STUDIES WITH TWIN BEEF FEMALES. I. SOME EFFECTS OF LEVEL OF NUTRITION. II. MILK PRODUCTION TECHNIQUES

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Submitted to the Faculty of the Graduate School of the
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Applied Science in partial fulfillment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY
August, 1963

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INTRODUCTION

The influence of energy level upon various economically important traits of beef cattle has received considerable attention in recent years. Most studies have been concerned with energy levels below those commonly recommended today, but observations made by livestock producers have led to the general belief that overfeeding to the degree that an animal becomes very fat is detrimental to its productivity. Basic information on the effect of a high degree of body fatness is needed in order to more fully elucidate the optimum energy levels for maximum production in the commercial beef cow herd. Such information, obtained by studying extremely high levels of energy intake compared to recommended levels, should also aid in the interpretation of results from research within more practical nutritional ranges.

The amount of milk that a cow provides for her calf has long been recognized as a major influence on the performance of the calf prior to weaning. However, until recent years, few attempts were made to estimate the milk yield of beef cows due to the difficulties encountered in obtaining an accurate estimate. As methods of estimation have been developed and refined it has become important to relate these estimations to the actual total milk production, utilizing complete records for the entire lactation.

Although the calf is almost entirely dependent upon milk to meet its nutritive requirements for the first few months, little is known about the amount of milk required to produce a calf of a specific weight at weaning age. Similarly, knowledge of the composition of milk with respect to calf performance prior to weaning would give a more accurate picture of the actual value of the dam's milk to her calf.

In an attempt to provide this information, a study was initiated to (1) determine the influence of moderate vs. very high levels of nutrition on the development, reproductive ability, milk production, and longevity of beef females; (2) to study some techniques of estimation and frequency of sampling interval with respect to the total milk yield of beef cows during a 210 day lactation; and (3) to relate the yield and composition of the milk to calf performance.

REVIEW OF LITERATURE

Part I. Effect of Level of Nutrition on Beef Females

Literature relating to the influence of plane of nutrition on cattle has been reviewed by numerous workers using various production criteria (Joubert, 1954; Burt, 1957; Reid, 1960; Holland, 1961; Furr, 1962; Pinney, 1962). This review is primarily confined to experiments in which high feeding levels were used in definite attempts to induce rapid growth and/or excessive fatness.

Growth and Development

Crichton *et al*. (1959) used 18 pairs of monozygotic twins and 6 pairs of dizygotic twins in a balanced incomplete block experiment to examine: (1) A continuous high plane of nutrition from birth to first calving; (2) A high plane for the first 44 weeks followed by a low plane until 2 months before calving; (3) A continuous low plane until 2 months before calving; and (4) A low plane for the first 44 weeks followed by a high plane until first calving. The high plane ration represented 110 percent of the Ragsdale recommendations and the low plane about 60 to 65 percent.

At 44, 80, and 104 weeks the high plane heifers significantly exceeded those on the lower plane in weight and in each of several body measurements. Low plane feeding retarded the live weight much more than it did the size of the skeleton. All groups reached sexual maturity at about the same stage of development but at different ages.

The same four systems of rearing were also studied by Crichton et al. (1960a) to determine their effects on growth rate to maturity. Body measurements indicated that all groups differed significantly from one another in the age at which maturity was reached. By about 6 years of age all groups had reached about the same body size, however, live weight continued to increase slowly up to 9 years of age.

Hansson (1956) studied the influence of rearing intensity on body development and production of 16 sets of identical twin heifers which varied in type from an extreme dairy type to fleshy dual purpose cattle. These twin pairs were divided into four groups. One heifer of each pair was used as a standard control while her mate was given nutritional levels of 60, 80, 120, or 140 percent of the standard level of nutrition. These levels were fed up to 25 months of age after which all animals received the same treatment. Each of the levels influenced rate of growth, but all heifers eventually reached the same body development at maturity.

Swanson (1960) separated seven pairs of identical twin dairy heifers at ages varying from 4 to 12 months. One member of each pair was fed a normal control ration and her mate was fed concentrates at a high level to induce rapid growth and fattening. All heifers were fed alike after their first parturition. The fattened heifers averaged 899 pounds compared to 683 pounds for the controls, or 32 percent heavier. The height at withers of fattened heifers was higher than that of the controls, however, none of the heifers averaged as high as the standard at any age, indicating an inherently small body size in the experimental animals. The fattened heifers lost an average of

143 pounds at parturition compared to a loss of only 50 pounds for the controls. Nine months postpartum the fattened heifers lacked 18 pounds of regaining their prepartum weight while the controls weighed 142 pounds more than their prepartum weight.

Reid _et al_. (1957) studied the effects of quantity of nutrients from birth to first calving upon the lifetime performance of Holstein cows. The feeding levels employed were 65, 100, and 140 percent of Morrison's feeding standards from birth until first calving. After first calving the groups received TDN levels of 118, 109, and 100 percent for the low, medium, and high groups, respectively. After the second calving all groups received TDN in accordance with Morrison's standards. At the time of first calving the weight, height, and length of the cows were correspondent to their feed intake. The low level heifers showed the capacity to grow later when adequate feed was provided. The group maintained on the high level of nutrition early in life maintained a weight advantage as late as 7 years of age.

Sorenson _et al_. (1959) reported results of an extensive study utilizing a randomized block design with energy levels of 60, 100, and 140 percent of the TDN recommended for growing dairy heifers by Morrison. A total of 65 Holstein calves were slaughtered at 16 week intervals up to 80 weeks within the three treatment levels. At the end of 80 weeks the average weights were 566, 919, 1125 pounds for the low, medium, and high levels, respectively. Measurements of heart girth, height at withers, and body length were significantly different for each level at each 16 week interval. There was a relatively large difference in body weight between medium and high level heifers as contrasted to smaller differences in height at the withers and body length. Animals on the high level were considered as fat but not excessively so.

Zimmerman (1960) studied the effects of four levels of winter supplement on the growth and development of beef heifers. Each of seven body measurements studied was affected by the level of winter supplement. Differences between treatment groups were reduced during the summer months when all heifers were treated alike. Low level heifers were about 96 percent as large as high level heifers in all measurements at 42 months of age.

Reproduction

Reid et al. (1957), using the feeding levels previously described, found that the level prior to first calving had a marked effect upon the age of sexual maturity. However, all heifers exhibited the first heat at about the same body size. There was no consistent effect upon the conception rate through the fifth pregnancy. Although the low level heifers required more assistance at first calving, little difference was noted thereafter. Through the fifth lactation the higher levels of feeding had resulted in more sterile cows. A later report by Reid (1960) indicated that although there was no difference in the number of services, the percentage conceiving at first service was: Low, 79; medium, 68; and high, 58. This indicated that the average number of services required by low level heifers may have been considerably lower had not a few of these heifers required several services.

The three treatment groups previously described (Sorenson et al., 1959) exhibited their first estrus at average ages of 37.4, 49.1, and 72.0 weeks for the high, medium, and low fed groups, respectively. Estrus cycles occurred with about equal regularity thereafter indicating that ovarian function was affected very little once puberty was reached.

Skeletal measurements of height at withers and body length were much less variable than body weights at first estrus. Histological studies of the reproductive tracts revealed no differences with all groups apparently normal and functional.

Zimmerman (1959) reported a 10 year summary of the production of range beef cows wintered at three levels of supplementation. Level of wintering had little effect on birth weight of the calves. The percent calf crop weaned favored the low and medium levels. Results of the same study to 13.5 years of age were reported by Pinney (1962). Cows wintered on the low level had a higher conception rate and lost fewer calves from birth to weaning. This resulted in a 7 percent higher calf crop weaned for the low level cows.

Chambers et al. (1960) observed that replacement heifers developed under full feeding from 7 to 12 months of age did not perform in the breeding herd as well as those developed at a lower level of nutrition. When 4 years data were combined about 5 percent more heifers in the lower level groups were diagnosed pregnany, 9 percent more of them calved, and 11 percent more raised calves to weaning.

Wiltbank et al. (1962) fed two levels of energy, 9.0 and 4.5 pounds per head daily, to mature Hereford cows prior to calving. After calving one-half of the cows in each group was fed 16.0 pounds of TDN per head daily and the remaining one-half of each group received 8.0 pounds of TDN per head daily. Treatment before calving had little influence on calving difficulty or percent of stillborn calves. The number of services per conception was less in cows on the higher level of energy after calving.

Graves et al. (1940) observed that Holstein cows fed on roughage rations were more regular breeders than those on rations in which grain was fed. However, there were other factors which may have influenced this breeding efficiency.

El-Sheikh et al. (1955) investigated the effect of roughage plus grain (high) and roughage only (low) on the development and functional activity of some of the reproductive organs in yearling ewes. Ewes on the high level of feeding had a significantly higher ovulation rate, larger follicles, and a higher number of follicles 2 mm. or more in diameter. The high level ewes had a lower embryonic survival.

Holland (1961) found no differences in breeding efficiency, difficulty at calving, or gross appearance of the reproductive tract in mature Hereford cows fed at moderate and high levels during gestation.

Milk Production

Chambers et al. (1960) noted that heifers which had been full-fed during a 5 month post-weaning gain test (7-12 months of age) weaned calves which were about 80 pounds lighter than heifers grazed on native pasture during the same 5 month period. Since weaning weights are markedly influenced by the milking ability of the dam this suggests that a high level of nutrition at this age may damage a heifer's potential milking ability.

