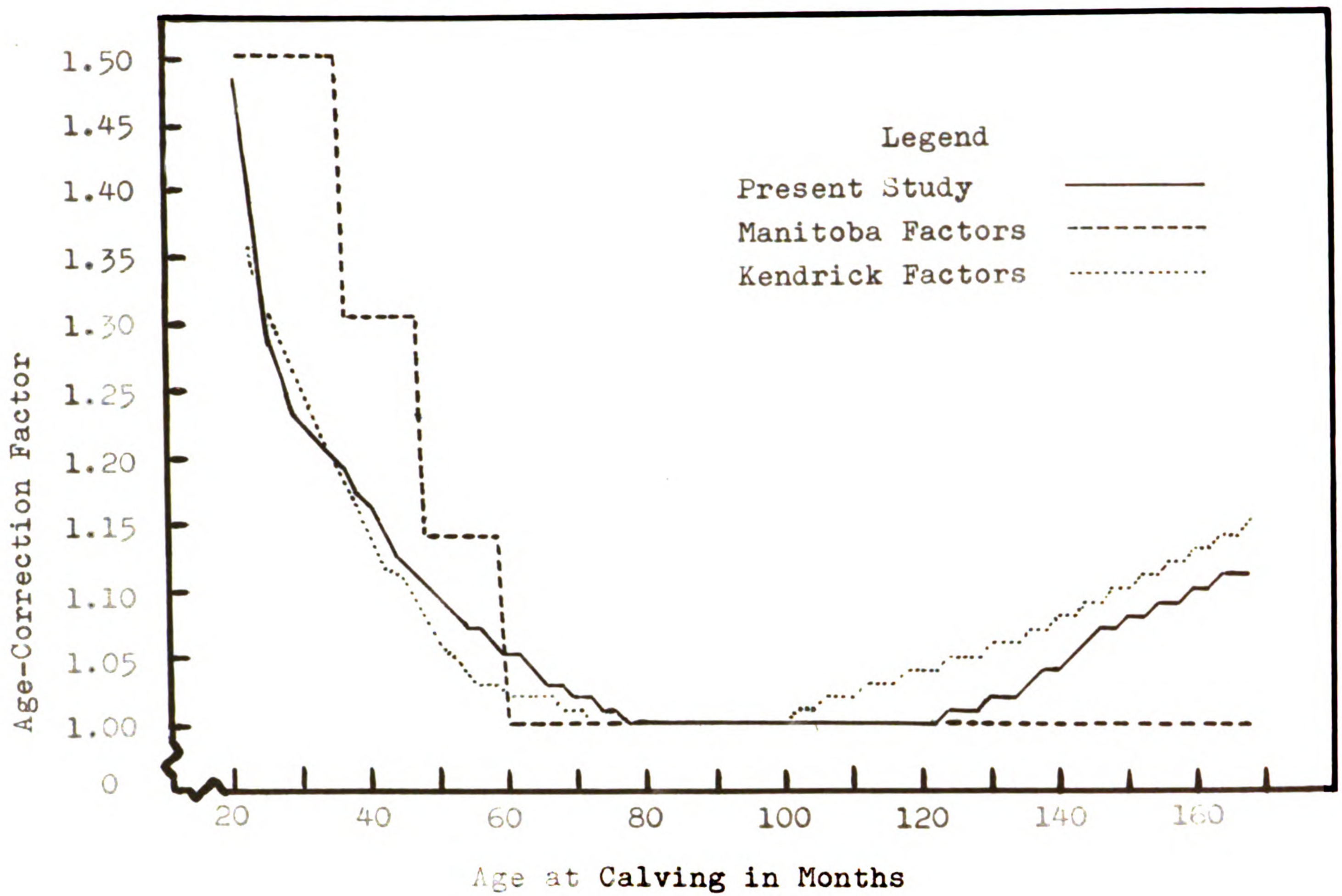

Figure 11 - A comparison of three sets of age-correction factors: present study, Kendrick, and Manitoba.

of the producing cows that are included in these younger groups.

