A STUDY OF METHODS FOR ESTIMATING MILK PRODUCTION IN RANGE BEEF COWS AND FACTORS ASSOCIATED WITH THE MILK PRODUCTION ESTIMATE

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Bachelor of Science

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Lafayette, Indiana

1967

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1971

A STUDY OF METHODS FOR ESTIMATING MILK PRODUCTION IN RANGE BEEF COWS AND FACTORS ASSOCIATED WITH THE MILK PRODUCTION ESTIMATE

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ACKNOWLEDGMENTS

The author wishes to express his appreciation to Dr. E. J. Turman, Professor of Animal Science, for his guidance and counsel during the duration of this study and the preparation of this thesis.

Appreciation is also extended to Dr. Robert Totusek, Professor of Animal Science, Dr. J. E. McCroskey, Associate Professor of Animal Science and to Dr. R. R. Frahm, Assistant Professor of Animal Science for their helpful suggestions and assistance in the preparation of this manuscript.

Grateful acknowledgement is also extended to Dr. J. V. Whiteman, Professor of Animal Science, Dr. R. D. Morrison, Professor of Mathematics and Statistics and to Mr. Byron Brandt, Graduate Assistant in Mathematics and Statistics for their assistance in planning and conducting the Statistical analyses of the data.

A vote of thanks is extended to fellow graduate students for their encouragement and assistance.

The author is extremely grateful to his wife, Beverly, for her patience, sacrifice and encouragement during the course of this study.

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CHAPTER I

INTRODUCTION

The lactational performance of the beef cow has long been recognized as one of the most important factors affecting the weaning weight of her calf. Therefore, in research studies involving beef cows, one important criteria for measuring productivity is the milk production of the dam.

There are three alternative methods that have been used to estimate milk production of the beef cow. The first method is an indirect measure, which relies upon the association of milk production of the dam and growth rate of the calf. A second method, hand or machine milking, involves separating the cow and calf for a period of time, injecting the cow with oxytocin to induce milk let-down, followed by hand or machine milking. The third method, calf-nursing, involves separating the cow and calf for a period of time, weighing the calf, allowing it to nurse and reweighing. The difference between the pre- and post-nursing weights is considered to be the milk production of the dam for the time period during separation.

The first method is advantageous in that it is suited for handling large numbers of cows and calves. Further, the cow and calf are not separated, therefore, are not subject to stress resulting from separation. The method is criticized because it does not provide samples of milk for constituent analysis and its accuracy is dependent upon the degree to which the calf relies upon supplemental feed for nutrients. The second method provides samples of milk for analysis, however, it creates an added stress upon the cow and calf due to separation along with having to restrain the cow to take the estimate. The stress is probably detrimental to growth rate of the calf as well as milk production of the dam during the period of estimation. The third method, calf-nursing is advantageous in that it is suited for handling large numbers of cows and calves and, because calves are allowed to nurse their dams, it does not create stressful conditions to the extent of method two. Its disadvantages include, no samples of milk for constituent analysis, errors may be introduced due to defecation and urination between weighings and very young calves may not be physically able to consume all of their dam's milk. The latter criticism may be important especially with dams having the potential for high milk production and when the interval between nursings is long.

Of the three methods, the calf-nursing is probably the most widely used in research studies. Thus, this study was initiated to compare the milk production estimate taken at either two or three times during a 24-hour period of cows with two different potential milk producing abilities. A further objective was to determine the magnitude to which various factors affect the daily milk production estimate of range beef cows.

CHAPTER II

LITERATURE REVIEW

Research work in the area of milk production of beef cattle has been hampered by the lack of a convenient and reliable method of measuring milk production in the range beef cow. Also, the importance and magnitude of the factors that are associated with milk production in beef cattle are not clearly understood. Thus, it is evident there is a need for an accurate method of measuring milk production in the beef cow and a better understanding of the factors that are associated with milk production in order to facilitate research with the beef cow.

McCance (1959) listed the following three requirements for an accurate method of estimating milk production:

(a) The udder must be emptied to the same degree at the beginning and end of the period of observation;

(b) the technique does not affect the rate of milk production while it is being applied;

(c) the rate of milk production during the period of observation is the same as for the other period to which the estimate will be referred.

Sere Del Campo (1946) suggested that the most accurate methods of calculating yield are (a) those in which the records are considered to be in the middle of the period whose yield for the period in question is calculated from the average between two successive recordings.

Owen (1957) reported that the best way for studying lactation in sheep and its effect on the lamb is by measuring the amount of milk consumed by the lamb. Barnicoat et al. (1949) stated that the most accurate and satisfactory measure of milk yield of ewes is presumably that amount which is made available to the lamb and any alternative method used must be judged by its approximation to this standard.

Factors Affecting the Milk Production Estimate

Sere Del Campo (1946) reported on various factors affecting the variance in milk recordings. In descending order of importance the factors are as follows: individual differences between cows; the method of calculating yield from records; the time in relation to calving at which records are begun; and the frequency with which the records are made. The remainder of the variance is almost entirely accounted for by the interaction between the above factors. The time in relation to calving at which recording is begun depends upon the number of days of the cow's lactation which have already elapsed at the time the record is taken; it is, therefore, intimately connected with the frequency with which recordings are made. It was found that the influence upon accuracy made by the time at which records were begun was relatively small unless the interval between recordings exceeded 42 days. The duration of recordings (24 vs. 48 hours) had no statistically significant influence upon the accuracy of the results.

McCance (1959), working with lactating ewes, reported that milk yield depended on the interval between milkings, the rate of secretion apparently being faster in the first 2 hours. Yield was independent of time of day and speed of milking. By the use of handmilking following the injection of posterior pitiutary extract it was observed that yields based on 2 hour intervals were higher than those based on 4 or 6 hour intervals.

Lakshmanan *et al.* (1958), using dairy cows, reported the effect on milk and milk fat production of frequent milking with the aid of oxytocin. When the cows were milked at 2 hour intervals, the average daily milk production was increased and fat percent in the milk was reduced for the high producers. Following return to twice a day milking, the milk production returned to normal, but there was an over compensatory increase in fat percent. It was found that the moderate producers among the cows showed no significant changes in milk production, or fat percent. The response of the high producers was believed to reflect the effect of intramammary pressure on fat uptake by the mammary gland and on the rate of milk secretion.

Peterson and Rigor (1932) reported that physical pressure in the udder exerts a marked influence upon the rate and character of milk secretion and indicated that osmotic pressure may play an important role in milk secretion. These workers found that the concentration of solutes affects both the character and amount of secretion. The depressing effect on milk secretion is in direct proportion to the solute concentration in the mammary gland.

Konkoly and Barczy (1954), using dairy cows, compared the milk production of cows which suckled their calves and that of cows milked without suckling. Cows suckled their calves three times daily for 10 weeks and twice daily for a further 6 weeks; once per week the calves were weighed before and after nursing and the amount milked was added to the difference. The average daily production was higher for those cows that were milked without suckling. There were greater fluctuations in the yields of the cows that suckled than in those cows that did not suckle their calves. Swanson et al. (1956) reported similar results using identical twin cows.

Cartwright and Carpenter (1961) studied the nursing habits of Hereford bull calves and Brahman X Hereford F_1 bull calves of similar ages. It was observed that the average diurnal nursing frequency and duration was greater for the crossbreds (4.2 times and 38.0 minutes) than for the Herefords (3.5 times and 28.7 minutes). There appeared to be no breed differences in time of day when nursing occurred.

Lactation Curves

Turner et al. (1923) working with a herd of Holstein cows, reported that 50% of the cows reached a maximum milk production of 37 pounds daily within 15 days after parturition, 40% reached a maximum daily production of 51.5 pounds within 19 days, whereas 10%, which finally gave a maximum of 83 pounds of milk per day, did not reach their peak production until 28 days after parturtion. After 30 - 50 days of lactation, the production began to decline gradually and continued downward until the end of the lactation period.

Brody (1945) confirmed the findings of Turner et al. (1923) that the time required for high producing animals to reach maximum production is usually longer than that for low producing animals. Waite and White (1956) showed that milk yields of dairy cows were at their peak 45 days after calving and then declined regularly to the end of lactation.

Cole and Johansson (1933) reported the milk yield and composition from seven purebred Angus cows fed and managed in the same manner as dairy cows. The lactation curve reached its peak at 4 weeks and decreased regularly thereafter until lactation ceased at 44 weeks. The Angus cows had a larger percentage of the total lactation yield in the first 20 weeks, but were not as persistent in lactation as Holstein cows.

Klett (1963) reported that in fall calving beef cows maximum milk production was reached about 77 days after parturition, a somewhat longer period than that reported by other workers. The data showed a steady decrease in milk production for the first 50 days followed by a gradual increase for the next 27 days. The following 70 days showed slight fluctuations, then a steady decline until the end of lactation.

Rakes <u>et al</u>. (1959), working with Holstein and Jersey cows, found that older cows required longer intervals to reach peak production.

Gifford (1953) reported that the maximum milk production of beef cows was reached during the first month of lactation and declined gradually until weaning. The following exponential curve was formulated which represents the course of lactation of beef cows following the first month after calving.

$$M = 16.32\ (10^{-2308t})$$

where M represents milk production at time t in months. The -2308 is a constant and represents the fractional decline in the time rate of milk secretion for the declining segment of the curve.

The chief difference between this lactation curve and the lactation curve of a dairy cow is the fact that only the declining segment of the curve is represented. Milk production does not follow the increase after the first month of lactation that is normally observed in dairy cows.

Since the reported lactation curve for beef cows, does not follow the norm described for dairy cows, there must be another factor or factors limiting production to a relatively low level during the first segment of the lactation curve. Certainly one factor is the milk-consuming capacity of the calves. If the calves consume only a portion of the milk available and the remainder is not removed from the udder, normal milk secretion can not take place. As pressure increases there is a decrease in the rate of milk secretion. If milk is not removed from the udder, pressure within the udder is created and at certain maximum resorption takes place (Petersen and Rigor, 1932). In the instance of beef cows it is quite evident that the production at any period could not exceed the daily capacity of the calves because the milk remaining in the udder would tend to slow down the secretory process.

Information on the amount of milk calves consume has been reported by a number of workers. Bohstedt et al. (1931) fed Holstein calves on whole milk as the only feed, for veal production. The calves averaged 96.2 pounds at birth and 173 pounds at market. They consumed an average of 22.2 pounds of milk daily during a 38 day feeding period. Bechdel (1917) fed whole milk as the only feed to veal calves averaging 85.2 pounds at birth. The calves gained an average of 1.85 pounds daily and consumed an average of 16.5 pounds of milk daily.

Yapp and Nevens (1926) suggested that 1 pound of milk should be fed daily to a calf for each 10 pounds of live weight with a maximum of 15-18 pounds per day. Gifford (1953) reported that the milk available to be consumed by beef calves in terms of their body weight ranges from 10.0 - 15.3 percent. It appears that the highest producing beef cows attain a level of production near the maximum daily consumption ability of their calves. Thus, it would appear that maximum daily production of a cow is limited by ability of the calf to consume the milk that is produced.

Within the beef cattle population, the desired level of milk production in cows seems to be a phenotypic intermediate trait. Within the combined population of beef and dairy cattle in the United States, it would no doubt be limited to the top segment of the lower quartile of the distribution which is an estimated production of approximately 6 - 18 pounds per day.

According to Gifford (1953), the three limiting factors affecting high milk production in most beef herds are; genetics, feeding and management, and calf effects on the physiological processes of milk secretion.

The varying levels of production during the lactation period gives rise to the question; what is the best time in the lactation period to estimate milk production? Van Vleck and Henderson (1960) reported that the best single months for estimating lactation yield in dairy cows are the fourth, fifth and sixth months and that bimonthly tests are more accurate than monthly tests for estimating lactation yield.

Methods for Estimating Milk Production

Several techniques have been used to estimate milk production in beef cows. Gifford (1953) allowed the calf to nurse half the udder while the other half was milked by hand for two successive milkings.

Calf weights before and after nursing were used to estimate milk production in beef cows (Knapp and Black, 1941; Drewry et al., 1959;

Dawson et al., 1960; Lampkin and Lampkin, 1960; Montsma, 1960; Neville, 1962; Van Cottem, 1962; Pope et al., 1963; Furr and Nelson, 1964; Rutledge, 1970 and Dickey et al. 1970).

Anthony (1959) developed a new technique using oxytocin to aid milk let-down prior to complete machine miling and handstripping.

The different techniques do not measure the same trait. During early stages of lactation milk consumption is not an accurate estimate of the total milk production of the cow (Gifford, 1953). A complete milking by machine or by hand provides no estimate of milk consumption.

Schwulst et al. (1966) developed a standard procedure for estimating both total milk production and milk consumption. Calves were weighed before and after nursing to estimate consumption. Cows were then milked by machine to withdraw residual milk. After an intramuscular injection of 2 ml. of oxytocin the cows were again milked. In some cases an amount equal to 1/3 of the calf's consumption was obtained.

Nursing Technique

Of all the methods used for estimating milk production in beef cows, the calf nursing technique is probably the most widely used.

Basically, the nursing technique involves separating the calf from its dam for a period of time (usually 8 - 14 hours) then weighing the calf, allowing it ot nurse its dam and immediately reweighing the calf upon completion of nursing. The difference between the two weights is considered to be the milk production of the dam for that for that period of time she was separated from her calf.

Research workers have used various modifications and have applied the nursing technique in different ways. These modifications are important to consider in that they do influence the milk yield record that is obtained.

Knapp and Black (1941) were among the early workers who estimated milk production in beef cows using the calf nursing technique. They measured milk consumption by weighing the calf 1 day each week before and after nursing.

Drewry et al. (1959) estimated milk production of beef cows for one day in the first, third and sixth months of lactation using the nursing technique. On the day prior to the test the calves were separated from their dams for 2 - 3 hours then allowed to nurse and again separated at 6:00 P.M. The following day the calves were weighed at 6:00 A.M., allowed to nurse and weighed immediately. The procedure was repeated again at 4:00 P.M. The daily milk production for a period of about 24 hours was estimated by the sum of the weight differences at the two nursing times. No additional milk was found in the udder after the calves had finished nursing except in heavier producing cows during the first month.

Neville (1962) estimated milk production in beef cows using the nursing technique but did not perform a pretest milkout as did Drewry et al. (1959). Estimates were based on twice daily nursings carried out four times at equal intervals between birth and weaning. Calves appeared to remove all the milk from the udder at each nursing.

Hunter (1956) measured the milk yield of ewes using the nursing technique and reported the pretest milkout was important as it affected both the rate of milk secretion and the appetite of the lamb, especially during the first few weeks of the lactation period.

Van Cottem (1962); Pope et al. (1963) and Melton et al. (1967) used the technique described by Drewry et al. (1959), however, milk yields were taken at monthly intervals during the lactation period. Melton et al. (1967) determined average daily milk yield by averaging the milk produced on the first day of each period and the first day of the subsequent period.

Dawson et al. (1960) measured milk yield in beef cows by weighing the calves at weekly intervals before and after nursing. The calf was taken off the cow the evening before the test and allowed to nurse at 4:00 A.M., 12:00 noon and 8:00 P.M. It was thought that more milk could be obtained from the low producing cows by allowing the calf to nurse three times a day rather than hand milking the cow twice a day. It was reported that this method is limited by the amount of milk the calf can consume. Cows with a very high milk producing potential would tend to adjust to the amount of milk the calf could take and their potential would thus be under-estimated.

Lampkin and Lampkin (1960) using the technique as described by Dawson et al. (1960), found that after an overnight separation period of 14 hours the calves consumed 54, 21, and 25 percent of the total daily milk at the morning, noon and evening tests, respectively. Owen (1957), working with ewes, used an udder cover for the ewes so that it was not necessary to separate the ewes and lambs.

Machine Milking and Use of Oxytocin

Anthony et al. (1959) developed a new technique for estimating milk production in beef cows. The procedure consists of separating the cow from her calf, injecting 40 U.S.P. units of oxytocin intramuscularly, washing the udder with warm water and using a portable milking machine followed by hand stripping to withdraw the milk. The first milking being considered a pretest milkout, thus no milk yield recordings were made.