Herman and Ragsdale (1946) and Herman et al. (1948) observed that dairy heifers fed a "rapid growth ration", ad libitum produced less milk and fat than heifers reared chiefly on roughages. The production of high level heifers remained low for the second and third lactations. A great deal of fat deposition was noted in the udder before freshening. Bonnier et al. (1948) noted that animals which were overfed, especially prior to first calving, had a disturbed general metabolism which resulted in a lower capacity to yield milk.

Sykes <u>et</u> <u>al</u>. (1948) fed two groups of white rats at 100 and 70 percent of <u>ad libitum</u> feeding. Mammary glands of the full-fed group were 80 percent heavier than those of the restricted group at parturition, however, after 21 days of lactation mammary gland weights were almost equal. The restricted rats raised superior litters, as indicated by gain per litter, average weight of young, and survival of young.

Swanson and Spann (1954) reared white rats on <u>ad libitum</u> and 80 percent <u>ad libitum</u> amounts of feed. Lactation was measured by growth of equalized litters. Rats raised by <u>ad libitum</u> feeding raised 59 percent of their young compared to 93 percent for the restricted group. Average litter gains were 136 gm. and 235 gm. for the <u>ad libitum</u> and restricted rats, respectively. The rapid growth rats produced litter gains of only 60 percent that of restricted rats in the second lactation. Mammary glands were not fully developed in the fattened animals.

Swanson (1960), using seven pairs of identical twin dairy heifers, fed one member of the pair a normal ration while the other was fed heavily on concentrates until first calving. The fat-corrected-milk (FCM) yield of the fattened heifers averaged 84.8 percent of the FCM yield of the controls. Butterfat and solids-not-fat production closely followed milk yields. The greatest difference was in the first 20 weeks of lactation. Similar results were found in the second lactation, although individual pairs reacted differently in the two lactations. Examination of the udders following slaughter revealed a lack of development of alveolar secreting tissue in the fattened twins.

Using the four levels of rearing previously described, Hansson

(1956) found that milk yield decreased slightly with each increase in rearing intensity. These differences were even more marked in the second lactation for the 120 and 140 percent of standard levels. There was little difference in butterfat percentage although the higher levels of nutrition tended to give slightly higher percentages.

Klett et al. (1962) estimated the milk production of 61 Hereford cows fed three levels of supplemental energy. The average milk yield was 7.04, 8.03, and 8.16 pounds per day for high, medium, and low levels of supplemental energy, respectively.

Holtz et al. (1961) used three breeds of dairy cattle to determine if average daily gain from birth to 6 months of age was related to later lactation yields. The slower gaining Jerseys in this study were significantly superior producers among the Jerseys. This difference did not exist with Holsteins or Guernseys. It was suggested that a different pattern of development might be involved since there was a positive relationship between weight during lactation and fat-corrected-milk yield. This might also indicate a breed characteristic.

Based on about 900 Lebedin cows, Kovalev (1962) found correlations between body weight and milk yield of 0.80 for cows with a body weight of 1320-1430 pounds, and -.02 for cows with a body weight over 1430 pounds.

Crichton et al. (1960b) compared the fat-corrected-milk yields, and the butterfat and solids-not-fat percentages of the milk of heifers reared on the four planes of nutrition described earlier. The group reared on the high-low level had the lowest fat-corrected-milk yield in each lactation. This difference was significant in the first two lactations. The plane of nutrition during rearing had no apparent effect on the normal pattern of change in milk composition and/or yield in the ensuing lactations. The first lactation was longer and the percentage of butterfat and solids-not-fat was larger in the first lactation than in succeeding lactations.

Reid et al. (1957) observed milk yields through five lactations for cows reared at three levels of nutrition during early life. Level of rearing did not have a significant effect upon the milk yield during any lactation period. However, the data indicate that the number of days in milk was less for the high level cows and total production was slightly lower in all lactations except the first.

Clanton et al. (1961) determined the milk production of beef heifers fed different levels of protein and energy during gestation. No significant differences were found in milk production, however, animal variation was very large.

Longevity

The duration of life is determined by the interaction of genetic and environmental factors which influence the rates of growth, development, and ageing, and which cause death through diseases and accidents or cause life to end in "physiological" death. Obesity has been recognized as deleterious to the longevity of humans and has been demonstrated in several species of laboratory animals. However, there is little sound experimental evidence as to the effects of high level feeding upon the incidence of disease or longevity with farm animals.

Osborn et al. (1917) observed that female rats stunted early in life lived longer than rats which were reared on a standard stock diet.

McCay et al. (1935) conducted experiments to determine the effect of retarded growth upon the life span of white rats by restricting the intake of an otherwise adequate diet. Retardation increased the average life span of male rats by 377 days. However, there was no significant difference in the average life span of female control and retarded rats. McCay et al. (1939) provided rats a basal diet in amounts sufficient only to keep the animals alive while those allowed a normal growth were given excess calories. Groups of retarded rats were realimented at 300, 500, 700, and 1000 days of age. Results confirmed the earlier studies in that members of each of the retarded groups were alive after all of the controls had died.

McCay et al. (1941) carried out a group of experiments to determine the effects of dietary and other regimes upon rats which had reached maturity and middle age. In general, these experiments showed changes in diet introduced during the latter half of life can affect the life span, but not to the degree noted when underfeeding was begun at the time of weaning. Rats kept slightly underweight outlived those allowed to fatten.

A further study by McCay et al. (1943) was designed to follow the development of chronic diseases in normal and retarded rats and to determine the effects of feeding an adequate basal diet supplemented with various additional sources of calories. Retarded rats were realimented at 300, 900, and 1150 days. Both the retarded and control groups followed the characteristic curve of mortality but the average duration of life was extended about 50 percent by retardation. The average life span was directly proportional to the length of retardation. The retarded rats were less subject to common diseases than the normal rats when groups equal in age were considered. The type of calories provided made little difference in regard to the span of life.

Ball et al. (1947) found caloric restricted mice outlived their littermate sisters when restricted to two-thirds the caloric intake of ad libitum fed controls. Twenty-five percent of female mice subjected to a lifetime calorie restriction were alive at an age when all of their full-fed littermate sisters had died.

Berg (1960) established levels of food restriction which prevented accumulation of excess body fat and yet provided for good skeletal growth. A total of 339 rats were maintained under ideal conditions on three levels of food intake; ad libitum, 33 percent restriction, and 46 percent restriction. Autopsy revealed little or no evidence of body fat in the restricted rats while in the non-restricted there were large amounts of fat. Berg and Simms (1960) reported on the longevity, mortality, and onset of disease as influenced by the level of food intake of the same group of rats. On ad libitum feeding only 48 percent of the males were alive at 800 days as compared with 81 to 87 percent survival for restricted male rats.

A further study by Berg and Simms (1961) was designed to extend to 1200 days with ad libitum feeding and 46 percent of ad libitum feeding. Restricted rats over 1000 days old were lively and had a sleek appearance which contrasted sharply with the obesity and sluggishness of animals fed ad libitum. Males fed a restricted diet were observed to have a life expectancy of about 200 days over that of the unrestricted males. Female rats showed an increased life expectancy of 364 days as a result of food restriction. In both males and females the lesions in the restricted rats were less severe than those in the ad libitum fed animals of the same age.

The similarity of results in organisms belonging to different groups, even those phylogenetically separated, indicates that over-nutrition may be a basic biological factor affecting the life span of all living organisms. This is suggested by the results reported by Ingle (1937) who demonstrated Daphnia which were "starved" throughout life lived about 40 percent longer than those fed well throughout life. Similar results have been obtained by Rudzinska (1952) in the protozoa, Tokaphrya Infusionum. Pauling (1958) observed that both obesity and emaciation decreased the life expectancy of humans.

Hansen and Steensberg (1950) compared three groups of cows reared on low, normal, and high levels of nutrition during winter feeding. The average length of life measured in number of calvings per cow was 4.6, 4.3, and 3.4 for low, normal, and high level winter feeding, respectively. Failure to conceive or fertility disturbances accounted for 27.6 percent of the removals in the low level group, 29.0 percent in the medium, and 51.0 percent in the high level group.

Reid et al. (1957) noted that more high level cows were discarded due to infertility in the lifetime study previously described.

Horn (1950) observed a difference in longevity between breeds and that early maturity was apparently associated with a shortened life span.

Hansson and Bonnier (1951) stated that since nutrition influences the rate of development, the process of ageing may also be affected. They noted that one member of a twin set fed at a high level became nymphomatic at 2 years of age and her low level twin at 3.5 years. This indicated that if this endocrinological disturbance is genetical the differences in physiological age were due to nutrition.

A later report by Hansson (1956) involving nine pairs of identical twins showed that the twins reared on a low level survived until 95 months of age compared to 75 months for their high level mates. He postulated that part of the difference might be due to increased stress on the organism which follows increased feeding. He noted that the heart rate and respiration rate were greater in the high level cows. This is in agreement with Ritzman et al. (1924), Sykes et al. (1954, Thomas and Moore (1951), and Reid (1956) who indicated that increasing intakes of energy are accompanied by accelerated heart rates.