The Kendrick factors, as indicated in figure 11, are more generous than the factors developed in this study at ages beyond maturity. This was also found by Lush and Shrode (1950) when comparing the earlier Kendrick (1941) factors with factors which they had developed by the paired-lactation method. No conclusion can be drawn from such a comparison of the factors beyond mature age in this study however since the average production of the groups beyond 120 months of age at calving represent few records. The difference between the two sets of factors is not large even at these older ages. The maximum difference of 0.04 between the two sets of factors is shown to be the equivalent of 475 pounds of milk when the average production of the cows calving at each month of age is corrected for age using the two sets of correction factors. This comparison is shown in figure 111.

The Manitoba factors, which correct records of two, three, and four year olds on the basis that they are 67, 77, and 88% of mature production respectively, have much greater differences than the Kendrick factors from the factors developed herein. The largest difference between the factors occurs at 34 months of age where the Manitoba factors are 0.29 larger. This difference, when expressed in terms of pounds of milk, (figure 111), amounted to 2,911 pounds. This is a very sizeable difference. A probable

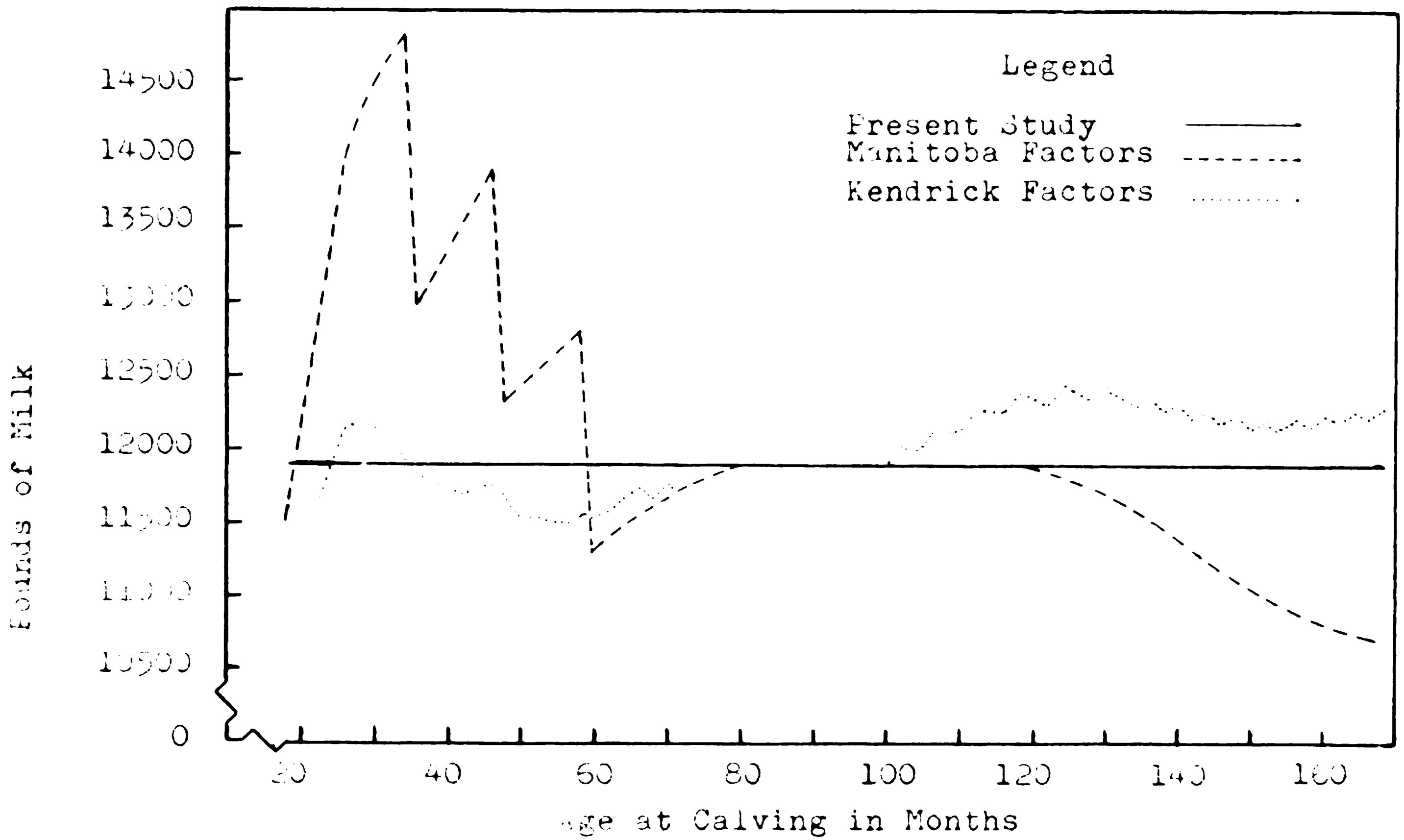

Figure 111 - The average milk production of cows calving at various ages corrected to mature equivalents using three sets of age-correction factors.

conclusion would be that the Manitoba factors, while being too generous over the whole three year period which they correct, are clearly much too generous in correcting records of cows that calve toward the end of the 12 month period corrected by each factor.

The fact that they are too generous over the whole three year period and particularly toward the end of the 12 month periods is illustrated by using the two year old factor, 67%, or 1.49 when expressed as a multiplicative factor, to convert the average production of 24 and 34 month groups to their mature equivalents. The mature-equivalent production, when this factor is used, is 13,432 pounds of milk for the group calving at 24 months of age and 14,011 pounds of milk for the group calving at 34 months of age when in fact, according to this study, the mature equivalent of these records should be 11,900 pounds in both cases.

The comparison, shown in figure IV, of the average production of the cows calving at each month of age determined in this study with the average used by the Canadian Holstein-Friesian Association (1960) in determining B.C.A. milk indexes, indicated that there was very little difference between these two sets of averages. The averages from this study were slightly higher from two to four years and again at ages beyond eight years. The Association averages were, however, slightly higher between 4 and 6.5 years of age. The mature production level for the Association