The test milking is made approximately 12 hours after the pretest milkout using the same procedures. The total production is weighed and a sample taken for butterfat analysis. Milk production is reported on a 12 hour, fat corrected milk basis according to the formula:

$$FCM = .4M + 15F$$

where M is milk and F is fat, all in the same unit of weight.

Coombe _et al._ (1960) began estimating the milk production of ewes 1 week after parturition. Milk yield tests were made at weekly intervals. The ewes were handmilked following injection of 5 I.U. of oxytocin intramuscularly at the beginning and end of a 2 hour period, during which the ewes were separated from their lambs. When no milk could be obtained, a supplementary injection of 2.5 I.U. of oxytocin was given intramuscularly and the ewes milked again. After this initial milking, the ewes were separated from their lambs until 2 hours later when the procedure was repeated. The total yield for the 24 hour period was then calculated by multiplying this recording by a factor of 12. Assumptions made for the calculation of final milk yield, were the following:

(a) For calculation of the total milk yield of each ewe, weekly averages were taken of daily milk yield, and these used to estimate total milk yield for the week.

(b) To estimate milk production during the first few days of lactation it was assumed that milk production rises during the first week of lactation at the same rate as it does during the second week of lactation therefore, the milk yields of the second week were used to estimate the yield of the first week.

Harris et al. (1963) worked with cows using the technique described by Anthony et al. (1959) with the milk production based on a daily (24 hour) basis by multiplying the 12 hour values by a factor of two. Klett (1963) estimated milk production in beef cows using the technique described by Anthony et al. (1959).

Hand Milking

Gifford (1953) milked one-half the udder by hand while the calf suckled the other half. The following day the opposite half was milked by hand and the two records combined as an estimate of one day's production. Milk production of beef cows was estimated by this technique at monthly intervals.

Totusek and Arnett (1965) used a technique similar to that designed by Gifford (1953), milking alternate udder halves morning and evening to estimate milk production at weekly intervals.

Comparison of Techniques for Estimating Milk Production

Totusek and Arnett (1965) compared three methods of estimating milk production in beef cows. Total milk production was determined by (1) weighing the calves before and after nursing (nursing technique) for 210 days, (2) handmilking one day each week with alternate udder halves milked morning and evening while calves nursed the opposite half and (3) body weight of the calves was used as an indirect estimate of milk production.

The correlations between total 210-day milk production and once-weekly handmilking estimates were 0.84, 0.90, and 0.95 at 70, 112 and 210 days respectively. Correlation between total milk production and body weight of the calf at 70, 112 and 210 days were 0.69, 0.80 and 0.88 respectively. Average daily milk production was estimated to be 12.92 lbs. by the nursing technique and 10.03 by handmilking. Correlations between daily estimates and total milk production increased with each additional daily estimate.

Wistrand and Riggs (1966) compared the milk production of beef cows as estimated by the calf nursing and machine milking methods. Cows were milked at monthly intervals using left and right udder halves as the experimental unit to test concurrently the calf nursing and machine milking techniques for measuring milk production. No significant difference in milk yield resulted from the two methods.

Barnicoat et al. (1949), working with lactating ewes, compared handmilking, machine milking, pituitrin injections and lamb-suckling to estimate milk production. Using handmilking, only about one-half of the milk could be extracted. Machine milking proved to be impracticable. Using intravenous injections of Pituitrin (posterior pituitary extract), to facilitate handmilking, the ewes yielded 80-100 percent of their milk accumulated during the preceding 6 hour period. The lamb-suckling technique when carried out four to six times (usually six) during a 24-hour period gave a reasonable estimate of the daily milk production of the ewe. Toward the end of lactation, the lambs were easily able to consume all of their mother's milk and the weighings were reduced to five and then to four in a 24-hour period.

Coombe et al. (1960), using 20 ewes, compared the lamb-suckling technique as described by Owen (1957) and the technique using oxytocin injections followed by handmilking. The oxytocin technique gave consistently higher values for milk production than the lamb-suckling technique. The between-ewe variation was similar for both techniques.

Hartman et al. (1962), working with sows, studied the associations of measuring milk production by (1) weighing the pigs before and after nursing; and (2) milking the sows by machine. The amounts of milk obtained by the use of a machine were found to be correlated with the weight of the pigs. The correlation coefficients for weights of pigs and amounts of milk received by them as measured by six hourly nursing intervals each week from the first to the sixth week were 0.08, 0.59 ($P < .01$), 0.62 ($P < .01$), 0.84 ($P < .01$), 0.54 ($P < .01$) and 0.44 ($P < .01$), respectively.

Weighing the pigs before and after nursing was found to be laborious, however, it was thought to be the most accurate method of determining the actual milk producing ability of the sow. Machine milking was found to be much faster and easier.

Pope et al. (1963) reported that as a result of using the nursing technique the first estimate of milk production may be somewhat in error if the young calves are unable to completely nurse out the cows. Similarly, the accuracy of the last sampling is probably influenced by the reduced milk flow of the cow and heavier weights of the calf. Another disadvantage of the nursing technique is that it is not possible to obtain samples of milk for chemical analysis. With any method, it is probable that the estimates obtained are conservative and that cows actually produce more milk while in the pasture. However, it is believed that the nursing method has an advantage over milking beef cows by hand or with a machine in that it takes advantage of any ability of the calf to encourage the cow to give milk.

Lam et al. (1969) estimated milk production in beef cows by the use of three techniques. The techniques used were: (A) 6-hour oxytocin test to determine rate of milk secretion, (B) 24-hour calf suckling method and (C) overnight calf suckling plus oxytocin which estimated udder capacity.

Methods A and B gave similar estimates for daily milk yield, whereas method C gave estimates which were 23 percent greater ($P < .01$). Those workers concluded that on the basis of practicability of handling large numbers of cattle under field conditions the 6-hour oxytocin method was the most satisfactory.

Serwanja et al. (1969) compared two methods of estimating milk yield in beef cows. Estimates were begun two weeks after calving and at 28 day intervals thereafter using the calf-nursing method, following by machine milking on the following day. The average daily milk yield for the calf nursing and machine milking was 14.7 and 14.6 pounds respectively for 8 months of lactation. Correlations between the two methods used to estimate milk production were 0.61, 0.78, 0.83, 0.90, 0.92, 0.96, 0.96, 0.95 for periods 1 to 8.

Important Factors Influencing the Nursing Technique

Birth Weight and Sex of Calf

Melton et al. (1967) reported that the heavier birth weight of bull calves and greater milk production of their dams supported the findings of Gifford (1953), Drewry et al. (1959) and Heynes (1960), that greater birth weight of the calf is associated with increased milk production of the dams.

Cartwright and Carpenter (1961) found that bull calves tend to nurse more frequently and may, thereby, stimulate greater milk production.

Hartman *et al*. (1962) reported that larger pigs appeared to be more vigorous, emptied the glands they were nursing more completely and thus stimulated greater milk production.

Frequency of Nursing

Owen (1957) reported that the frequency of suckling is governed mainly by two considerations:

(1) The interval must be short enough to ensure that no undue udder pressure is developed and that the lamb can easily consume all the milk as occurs under normal conditions;

(2) the number of sucklings should be kept to a minimum compatible with the first consideration, in order to reduce the number of times the ewes and lambs have to be gathered and handled.

Barnicoat *et al*. (1949) suggested that the procedure is really a compromise between two undesirable sets of conditions; (a) allowing insufficient opportunities for the lamb to suckle, and (b) allowing insufficient time for the ewe to graze and "settle down" between sucklings.

Interval Between Tests

Lampkin and Lampkin (1960) observed that the errors in estimation increased as the interval between tests became greater. Experimental design, however, demanded that the advantages of testing every day be weighed against practical considerations, particularly if the method were to be used regularly for many calves.

If growth rates are not to be greatly affected, it is desirable to interfere as little as possible with the grazing habits of the herd. It is further necessary to reduce to a minimum the distress of the cows as a result of being separated from their calves. The effects of such distress were demonstrated by Hunter (1956), who found that in 4 hour tests throughout a weekly 24-hour period, ewes produced less milk in the second 12 hours than in the first, irrespective of the time of day at which the total period was commenced.

Barnicoat _et al._ (1949) reported that with ewes early in the lactation period, weekly intervals are considered desirable. Towards the end of lactation, when milk production becomes less, 14 day intervals are sufficient.

Intervals used by researchers working with beef cattle have ranged from weekly to as long as 3 months, however, the monthly interval is most commonly used.

Speed of Handling

According to Owen (1957), speed of handling is especially important when the lambs are fairly old, since there is the likelihood of errors due to excretory losses if the lambs are allowed to stand between the two weighings before and after nursing. In order to facilitate speed of handling this researcher worked with only 10 ewes and lambs at a time.

Lampkin and Lampkin (1960) did not consider the losses of defecation and utination to be important. They observed that most calves tended to excrete when moving from their pens to the scales before the first weights were taken.

It is generally agreed by most researchers that the errors due to losses from defecation and urination become greater as the size of the calf increases, since the losses make up a greater percentage of the total milk consumed by the calf.

CHAPTER III

MATERIALS AND METHODS

This study conducted at the Ft. Reno Livestock Research Station located at El Reno, Oklahoma, was initiated in February of 1968 and terminated in October of 1968. The data reported were collected on a total of 48 first calf heifers calving at approximately 2 years of age. The 48 heifers consisted of 36 Angus X Holstein F_1 crossbreds with varied genetic background and 12 Angus X Hereford F_1 crossbreds of similar genetic background.

The heifers used in this study were obtained in the fall of 1966. During the winter of 1966-67 the heifers grazed native grass pastures supplemented with 2-4 lb. of milo and 2 lb. of cottonseed cake. Supplemental feeding was discontinued in April at which time the heifers were grazed solely on native grass pastures with salt and bonemeal fed free-choice.

The heifers were bred to three Angus bulls during the spring and summer of 1967 to begin calving in February of 1968. During the winter of 1967-1968 the native grass pastures were supplemented with 2 lb. of cottonseed cake until mid December at which time the cottonseed cake was replaced with approximately 6 lb. of alfalfa hay.

After calving the heifers were stratified into two treatment groups according to breed, sex of calf, birth weight of calf and date of calving.

Techniques of Estimating Milk Production

Two methods of estimating milk production were applied as treatments. Both methods were based on the calf-nursing technique. One method consisted of allowing the calves to nurse twice daily with a 12 hr. interval between nursings. This method was similar to that described by Pope et al. (1963). The other method used allowed the calves to nurse three times daily with an 8 hr. interval between nursings. These methods will hereafter be referred to as 2X and 3X methods, respectively. Milk production of the heifers was estimated by these two methods on the respective treatment groups at monthly intervals from April 1968 to September 1968.

The 2X method consisted of separating the calves from their dams at approximately 10:00 A.M. the day prior to the test. The calves remained separated until 6:00 P.M. when they were allowed to nurse their dams. This was simply a pretest milkout in an attempt to place both the cows and calves on an equal basis relative to udder fill and hunger, respectively. The calves were separated immediately after this nursing. At 6:00 A.M. the day of the test, the calves were weighed, allowed to nurse and reweighed immediately after nursing. The increase in weight was taken as the milk production of the dam for the 12 hr. overnight period. The calves were separated from their dams until 6:00 P.M. at which time the weighing and nursing procedure was again repeated. The sum of the two weight differences was considered to be the milk production of the dam for a 24 hr. period.

The 3X method of estimating milk production consisted of separating the calves from their dams at 1:00 P.M. the day prior to the test and allowing them to nurse at 9:00 P.M. the same day and again separated.

This was the pretest milkout which was explained previously. At 5:00 A.M. the day of the test, the calves were weighed, allowed to nurse their dams and immediately reweighed after nursing. The increase in weight of the calf was considered to be the milk production of the dam for the 8 hr. overnight period. This procedure was repeated at 1:00 P.M. and at 9:00 P.M. each test day. The sum of the three weight differences was considered to be the milk production of the dam for a 24 hr. period.

During the test days the calves were held in shaded pens and had free access to water but no feed. The dams were allowed to run on pasture with free access to water and grass. It was observed that during the test days of the first three estimations the heifers grazed readily during the interval between nursings, however, during the latter months of testing the heifers tended to remain closer to the calf pens and did not graze readily for the entire interval between nursings. The calf pens were located relative to the pastures such that the dams could see and hear their calves but could not get adjacent to them.

The calves were weighed to the nearest 0.25 lb. and nursed in the same groups of 12 during each estimation with the exception of the months of May and June when all calves on a given treatment were weighed and nursed together. Handling the smaller group was considered to be advantageous over the larger in that the calves can be weighed more rapidly after nursing thus reducing the error due to urination and defecation.

Observations taken during the study included birth weight, birth date and sex of calf. At each test date observations included weight of calves (after overnight separation), age of calves, pounds of milk produced at each estimate during the day and total daily milk. Actual and adjusted* weight of calves were recorded at weaning.

Statistical Analysis

The milk yield estimates were analyzed for the effects of birth date of calf, birth weight of calf, sex of calf, breed of cow and treatment (method of measuring milk yield). The 24-hour estimates of milk yield obtained at each period and the average yield estimates over the entire lactation were analyzed by the abbreviated Doolittle method of obtaining least squares constants (Steel and Torrie, 1960). Estimates of the constants were obtained by solving a set of simultaneous equations represented by $(X'X)\ (\hat{\beta}) = (X'Y)$ with X being the observation matrix, X' being the transpose of the observation matrix, Y being the vector of the observation matrix and $\hat{\beta}$ being the vector of the least squares constants. Estimates of the least squares constants were obtained by solving the equation $(\hat{\beta}) = (X'X)^{-1}\ (X'Y)$. The procedures for constructing the observation matrix are outlined by Cunningham (1968).

The restriction applied to solve the system of equations for the parameters to be estimated was to set certain effects equal to zero thus, the least squares constants obtained were expressed as deviations from the effects set equal to zero. The effects set equal to zero are indicated in the description of the model:

$$Y_{ijkl} = \mu + ax_1 + bx_2 + S_i + B_j + T_k + (SB)_{ij} + (ST)_{ik} + (BT)_{jk} + (SBT)_{ijk} + e_{ijkl}$$

---

*Female calf weaning weights were adjusted to a steer equivalent by multiplying 205 day weight by 1.05. No age of dam correction was made since all dams were near the same age.

where,

Y_{ijkl} = individual 24-hour estimate of milk production.

μ = mean estimate of milk production for an Angus X Hereford cow nursing a female calf and measured by the 3X method.

x_1 = birth date of calf (day of year).

x_2 = birth weight of calf.

S_i = a constant for the effect of sex of calf with i = 1 (male), 2 (female) and 2 set equal to zero.

B_j = a constant for the effect of breed of cow with j = 1 (Angus X Holstein), 2 (Angus X Hereford) and 2 set equal to zero.

T_k = a constant for the effect of method of measuring milk production with k = 2(2x), 3(3x) and 3 set equal to zero.

$(SB)_{ij}$ = interaction between ith Sex and jth Breed.

$(ST)_{ik}$ = interaction between ith Sex and kth Treatment.

$(BT)_{jk}$ = interaction between jth Breed and kth Treatment.

$(SBT)_{ijk}$ = interaction among ith Sex, jth Breed and kth Treatment.

e_{ijkl} = failure of the above model to estimate milk production.

The analysis of variance for the previous model is shown in Table I.

In the analysis of variance, sums of squares were obtained for each variable in the model. However, due to the type of analysis (abbreviated Doolittle) and the model used, only the sum of squares for the last variable in the model was adjusted for everything else in the model. Thus, only F tests for the effects of the last variable in the model upon milk production could be conducted. Due to this circumstance an

TABLE I

ANALYSIS OF VARIANCE FOR COMPLETE MODEL

Source	df
Total	47
Birth Date	1
Birth Weight	1
Sex of Calf	1
Breed of Cow	1
Treatment (technique of estimation)	1
Sex x Breed	1
Sex x Treatment	1
Breed x Treatment	1
Sex x Breed x Treatment	1
Error	38

analysis was first conducted by arranging the model such that all possible interactions could be tested before the effects due to treatments were analyzed.