Pinney (1962) reported some long term effects of three levels of winter supplementation on the productive life span of Hereford cows. The productive life in the herd was inversely related to level of winter supplementation, with 16, 11, and 5 of an original 30 cows in each group remaining on test at 14 years of age for the low, medium, and high groups, respectively. Failure to wean a calf for two successive years was the greatest reason for removal and was greater at the higher feeding levels. Cancer eye, spoiled udders, and other diseases were the next major reasons for removal and were more prevalent in the cows on the high level.

Part II. Milk Production Techniques

Methods

As early as 1904, Fuller and Klienheinz noted that by weighing a lamb immediately before and after nursing over twice as much milk was obtained as by handmilking. Barnicoat et al. (1949) investigated several methods of estimating milk production in the ewe. They noted that by handmilking not more than one-half of the milk could be extracted. The use of a milking machine was impractical for large numbers. In general, pituitrin injections facilitated milk let down for handmilking with yields ranging from 80 to 100 percent of those obtained by weighing the lambs before and after nursing. This weight-change technique of weighing the lambs before and after nursing was considered the best for estimating milk yield, and was adopted to estimate the milk production of ewes by Burris and Baugus (1955), Guyer and Dyer (1954), and Wallace (1948).

Owen (1957) devised an udder cover which prevented suckling between weighing times without separation of the ewe and lamb. This cover caused no apparent inconvenience to the ewe and prevented the lamb from reaching the ewe's udder.

McCance (1959) reported that more milk was obtained by handmilking after an injection of posterior pituitary extract than by weighing the lamb before and after nursing. Coombe et al. (1960) compared the weight-change technique using udder covers and handmilking following stimulated let down by injection of posterior pituitary extract (oxytocin technique) in estimating milk yields of grazing ewes. The oxytocin technique gave significantly higher values for milk production than did the weight-change technique. Variation between ewes was similar for both techniques.

Similar techniques have also been used in estimating the milk production of sows. Bouland et al. (1949) used the oxytocin technique followed by handmilking and Allen and Lasley (1960) used the weight-change technique to estimate milk production in sows.

Each of these methods with various modifications have been used to estimate milk production in beef cows. Although the frequency of sampling has varied, the weight-change technique of weighing the calf immediately before and after nursing has been the most widely used of these techniques for estimating milk production in beef cows (Knapp and

Black, 1941; Howes et al., 1958; Arbuckle, 1959; Drewry et al., 1959; Dawson et al., 1960; Lampkin and Lampkin, 1960; Montsma, 1960, 1962; Neville, 1960; Kuhlman et al., 1961; Furr, 1962; Wiltbank, 1962; VanCottem, 1962; Velasco, 1962). Heyns (1960a,b) used the weight-change technique but calves were fitted with "weaners" and allowed to run with their dams.

Lampkin and Lampkin (1960), using the weight-change technique, calculated that 54 percent of the total yield was produced during an overnight period of 14 hours. The milk yielded after this 14 hour period of separation was then regarded as 54 percent of the total daily production.

Gifford (1953) milked one-half of 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. This suckling and handmilking technique was adopted by Howes et al. (1958).

In some studies beef cows have been milked and handled as dairy cows (Cole and Johansson, 1933; Dawson et al., 1960).

Anthony et al. (1959) reported a procedure which permitted direct measurement of milk secretion and composition. The cow was separated from her calf, injected intramuscularly with 40 U.S.P. units of oxytocin, and subsequently milked dry with a milking machine followed by hand stripping. The calf remained separated from the cow for a 12 hour period, then the milking procedure was repeated in the same manner described for the pre-test. Milk production was reported on a 12 hour, fat-corrected basis. The technique was used routinely with large numbers of cattle, the entire procedure taking about 5 minutes per cow. This has been the technique used by Anthony et al. (1962), Caldwell et al. (1962), and Harris et al. (1962), all from the Alabama station. Klett et al. (1962) also used the oxytocin technique at 13 or 14 hour intervals to estimate the milk yields of several breeds of beef cows.

Sampling Intervals

Sere Del Campo (1946) listed several factors affecting variance in milk recordings. These factors in descending order of importance were individual differences between cows, the method of calculating yield from records, time of beginning records in relation to calving, and frequency with which the records are made, with the remainder of the variation accounted for by interaction of the above factors.

Lampkin and Lampkin (1960) conducted a trial using four calves in order to get an estimate of errors involved at different intervals. Calves were allowed to nurse three times daily during a 12 week period. Of the total milk consumed, 54, 21, and 25 percent was taken at the morning, noon, and evening test, respectively. The calves appeared capable of taking all the milk except possibly in the first 2 weeks. Milk production was estimated at 1, 2, 3, 4, and 7 day intervals. The errors were increased as intervals became greater, however, these errors were probably not large enough to offset disturbances in grazing behavior.

Weekly estimates of milk production was the interval chosen for later work by Lampkin and Lampkin (1960) and was also used by Knapp and Black (1941), Dawson et al. (1960), and Heyns (1960a,b). Two week intervals were used by Kuhlman et al. (1961). Gifford (1953), Howes et al. (1958), and Velasco (1962) used monthly intervals to obtain estimates of milk production. Two month intervals were used by Neville et al. (1960) and Neville (1962). Caldwell et al. (1962) collected milk production data at 30, 60, 90, 180, and 250 days postpartum. Sere Del

Campo (1946) stated that the influence of frequency upon accuracy of records was relatively small unless the interval between recordings exceeded 42 days and that the accuracy decreased considerably by 60 days.

Sere Del Campo (1946) noted that the most accurate methods of estimating yield are those which are calculated from the average of two successive recordings and from records considered to be in the middle of the period whose yield they represent.

The preceding observation is supported by studies with dairy cows. Cannon _et al_. (1942) stated that the prediction of yield could be most accurately made from a test taken during the fifth month of lactation. The sixth month was the next most accurate followed by the fourth and seventh months. Less accuracy was noted for early or late stages of a 10 month lactation. VanVleck and Henderson (1960) found that the fourth, fifth, and sixth were the best single months for estimating lactation yields of Holstein cows. The correlation between the predicted and actual record was 0.85 for these months. Madden and McGilliard (1959) observed that the variation in milk yields was less during the fourth through the seventh months of lactation. Therefore, these months were more highly correlated with the total milk production than were the months of maximum production, the first three months. The same relationship between part and whole production was found to exist for low and high producers.

Milk Production Studies With Beef Cattle

The early literature contains very little information concerning the milk yields of beef cows. However, in the past decade there has been an increasing interest in measuring the yield and composition of milk and its relationship with calf performance in beef cows.

Gowen (1918, 1920), reporting the lactation records for three purebred Angus cows in crossbreeding studies conducted in Maine, noted that quality had little relation to the quantity of milk flow. He found high milk production is dominant to low production, but high fat percentage is recessive to a low fat percentage in the milk.

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 cows produced an average of about 3100 pounds of milk per lactation with a 4.1 percent butterfat content, but there was a large range in the milk yield. The lactation curve reached its peak at 4 weeks and decreased regularly thereafter until lactation ceased at 44 weeks. 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. The maximum average yields of milk for a 4 week period were 376, 543, and 549 pounds for the first, second, and third lactations, respectively. Percentage of fat and protein showed a slight, but consistent decrease with increasing age of the cow. Other milk constituents were not affected.

A study of factors influencing the rate of gain of Shorthorn calves during the suckling period by Knapp and Black (1941) indicated that the quantity of milk consumed had a greater influence on rate of gain than any other factor studied, including birth weight, sire, dam, sex, and feed consumption. The actual level of milk production of the dams was not given. The heaviest gaining bull calves to 140 days were from the poorest scoring cows for beef characteristics.

Cook et al. (1942) obtained carcass data on 83 milking Shorthorn steers and milk production data from their dams. Milk records were converted to 4 percent fat-corrected-milk and converted to a mature basis. Steers were weaned at approximately 500 pounds and fattened to 900 pounds before slaughtering. Correlation between milk production and efficiency of gain in the feedlot of offspring was 0.10, but was not significant. These authors found a low negative correlation between milk production and percent fat in the carcass and also between milk production and carcass grade. The progeny of dams with a mature equivalent of up to about 8000 pounds of fat-corrected-milk showed a decrease in carcass grade as milk production increased, but from that level upward there was no further decrease in carcass grade.

The first extensive studies of milk production in beef cows were reported by Gifford (1949, 1953). Milk and butterfat production were determined by the suckling and handmilking technique over an 8 month lactation period. The cows were kept on pasture 9 to 10 months and were fed silage, prairie hay, and 1.5 pounds of cottonseed cake daily during the remainder of the year. The cows which calved during the winter months were fed an additional grain supplement of 2 to 4 pounds per head daily. A total of 77 records were obtained from 28 Hereford cows, 14 Angus cows, and 5 Shorthorn cows.

The average production for all cows was 1498 pounds of milk with an average butterfat test of 3.08 percent. The amount of milk produced tended to increase up to about 6 years of age or through the fourth lactation. Beef cows between 2 and 3 years of age produced less milk than cows of any other age studied. The average maximum milk and butterfat production was reached during the first month of lactation and declined at an ever decreasing rate until the end of lactation. The average daily milk production for Hereford cows for each of the 8 months of lactation was 8.52, 7.67, 7.26, 6.07, 5.25, 4.79, 4.80, and 4.14 pounds.

Correlation coefficients between average daily milk production of the Hereford dams and monthly gains of their calves for the 8 months of lactation were 0.60, 0.71, 0.52, 0.35, 0.19, 0.24, 0.39, and 0.57. The gross correlation coefficients between daily milk production and several body measurements were lower than for the weight gains. Correlations between butterfat production of the cows and gain in weight of calves were slightly less than those for milk production.