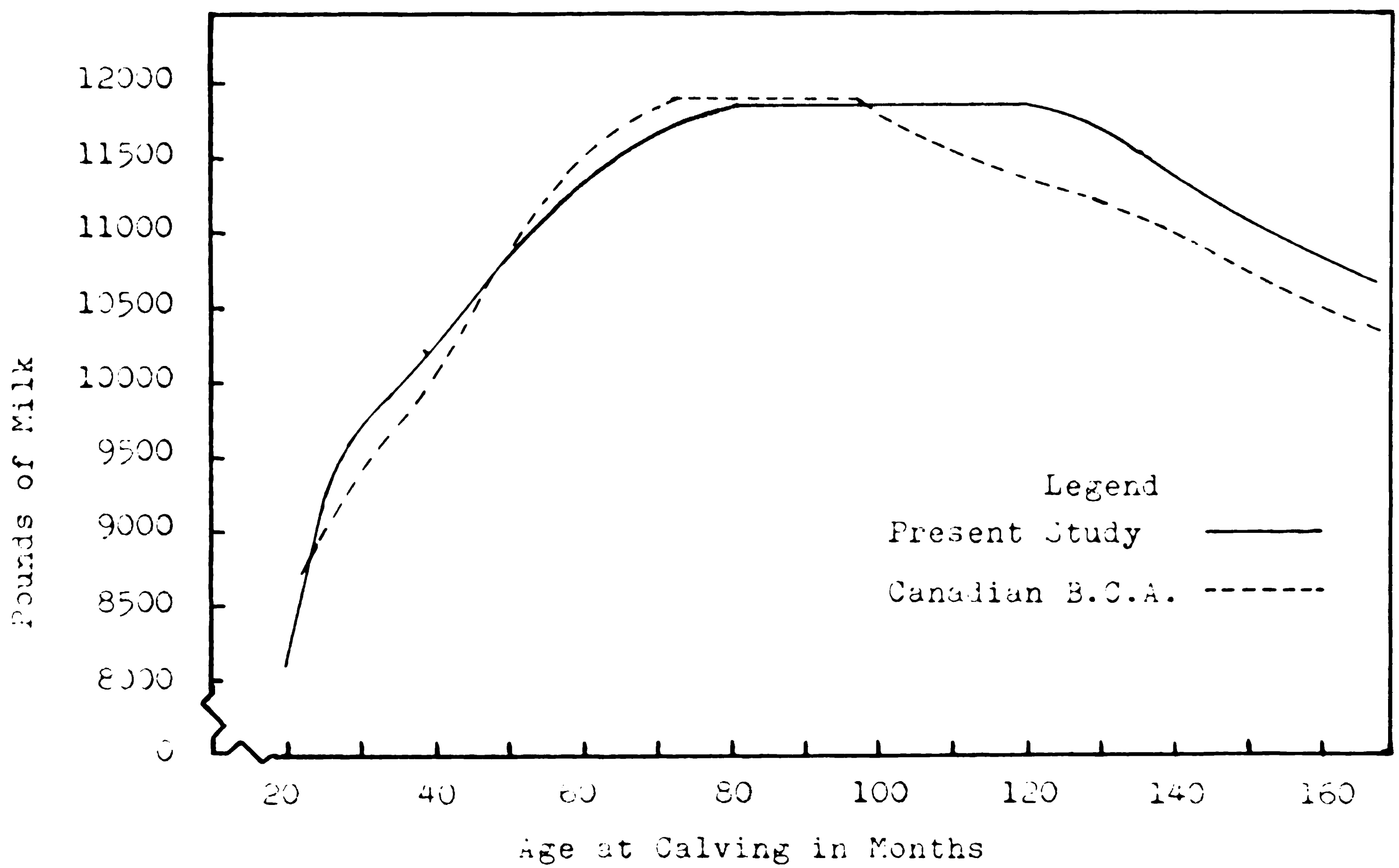

Figure 17 - A comparison of calculated milk production averages with Canadian Breed Class Averages.

(1960) averages, which were derived from records of Holstein-Friesian cows located in all parts of Canada, is 11,903 pounds of milk, a figure almost identical to the mature production level of 11,900 pounds determined for the group of records studied.

In assessing this comparison it is necessary to recognize that a trend to increasing production over time would favor those averages developed in this study since they were developed from 1955-58 records while the Association averages were developed from records made three and more years earlier. This advantage would exist if the average production of Western Canadian Holstein-Friesian cows has increased gradually due to improved breeding and environment and to more intensive culling. This no doubt has occurred but the extent to which it has taken place is undetermined, although only small changes in the average production of the population would be expected in such a short period of time.

Effect of Season of Calving on Milk Production

The influence of season of calving on milk production was considered in this study in view of the possibility that it had confounded the age-production relationship found in the records studied. This appeared to be a possibility since Mahadevan (1951) found a relationship between milk production and month of calving as well as between age at calving and month of calving.

The average milk production, age at calving, B.C.A. milk index and lactation butterfat percentage for those cows calving in each month of the year are shown in table 111. Very little variation was evident in lactation butterfat percentage. It showed no consistent relationship with month of calving as it ranged from a low of 3.50% for cows that calved in June and December to a high of 3.57% for cows that calved in October.