All interactions tested were nonsignificant thus the model was reduced to the following:

$$Y_{ijkl} = \mu + ax_1 + bx_2 + S_i + B_j + T_k + e_{ijkl}$$

The analysis of variance for the above model is shown in Table II. Standard errors for the estimated constants were computed using the formula;

$$\text{Standard error} = \sqrt{c^{ii}\,\hat{\sigma}_e^2}$$

where c^{ii} is the corresponding diagonal element of $(X'X)^{-1}$ for the par

TABLE II

ANALYSIS OF VARIANCE FOR REDUCED MODEL

Source	df
Total	47
Birth Date	1
Birth Weight	1
Sex of Calf	1
Breed of Cow	1
Treatment	1
Error	42

ticular constant and $\hat{\sigma}_e^2$ is the error mean square. Least squares constants (k_i) were tested for significant difference from zero by the method outlined in Steel and Torrie (1960) with calculated $t = k_i/S_{\hat{B}_i}$; k_i being the least squares constants considered and $S_{\hat{B}_i}$ being the standard error corresponding to that constant. For analyses not using least squares, data were analyzed as a Factorial experiment as outlined in Steel and Torrie (1960). In these analyses no adjustment was made for birth date or birth weight of calf. The analysis of variance is shown in Table III.

TABLE III

ANALYSIS OF VARIANCE FOR DISCRETE VARIABLES

Source	df
Total	47
Breed	1
Sex of Calf	1
Treatment	1
Error	44

CHAPTER IV

RESULTS AND DISCUSSION

Before the effects due to method of measuring milk production were compared, all possible interactions of effects were tested and found to be nonsignificant ($P > .05$) at all periods of lactation when milk yield was estimated. This made it possible to test the effects of each variable singly. Table IV summarizes the least squares constants for their effect upon the total daily milk production estimate at six different times during lactation. The effects will be discussed chronologically as they appear in the statistical model.

Birth Date Effect

All least squares constants for the effect of birth date on milk production were positive, indicating that, at the time milk production estimates were taken, cows which calved later in the season were producing more milk than cows which calved earlier. The least squares constants generally agree with those reported by Hughes (1971) who suggested that the increased milk production of later calving cows is largely due to them being in a better nutritional environment than early calving cows because of the beginning growth of spring grass. Another possible explanation for the increased milk production of late calving cows may be due to the fact that at each date when milk production was estimated, those cows calving later were in an earlier stage of lactation when pro-

TABLE IV

LEAST SQUARES CONSTANTS FOR EFFECT OF VARIOUS FACTORS ON 24-HOUR MILK YIELD ESTIMATE AT SIX DIFFERENT STAGES OF LACTATION

Days of Lactation	Mean	Birth Date	Birth Weight	Sex of Calf[a]	S.E.[b]	Breed of Cow[a]	S.E.[b]	Treatment[a]	S.E.[b]
61	5.667	0.023	0.073	1.606	0.968	4.259**	1.076	0.458	0.817
82	3.060	0.064**	0.052	1.719	1.028	5.089**	1.143	-0.672	0.868
110	9.132	0.067*	0.013	2.834*	1.243	3.841**	1.382	-2.939**	1.049
145	5.344	0.035	0.051	0.370	0.874	5.241**	0.964	0.237	0.741
172	4.833	0.037*	0.054	1.073	0.774	4.009**	0.855	-2.754**	0.657
200	5.276	0.038	0.043	0.468	0.965	3.359**	1.046	-0.833	0.792
Entire Lactation	5.428	0.048**	0.039	1.456**	0.658	4.497**	0.726	-1.152**	0.558

[a]The restriction used for solving the simultaneous equations was $\hat{S}_n = 0$, where n = 2 = female calves, Angus X Hereford cows and treatment 3X.

[b]Standard error of estimate.

*P < .05, significantly different from zero.

**P < .01, significantly different from zero.

duction is greater, than were cows calving previous to them.

The effect of birth date of calves appears to be of greater magnitude earlier in lactation, declining as lactation progresses. As shown in Table IV at 82 days of lactation, the regression coefficients of milk yield on birth date was .064 lb. ($P < .01$) while at 172 days the regression coefficient was 0.038 lb. ($P < .05$). The overall regression coefficient of average daily milk yield for the entire period upon birth date was 0.048 lb. ($P < .05$). Birth date did not appear to have any significant effect upon total daily milk yield when the first estimate was taken. This may be explained by the fact that cows which had calved early had already reached their peak production and were on the decline when the first estimate was taken, whereas cows which had calved later were increasing in their milk production thus the lactation curves of the cows calving on different dates happened to be near the crossing point when the first milk production estimate was taken.

To better illustrate the relationship between calving date and milk yield, cows were separated into two groups according to date of calving disregarding the method of measuring milk yield. Calving began on February 1 and continued through April 9 with a mean calving date of March 6. Since date of calving did not follow a normal distribution (Figure 1), cows were separated into the two groups according to those calving before and after February 21 in order to better equalize numbers in each group. These groups will be referred to as early and late calving respectively for this particular portion of the discussion. Figure 2 illustrates the difference in average daily milk yield estimates of these two groups of cows. The milk yield estimate was larger for late calving cows at all periods when milk yield was measured, however,

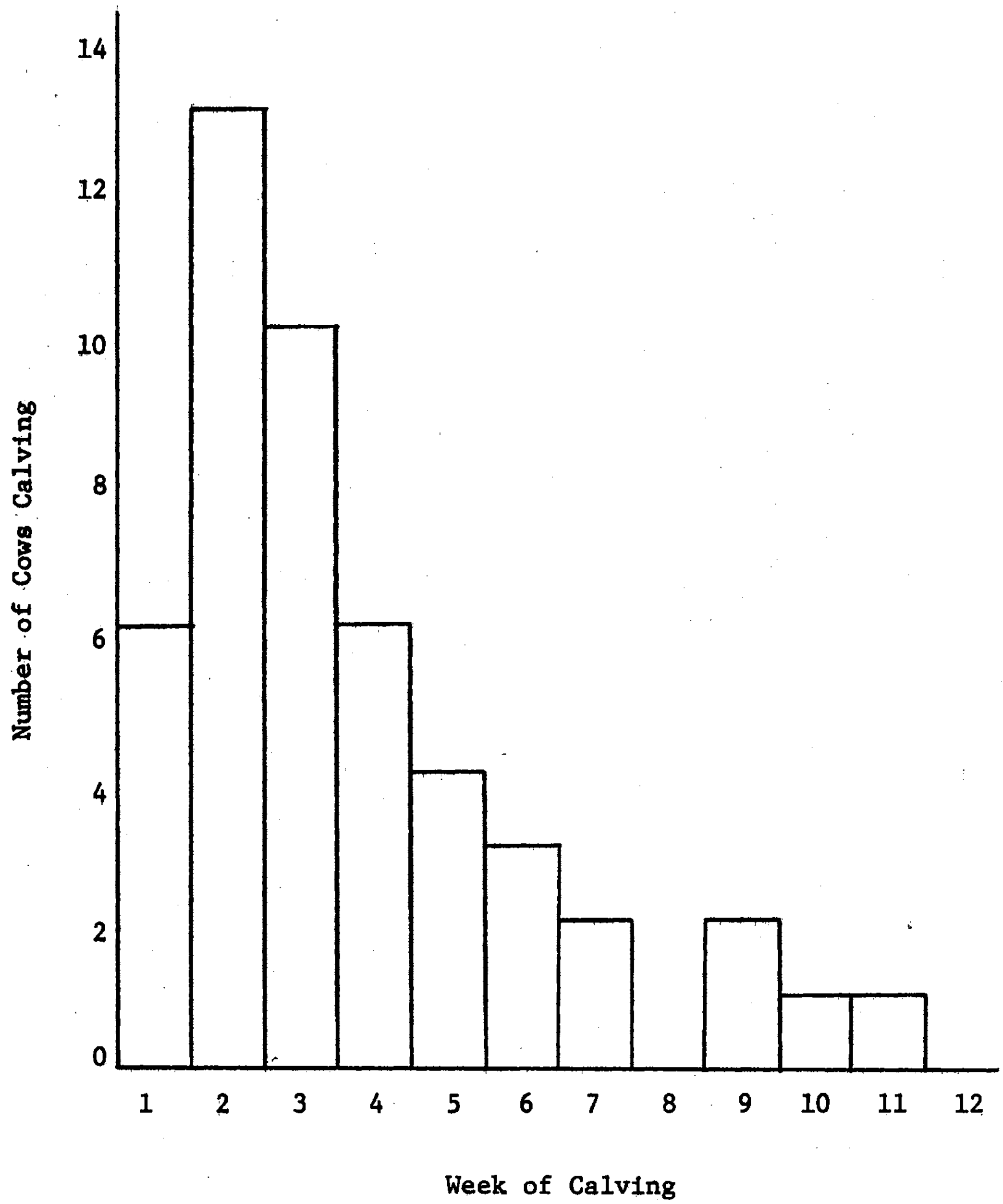

Figure 1. Distribution of Calving

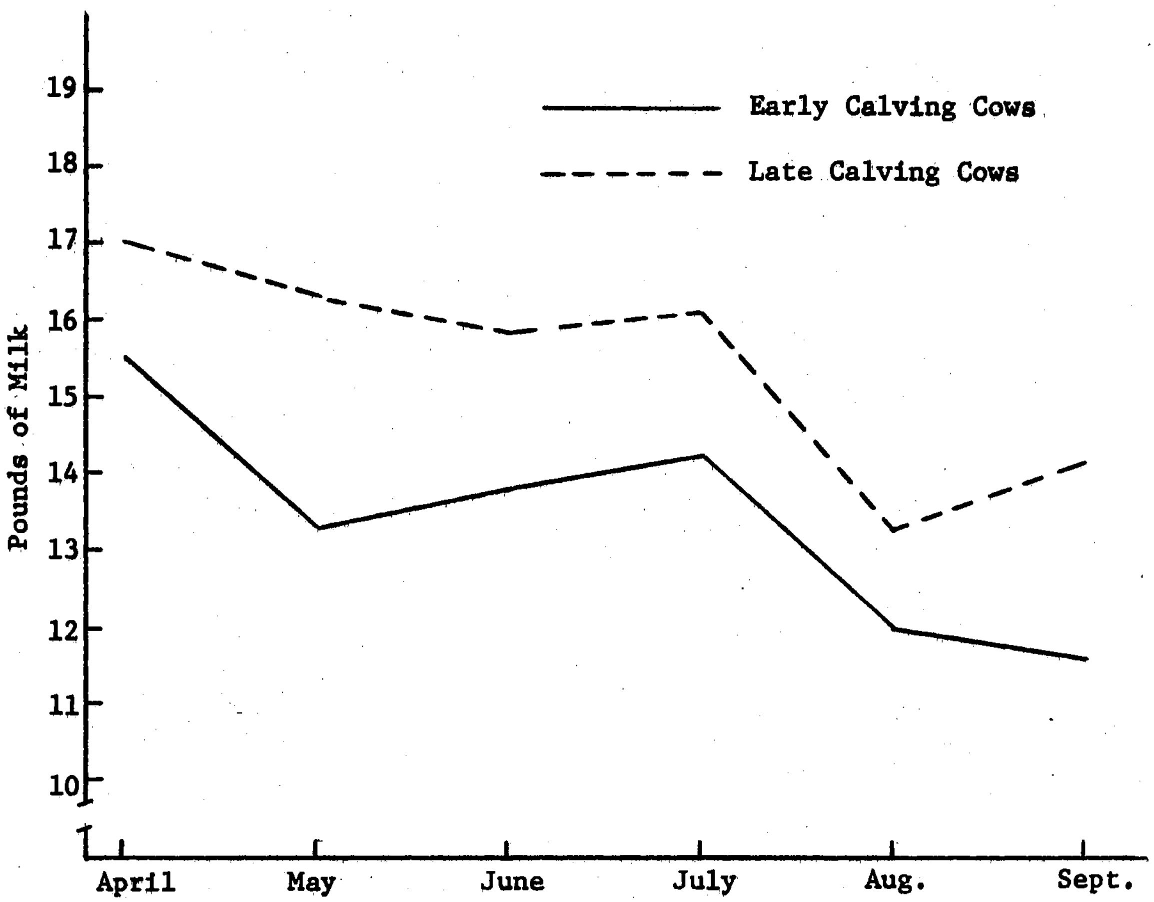

Figure 2, Average Daily Milk Yield Estimate of Early and Late Calving Cows at Six Different Periods of Lactation only the estimates taken during May and September were significantly ($P < .05$) different. Wilson (1964) observed a similar relationship with dairy cows and suggests the difference, especially early in lactation may be due to deficiencies in the quality or quantity of pasture available for cows with early calves and stated that under-nutrition immediately before or just after calving can influence milk production.

Since birth date and stage of lactation are highly related and somewhat confounding, in that birth date determines the stage of lactation a cow is in relative to nutritional environment as well as when milk yield is measured, the effects of birth date and its relationship to stage of lactation will be discussed to a greater extent in this paper during the discussion of the effect of stage of lactation.

Birth Weight Effect

The least squares constants for the effect of birth weight (Table IV) upon daily milk yield were positive, however nonsignificant ($P>.05$) throughout all stages of lactation indicating that there was no effect upon milk yield due to birth weight of the calf. Since all constants were positive indicates a trend that increased birth weight of the calf may be associated with increased milk production of the dam. Gifford (1953) and Heynes (1960) reported that greater birth weight of the calf is associated with increased milk production of the dam.

Table V contains the correlation coefficients between birth weight and milk yield. All correlations were nonsignificant at all stages of lactation with the exception of 0.54 for the Angus X Holstein cows at 172 days of lactation when milk yield was estimated by the 2X method and 0.76 for Angus X Hereford cows at 110 days measured by the 3X method.

TABLE V

CORRELATION BETWEEN BIRTHWEIGHT OF CALF AND DAILY MILK PRODUCTION ESTIMATE OF THE DAM AT SIX DIFFERENT PERIODS OF LACTATION

Method of Measurement	Breed			
	Angus X Holstein		Angus X Hereford	
	2X	3X	2X	3X
Period of Lactation				
61	.26	.49	.24	.35
82	.28	.46	-.12	.67
110	-.02	.32	.02	.76*
145	.24	.30	.25	.05
172	.54*	.30	.54	.19
200	.06	.32	.26	.21

*P < .05

Correlations of 0.49, 0.46, 0.32, 0.30, 0.30, 0.32 for periods 1 - 6 respectively for Angus X Holstein measured by the 3X method are in general agreement with those of Dickey et al. (1970) and Drewry et al. (1959) who reported a positive relationship between birth weight of calf and milk production of the dam. Christian et al. (1965) and Gleddie and Berg (1968) reported that birth weight of calves was not significantly correlated with milk yield of the dam.

Although there was considerable variation in birth weight between the two breeds, the variation of birth weight within each breed was quite small which may account for the non-significant regression coefficients. The relationship between birth weight and milk yield of the cows is illustrated in Figure 3. There does appear to be a slight positive association between birth weight and milk yield which would support the findings of Drewry et al. (1959) and Heynes (1960). There is a large amount of individual variation in milk yield among the cows with varying birth weight in their calves, making it extremely difficult to fit a representive line through the observations. The large amount of variation in milk yield among cows along with little variation among birth weight of calves may partially explain the lack of a significant association between milk yield and birth weight of calves in this study.

The following three variables to be discussed are discrete variables. When interpreting these results it must be kept in mind that the effect of female calves, Angus X Hereford cows and the 3X method of measuring milk production were set to zero, thus the least squares constants represent the difference between the variables adjusted for everything before them in the statistical model.