When cows were grouped according to their average daily maximum production, those producing less than 6.5 pounds of milk weaned calves averaging 354 pounds. Cows that produced 6.5 to 12.9 pounds daily weaned calves averaging 405 pounds and cows which averaged more than 13 pounds during their highest producing period produced calves that averaged 475 pounds at weaning.

Milk production data obtained earlier at Beltsville, Maryland, on 30 beef Shorthorn cows was summarized by Dawson et al. (1960). Milk production was estimated by the weight-change technique, and weekly samples were taken by hand for butterfat determinations. The average milk production for a 252 day lactation was about 4400 pounds of milk and the average butterfat content was 3.98 percent. The average milk production was 22.7 pounds per day during the second 28 day period but had decreased to an average of 13.6 pounds per day by the last month of lactation. The age of cows and year both had a marked effect on milk production.

In the same publication, Dawson et al. (1960) also summarized early results obtained at Manhattan, Kansas, with 24 cows selected because of their ability to produce beef calves of exceptional merit. These cows were milked and handled as dairy cows. Average production for 42 complete lactations was 4862 pounds of milk with an average fat test of 3.95 percent.

In Australian studies, Arbuckle (1959) ascertained milk production by the weight-change technique five to seven times between birth and weaning. During a drier than average year, 19 cows produced an estimated average of 1109 pounds, starting with 12.2 pounds per day and gradually decreasing to nothing. In a year with better than average pastures, 11 early calving cows and 12 late calving cows produced an estimated average of 1393 and 1600 pounds of milk, respectively.

Drewry et al. (1959) obtained data on 48 Angus cows and calves to study the relationships among factors affecting mothering ability. Milk production was estimated for 1 day in the first, third, and sixth month of laction by the weight-change technique. The average milk production of the dams was 14.1, 16.0, and 9.0 pounds for the first, third, and sixth month, respectively. Milk required per pound of calf gain was estimated to be 12.5, 10.8, and 6.3 pounds for the first, third, and sixth months, respectively. The amount of forage consumed in addition to milk was unknown since the calves remained on pasture with their dams at all times. Calves suckling heavier producing cows required more milk per pound of gain.

Correlation coefficients between average daily milk production and birth weight of the calf were 0.43, 0.29, and 0.12 for the first, third, and sixth months, respectively. The correlation values between total gain from birth and estimated daily milk production of the dam were -.15, 0.35, and 0.48 for the same three months.

Howes et al. (1958) allotted 12 Hereford and 12 Brahman heifers into two groups which received 100 or 50 percent of N.R.C. recommended protein allowances. Milk production was estimated at monthly intervals by the suckling and handmilking technique. Protein level significantly affected calf growth and milk yield. The correlation coefficients between calf growth and milk production through the first 4 months of lactation were 0.67, 0.83, 0.50, and 0.45.

Brahman were superior to Herefords in milk yield, calf growth, milk protein, solids-not-fat, and total solids, especially through the first 3 months. The calculated dry matter and protein supply from the milk was inadequate to maintain the growth observed at about the third month, indicating the calves were less dependent on the dams after this time.

Milk production estimates were obtained in three trials with fall calving Hereford cows by Furr (1962). These cows were fed different levels of supplemental winter feed in addition to native grass or prairie hay. Milk production was estimated by the weight-change technique. In trial I cows wintered at a lower level of nutrition produced an average of 5.92 pounds of milk per head daily compared to 6.40 pounds for high level cows over the last 172 days of lactation. Correlation coefficients of 0.81 and 0.85 between average daily gain of the calves and milk production of the cows were found for the low and high level groups, respectively. Milk production declined in late winter for both groups but increased again in the spring when the nutritive value of the grass increased. Cows wintered at the lower level showed the greatest increase when spring grass became available.

A second trial also indicated a higher level of winter supplementation significantly increased milk production. In this trial the correlations between daily gain and milk yield were -.31 and 0.53 for the low and high groups, respectively, and 0.15 for another low level group in which the calves were creep fed. These correlations were not statistically significant.

In the third trial, average milk yields were 6.82, 6.88, 5.33, and 6.54 pounds for cows supplemented at low and high levels in traps with prairie hay as the roughage, and on native range, respectively. Correlations of daily gain with milk production for the same groups were 0.75, 0.91, 0.80, and 0.80.

Velasco (1962) conducted a similar study to determine the effects of different levels of winter supplement on spring calving Hereford cows grazing native pasture. Average milk production estimated by the weight-change technique at approximately monthly intervals was 6.25 and 8.12 pounds per day for low and high level lots in one trial, and 9.20 and 10.32 pounds per day for the low and high level lots for the first 145 days in another trial.

Correlation coefficients between average daily gain of the calves and estimated milk production of their dams were 0.76 and 0.55 for the low and high levels in the first trial, and 0.71 and 0.01 for the same levels in the second trial. The correlations were highest in the first 3 months and decreased in later months. The average peak of lactation was at the end of the second month and slowly decreased thereafter.

Harris _et al_. (1962), using the oxytocin technique, studied the effects of two wintering levels on milk production of Hereford cows. The average daily fat-corrected-milk production in early spring was 9.18 and 6.02 pounds for optimum and restricted fed groups, respectively. After 56 days on good spring grass the comparable milk production values were 8.9 and 9.0 pounds, indicating the ability to respond with increased milk production if adequate nutrients are available.

Neville _et al_. (1960) studied the influence of milk production and other factors on 120 and 240 day weights of 135 Hereford calves whose dams were fed at three nutritional levels until the calves were 4 months old. Milk production was estimated by the weight-change technique at 2 month intervals between birth and weaning at 8 months. Average daily milk production at 4 and 8 months was: low plane 8.5, 8.1; medium plane 10.2, 9.6; and high plane 11.5, 10.5. A correlation coefficient of 0.798 was obtained between the total milk production and eight month calf weight on a within year, nutrition, sex, and sire basis.

Neville (1962), in a more detailed report, estimated that the average milk consumption by calves to 8 months of age was 1944, 2304, and 2520 pounds, respectively, for the three nutritional levels mentioned above. He reported an average of 12.5, 12.5, and 23.5 pounds of milk were required to produce a pound of calf gain for the low, medium and high levels, respectively. Correlations of average daily calf gains and daily milk production for four 60 day periods between birth and weaning were 0.74, 0.63, 0.59, and 0.66 for the first through the fourth periods, respectively.

Montsma (1960) found that Sokoto (Zebu) cattle produced more milk than West African Shorthorn or N'Dama cattle under Ghana conditions. Milk production was estimated by the weight-change technique. Cows calved at the beginning of the dry season and received only available grass, silage, and a small amount of concentrate at the peak of the dry season. The correlation between milk yield and growth up to 8 weeks was 0.96. During this 8 week period calves gained 12.4 pounds per 100 pounds of milk. Calves from high yielding dams had better conversion rates than those from low yielding dams.

Montsma (1962) reported other data which was recorded similarly but under different environmental conditions. In this trial cows calved during the rainy season and received a concentrate supplement in addition. Total milk yields for a 26 week period were 846, 1015, and 1330 pounds in trial I compared to 1724, 1594, and 2599 pounds in trial II for West African Shorthorn, N'Dama and Sokoto cows, respectively. Although Sokoto cows produced more total milk, there was little difference when expressed in terms of yield per pound of body weight.

In this second trial the correlation between milk yield and growth was positive in each breed but significant only in the Sokoto. The gain per 100 pounds of milk over the 26 week period was 17.4, 15.1, and 15.9 pounds in trial I compared to 12.5, 12.2, and 11.6 pounds in trial II for the West African Shorthorn, N'Dama, and Sokoto breeds, respectively.

Lampkin and Lampkin (1960) conducted a 3 year study on milk production and other factors which influence the growth of suckling calves from birth to weaning. Milk production was estimated by the weight-change technique for 164 Zebu cows grazing grass only. The average estimated milk yield over a 36 week lactation was 2486 pounds. When the 36 weeks were divided into three 12 week periods, 40, 35, and 25 percent of the milk was produced in the first, second, and third periods, respectively. A peak daily average of 13.1 pounds was reached during the seventh week of lactation. It was observed that animals with a higher yield in the first 12 week period generally remained superior throughout the lactation.

The average amount of milk required per pound of gain by calves, with access to grass, was 7.2 pounds for male calves and 7.9 pounds for females. The amount of milk required per pound of calf gain decreased with each period indicating that milk became less important to the calf as he was able to utilize more nutrients from grass. When comparisons were made between cows which calved within 2 weeks of one another, within-pair correlations between total milk production and calf rate of gain were 0.675 for the males and 0.523 for the females. Between pair correlations were 0.795 and 0.650 for males and females, respectively.

Heyns (1960a) determined the milk production of 24 Afrikaner cows at weekly intervals over an 8 month lactation period by the weight-change technique. The cows consisted of eight 4 year old cows in their second lactation, seven 6 to 7 year old cows in their fourth lactation and nine cows from 9 to 14 years of age in their sixth to twelfth lactations. Milk samples were taken by machine for composition analyses. The average total milk production during a 238 day lactation was 2892 pounds, or an average of 12.2 pounds per day. The peak of the lactation curve was 28 days after parturition, at which time the daily milk production was 22.5 pounds.