TABLE 111

RELATIONSHIP OF AGE, MILK PRODUCTION, BUTTERFAT PERCENTAGE AND B.C.A. MILK INDEX, TO MONTH OF CALVING

Month of calving	Number of records	Average age at calving (mos.)	Average milk prod. (lbs.)	Average B.C.A. milk index	Average butterfat (%)
January	1023	57.23	10,930	102.07	3.52
February	836	59.71	10,813	99.51	3.51
March	889	60.78	10,853	99.46	3.52
April	800	63.94	10,695	97.61	3.52
May	531	64.26	10,630	96.71	3.53
June	558	62.66	10,568	97.15	3.50
July	679	58.27	10,236	95.59	3.54
August	958	54.34	10,385	96.56	3.53
September	1129	53.86	10,531	99.08	3.55
October	1137	53.45	11,013	104.49	3.57
November	1139	56.87	11,188	104.49	3.54
December	1167	57.81	11,081	102.87	3.50

The average B.C.A. milk index and the average milk production with month of calving showed a very definite trend toward higher milk production for cows calving in October and November with a fairly constant decline to those calving in July. Figure V illustrates this relationship. Those cows calving in the month of November produced the largest amount of milk, 11,138 pounds, while the production of cows calving in subsequent months declined almost consistently to the month of July in which the average production was 10,236 pounds.

Observation of the average age of cows calving in each month, shown graphically in figure VI, indicated that there was also some relationship between age of cow and month of calving. The youngest group calved in October while the average age of those cows that calved in each month increased steadily to the month of May. There was an apparent tendency for younger cows to calve in the fall and older cows to calve in the spring.

The differences between the average age of cows that calved in different months was statistically significant as shown in table IV.

TABLE IV

ANALYSIS OF VARIANCE OF THE AVERAGE AGE OF COWS CALVING IN EACH OF THE 12 MONTHS OF THE YEAR

Source of variation	Degrees of freedom	Mean square
Total	10,945	
Between month	11	6,335.9 **
Within month	10,934	761.51

**Significant at 1% level.

These differences may be due to a conscientious

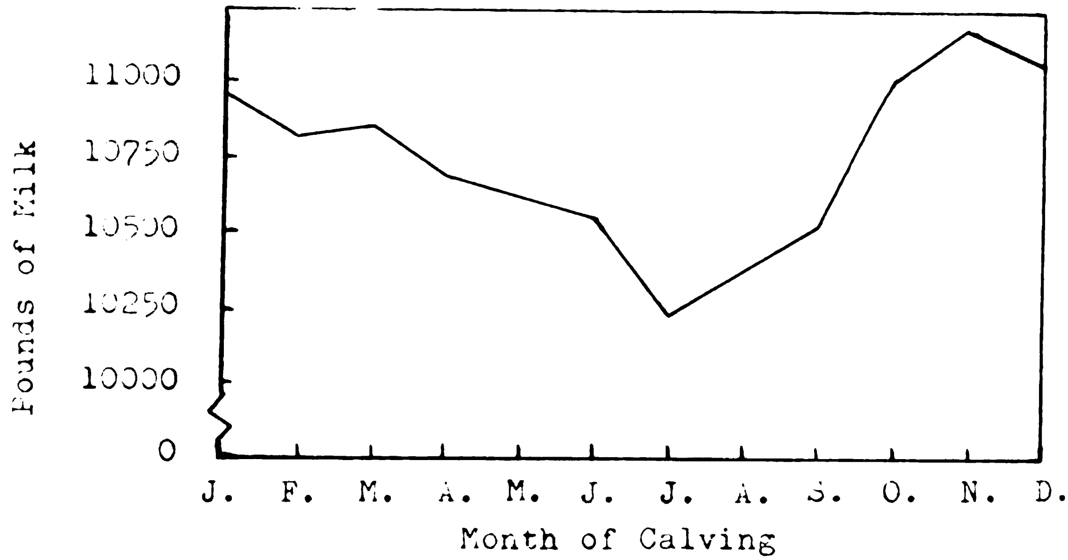

Figure V - Average milk production of cows calving in each month of the year.