Sex of Calf Effect

Least squares constants for effect of sex of calf on milk production (Table IV) were all positive, indicating that cows nursing male calves produced more milk during the periods when milk yield estimates were made. Constants of 2.834 and 1.456 for 110 days of lactation and for the entire lactation respectively were significantly ($P < .05$) different from zero. All values in general were larger than those reported by Hughes (1971). The estimate of constants appear to indicate that sex of calf has its greatest effect upon milk production during the first one-half of the lactation period. Thereafter the difference appears to decrease. Figure 4 illustrates the magnitude of the difference between

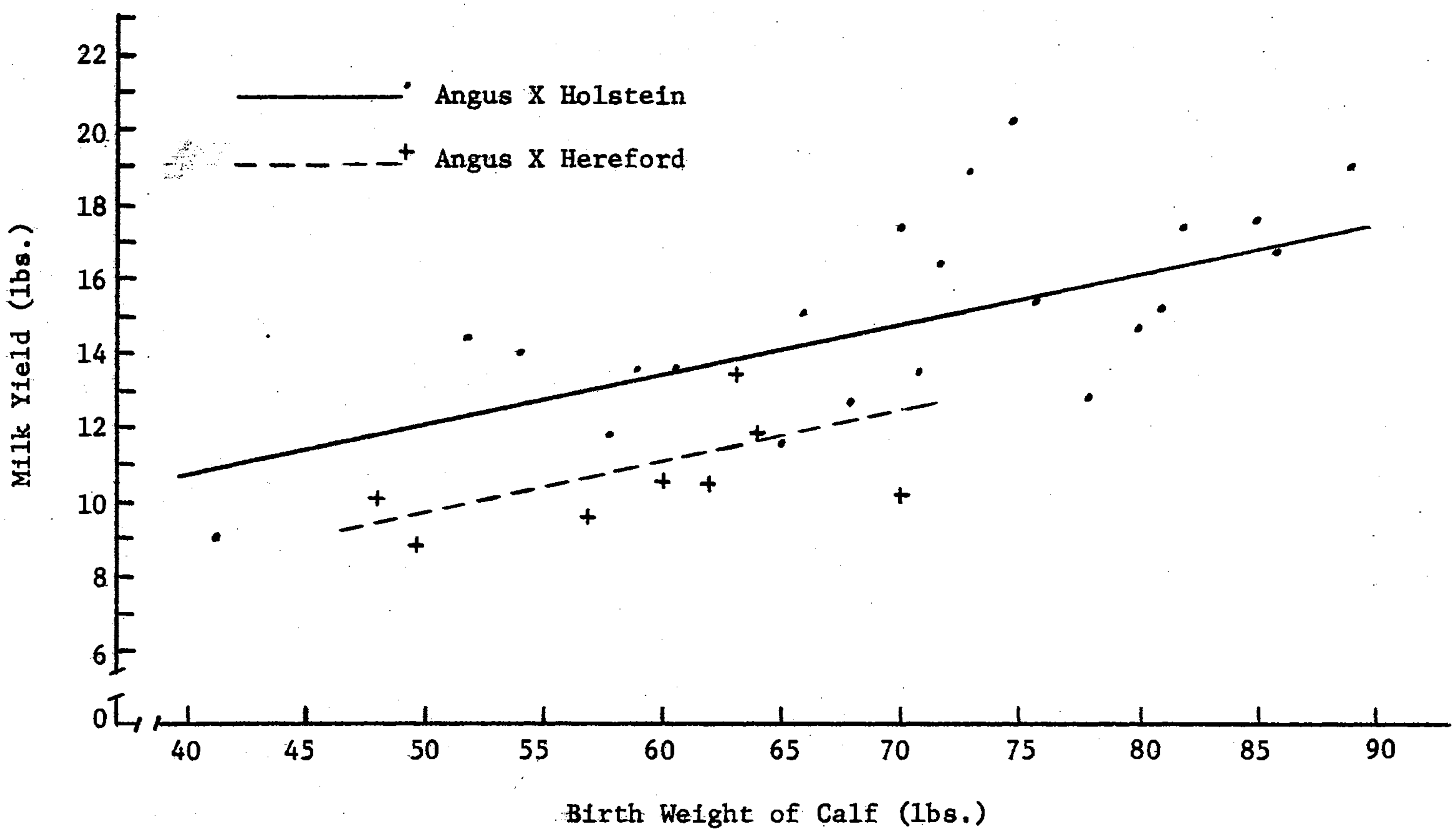

Figure 3. Relationship Between Birth Weight of Calf and Daily Milk Yield of Dam

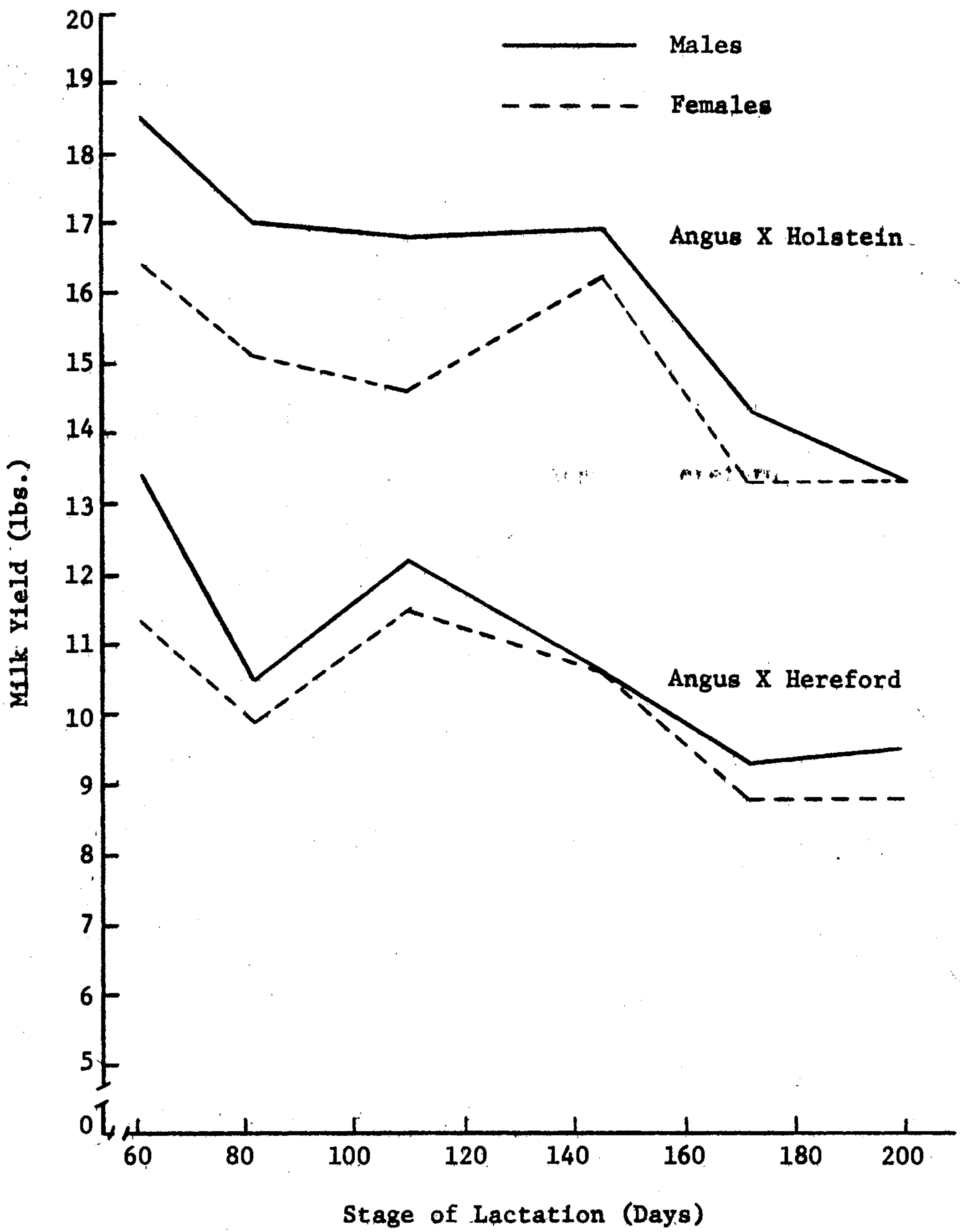

Figure 4. Average Daily Milk Yield Between Cows Nursing Male and Female Calves Within Breed of Cow

male and female calves for each breed of cows. The difference between male and females appears to be of greater magnitude for the Angus X Holstein cows than for Angus X Herefords.

Table VI summarizes the means, standard deviations, coefficients of variation and standard error of the differences between male and female calves for each breed at various stages of lactation. In general the coefficients of variation tend to be smaller for female calves than for male calves from cows of each of the two breeds, indicating that less of the total variation in the daily milk production estimate is accounted for in cows nursing male calves. The increased milk production of cows nursing male calves supports the findings of Cartwright and Carpenter (1961) that bull calves tend to nurse more frequently and may thereby stimulate greater milk production. This quite possibly is a partial explanation for the larger amount of variation in milk yield that was observed with cows that nursed male calves. The differences ranged for 0 to 2.2 lb. per day between male and female calves. Dickey et al. (1970) reported that Angus cows nursing male calves produced 0.62 lb. more milk than cows nursing female calves.

Breed of Cow Effect

As was expected, the Angus X Holstein cows produced significantly ($P < .01$) more milk at all stages of the lactation period. Estimates of the constants (Table IV) for breed range from 3.359 at 200 days of lactation to 5.241 at 145 days of lactation.

The average daily milk yield difference between the two breeds for the entire lactation after adjusting for birth date, birth weight and sex of calf was 4.497 lbs. Deutscher (1970) observed an average milk

TABLE VI

AVERAGE DAILY MILK PRODUCTION OF COWS NURSING MALE AND FEMALE CALVES WITHIN EACH BREED

Stage of Lactation (days)	Males			Females			Difference	S.E.[c]
	Mean[d]	S.D.[a]	C.V.[b]	Mean[d]	S.D.[a]	C.V.[b]		
				Angus x Holstein				
61	18.5	3.20	17.3	16.4	2.98	18.2	2.1*	1.05
82	17.0	6.01	35.3	15.1	3.05	20.2	1.9	1.60
110	16.8	6.65	39.6	14.6	5.18	35.5	2.2	1.99
145	16.9	3.08	18.2	16.2	2.75	17.0	0.7	0.98
172	14.3	2.82	19.7	13.3	3.03	22.8	1.0	0.99
200	13.3	3.27	24.6	13.3	2.63	19.8	0.0	1.03
				Angus x Hereford				
61	13.4	2.69	20.1	11.3	1.44	12.7	2.1	1.23
82	10.5	2.26	21.5	9.9	0.52	5.3	0.6	0.95
110	12.2	2.33	19.1	11.5	1.79	15.6	0.7	1.17
145	10.6	1.75	16.5	10.6	1.08	10.2	0.0	0.83
172	9.3	2.45	26.3	8.8	1.67	19.0	0.5	1.19
200	9.5	1.92	20.2	8.8	1.91	21.7	0.7	1.07

[a]Standard Deviation.

[b]Coefficient of Variation.

[c]Standard Error of Difference.

[d]Pounds.

*$P < .05$.

yield difference of approximately 3.4 lb. between Angus X Holstein and Angus cows over the entire lactation period with the difference ranging from 2.9 to 9.0 lb. at various stages in the lactation period. Figure 5 illustrates the difference in the lactation curves of the two breeds. The curves appear to follow the same pattern with exception of the last 28 days of lactation. For some unexplained reason, the average milk yield of Angus X Hereford cows tended to increase at 200 days of lactation rather than continue to decline as did that of the Angus X Holstein.

Effect of Method of Measuring Milk Yield

Table VII contains the least squares constants for the effect of technique of estimation upon 24-hour milk production. With the exception of the milk production estimate at 110 and 172 days of lactation, least squares constants were small and nonsignificant, indicating that there was no difference in level of the milk yield estimate of cows measured by the two different techniques during the particular periods when

TABLE VII

LEAST SQUARES CONSTANTS FOR EFFECT OF METHOD OF MEASUREMENT UPON THE MILK PRODUCTION ESTIMATE

Period of Lactation (days)	61	82	110	147	172	200	Entire Period
Constant	0.458	-0.672	-2.939**	0.237	-2.754**	-0.833	-1.152**
S.E.[a]	0.817	0.868	1.049	0.741	0.657	0.792	0.558

**P < .01 significantly different from zero.

[a]Standard Error of Estimate.

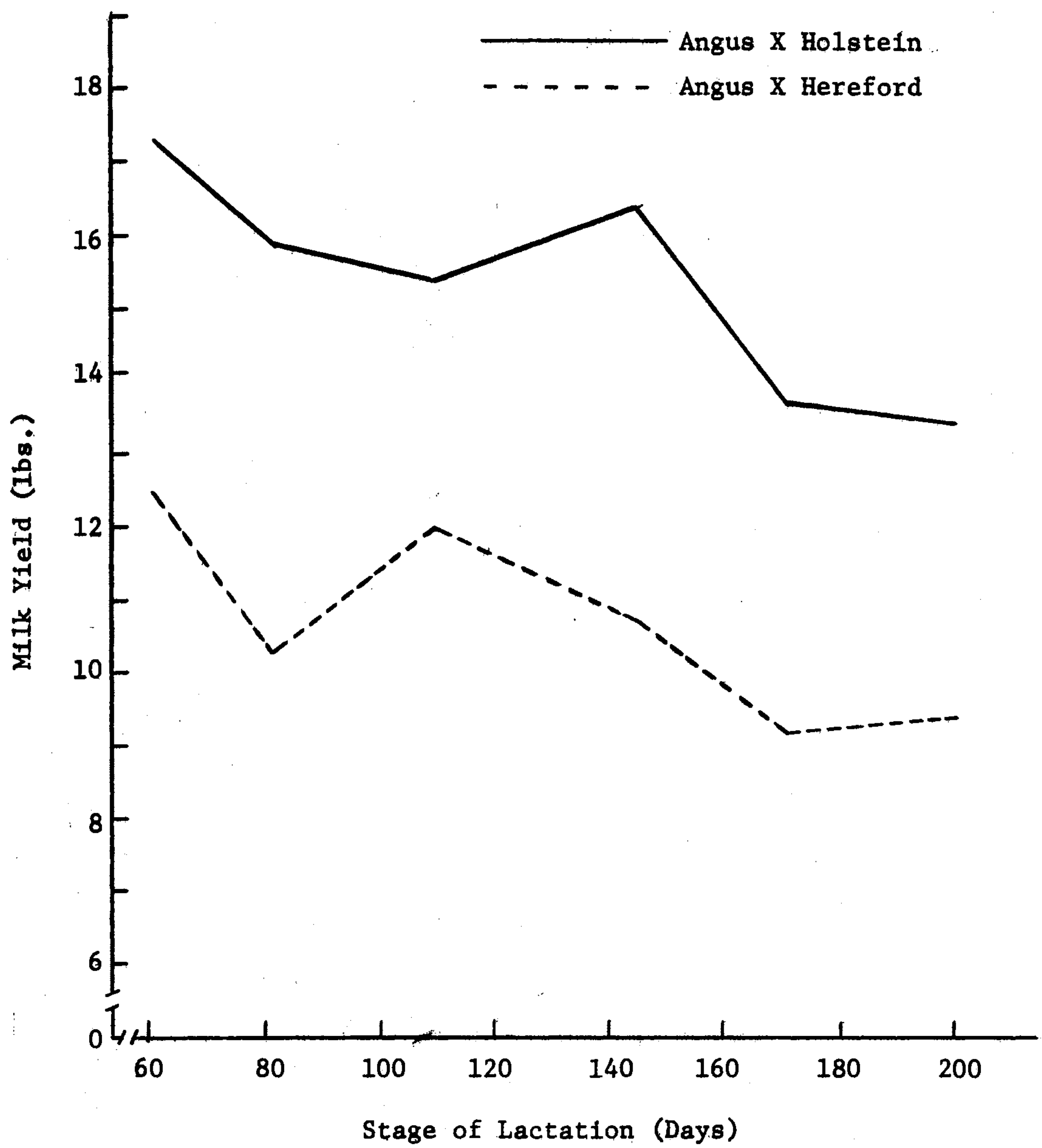

Figure 5. Average Daily Milk Yield for the Two Breeds of Cows Over the Entire Lactation Period

milk yield was measured. At 110 and 172 days of lactation and when the average yield over the entire lactation was considered, the least squares constants were negative and significantly ($P < .01$) different from zero indicating that the milk production estimate for cows measured by the 3X technique was larger than the estimate for cows measured by the 2X technique. The least squares constant for the average daily milk production estimate over the entire lactation was -1.152 lb. ($P < .01$). Figure 6 illustrates the average milk production estimate of cows from 61 to 200 days after parturition. With the exception of the production at 61 and 145 days of lactation, the estimates taken by the 3X technique tend to be higher than those taken by the 2X technique.