The production of milk constituents, by weight, followed a trend similar to that of the lactation curve. The percentages of solids-not-fat, protein, ash, and calcium increased as the volume of milk decreased With the exception of lactose and ash, the quality of milk decreased with increase in the age of the cow. The percentage protein was greatly reduced in older cows.

A second report by Heyns (1960b) related the milk production of the dam and growth of the calf. The correlation between weight gain of the calves and average daily milk yield was 0.64. The correlation between weight gain and protein production was 0.67. Correlation coefficients between birth weight and total milk production of the dam, gain in weight of the calf, and weaning weight were 0.75, 0.73, and

0.75, respectively.

The correlation between birth weight and consuming capacity of the calf for one feeding period during the first week after parturition was 0.78. The correlation between birth weight and daily milk intake remained significant through 24 weeks after parturition. For each additional 10 pounds in weight at birth, the calf possessed the capacity to consume 3.9 pounds more milk during one feeding at the age of 1 week. It was suggested that a heavier calf at birth exerts a greater stimulation on the milk production of its dam and that this tends to be continuous throughout the lactation period. Milk production of cows and weaning weights of their calves increased up to a maternal age of 6 to 7 years and subsequently decreased.

Klett et al. (1962) used the oxytocin technique to estimate the milk production of 15 Angus and 15 Hereford cows at College Station, Texas. Angus cows produced a 205 day total milk yield of 1765 pounds or an average of 8.61 pounds per head daily compared to a total of 1321 pounds and a daily average of 6.44 pounds for Hereford cows. Hereford cows had higher yields at the beginning of lactation but were not as persistent in milk flow as the Angus. The weight per day of age was 2.11 and 1.82 pounds for Angus and Hereford, respectively. Angus calves required 4.73 pounds of milk per pound of calf gain compared to 4.26 pounds for Hereford calves. Differences in milk composition were minor, however, the quantity of total solids obtained during the 205 day period was estimated at 220 and 164 pounds for the Angus and Hereford calves, respectively.

The same techniques were used with 22 Hereford and 24 Brahman-Hereford crosscows at Angleton, Texas. Average milk yield was 4.14

pounds per day for Herefords and 8.60 pounds for the crossbred cows.

In another study near Menard, Texas, 55 Hereford cows yielded an average of 7.11 pounds of milk over a 138 day period. Cows 7 years of age and over yielded more milk than those 4 years old and under.

The weight-change technique was also used by Klett et al. (1962) to estimate the milk production of 61 Hereford cows fed three levels of supplemental energy. The average daily milk production was 7.72 pounds per day when all groups were combined. The average milk yield by treatment groups was 7.04, 8.03, and 8.16 pounds for the high, medium, and low levels of supplemental energy, respectively.

Caldwell et al. (1962) calculated milk production on a 12-hour basis for 48 Angus, 53 Hereford, 20 Shorthorn, and 14 crossbred cows using the oxytocin technique. The 12-hour milk yields at 30 days were 6.41, 5.85, 5.67, and 5.15 pounds for Angus, Hereford, Shorthorn and crossbred cows, respectively. The milk yield, relative to breed, remained the same throughout lactation although steadily decreasing to 4.48, 3.71, 3.51, and 3.37 pounds at 250 days postpartum.

The pooled correlations for all breeds between calf gain and total milk yield at 30, 60, 90, 180, and 250 days of lactation were 0.618, 0.542, 0.465, 0.564, and 0.340, respectively. The correlations between calf gain to 250 days and percent fat, percent protein, and percent total solids were -.182, -.287, and -.254, respectively.

Repeatability of successive measurements of total milk, fat-corrected-milk, and percent fat taken every other day for three milkings at the end of lactation was determined. Repeatabilities were 0.919 for total milk, 0.888 for fat-corrected-milk, and 0.677 for percent fat.

Repeatability of fat-corrected-milk for Herefords from year to year was 0.671, 0.496, and 0.486 at 90, 180, and 250 days of lactation, respectively. Angus had repeatabilities of 0.235, 0.773, and 0.655 for the same days of lactation.

EXPERIMENTAL PROCEDURE

A total of 12 sets of twin beef females were used to determine the influence of moderate vs. very high levels of energy on the performance of beef cows. This study was initiated in July, 1956, with three sets of twins which were approximately 16 months of age when started on the trial. In January, 1958, eight additional sets of twins ranging in age from 8 to 18 months were started on trial. One additional set was added in May, 1958, at 8 months of age. A blood-antigen test was conducted to determine if the twins were monozygotic or dizygotic. Table I indicates the breed, approximate age when started on trial, and results of the blood-antigen test.

One member of each set was fed a high energy ration to achieve maximum possible gain and to maintain the cow at a high degree of body fatness. The second member of the set was fed a ration adequate in all nutrients but containing a moderate level of energy. Moderate level cows were fed to make average daily gains of one-half to two-thirds pounds prior to first parturition and to maintain a healthy, thrifty condition thereafter. All of the cows were kept in drylot and fed individually in stanchions to facilitate accurate feed intake data and to control weight gains. The average daily rations which were fed prior to first parturition, during lactations, and between lactations are given in Table II. All cows received identical amounts of protein supplement, vitamin and mineral supplement, alfalfa pellets, and salt. The energy level required to achieve and maintain the desired difference in fatness

TABLE I

BREED, AGE STARTED ON TEST, AND RESULTS OF BLOOD-ANTIGEN TEST

Cow Number	Breed	Age Started On Test (Mo.)	Blood-Antigen Test[1]
3,4	Hereford X Brahman	16	+
5,6	Hereford	16	+
7,8	Angus	16	+
9,10	Shorthorn	12	+
11,12	Hereford X Shorthorn	18	-
13,14	Hereford X Santa Gertrudis	8	-
15,16	Hereford	14	+
17,18	Hereford X Angus	10	+
19,20	Hereford	13	+
21,22	Angus	14	+
23,24	Angus	10	+
25,26	Angus	8	-

[1]Negative sign indicates vascular anastomosis, considered positive proof that twins are not identical.
Positive sign indicates no vascular anastomosis detected, highly reliable but not positive indication that the twins are identical.

TABLE II

AVERAGE DAILY RATIONS AND INTAKES OF T.D.N. BY TWIN COWS PRIOR TO, BETWEEN, AND DURING LACTATIONS

Treatment Level	Supplement[1]	Dehydrated Alfalfa Pellets	Cottonseed Hulls	Cracked Corn	T.D.N.
	lbs.	lbs.	lbs.	lbs.	lbs.
Prior to First Parturition					
Moderate	2.0	2.0	10	0	6.85
High	2.0	2.0	7	8	11.95
During Lactations					
Moderate	2.0	4.0	16	4	13.77
High	2.0	4.0	6	10	14.20
Between Lactations					
Moderate	2.0	2.0	11	3	9.78
High	2.0	2.0	8	8	12.48

[1] Supplement composition: Cottonseed Meal, 47.0%; Soybean Meal, 46.1%; Bonemeal, 4.6%; Salt, 2.3%.

TABLE III

COMPOSITION OF CALF RATION

Ingredient	Percent of Total	lbs. T.D.N.
Cottonseed Hulls	20	8.74
Cracked Corn	30	24.03
Cottonseed Meal	10	6.33
Alfalfa Leaf Meal	10	5.44
Rolled Oats	20	14.02
Molasses	10	5.37
Total	100	63.93

between the two levels was induced by varying the proportion of corn and cottonseed hulls in the ration of the moderate level cows. High level cows received a full feed of corn and a minimum of cottonseed hulls at all times. During lactation an attempt was made to provide energy intakes sufficient to maintain small but constant gains in weight for all cows. This level of energy intake was considered adequate to allow full expression of the milk producing potential of the cow. All cows were returned to their prepartum level of feeding during the period between lactation and the next parturition.

With the exception of the first matings of the initial three sets of twins, all cows were mated to the same purebred Angus bull. A half-sib of this bull was mated to the first three sets of cows the first year but was replaced because of low fertility. Cows were exposed to the bull each feeding period and at other times when a cow was observed in heat. All cows were mated when 21 to 30 months of age. Following a 45 day postpartum interval, the cows were remated.

The calves were separated from their dams and placed in individual drylot pens when they were 10 days of age. From birth to 112 days of age the calves received only the milk from their dams with no supplemental feed. From 112 days of age until weaning at 210 days the calves were handfed the supplemental ration shown in Table III. The daily intake of this supplement was adjusted at 14 day intervals, by the method of Winchester (1953), to amounts calculated as adequate to satisfy the maintenance requirements of the calves. Under these conditions, differences in calf performance should be a good estimate of treatment effect on the milk production of the dam on a within-twin basis.

Milk production of the cows was estimated by the following techniques:

1. Handmilking the cows during the feeding periods 1 day each week. Milk was drawn from one-half of the udder while the calf was nursing the opposite side. The opposite udder half was milked the following week.
2. Weighing the calves immediately before and after nursing each day. Calves were allowed to nurse twice daily while the cows were in stanchions during the feeding periods. This procedure was not initiated until January, 1960, therefore, data for three complete lactations using this technique are not available.
3. Performance of the calves.

On the day that handmilking was conducted, composite samples of the morning and evening milkings were taken. The butterfat and total solids content were determined by standard Babcock and Monjonnier methods, respectively.