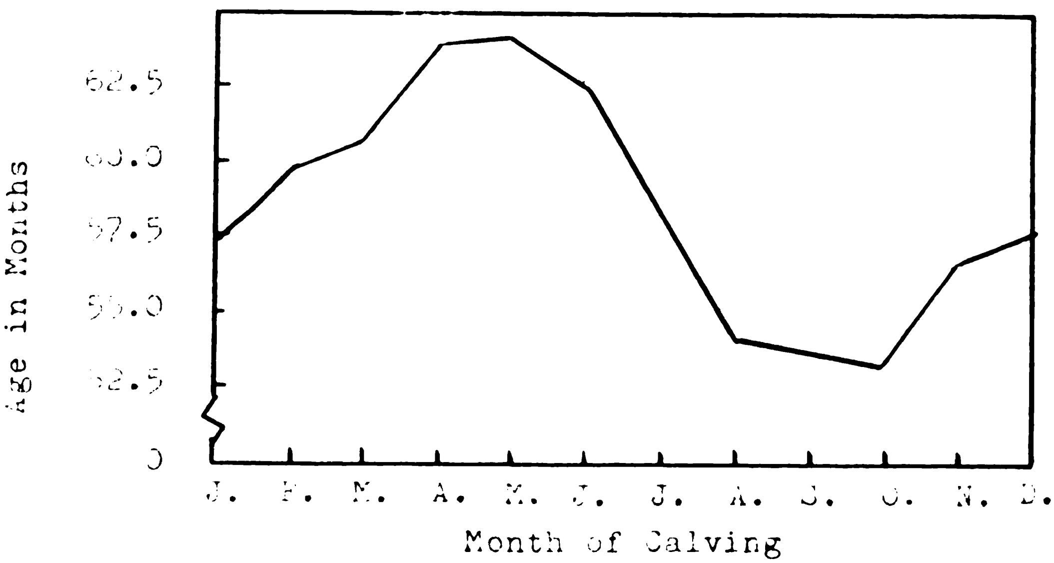

Figure VI - Average age of cows calving in each month of the year.

effort by dairymen to breed heifers to calve in the fall. The heifers, which first calved in the fall, would probably tend to calve later each year, due to a calving interval of more than 12 months, with the result that with increasing age, they would calve closer to spring.

The group of cows that calved in each month of the year was subdivided into seven groups according to age at calving in order to determine whether cows of all ages responded in a similar manner to month of calving. The average production of each group was determined and is shown in table V. The influence of month of calving on milk production is similar in extent on cows of all ages.

TABLE V

AVERAGE MILK PRODUCTION OF COWS OF SEVEN AGE GROUPS CALVING IN EACH MONTH OF THE YEAR

Month of calving	Months of Age at Calving: up to 36	37-48	49-60	61-72	73-84	85-96	97-over
	Hundreds of pounds						
Jan.	95	108	112	116	125	121	120
Feb.	94	105	111	115	125	114	117
Mar.	95	103	107	118	120	118	118
Apr.	93	102	109	112	111	122	115
May	92	102	107	111	113	116	114
June	92	97	109	115	113	116	116
July	91	98	107	108	118	110	110
Aug.	96	101	104	111	114	120	116
Sept.	95	102	110	114	119	119	122
Oct.	102	109	114	118	118	117	123
Nov.	100	109	116	121	121	121	120
Dec.	99	107	114	119	121	121	118

The analysis of variance, by the unweighted average method, and the F test of the relationship between milk production and month of calving showed that there was a significant difference between the amount of milk produced by cows calving in various months of the year. This analysis is shown in table V1.

TABLE V1

ANALYSIS OF VARIANCE OF THE AVERAGE MILK PRODUCTION OF COWS CALVING IN EACH OF THE 12 MONTHS OF THE YEAR

Source of variation	Degrees of freedom	Mean square
Age	6	8,274,804
Month	11	636,197**
Age x month	66	58,265
Within age and month	10,862	57,250

**Significant at 1% level

The average production of those cows calving in November was significantly greater than that of cows calving in all other months with the exception of October and December. The production of those calving in July was significantly lower than that of all other months with the exception of August.

There was a significant difference between the average milk production of cows calving in three seasons, winter, spring and fall. The seasons included the months December through March, April through July, and August through November, respectively. These differences were statistically significant as shown in table V11.