Tests for equality of variances was conducted between the two methods of estimation within each breed of cows. For Angus X Holstein cows tests indicated no significant difference between variances at all periods of milk yield estimation with the exception of the 110 day estimate. The test for equality of variance revealed that Angus X Holstein cows measured by the 3X method had a significantly ($P < .05$) larger variation in milk yield estimate than those measured by the 2X method. Milk yield estimates on cows measured by the 3X method varied from 12.75 to 29.75 lb. compared to 10.00 to 21.50 for cows measured by the 2X method. For the Angus X Hereford cows, 61 days of lactation was the only period in which the variances between the two methods were not equal. The estimate of cows measured by the 2X method varied significantly ($P < .05$) more than that of cows measured by the 3X method. The estimate for cows measured by the 2X method varied from 8.75 to 17.50 lb. compared with 11.75 to 13.50 for cows measured by the 3X technique.

Tests for equality of variance between breeds, pooling across meth-

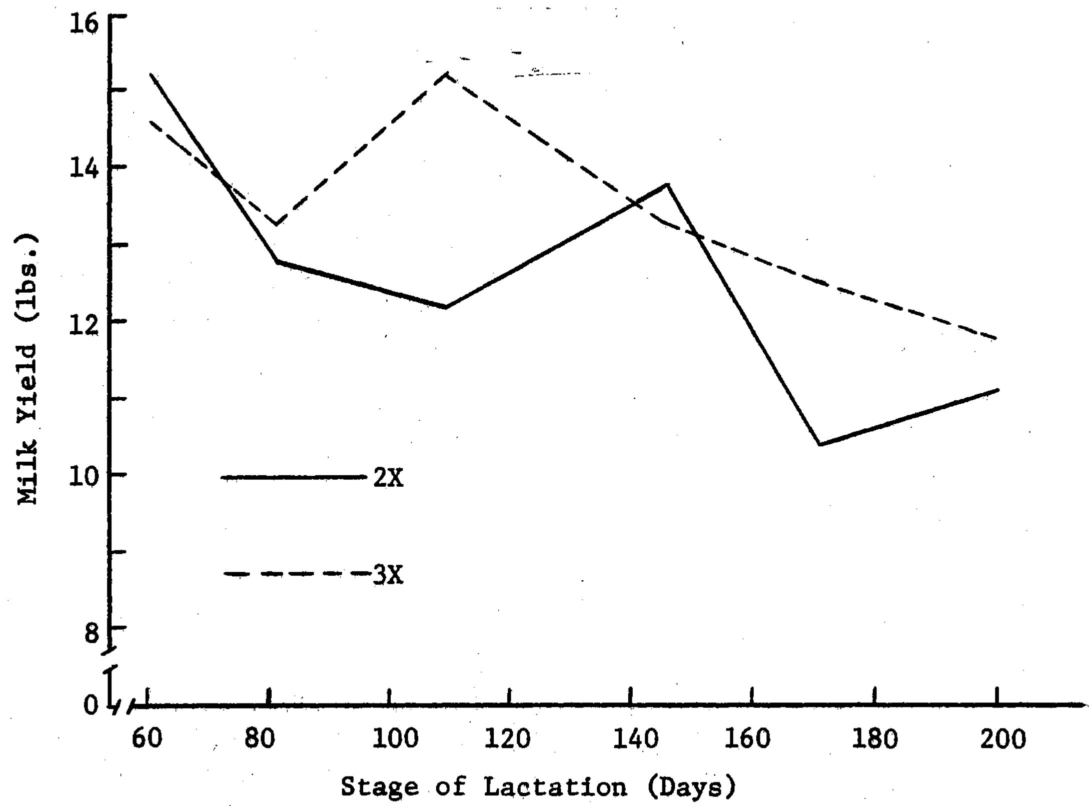

Figure 6. Average Daily Milk Yield Estimate for Each Method of Measurement Over the Entire Lactation Period

ods of measurement when possible indicated that in all periods of lactation except at 172 days, the variation in milk yield estimate of Angus X Holstein cows was significantly (P $<$ .05) larger than that of Angus X Hereford cows. The milk yield estimate for the Angus X Holstein cows varied from 7.25 lb. to 29.75 lb. throughout the entire lactation compared to 6.75 to 17.50 for Angus X Hereford cows. These variations are somewhat greater but in general agree with those of Deutscher (1970) who reported that the variation in milk yield of Angus X Holstein cows early in lactation was 12.3 to 18.0 pounds compared with 3.4 to 9.0 pounds for Angus cows. Dawson et al. (1960) reported the variation in peak production of beef Shorthorn cows to be from 12.4 to 35.5 pounds per day.

Table VIII contains the means, standard errors and coefficients of variation of the milk production estimates. In general the coefficients of variation tend to be lower for the Angus X Holstein cows when measured by the 2X technique whereas, for the 3X technique the coefficients of variation are less for the Angus X Hereford cows. Coefficients of variation for the 2X technique range from 15.3 to 22.6 with Angus X Holstein cows and from 18.3 to 27.0 with Angus X Hereford cows. For those cows estimated by the 3X technique, the coefficients of variation range from 18.7 to 31.2 for the Angus X Holstein cows and from 12.6 to 16.1 for the Angus X Hereford cows. These data appear to indicate that more of the variation in milk production of high producing cows was accounted for with the 2X technique whereas with moderate milk producing cows more variation was accounted for with the 3X technique. In general the magnitude of the coefficients of variation reported here are rather high especially for the high producing cows measured by the 3X method and the low-moderate producing cows measured by the 2X method. However, they may

TABLE VIII

MEANS, STANDARD ERRORS AND COEFFICIENTS OF VARIATION FOR THE TWO METHODS OF ESTIMATING MILK PRODUCTION AT SIX DIFFERENT PERIODS OF LACTATION

Method of Measurement	Day of Lactation	Breed of Cow: Angus x Holstein Mean	S.E.	C.V.	Angus x Hereford Mean	S.E.	C.V.
2X	61	18.1	0.67	14.9	12.3	1.25	27.0
	82	15.8	0.83	20.8	9.8	0.72	19.6
	110	14.1	0.69	20.2	10.3	0.71	18.3
	145	16.8	0.63	15.3	10.8	0.70	17.1
	172	12.2	0.54	18.3	8.5	0.62	19.4
	200	12.8	0.62	19.8	9.3	0.76	21.6
3X	61	16.5	0.96	21.9	12.6	0.26	5.1
	82	15.9	1.08	26.4	10.7	0.53	12.1
	110	16.7	1.38	31.2	13.6	1.05	18.9
	145	16.0	0.82	19.8	10.5	0.34	7.9
	172	15.1	0.74	18.7	9.8	0.98	24.7
	200	14.0	0.87	24.2	9.6	0.73	18.6

not be uncommon in estimating milk production of cattle since the coefficients of variation are in close agreement with those reported by Arnett (1963). Lucas (1960) stated that the coefficient of variation in production rate between cows is ordinarily in the order of 25 percent and may be higher. The large variation in milk production between cows probably explains the failure to obtain a significant difference between the methods of measurement. Broster and Curnow (1964) stated that with a coefficient of variation of 20 percent, thirty-two cows per treatment would be required to have a 50-50 chance of establishing as significant ($P < .05$) a treatment difference of 10 percent. In this study, the difference between methods of measurement was often less than 10 percent.

A comparison of the two methods of estimating milk production within breed is summarized in Table IX. Tests for differences revealed a significant ($P < .01$) difference in yield estimate only at 172 days of lactation for Angus X Holstein cows. The milk yield estimate from cows measured by the 3X method was significantly ($P < .01$) greater than for those cows measured by the 2X method. There was a trend for the estimate to be greater when measured by the 3X method during most periods when milk production was estimated. There appeared to be no trend for the magnitude of the difference as it varied from 0.1 to 2.9 pounds over the entire lactation period. Considering the Angus X Hereford cows, the only significant difference in milk yield estimate occurred at 110 days of lactation when the estimate for cows measured by the 3X technique was 3.3 pounds greater ($P < .05$) than that for cows measured by the 2X method. As was the case with Angus X Holstein cows, there appears to be no definite trend as to the magnitude of the difference during the entire

TABLE IX

COMPARISON OF MILK PRODUCTION ESTIMATE BETWEEN METHODS OF MEASUREMENT WITHIN EACH BREED OF COW

Period of Lactation (Days)	Method of Measurement				Difference	
	2X		3X			
	Mean	S.E.[a]	Mean	S.E.[a]	(2X - 3X)	(S.E.)[b]
			ANGUS X HOLSTEIN			
61	18.1	0.67	16.5	0.96	1.6	1.14
82	15.8	0.83	15.9	1.08	-0.1	1.34
110	14.1	0.69	16.7	1.38	-2.6	2.38
145	16.8	0.63	16.0	0.82	0.8	1.02
172	12.2	0.54	15.1	0.74	-2.9**	0.88
200	12.8	0.62	14.0	0.87	-1.2	1.05
			ANGUS X HEREFORD			
61	12.3	1.25	12.6	0.26	-0.3	1.28
82	9.8	0.72	10.7	0.53	-0.9	0.92
110	10.3	0.71	13.6	1.05	-3.3*	1.24
145	10.8	0.70	10.5	0.34	0.3	0.82
172	8.5	0.62	9.8	0.98	-1.3	1.13
200	9.3	0.76	9.6	0.73	-0.3	1.06

*$P < .05$.

**$P < .01$.

[a]Standard Error of Mean.

[b]Standard Error of Difference.

lactation period but there was again the tendency for the estimate to be greater for cows measured by the 3X method.

Figure 7 graphically compares the average milk production of the two breeds when measured by the two techniques. Considering the Angus X Holstein cows, the 3X technique for estimating milk production tends to give a more uniform lactation curve with an initial decline from 61 to 82 days of lactation followed by a gradual rise at 110 days then declining gradually to the end of lactation. The 2X technique gave a lactation curve with less uniformity than the curve with the 3X technique. Milk production declined quite rapidly from 61 to 110 days of lactation then increased sharply at 145 days. After 145 days there was a sharp decline to 172 days followed by a gradual increase to the end of lactation.

The difference in these curves, gives rise to the question of which curve more nearly represents the true lactation of the high producing cows? The curve indicated by the 3X technique may be partially explained by the level of nutrition. Assuming that there was a peak production at some time previous to the 61 days, the decline could be the result of limited nutrient intake, due to the shortage of grass early in the lactation period. As grass becomes more ample during the spring and early summer one would expect a slight increase in milk production. After the month of June, the date of the 110 day estimate, the grass matures and its nutrient content begins to decrease. This, along with the natural tendency of the cows to decline in milk production, would result in the declining portion of the curve. One would not expect the sharp increase in milk production that was observed with the cows estimated by the 2X technique at 145 days of lactation nor the gradual increase near the end of lactation. Turner (1923) and Waite and White (1956) reported that

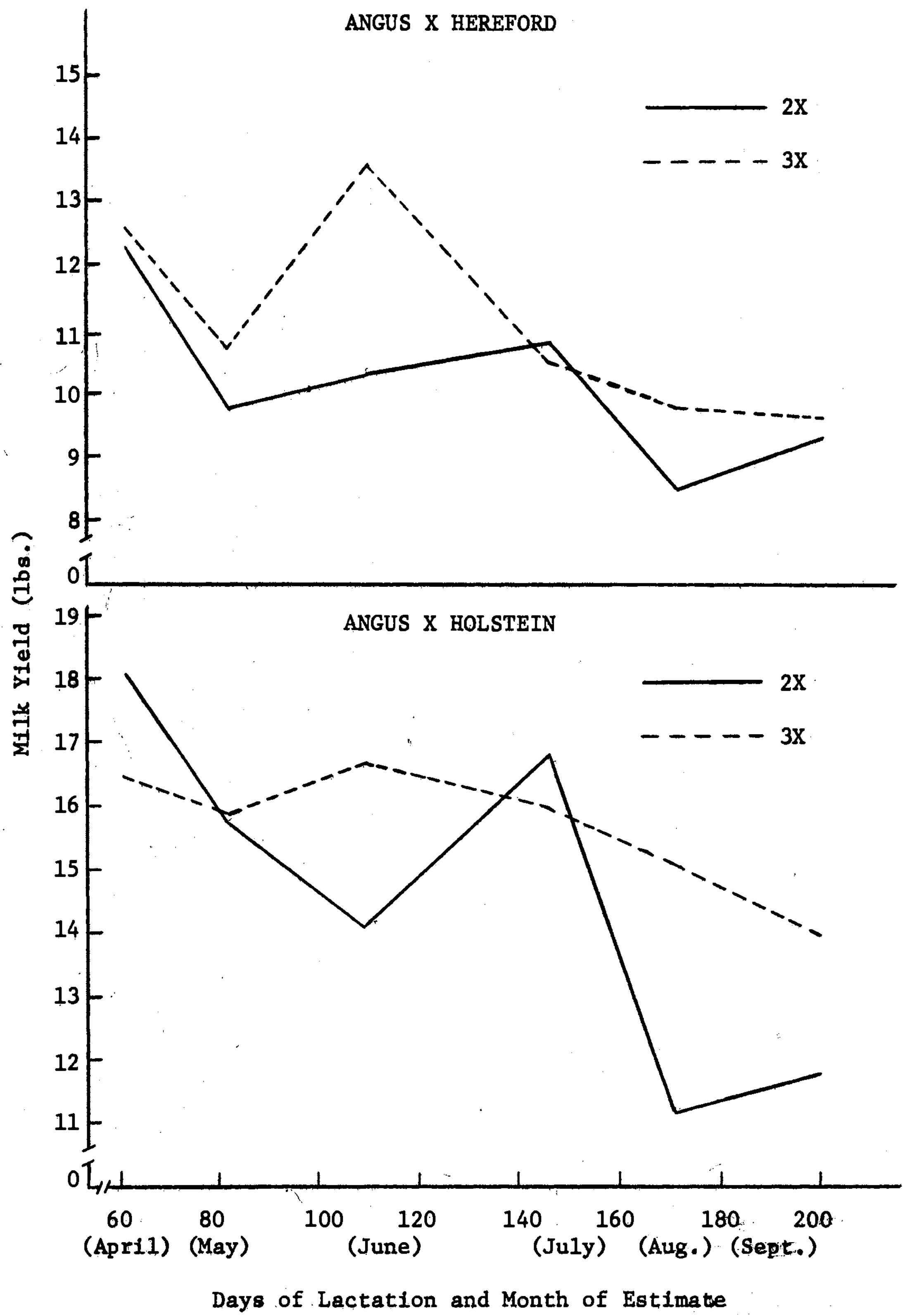

Figure 7. Average Daily Milk Yield Estimate for Each Method of Measurement Over Entire Lactation Period Within Each Breed of Dam

after 30 - 50 days of lactation, milk yield of dairy cows declined gradually to the end of lactation. However, one must take into account that the lactation curve of cows handled as dairy cows may be different since nutrient intake would be less limited than with those handled as beef cows on pasture suckling a calf.

Considering the Angus X Hereford cows, the curves indicated by each technique decline quite rapidly from 61 to 82 days of lactation. The 3X technique then was characterized by a curve rising sharply to 110 days followed by a rapid decline to 145 days which becomes more gradual to the end of lactation. The 2X technique indicates a more gradual rise to 145 days of lactation, when the milk production of cows for each estimating technique appears to become nearly equal. Following 145 days of lactation, the 2X technique indicates the curve declining somewhat more rapidly than that of the 3X technique, then rising slightly to the end of lactation. For reasons explained previously, one might expect a rise in milk production at 110 days but perhaps not as large as was observed by the 3X technique.

Van Cotthem (1962) found that the lactation curve of three year old beef cows fed on a medium plane of nutrition followed a steady decline from approximately 60 days of lactation (April) to the end of lactation while that of cows on a low or high plane of nutrition followed a slight increase to approximately 100 days of lactation (June) with a steady decline to the end of lactation. The cows used in this particular study were considered to be on a low to medium plane of nutrition. Arnett (1963) reported a lactation curve of cows measured by the calf-weight change technique as having a rapid rise in milk yield for the first 3 to 4 weeks followed by a smaller increase until the peak production was reached at the seventh week. Milk production remained relatively constant for approximately 4 weeks followed by a steady decrease in production until the end of lactation. The lactation curve estimated from data obtained by handmilking at weekly intervals indicates the peak production occurred at 3 weeks, followed by a rather rapid decline in milk yield to the end of lactation. Furr and Nelson (1964) working with fall calving beef cows observed that milk production decreased during the winter, reaching a low point in March or April then increased in production with the availability of spring grass and then declined until weaning in July. The increase in milk production was greatest for cows on a low-plane of nutrition.