Calves were weighed at birth, 70 days, 112 days, and at 210 days (weaning). Birth weights of heifer calves were adjusted to a bull equivalent using the methods of Botkin (1952). The 210 day weaning weights of heifer calves were adjusted to a bull equivalent using the methods of Koch _et al_. (1959).

Reproductive data collected included the number of services required per conception, length of gestation, and observations concerning calving difficulty. The condition of the calves at birth and the general health of both cows and calves were also recorded. Gross examinations of the reproductive tract and pregnancy checks were conducted at various intervals.

The weights of all cows were recorded at 28 day intervals. Several body measurements, including height at withers, depth of chest, heart girth, width at hips, and length of head were taken at approximately yearly intervals and at time of slaughter. Accurate individual feed records were kept for each cow.

The rectal temperatures and respiration rates were determined for periods of 10 consecutive days each during April, June, August, 1961, and February, 1962.

Both members of a twin set were slaughtered after finishing the third lactation. Carcass data obtained included conformation grade, quality grade, overall grade, rib eye area, and thickness of external fat. The external fat was measured by methods described by Malkus *et al.* (1961). The weight of the hear, liver, brain, ovaries, and pituitary were recorded.

RESULTS AND DISCUSSION

Part I. Effect of Level of Nutrition on Beef Females

Due to the large amount of genetic variation between sets of twins, the data making up treatment averages include only those sets of twins for which complete records are available. Results presented here are complete through three lactations.

Body Weight and Development

Table IV summarizes the weight of the cows at 6 month intervals at ages from 12 to 72 months. The average body weights of the cows are illustrated graphically in Figure 1. The weight of high level cows increased rapidly up to 30 months of age. They continued to increase in weight until approximately 42 months, after which they maintained a relatively constant weight. The weight of moderate level cows increased steadily until about 48 months and then tended to remain fairly constant. The greatest differences in weight at any of the 6 month intervals occurred at 30 and 36 months of age.

High level cows averaged 483, 342, and 273 pounds heavier than the moderate level cows at the first, second, and third parturition, respectively (Table V). The 483 pound difference just prior to the first parturition was the greatest actual difference between the two levels at any time.

They body measurements given in Table VI indicate that the high level cows had a larger skeletal size than moderate level cows at all

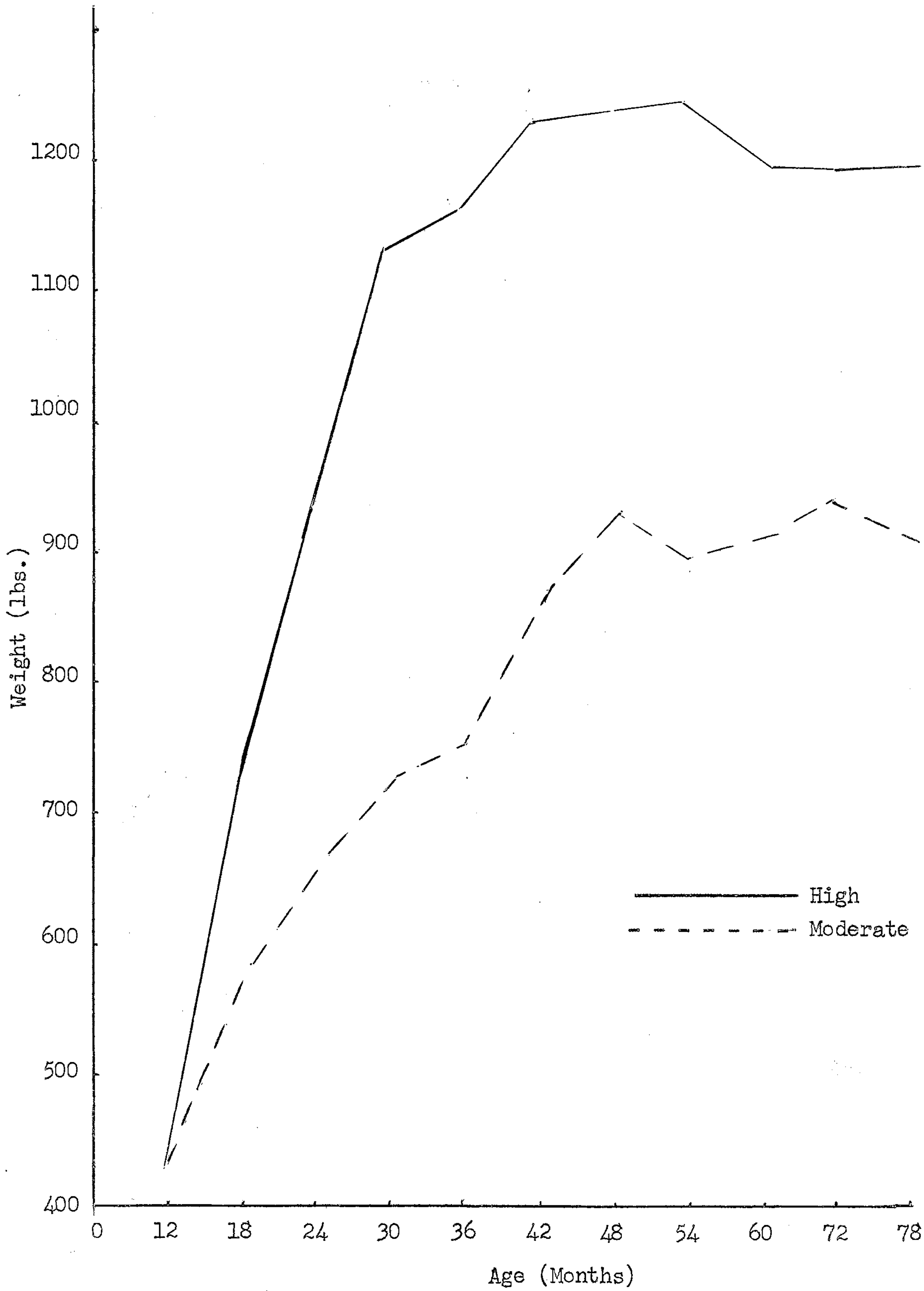


Figure 1. Weight of Moderate and High Level Cows of Ages from 12 to 72 Months.

TABLE IV

WEIGHT OF MODERATE AND HIGH LEVEL COWS AT 6 MONTH INTERVALS[a]

Average Age	Treatment Level		Weight Difference[b]
	Moderate	High	
(Mo.)	(lb.)	(lb.)	(lb.)
12	437	428	-9
18	574	717	143
24	659	928	269
30	728	1125	397
36	757	1154	397
42	876	1224	348
48	929	1229	300
54	896	1232	336
60	917	1202	285
66	931	1198	267
72	912	1202	290

[a]Includes eight complete twin sets with both members remaining at 72 months.
[b]High level minus moderate level.

TABLE V

WEIGHT OF MODERATE AND HIGH LEVEL COWS AT THE BEGINNING OF THE TRIAL, AT FIRST MATING, AND AT TIME OF PARTURITION

Time of Cow Weights	No. Complete Sets	Treatment Level		Weight Difference[a]
		Moderate	High	
		(lb.)	(lb.)	(lb.)
Beginning of Trial	12	462	458	-4
First Mating	12	686	979	293
First Parturition	12	822	1305	483
Second Parturition	10	1046	1388	342
Third Parturition	9	1096	1369	273

[a]High level minus moderate level.

ages. The largest differences in the body measurements occurred at approximately 3 years of age.

The high level cows continued to increase in weight and skeletal size after the period of their most rapid development, but at a slower rate than the moderate level cows. This indicates that cows reared on a high energy level approached mature size earlier. These results are in agreement with those of Reid et al. (1957) who found that the weight, height, and length of Holstein cows was correspondent to their level of feed intake. Hansson (1956) noted that rearing intensity influenced the rate of growth but that all heifers eventually reached the same body development. Crichton et al. (1959, 1960a) observed that heifers reared on a high plane exceeded those reared on a lower plane in weight and in each of several body measurements, but that all groups eventually reached the same size.

Table VII shows the weight, height at withers, depth of chest, heart girth, width at hips, and length of head of the moderate level cows expressed as a percentage of the same trait of the high level cows. In general, differences in body measurements were correspondent to the differences in weight. The level of feeding influenced the live weight much more than it did body measurements, indicating that much of the difference in weight was due to fat. Among the body measurements, heart girth and the width of hips were affected most by level of feeding, probably because they are influenced to a greater extent by the degree of fatness. The length of head and height at withers were almost equal for the two feeding levels. This indicates that the moderate level of feeding was adequate to produce near normal skeletal growth, since the amount of fat has little influence on these two measurements. Similarly,

TABLE VI

BODY MEASUREMENTS OF MODERATE AND HIGH LEVEL COWS AT VARIOUS INTERVALS

Measurement[a]	Treatment Level	Age (Months) 18	23	33	58	76
Height at Withers	Moderate	39.1	41.0	43.7	45.4	44.9
	High	39.4	42.5	44.8	46.0	45.2
Depth of Chest	Moderate	20.8	21.7	23.6	25.5	26.2
	High	21.3	23.8	26.8	28.4	27.6
Heart Girth	Moderate	55.5	58.6	63.5	68.9	71.4
	High	59.0	66.7	75.9	78.2	78.6
Width of Hips	Moderate	12.6	15.5	17.3	19.3	20.2
	High	14.6	17.4	20.5	21.7	22.0
Length of Head	Moderate	14.2	15.0	16.5	16.9	17.4
	High	14.2	15.2	16.6	17.0	17.2

[a]All measurements in inches.