TABLE V11

ANALYSIS OF VARIANCE OF THE AVERAGE MILK PRODUCTION OF COWS CALVING IN THREE SEASONS OF THE YEAR

Source of variation	Degrees of freedom	Mean square
Age	6	2,252,561
Season	2	5[illegible],078**
Age x season	12	15,724
Within age and season	10,925	12,212

**Significant at 1% level.

There was no significant difference between the average production of cows calving in the fall and winter but the average production of each of these two groups was significantly greater than the average of those cows calving in April, May, June and July.

These differences in milk production with season of calving were perhaps to be expected although such differences have not been shown to exist in records of cows on all parts of the continent. Hickman and Henderson (1955), who worked with New York D.H.I.A. - I.B.M. records and who divided the year into three seasons by grouping the months of December through March, April through August, and September through November, found a marked seasonal variation in lactation records. Sanders (1927), working with the records of several dairy breeds in England, found effects of season of calving similar to those found in this study.

Sanders suggested that the decreased production observed among cows calving in the spring and early summer was a reflection of poor summer feeding conditions. This is probably still true today. More facts about this possible cause could be revealed by a study of lactation records accompanied by a detailed set of feed intake records. Hot summer weather and insects undoubtedly also play a part in this effect of season of calving. Careful management of pastures and other aspects of husbandry during the summer months would alleviate the seasonal effect considerably.

Although there were significant differences between the average age of cows and the average milk production of cows calving in various months of the year, it was concluded that these relationships had not confounded the age-production relationship. This conclusion was reached after comparing the value of two ratios.

The first was a ratio of production averages which would not reflect the unequal distribution of calving of cows, of a particular age, among the various months of the year. This was accomplished by determining the average production of all cows of a particular age which calved in each month of the year thus providing 12 means, (table 7) each of which represented the average milk production of cows of a particular age which calved in a particular month of the year. The average of the 12 means was calculated for two age groups, those cows up to 36 months of age at calving and those 73 to 84 months of age at calving. Each of the two averages would be free of the effects of the unequal distribution mentioned above. The ratio of these two averages then, too, would be free of this effect.

The second ratio was one of the average production of all cows calving up to 36 months of age to that of all cows that calved between 73 and 84 months of age, regardless of the month of calving. This ratio would reflect the effect of an unequal distribution of the calving of cows, of each age, among the months of the year if such an effect existed. The two ratio values proved to be equal so one could conclude with reasonable certainty, that the effect of season of calving had not influenced the age-correction factors developed in this study.

SUMMARY

The milk production records of 10,946 Western Canadian Holstein-Friesian cows have been studied to determine the influence of age at calving on milk production and to develop factors that may be used to correct for this effect. The study also involved determination of the influence of season of calving on milk production.

Multiplicative age-correction factors were developed using the cross-comparison method with production averages determined from the age-production curve. The curve had been smoothed by a nine year moving weighted average and by sight. The factors developed were compared with the Kendrick, and Manitoba factors. The average production of cows calving at various ages was compared with the Canadian Holstein-Friesian Association Breed Class Averages.

CONCLUSIONS

The cows included in this study produced at a maximum level between 81 and 119 months of age.

Age-correction factors developed from the age-production curve were very similar to the Hendrich factors. Differences were so small that it would seem records of Western Canadian Holstein-Friesian cows could be corrected using either set of factors with equal accuracy.

The factors presently used in adjusting Manitoba D.H.I.A. records for age were found to be too generous over most of the three year age range in which they are used. Greater accuracy would apparently be attained by decreasing the range of age corrected by one factor from 12 months to a shorter period.

Cows calving in November produced 9.5% more milk than cows calving in July while those cows calving in the spring season produced significantly less than those calving in either the fall or winter. Cows calving in May were, on the average, 11 months older than those that calved in October.

The age-correction factors developed in this study were not confounded by the relationship of milk production and age at calving with month of calving.

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