Association of Average Daily Milk Production of Dams and Growth Rate of Calves

The simple correlations obtained between average daily milk production of cows and the average daily gain of their calves at four different stages of the lactation period are summarized in Tables X, XI, XII and XIII. The daily milk yield for each period represents the observations taken at the end of each period. The average daily gain of calves corresponds to the difference in body weight at the beginning and end of each period, divided by the number of days elapsing. The weaning weight of the calves is a 205 day weight adjusted to a steer equivalent by adding 5% of 205 day weight to the female calves.

Pooled correlations for the two breeds between average daily gain and total daily milk production of cows estimated by the 2X technique were highest at 61 days of lactation and decreased thereafter until a negative of -0.29 was observed at 200 days of lactation. Correlations

TABLE X

CORRELATION COEFFICIENTS BETWEEN VARIOUS VARIABLES FOR EACH TREATMENT WITHIN BREED AND POOLED ACROSS BREEDS AT 61 DAYS OF LACTATION

Method of Measurement	Total Daily Milk		Morning Milk	
	2X	3X	2X	3X
	ANGUS X HOLSTEIN			
Total Daily Milk			0.76**	0.91**
Evening Milk[a]	0.85**	0.97**	0.32	0.80**
Weaning Weight[b]	0.54*	0.68**	0.64**	0.70**
Average Daily Gain	0.46	0.72**	0.40	0.70**
	ANGUS X HEREFORD			
Total Daily Milk			0.98**	-0.17
Evening Milk[a]	0.96**	0.87*	0.88**	-0.63
Weaning Weight[b]	0.59	0.42	0.60	-0.47
Average Daily Gain	0.88**	0.86*	0.90**	-0.09
	POOLED ACROSS BREED			
Total Daily Milk			0.84**	0.90*
Evening Milk[a]	0.87**	0.82*	0.46*	0.76*
Weaning Weight[b]	0.56**	0.68**	0.63**	0.67**
Average Daily Gain	0.60**	0.71**	0.57**	0.68**

[a] Evening milk includes midday milk yield for 3X method.

[b] Weaning weight adjusted to 205 day steer equivalent.

*P < .05

**P < .05

TABLE XI

CORRELATION COEFFICIENTS BETWEEN VARIOUS VARIABLES FOR EACH TREATMENT WITHIN BREED AND POOLED ACROSS BREEDS AT 82 DAYS OF LACTATION

Method of Measurement	Total Daily Milk		Morning Milk	
	2X	3X	2X	3X
ANGUS X HOLSTEIN				
Total Daily Milk			0.66**	0.74**
Evening Milk[a]	0.85**	0.92**	0.16	0.06
Weaning Weight[b]	0.63**	0.75**	0.64**	0.64**
Average Daily Gain	0.23	0.56*	0.36	0.47
ANGUS X HEREFORD				
Total Daily Milk			0.80*	-0.31
Evening Milk[a]	0.93**	0.95**	0.53	-0.58
Weaning Weight[b]	0.21	0.66	0.04	0.23
Average Daily Gain	-0.05	0.18	-0.35	-0.09
POOLED ACROSS BREED				
Total Daily Milk			0.67**	0.71**
Evening Milk[a]	0.86**	0.61**	0.19	0.37
Weaning Weight[b]	0.50*	0.75**	0.47*	0.63**
Average Daily Gain	0.15	0.54**	0.20	0.43*

[a]Evening milk includes midday milk yield for 3X method.

[b]Weaning weight adjusted to 205 day steer equivalent.

*$P < .05$.

**$P < .01$.

TABLE XII

CORRELATION COEFFICIENTS BETWEEN VARIOUS VARIABLES FOR EACH TREATMENT WITHIN BREED AND POOLED ACROSS BREEDS AT 110 DAYS OF LACTATION

Method of Measurement	Total Daily Milk		Morning Milk	
	2X	3X	2X	3X
	ANGUS X HOLSTEIN			
Total Daily Milk			0.78**	0.58*
Evening Milk[a]	0.63**	0.96**	0.63**	0.32
Weaning Weight[b]	0.12	0.58*	-0.18	0.61*
Average Daily Gain	-0.08	0.63**	-0.28	0.58*
	ANGUS X HEREFORD			
Total Daily Milk			0.86**	0.67
Evening Milk[a]	0.87**	0.82*	0.50	0.12
Weaning Weight[b]	0.18	0.44	0.57	0.12
Average Daily Gain	0.14	0.91**	0.42	0.66
	POOLED ACROSS BREED			
Total Daily Milk			0.78**	0.58**
Evening Milk[a]	0.67**	0.95**	0.06	0.29
Weaning Weight[b]	0.14	0.57*	-0.03	0.55**
Average Daily Gain	-0.03	0.65**	-0.16	0.57**

[a]Evening milk includes midday milk yield for 3X method.

[b]Weaning weight adjusted to 205 day steer equivalent.

*P < .05.

**P < .01.

TABLE XIII

CORRELATION COEFFICIENTS BETWEEN VARIOUS VARIABLES FOR EACH TREATMENT WITHIN BREED AND POOLED ACROSS BREEDS AT 200 DAYS OF LACTATION

Method of Measurement	Total Daily Milk		Morning Milk	
	2X	3X	2X	3X
	ANGUS X HOLSTEIN			
Total Daily Milk			0.89**	0.77**
Evening Milk[a]	0.76**	0.89**	0.39	0.38
Weaning Weight[b]	-0.16	0.54*	-0.13	0.35
Average Daily Gain	-0.33	0.65**	-0.26	0.36
	ANGUS X HEREFORD			
Total Daily Milk			0.66	0.95**
Evening Milk[a]	0.79*	0.89**	0.07	0.74
Weaning Weight**	0.19	0.55	0.12	0.25
Average Daily Gain	0.01	0.65	-0.07	0.62
	POOLED ACROSS BREED			
Total Daily Milk			0.85**	0.79**
Evening Milk[a]	0.75**	0.88**	0.30	0.31
Weaning Weight[b]	-0.05	0.53*	-0.06	0.34
Average Daily Gain	-0.29	0.64**	-0.25	0.41

[a]Evening milk includes midday milk yield for 3X method.

[b]Weaning adjusted to 205 day steer equivalent.

*$P < .05$.

**$P < .01$.

of 0.60, 0.15, -0.03 and -0.29 at 61, 82, 110 and 210 days of lactation, respectively, compare favorably to those observed by Van Cotthem (1962), but are somewhat less than those observed by Gifford (1949).

There appears to be a breed difference for cows estimated by the 2X technique. The correlations for the Angus X Holstein cows were 0.46, 0.23, -0.08 and -0.33 at 61, 82, 110 and 210 days respectively as compared to 0.88 ($P < .01$), -0.05, 0.14 and 0.01 for Angus X Hereford cows. However, caution must be taken in interpreting correlation coefficients from the Angus X Hereford cows since numbers were quite small in this study.

The correlations between average daily gain of calves and total milk production of their dams measured by the 3X technique tend to be higher at each stage of lactation and decline to a lesser extent than those of cows estimated by the 2X technique. The observed pooled correlations were 0.71 ($P < .01$), 0.54 ($P < .05$), 0.65 ($P < .01$) and 0.64 ($P < .01$) for 61, 82, 110 and 200 days of lactation, respectively. These results are in close agreement with those observed by Neville (1962). The difference between the two breeds was less than it was for those cows estimated by the 2X technique. There was a trend for each breed to have similar correlation coefficients.

Arnett (1963) observed correlations of 0.83, 0.82 and 0.88 between average daily gain of calves and milk production of their dams at 70, 112 and 210 days of lactation, respectively, when cows were allowed to suckle their calves twice daily. These cows and calves however, were maintained in drylot and the calves had access to only limited feed in addition to milk.

Using average daily gain as a criteria for evaluating a technique of estimating milk production may be valid, especially early in the lactation period when the calf relies upon milk for its primary source of nutrients. Robinson et al. (1968) postulated a technique of estimating milk production of ewes using the relationship between milk production of the ewe and body weight gain of the lamb. The accuracy of the method was dependent upon the degree to which the lamb is prevented from consuming supplemental feed. One would expect the level of milk production and calf gain to be closely associated early in lactation but become less associated as lactation progressed when the calf begins to rely more upon additional nutrients from pasture for growth. This phenomenon was observed with the 2X technique but not with the 3X technique. One might also expect a higher correlation between average daily gain and milk production of calves nursing high milk producing dams than low to moderate producing dams assuming that a larger portion of the calves nutrient requirements would be met from the milk rather than grass. This phenomenon was not observed using either technique of estimating milk production. On the other hand calves from high producing dams, since they tend to have a higher rate of gain may have a substantial higher maintenance requirement. Thus, they would rely on sources of nutrients other than milk for growth to as great, or greater, an extent than do those calves nursing low-moderate producing dams. The difference in rate of gain of calves from the two breeds was not in proportion to the difference in level of milk production. Results of Drewry et al. (1959) indicate that calves suckling higher producing dams make the least gains from a given volume of milk.

Association of Average Daily Milk Production of Dams and Weaning Weight of Calves

The correlation coefficients were similar for each breed with the exception of some variation at 82 and 200 days of lactation for cows estimated by the 2X technique. At 82 days of lactation the correlation coefficient between milk production and weaning weight was 0.63 ($P < .01$) for Angus X Holstein cows as compared to 0.21 for Angus X Hereford cows. These results tend to indicate that milk production is more highly associated with weaning weight at this particular stage of lactation for high milk producing cows than for low-moderate milk producing cows. At 200 days of lactation, a different effect appears to occur with the correlation for Angus X Holstein being -0.16 as compared to 0.19 for Angus X Hereford. Since neither of the coefficients are significantly different from zero ($P < .05$) and the fact that the correlations for the Angus X Hereford cows may or may not be valid, this portion of the results will be discussed in terms of the pooled correlations rather than within each breed. Pooled correlations of 0.56 ($P < .01$), 0.50 ($P < .05$), 0.14 and -0.05 were observed 61, 82, 110 and 200 days of lactation, respectively, for the estimates taken by the 2X technique. As would be expected these tend to coincide with correlations observed between average daily gain and milk production discussed earlier.

The difference in magnitude of the correlation coefficients indicate that the association between weaning weight and milk production estimated by the 3X technique is greater than when milk production is estimated by the 2X technique. For 61, 82, 110 and 200 days of lactation, the pooled correlations observed were 0.68 ($P < .01$), 0.75 ($P < .01$), 0.57 ($P < .01$) and 0.53 ($P < .05$) respectively. These data too coincide with those observed with average daily gain with the 3X technique. It appears that the milk production estimates by the 3X technique are more highly associated with both average daily gain and weaning weight of the calves. These results indicate that milk production early in lactation has a greater influence upon weaning than at later stages of lactation. This would be expected due to the greater dependence of the calf upon the milk for its source of nutrients early in lactation. The highest correlation for the 2X method was observed at 61 days of lactation 0.56 ($P < .01$) thereafter the correlation coefficients declined to a low of -0.03 at 200 days of lactation. The highest correlation for cows estimated by the 3X technique, 0.75 ($P < .01$) was observed at 82 days of lactation. Thereafter the correlation coefficients declined to 0.53 ($P < .05$), a somewhat smaller decline than was observed with the 2X technique.

Milk Production Measured at Morning as an Indicator of Total Daily Production

If the morning milk production estimate of a cow after an overnight separation period from her calf is an accurate indicator of total daily milk production much time and labor could be saved. It would be necessary to measure milk production only once daily rather than twice or more. Harris _et al_. (1963) and Wilson _et al_. (1969) estimated milk production of cows for a 24-hour period by multiplying the recording after a 12-hour separation by a factor of two. Coombe _et al_. (1960) converted a single daily estimate from ewes after a 2-hour separation from their lambs by multiplying the amount measured by a factor of 12. Table XIV contains the correlation coefficients between the morning estimate and

TABLE XIV

CORRELATION COEFFICIENTS BETWEEN THE MORNING MILK PRODUCTION ESTIMATE AND THE TOTAL DAILY MILK PRODUCTION ESTIMATE AT FOUR STAGES OF LACTATION AND FOR THE ENTIRE LACTATION PERIOD

Breed of Cow	Angus X Holstein		Angus X Hereford	
Method of Measurement	2X	3X	2X	3X
Stage of Lactation (Days)				
61	0.76**	0.91**	0.98**	-0.17
82	0.66**	0.74**	0.80*	-0.31
110	0.78**	0.58*	0.86**	0.67
200	0.89**	0.77**	0.66	0.95**
Entire Period	0.78**	0.70**	0.85**	0.67**

*P < .05 significantly different from zero.

**P < .01 significantly different from zero.

the total daily milk production estimate at four stages of lactation and for the entire lactation period. Care must be taken in interpreting these values since they are part-whole correlations. It must be kept in mind that cows on the 2X treatment were separated from their calves for 12 hours while those on the 3X treatment were separated for a period of 8 hours. Since there appears to be a definite difference between the two breeds, they will be discussed separately.

Correlation coefficients between the amount of milk obtained from the morning estimate and total daily milk yield for the Angus X Holstein cows appear to indicate that early in lactation the morning estimate of the 3X technique is more closely associated with total daily yield than is the morning estimate from the 2X technique. Correlation coefficients at 61, and 82 days of lactation were 0.91 and 0.74, respectively, for the 3X technique as compared to 0.76 and 0.66 for the 2X technique. Later in lactation at 110 and 200 days coefficients of 0.58 and 0.77 for the 3X technique as compared to 0.78 and 0.89 for the 2X technique appear to indicate that the morning estimate from the 2X technique becomes more closely associated with total daily milk production. These values indicate that the morning estimate at the respective stages of lactation account for approximately 80% of the total variation in the total daily milk production estimate.

Figure 8 illustrates graphically the relationship between the morning estimate and the total daily milk production estimate. The curves do not show the relationship that the correlation coefficients indicated early in the lactation period. The morning estimate tends to coincide with the total daily estimate for each estimating technique. However, later in lactation the curves do indicate the difference between the 2X

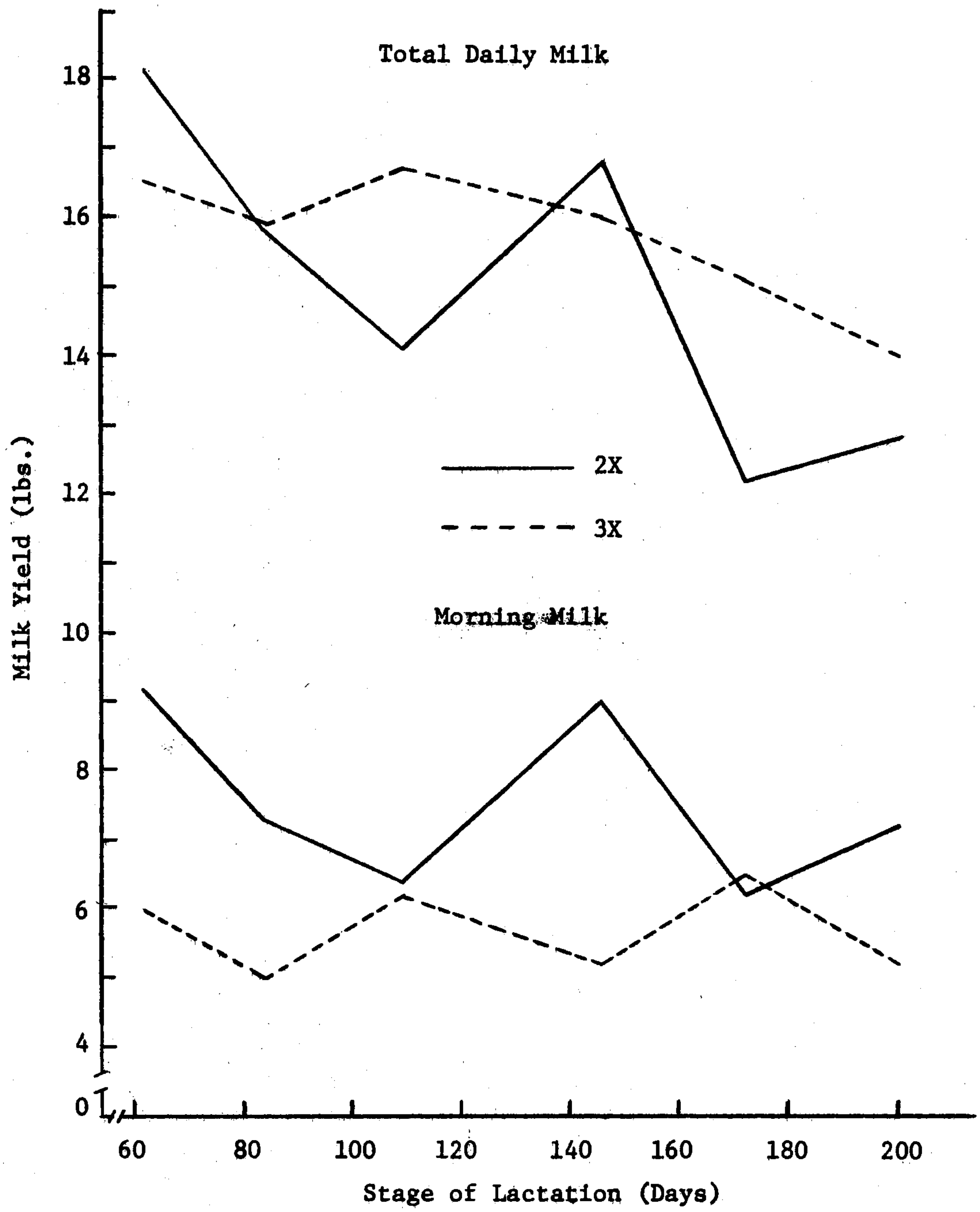

Figure 8. Relationship Between Total Daily Milk Yield and the Morning Milk Yield Estimate of Angus X Holstein Cows for Each Method of Measurement

and 3X techniques. The curve indicated by the 2X technique does appear to follow more closely the curve of total daily production.