TABLE VII

WEIGHT AND BODY MEASUREMENTS OF MODERATE LEVEL COWS EXPRESSED AS A PERCENTAGE OF THE SAME TRAIT OF HIGH LEVEL COWS[a]

Average Age	Weight	Height Withers	Depth Chest	Heart Girth	Width Hips	Length Head
(Mo.)	(%)	(%)	(%)	(%)	(%)	(%)
18	79.0	99.2	97.7	94.1	86.3	100.0
23	74.2	96.5	91.2	87.8	89.1	98.7
33	70.0	97.5	88.0	83.7	84.4	99.3
58	74.1	98.7	89.9	88.1	88.9	99.4
76	76.8	99.3	94.9	90.8	91.8	101.2

[a]Based on eight complete sets of twins.

TABLE VIII

WEIGHT OF MODERATE AND HIGH LEVEL COWS BEFORE AND AFTER CALVING AND AT THE END OF LACTATION[a]

Time of Weight	Treatment Level	Year of Calving		
		1	2	3
Before Calving	Moderate	815	1028	1065
	High	1289	1351	1347
After Calving	Moderate	749	897	926
	High	1175	1192	1196
End of Lactation	Moderate	801	905	870
	High	1133	1196	1156

[a]Based on ten complete sets of twins the first year, eight the second, and seven the third year.

Chrichton et al. (1959) and Sorenson et al. (1959) have reported relatively large differences in body weight as contrasted to smaller differences in body measurements when heifers were reared on different planes of nutrition.

High level cows lost more weight than the moderate level cows at each parturition (Table VIII). This difference in weight loss was significant ($P < 0.01$) at the first parturition when the high level cows lost 114 pounds compared to 66 pounds for the moderate level cows. These results substantiate the observation of Swanson (1960) that fattened Jersey heifers lost more weight at parturition than normally fed controls.

The moderate level cows gained 52 pounds during the first lactation while the high level cows lost 42 pounds. This difference in weight change during the first lactation was significant ($P < 0.05$), however, the weight changes during later lactations were quite similar. In the study reported by Swanson (1960), the fattened heifers did not regain their prepartum weight while the controls gained weight during the first lactation.

Reproductive Performance

Poor conception rates were observed for the three sets of twins initially started on experiment. This was especially true in the high level group. Observations indicated that the libido and possibly the fertility of the bull was below normal, thus contributing to the poor reproductive efficiency of the cows. The bull was replaced and all subsequent matings were made to a half-sib of the original bull. The average number of matings required per conception shown in Table IX does not include the matings of the three twin sets of the original bull.

The breeding efficiency for both treatment levels was good as indicated by the overall averages of 1.43 and 1.70 services per conception for the moderate and high level groups, respectively. Although the high level cows consistently required more services for conception, none of these differences were statistically significant. The general trend toward decreased breeding efficiency of the high level cows with increasing age indicates that excessive body fatness may exert more detrimental influence on reproductive efficiency with increasing age. Reid et al. (1957) found no consistent effect upon the conception rate with

TABLE IX

AVERAGE NUMBER OF MATINGS REQUIRED FOR CONCEPTION BY MODERATE AND HIGH LEVEL COWS[a]

Treatment Level	First Pregnancy	Second Pregnancy	Third Pregnancy	Overall Average
Moderate	1.27 ± 0.14[b]	1.67 ± 0.33	1.50 ± 0.34	1.43 ± 0.14
High	1.36 ± 0.20	1.83 ± 0.48	2.17 ± 0.40	1.70 ± 0.20

[a]Based on eleven complete sets of twins the first year, six the second, six the third, and 21 overall.
[b]Standard error of the mean.

low, medium, and high levels of feeding, however, the percentage conceiving at first service was 79, 68, and 58 for the respective levels. Bratton (1957) similarly reported that there was no difference in the number of services required for conception between groups of heifers fed at 100 or 140 percent of Morrison's standards. Sorenson _et al_. (1959) indicated that level of feeding had little effect on ovarian function once puberty was reached.

In each year of this study the high level cows required more assistance at calving than the moderate level cows (Table X). This was

TABLE X

NUMBER OF COWS REQUIRING ASSISTANCE AT CALVING AND CALVES LOST

Year of Calving	Number of Complete Sets	Treatment Level	Cows Requiring Assistance	Calves Lost[a]
First	12	Moderate	1	1
		High	7[b]	4[c]
Second	10	Moderate	1	3
		High	2	3
Third	9	Moderate	0	0
		High	3[b]	1
Overall	31	Moderate	2	4
		High	12[b]	8[c]

[a]Includes calves which were born dead or died within 10 days after birth.
[b]Includes two cows requiring caesarean delivery the first year, one the third year, and three overall.
[c]Failure of one high level cow to produce a calf the first year included as a calf loss.

especially true at the first parturition, when seven of twelve high level cows required assistance compared to only one of twelve for the moderate level group. Considering the overall total of 31 parturitions per treatment group, almost 40 percent of the high level cows required assistance compared to only about 6 percent of the moderate level cows. Two of the high level cows required caesarean sections for delivery at first parturition. One of these cows required a caesarean delivery again at the third parturition although she calved normally at the second parturition. Zimmerman (1960) noted a slight trend toward more calving difficulty in heifers with each successive increase in four levels of winter supplement. Results contrary to those observed in the present study were noted by Reid _et al._ (1957) who reported that level of feeding prior to calving had little influence on calving difficulty. In the study of Reid _et al._ (1957) the Holstein heifers were considered fat but not excessively so, while those used in the present study were excessively fat. Holland (1961) found no differences in calving difficulty with mature Hereford cows fed at moderate and high levels during gestation.

Calf losses include all calves which were born dead and those which were lost prior to separation from their dams at 10 days of age. The moderate level cows had an overall loss of four calves compared to eight for the high level group. Four of the losses in the high level group occurred the first year. Three of these calf losses were associated with the calving difficulty of the cows. The fourth calf loss was assessed against the high level group due to the failure of one cow to produce a calf the first year, although pregnancy checks indicated that she conceived but reabsorbed her fetus at about 7 months. Two calves in each group were born dead at the second calving and one additional calf in each group failed to survive the first week after birth. The calf lost in the third year by a high level cow was the one taken by caesarean delivery. No large visual differences were noted in vigor of the calves at birth. Chambers et al. (1960) observed that heifers developed at a lower level of nutrition sustained less fetal death losses, and raised more calves to weaning than those developed under full feeding. Zimmerman (1959) and Pinney (1962) found that cows wintered on lower levels of supplementation weaned a higher percent calf crop than those wintered on high levels.

The moderate level cows had a slightly longer gestation period each year (Table XI). The average length of gestation for the 3 years was

TABLE XI

AVERAGE LENGTH OF GESTATION FOR MODERATE AND HIGH LEVEL COWS[a]

Treatment Level	First Gestation	Second Gestation	Third Gestation	Overall Average
Moderate	281.8 ± 1.2[b]	279.0 ± 3.4	281.1 ± 1.8	281.0[c] ± 1.1
High	279.2 ± 1.4	278.6 ± 2.3	279.5 ± 1.2	279.1 ± 0.9

[a]Based on ten complete sets of twins the first year, five the second, six the third, and 21 overall.
[b]Standard error of the mean.
[c]Moderate level significantly different from high level at $P \simeq 0.14$.

281.0 days for the moderate level group compared to 279.1 days for the high level group.

The average birth weight of the calves is summarized in Tabe XII. Treatment level had little effect on the birth weight of the calves, although high level cows produced slightly heavier calves the first 2 years. Zimmerman (1960) reported that heifers wintered on a high level produced slightly heavier calves at birth than medium level heifers during the first and second calving periods but slightly lighter calves the third year. However, in one trial, heifers wintered at a very high level

TABLE XII

AVERAGE BIRTH WEIGHT OF CALVES

Year of Calving	Number of Complete Sets	Treatment level of dams Moderate	High
		(lb.)	(lb.)
1	10	58.4 ± 2.1[a]	58.9 ± 4.2
2	10	64.5 ± 3.0	66.1 ± 3.5
3	9	71.0 ± 1.8	69.9 ± 2.1
Overall	29	64.4 ± 1.6	64.8 ± 2.1

[a]Standard error of the mean

produced lighter calves at birth than the high level cows.

Milk Production and Calf Performance

The number of intact twin sets with complete records available for analysis of milk production and calf performance data is shown in Table XIII.

The average daily milk production through three lactations is summarized in Table XIV. Milk production estimates are based on 6 days per week for the calf-weight-change technique and 1 day per week for the handmilking technique. A discussion of these two techniques for estimating milk production is given in Part II of this thesis.

Although the average milk production of the moderate level cows was consistently higher at each stage of lactation, no significant differences were found for any single lactation, except at 112 days with the weight-change technique ($P \simeq 0.12$). The failure to detect statistically significant differences may be partially attritubed to the limited number of pairs and to the large variation within sets of twins. This variation within twin sets is principally due to extremely low milk production

TABLE XIII

NUMBER OF COMPLETE TWIN SETS FOR ANALYSIS OF MILK PRODUCTION AND CALF PERFORMANCE DATA

Measurement	Year			
	1	2	3	Overall
Milk Production (Weight-change)	-	5	6	11
Milk Production (Handmilk)	8	8	7	23
Percent Fat	7	7	6	20
Percent Total Solids	7	7	6	20
Calf Weight	7	5	6	18
Average Daily Gain of Calves	7	5	6	18

by some high level cows while other cows also fed the high level equaled or surpassed their moderate level mates. This variation among high level cows is reflected by the rather large standard error of the means which in every case was considerably larger for the high level cows than for the moderate level cows.