In considering the Angus X Hereford cows, the correlations of 0.98 and 0.80 for the 2X technique at 61 and 82 days respectively are significantly ($P < .05$) higher than those of -0.17 and -0.31 observed for the 3X technique.

The morning estimate of the 2X technique appears to be a more accurate indicator of total daily milk production at 61, 82 and 110 days of lactation, however, at 200 days the correlation of 0.95 observed with the 3X technique indicates a closer association between this morning estimate than with that obtained by the 2X technique. Figure 9 illustrates the relationship between the morning estimate and total daily production. Early in lactation the curves observed for the morning estimate of each estimating technique appear to follow the pattern of the curve for total daily production. However, later in the lactation period neither curve appears to follow, since the morning estimate indicates a rise in production whereas the total daily production actually declines.

One might expect the morning estimate obtained from the 2X technique to be the most accurate indicator of total daily milk production throughout the entire lactation period since it makes up a greater portion of the total daily production. It is possible, however, that with high milk producing cows early in lactation when production is highest the 12-hour separation period may be too long. The long period of separation may permit excessive quantities of milk to accumulate in the udder increasing the intra-mammary pressure which has been reported to adversely affect milk production (Petersen and Rigor, 1932). Another possibil-

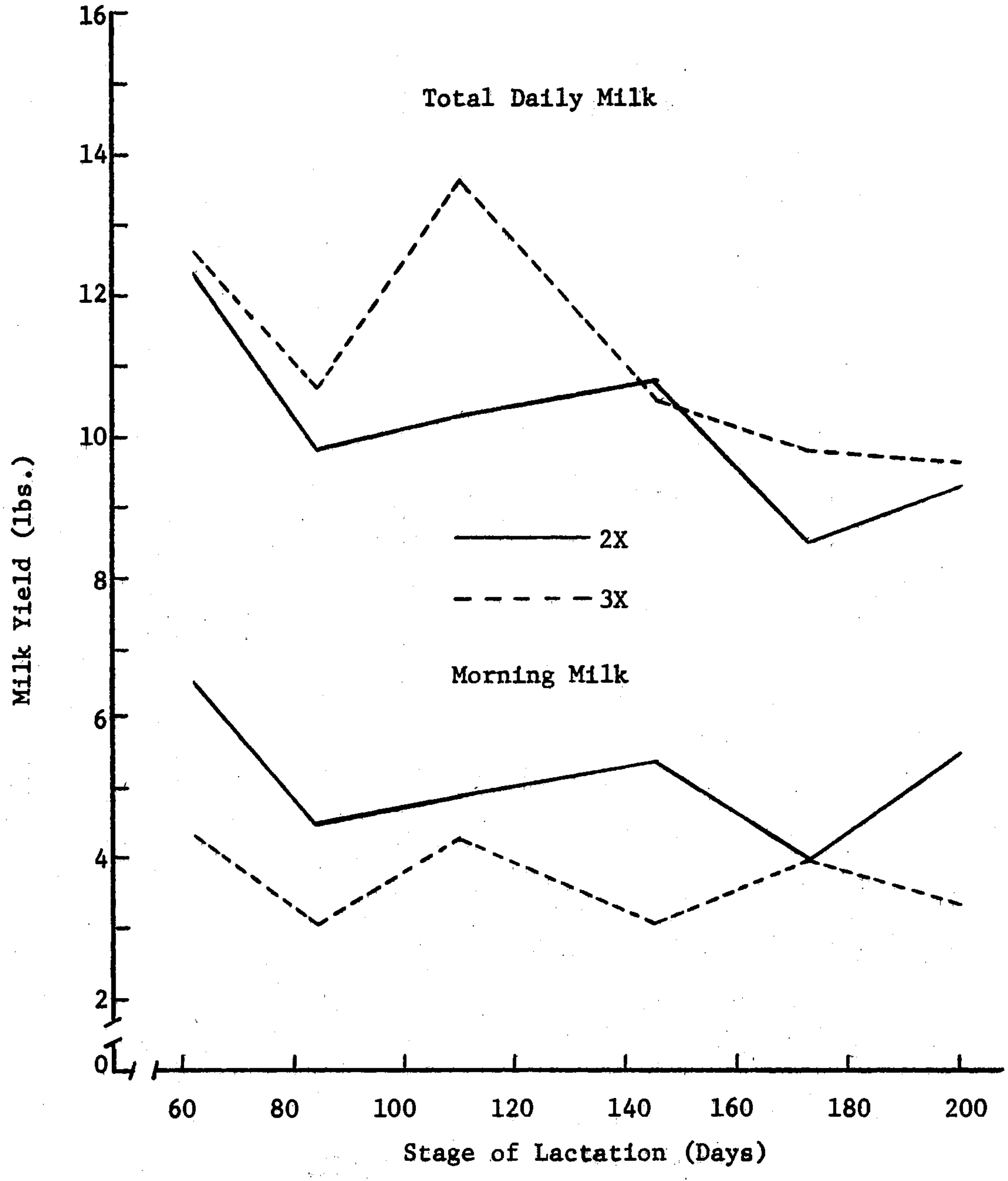

Figure 9. Relationship Between Total Daily Milk Yield and the Morning Milk Yield Estimate of Angus X Hereford Cows for Each Method of Measurement

ity is that the calf may be too small early in lactation to remove the entire amount of milk that has accumulated during the 12-hour period for the high producing cows. A shorter period combined with more frequent nursings would reduce the quantity of milk in the udder and may allow the smaller calves to nurse-out the high producing cow to a greater extent. Later in lactation when milk production declines and the calf is larger, the longer separation period may be adequate.

Table XV summarizes the means, and coefficients of variation for the morning estimate and total daily estimate along with the percent of the total daily estimate the morning estimate made up for each of the two techniques of estimating milk production. In general the coefficients of variation tend to be smaller for the total daily estimate indicating that a greater portion of the variation in milk production is accounted for when total daily estimates are made. With the exception of 110 days of lactation the coefficients of variation of the morning estimate for the Angus X Holstein cows are smaller when estimated by the 2X technique. The morning estimate after a 12-hour separation period appears to make up from 44 to 56 percent of the total daily milk yield while the morning estimate after an 8 hour overnight separation period makes up 31 to 37 percent of the total daily milk yield. The results agree favorably with those observed by Lampkin and Lampkin (1960).

The coefficients of variation of the Angus X Hereford cows do not follow the same pattern as for Angus X Holstein cows. Although those of the total daily estimate do tend to be smaller than those of the morning estimate, for cows measured by the 3X technique the coefficients of variation for both the morning and total estimate are considerably less early in lactation than those of cows estimated by the 2X technique.

TABLE XV

MEANS, COEFFICIENTS OF VARIATION OF THE MORNING MILK PRODUCTION ESTIMATE AND THE TOTAL DAILY MILK PRODUCTION ESTIMATE AND THE PERCENTAGE OF TOTAL DAILY MILK THAT IS COMPOSED OF MORNING MILK

Method of Measurement	2X					3X				
Stage of Lactation (Days)	Morning[a]	C.V.	Total[a]	C.V.	%[b]	Morning[a]	C.V.	Total[a]	C.V.	%[b]
ANGUS X HOLSTEIN										
61	9.2	16.3	18.1	14.9	51	6.0	24.8	16.5	22.5	36
82	7.3	25.0	15.8	20.8	46	5.0	35.2	15.9	26.3	31
110	6.4	34.8	14.1	22.6	45	6.2	26.7	16.7	32.0	37
145	9.0	14.5	16.8	15.3	54	5.2	29.2	16.0	19.8	32
200	7.2	26.6	12.8	19.8	56	5.2	32.5	14.0	24.4	37
ANGUS X HEREFORD										
61	6.4	30.5	12.3	27.1	52	4.3	9.5	12.6	5.2	34
82	4.5	18.2	9.8	19.6	46	3.1	15.7	10.7	12.2	29
110	4.9	22.0	10.3	18.3	47	4.3	34.2	13.6	18.9	32
145	5.5	20.7	10.8	17.1	51	3.1	34.8	10.5	7.9	30
200	5.5	22.2	9.3	21.6	59	3.4	31.0	9.6	18.6	35

[a]Pounds.

[b]Morning/Total x 100.

Coefficients of 9.5 and 15.7 percent for the morning estimate and 5.2 and 12.2 percent for the total daily estimate at 61 and 82 days of lactation, respectively, for cows estimated by the 3X technique, indicates that a considerable amount of the variation is being accounted for with this techniuqe. However, later in lactation the coefficients of variation increase to 34.8 which are considerably above those of 22.2 for the 2X technique making it doubtful that the 3X technique is giving a precise measurement of milk production. For cows estimated by the 2X technique the morning estimate makes up from 46 to 51 percent of the total daily yield for 61 to 145 days of lactation but increased to 59 percent at 200 days of lactation. For cows estimated by the 3X technique the morning estimate made up 29 to 36 percent of the total daily estimate, which is similar to those observed for Angus X Holstein. Lampkin and Lampkin (1960) measured milk production of beef cows using the calf nursing method three times per day for 12 weeks. He observed that 54, 21 and 25 percent of total daily milk was produced at the morning, noon and evening tests respectively. Lamond et al. (1969) observed that time of day a test is conducted did not significantly affect the milk produced by a cow in a 6-hour period.

If total daily milk yield is to be estimated using only one measurement per day and multiplying it by some factor, two important elements to consider are the accuracy desired to obtain the level of production and the frequency with which the estimates will be taken. These data indicate that when milk production is estimated at monthly intervalus, one daily estimate may not be as accurate as two or more. It is quite possible that one estimate per day taken at 2 week intervals is a more accurate measure of milk production than is two or more per day taken at monthly intervals. Arnett (1963) reported that milk yield determined 6 days per week by the calf-nursing method and estimates obtained at weekly and monthly intervals were highly correlated at each stage of lactation. In general, correlations between total production and estimates made on selected days increased with each additional sample taken. Estimates made on days 90 and 180 and days 30, 70, 112, 140 and 210 appear to be satisfactory intervals for estimating 210 day milk production by the calf-nursing method.

If cows to be estimated are high producers such as beef x dairy crossbreds, the period of separation from the calf should probably be less than 12 hours, especially early in lactation, to insure that the calf is capable of consuming all the milk that has accumulated. Wilson et al. (1969) estimated milk consumption of calves and total daily milk production using the calf-nursing and machine milking technique, respectively, for Angus X Holstein cows after a 12-hour separation from the calf. They reported that the difference between milk production measured by the milking machine and by the calf-nursing methods averaged 0.77 lb. and 1.45 lb. for cows on an 85 percent and 115 percent of N.R.C. energy level requirement respectively. Expressing retained milk as a percent of 12-hour yield resulted in averages of 8.8 and 12.1 percent for the 85 and 115 percent energy levels, respectively.

Effect of Stage of Lactation Upon the Milk Production Estimate

Table XVI shows the means and standard deviations of cows that were in three different stages of lactation when the milk production estimates were taken.

In this portion of the results, discussion will be confined to

TABLE XVI

AVERAGE DAILY MILK PRODUCTION OF COWS THAT WERE IN THREE DIFFERENT STAGES OF LACTATION WHEN ESTIMATES WERE BEGUN

Group No.		1[a]			2[b]			3[c]	
Month of Estimate		Mean	S.D.		Mean	S.D.		Mean	S.D.
April	(31)[d]	16.2	4.43	(62)[d]	16.4	4.05	(75)[d]	15.7	3.22
May	(52)	16.6*	3.81	(83)	14.4	5.04	(96)	13.3*	3.13
June	(80)	16.0	3.99	(111)	14.2	4.59	(124)	14.1	4.51
July	(115)	16.3	3.87	(146)	14.5	4.32	(159)	14.5	2.91
August	(142)	13.7	3.54	(173)	12.0	3.57	(186)	12.3	3.32
September	(170)	13.4	2.49	(201)	11.8	3.56	(214)	12.1	3.10

[a]Group 1; Cows ≤ 45 days into lactation when estimate begun.

[b]Group 2; Cows ≥ 46 days ≤ 69 days into lactation when estimate began.

[c]Group 3; Cows ≥ 70 days into lactation when estimate began.

[d]Average stage of lactation cow was in when estimate was taken.

*Numbers in same row with same superscript differ significantly $P < .05$.

stage of lactation only, since further separation would reduce numbers to such an extent that the validity of the results would be greatly reduced.

Group 1 cows were approximately 4 weeks into their lactation, group 2 cows were 8 weeks and group 3 cows were slightly over 10 weeks into their lactation when milk production estimates were begun. Since the milk production of all cows was estimated on the same day throughout the lactation period, this resulted in cows being in different stages of their lactation period when milk production was estimated. Cows that were in an earlier stage of lactation when the estimate was taken produced more milk with the exception of the first estimate. This same relationship was discussed earlier in this paper during the discussion of the effect of date of calving. If milk production estimates are taken on selected dates as they were in this study, a cow that calves late will be in an earlier stage of lactation when each estimate is made compared to a cow that calves earlier. It is extremely difficult to measure the extent to which milk yield is influenced by stage of lactation and calving date because these two factors are confounded with each other as well as being confounded with nutritional environment.

The general trend of the magnitude of standard deviations is that they tend to be large early in lactation and decline as the lactation period progresses. This indicates that the variation in the average milk production estimate becomes less as the cow progresses into later stages of lactation. The largest variation was observed with the group 2 cows or those that were in the 8th week of lactation when estimates were begun. The large variation may result due to part of the cows being at their peak production while others may have not reached or may have already past their peak production. The standard deviations become less later in the lactation period of group 2 cows and throughout the entire lactation of group 3 cows with exception of collection 3. This probably results because at these stages of lactation most cows are on the declining segment of the lactation curve. Figures 10 and 11 illustrate the lactation curves observed for the three groups of cows within each breed. Considering the Angus X Holstein cows, the indicated peak production for group 1 occurred at 52 days of lactation. These results agree with those observed by Waite and White (1956). Cows that were earlier in their stage of lactation when estimates were taken had a higher average milk production than those cows which were later in their lactation, in all instances except the first milk production estimate. This would be expected due to the decline in milk production as lactation progresses. From these data it is not possible to determine when group 2 and 3 cows reached their peak production. The declining segments of the curve indicate that the peak production occurred some time prior to the first estimate. One may assume that these cows also reached their peak at near 52 days of lactation keeping in mind that they calved considerably earlier, placing them in a different nutritional environment relative to pasture conditions. The rate of change of the lactation curve between estimates one and two for groups 1 and 2 was significantly different ($P < .05$). The lactation curve of group 2 cows declined to a greater extent than the increase in the curve of group 1 cows.

Due to a small number of animals and large variation in the milk production estimate the difference in average milk production was significant only between groups 1 and 3 at the second production estimate.

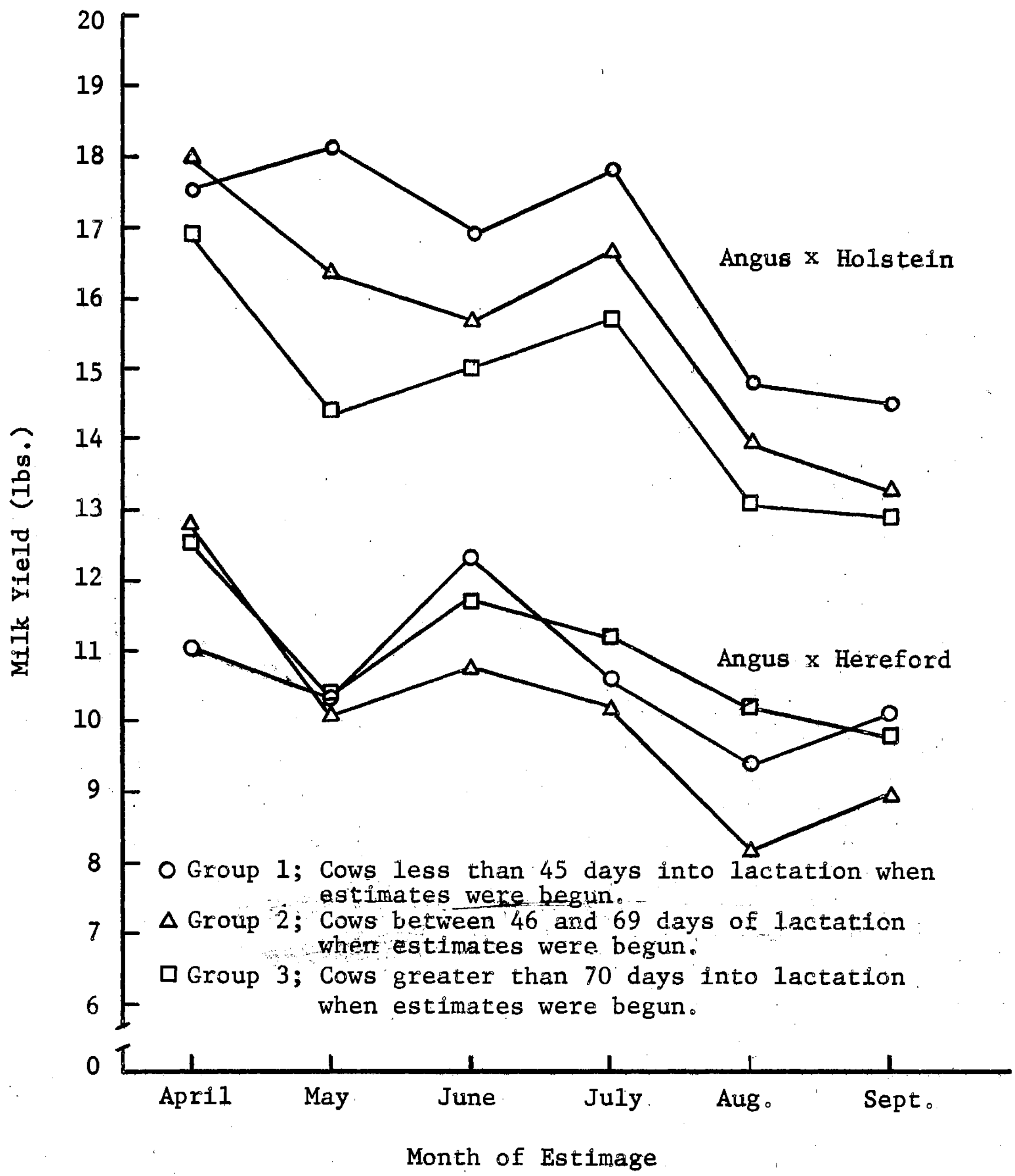

Figure 10. Average Daily Milk Yield Estimate of Cows Within Breed When Measurement was Begun at Three Different Stages of the Lactation Period

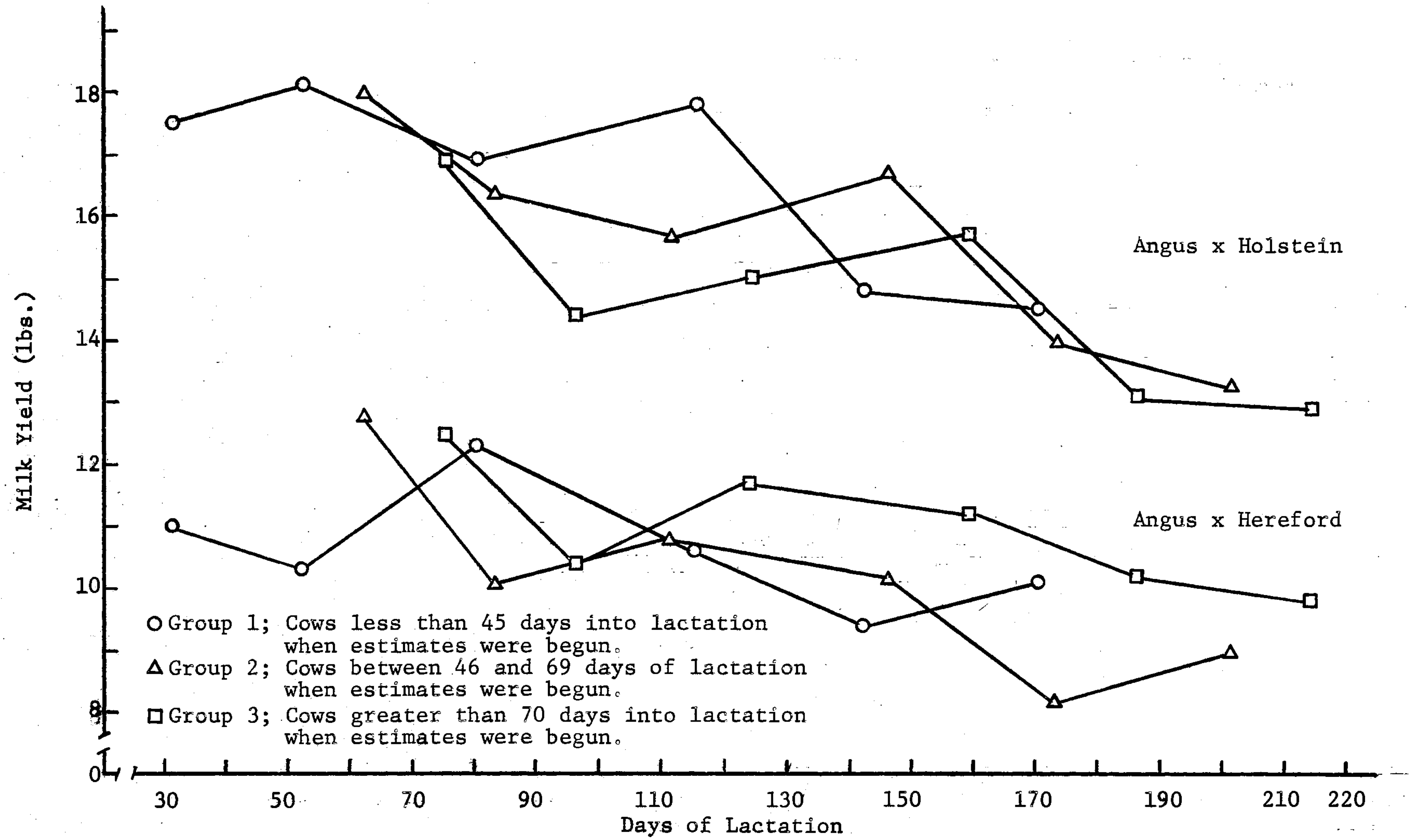

Figure 11. Relationship Between Average Daily Milk Yield and Stage of Lactation When Cows Were in Varying Stages of Lactation at the Time Milk Yield Estimates Were Begun

Considering Angus X Hereford cows, the difference in the lactation curves between the three groups was not observed to the extent that it was for Angus X Holstein cows. The means of daily milk production were not significantly different at any date that estimates were taken. The shape of the lactation curves of groups 2 and 3 of Angus X Hereford cows are similar to those of groups 2 and 3 for Angus X Holstein with the exception of the increase in production of group 3 Angus X Hereford cows. The shape of the curve for Angus X Hereford group 1 cows appears to be somewhat different early in the lactation period from groups 2 and 3 as well as group 1 for Angus X Holstein cows. The curve indicates that the cows which calved late (group 1) did not reach a peak production early in the lactation period that was observed for Angus X Hereford cows calving earlier (groups 2 and 3) and for all the Angus X Holstein cows. Late calving Angus-Hereford cows did not reach maximum production until approximately 80 days of lactation. These results disagree with those observed by Gifford (1953) who observed maximum milk yield was obtained during the first month of lactation. The possibility exists that the late calving low-moderate producing cows reached a peak some time prior to four weeks of lactation and the decline, results due to the inadequacy of the nutritional environment. The increase in milk production near the end of the lactation period for groups 1 and 2 of the low-moderate producing cows is not typical and may not represent the true pattern of the curve.

In discussing the lactation curves of all groups of each breed, in general there are two peaks occurring during the lactation period. The first peak is not observed in all curves of Figures 10 and 11, however, they are indicated by the declining segments of the curves between the first and second estimate. It is possible that these peaks result from different factors. The first peak may result from the physiological processes of the cow to produce near her maximum potential regardless of the nutritional environment she may be in. The nutritional environment is probably one of the more important factors determining the length of time any given cow remains at the first peak of production. The decline of the first peak is probably the result of inadequate nutrient intake since the quality and quantity of pasture is limited early in the lactation period of spring calving cows. The second peak in milk production may be explained as a result of improved pasture quality and quantity in late spring and early summer. Hughes (1971) who studied the lactations of beef cows from 1961 through 1967 at the same location of this particular study observed a similar lactation curve for cows calving in 1967 which was different from that observed in previous years. A peak in production was observed at 57 days of lactation and another peak at approximately 117 days of lactation. The range in calf age at time of the first peak was 30 - 79 days. He suggested that severity of winter and grazing conditions in early lactation are important factors in determining the time of peak milk production and attributed the second peak in production to the occurrence of improved grazing conditions in the spring and early summer.

The Angus X Hereford cows appeared to reach their second peak production approximately 4 weeks prior to the Angus X Holstein cows. This agrees with the observations of Turner et al. (1923) and Brody (1945) that the time required for high milk producing animals to reach peak production is usually longer than that for low milk producing animals. Another explanation may be that the body stores of the Angus X Holstein cows were depleted to a greater extent than those of the Angus X Hereford. The additional time required to reach the second peak may be in essence the time required to replenish the body stores of the high producing cows. Although the cows were not scored for condition at any time during the lactation period the Angus X Holstein cows appeared to be in lower condition than the Angus X Hereford cows during the lactation period.

The varying level of production for cows in different stages of lactation illustrates the importance of considering the stage of lactation of the animals if milk yield is to be used as a criteria for evaluating animal performance in research studies. The difficulty in controlling the large variation in milk yield estimate due to errors in measurement, between cow variation and other factors, illustrates the need for a method of measurement or use of an experimental design that will reduce the variation to an extent that small differences between treatments can be detected. Lucas (1960), in a discussion concerning dairy feeding experiments implied that in single-lactation studies, one should strive to use only cows which will be in the interval from peak production to mid-gestation. It is highly probable that this method would be impractical for studies involving beef cows due to the difficulty of obtaining enough animals at the right time to meet the qualifications. Also, most studies are conducted to determine the effects of treatment upon early lactation or over the entire lactation period. The change over design has been suggested and used satisfactorily by many workers to reduce the coefficient of variation. However, this design is criticized because the results have strictly limited practical application due to possible carry-over effects from certain treatments and the lack of information obtained regarding long term treatment effects. This particular study along with many previous studies of similar nature was conducted using the continuous treatment design and applying covariance analysis. The covariables in this particular study as stated earlier were birth date and birth weight of calf. Broster and Curnow (1964) conducted a covariance analysis study involving factorial sequences of treatments using dairy heifers. The level of production in weeks 5-12 of lactation was used to adjust the measurement of milk production in weeks 13-22 of lactation. They reported that the coefficient of variation of milk yield was reduced from 18 to 8 percent by analysis of covariance using yield in the control period as the independent variate. With the slope of the lactation curve in the control period as a second independent variate it was further reduced to 6 percent. Adjustment of butterfat and solids-not-fat percentages for values in the control period reduced the coefficients of variation from 11 to 8 percent and 3 to 2 percent respectively. The coefficients of variation for the adjusted data were not much larger than those obtained in changeover experiments. It is quite possible that such approach could be used in beef cattle research studies involving milk production of the cow and possibly enhance the precision of the experiment.

CHAPTER V

SUMMARY

A study was initiated in February of 1968 to compare two techniques for estimating milk production in range beef cows having two different potential milk producing abilities. A total of 48 first calf heifers consisting of 36 Angus-Holstein crossbreds and 12 Angus-Hereford crossbreds were used. Both techniques for estimating milk production were based on the calf-nursing method. One method consisted of allowing the calves to nurse twice daily (2X) with a 12 hr. interval between nursings. The second method consisted of allowing the calves to nurse three times (3X) daily with an 8 hr. interval between nursings. The magnitude of the effects of birth date, birth weight, sex of calf and stage of lactation upon the milk production estimate were also studied.

Least squares constants for the effect of birth date on milk production were positive at all periods of lactation when milk yield was measured, indicating that the milk yield estimate for cows calving later was greater than for cows calving earlier. The effect appeared to be of greater magnitude early in lactation, declining as lactation progressed.

Birth weight of calf did not significantly affect milk production at any stage of lactation. However, all least squares constants were positive indicating a trend that increased birth weight of the calf may be associated with increased milk production of the dam.

The milk yield estimate of cows nursing male calves tended to be larger than for those nursing female calves. The difference ranged from 0.0 to 2.2 pounds per day. The difference was greater in Angus-Holstein cows than in Angus-Hereford cows. Sex of calf appeared to have a greater effect upon milk yield during the first half of the lactation period.

As expected, Angus-Holstein cows produced significantly more milk than Angus-Hereford cows at all stages of lactation. The difference ranged from 3.3 to 5.2 pounds per day.

Milk yield estimates of cows measured by the 3X method were in general greater at most stages of lactation, however, the difference was significant only at 110, 172 days and when the average yield over the entire lactation was considered. Coefficients of variation on milk yield were lower in Angus-Holstein cows measured by the 2X method, whereas, for the Angus-Hereford cows the coefficients of variation were less for the 3X method. The association of average daily gain and weaning weight of calves with milk production appears to be greater in those cows whose milk production was measured by the 3X method.

The use of one daily estimate measured at morning after an overnight separation of 12 or 8 hr. for the 2X and 3X methods, respectively, indicate a considerable breed difference. The morning estimate taken by the 3X method for Angus-Holstein cows appears to be more highly associated with total daily milk yield early in lactation, however, during the latter 1/3 of lactation the morning estimate taken by the 2X technique tends to be a better indicator of total daily milk. For Angus-Hereford cows, the morning estimate taken by the 2X technique resulted in a measurement more highly associated with total daily milk early in lactation, however, late in the lactation period the morning estimate taken by the 3X method resulted in a measurement more highly associated with the total daily milk.

Stage of lactation that the dam was in when milk yield estimates were begun significantly affected the magnitude of the estimate. Cows early in lactation had significantly greater yield estimates than cows that were later in lactation.

Data in this study illustrates the importance in considering certain factors when using milk yield as a criteria for measuring the productivity of beef cows in research work. Coefficients of variations for milk yield ranging from 12.6 to 31.2 observed in this study illustrate the need for an experimental design or statistical analysis that will reduce the variation of milk yield so that the precision of the experiment can be enhanced and small treatment differences detected.

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VITA

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