When the 3 years data was pooled the milk production was significantly different at 112 ($P \simeq 0.11$) and 210 ($P \simeq 0.10$) days with the weight-change technique. Pooling data obtained by the handmilking technique resulted in a significantly higher milk production estimate for the moderate level cows at 70 ($P \simeq 0.08$), 112 ($P \simeq 0.06$), and 210 ($P \simeq 0.02$) days.

The average lactation curves are shown in Figure 2. The peak milk yield of moderate level cows was at 9 weeks and remained relatively constant until 16 weeks while the milk yield of high level cows declined steadily from 2 weeks until the end of lactation. After 16 weeks the

TABLE XIV

AVERAGE DAILY MILK PRODUCTION OF MODERATE AND HIGH LEVEL COWS FOR 70, 112, AND 210 DAYS

Milk Production Method	Lactation Number	Stage of Lactation							
		70 day		112 day		210 day		210 day FCM	
		Moderate	High	Moderate	High	Moderate	High	Moderate	High
		(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)	(lb.)
Calf-weight-change	1	-----[a]	-----[a]	-----[a]	-----[a]	-----[a]	-----[a]	-----[a]	-----[a]
	2	16.3±0.3[b]	14.6±1.7	16.1[d]±0.5	13.7±1.7	14.6±0.9	11.8±1.6	13.2±0.9	10.7±1.8
	3	13.2±0.9	12.2±1.6	13.2±0.7	11.7±1.7	12.1±1.4	10.7±1.7	10.3±1.0	9.2±1.6
	Overall	14.6±0.7	13.3±1.2	14.5[e]±0.6	12.6±1.2	13.2[g]±0.8	11.2±1.1	11.6[i]±0.8	9.9±1.2
Handmilking	1	11.0±0.9	8.4±1.9	10.8±0.8	8.1±1.9	10.0±0.8	7.1±1.8	8.9±0.8	6.4±1.8
	2	12.3±1.2	10.6±2.7	11.8±1.2	9.5±2.4	10.4±1.2	7.7±2.0	10.7±1.0	8.3±1.7
	3	11.1±1.1	8.7±2.0	10.4±0.8	9.1±1.7	9.4±1.2	8.2±1.6	7.6±1.2	7.0±1.8
	Overall	11.5[c]±0.6	9.3±1.2	11.0[f]±0.6	8.9±1.1	10.0[h]±0.6	7.6±1.0	8.3[j]±0.8	6.6±1.1

[a]Number of complete twin sets insufficient for compairson
[b]Standard error of the mean
[c]Moderate level significantly different from high level at $P \simeq 0.08$
[d]Moderate level significantly different from high level at $P \simeq 0.12$
[e]Moderate level significantly different from high level at $P \simeq 0.11$
[f]Moderate level significantly different from high level at $P \simeq 0.06$
[g]Moderate level significantly different from high level at $P \simeq 0.10$
[h]Moderate level significantly different from high level at $P \simeq 0.02$
[i]Moderate level significantly different from high level at $P \simeq 0.14$
[j]Moderate level significantly different from high level at $P \simeq 0.07$

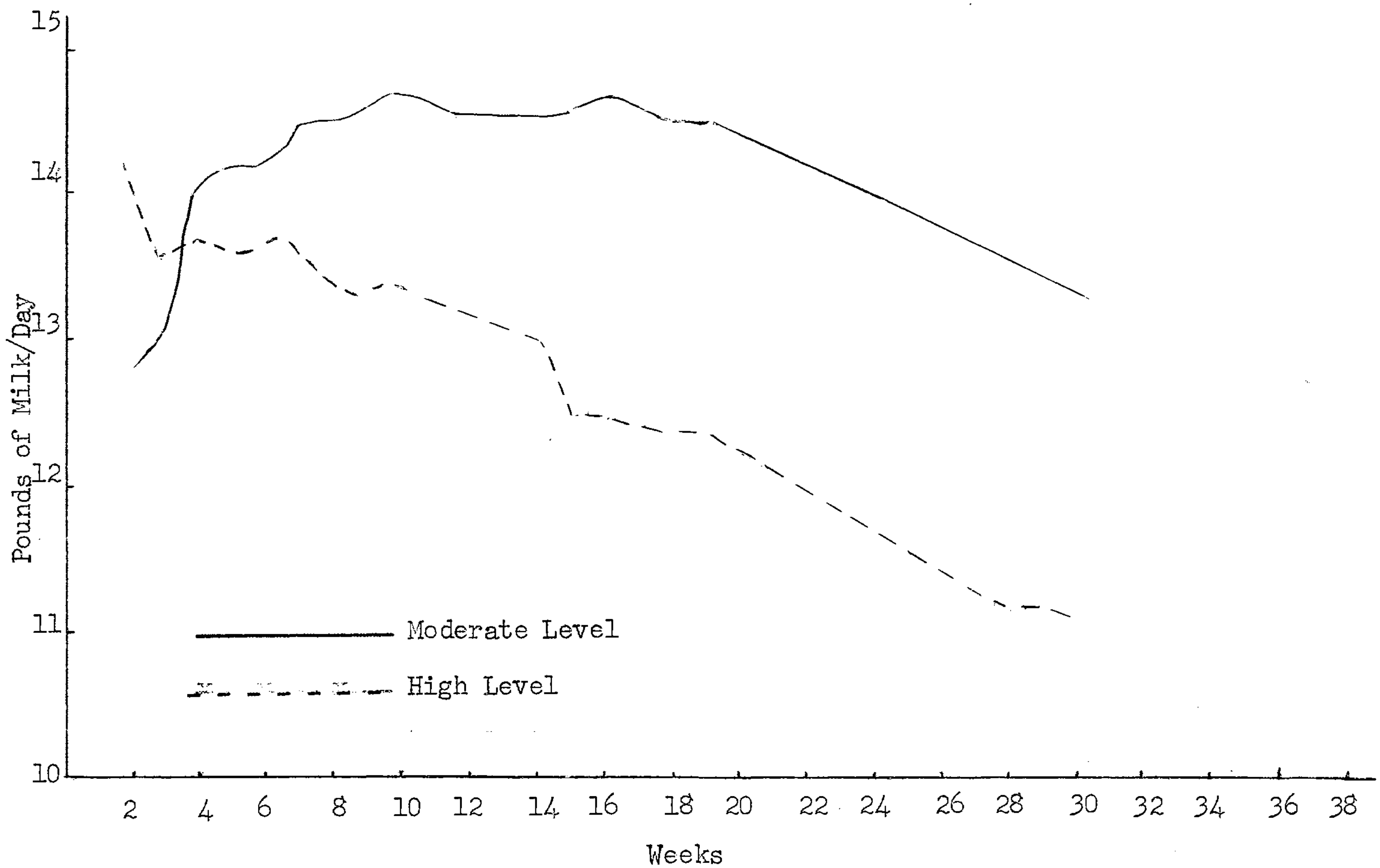
lactation curves were roughly parallel with the moderate level cows yielding approximately two pounds more milk per day.

The moderate level cows yielded more milk on a fat-corrected basis than their high level mates. The difference between average daily milk yields for the two levels was less than if expressed on the basis of actual 210 day yield. The higher fat-corrected-milk production of the moderate level cows was statistically significant only when the 3 years data were pooled (weight-change, $P \simeq 0.14$; handmilking, $P \simeq 0.07$).

Several investigators (Herman and Ragsdale, 1946; Hansson, 1956; and Klett et al., 1962) have reported results which indicate an inverse relationship between high feeding levels and milk yield. Sykes et al. (1948) and Swanson and Spann (1954) have also recorded similar results with restricted and ad libitum fed rats. Utilizing an experimental design similar to the one reported here, Swanson (1960) found that fattened Jersey heifers averaged 84.8 percent the fat-corrected-milk yield of controls. He also noted a wide variation in milk production within twin sets and that individual pairs reacted differently in two lactations. On the other hand, Reid et al. (1957) found that a high level of feeding had no significant effect on the milk yield of Holstein cows.

Swanson and Spann (1954) found that mammary glands were not fully developed in rats which had been fattened. Swanson (1960) also noted a lack of alveolar secreting tissue in the udders of fattened Jersey heifers. In the present study, gross examination at time of slaughter did not reveal any major differences in the development of the udders, however, large deposits of fat were present in the udders of high level cows. The presence of large amounts of fat in the udder may have contributed to the lower milk yield of the high level cows. Herman et al. (1948) also

Figure 2. Average Daily Milk Production of Moderate and High Level Cows[a,b]



[a]Average of three years data (total of 11 twin sets).

[b]Milk production estimated by weighing the calf before and after nursing

observed fat deposition in the udders of heifers which were inferior milk producers when reared *ad libitum* on a "rapid growth ration". The metabolism of overfed, excessively fat, animals may be disturbed in such a way as to lower yielding capacity (Bonnier *et al.*, 1948).

The variation in milk production within twin sets suggests that individual differences may occur in susceptibility to damage from excessive fatness brought about by high levels of feeding. Although the limited number of twin sets of any one breed prevent definite conclusions regarding breed-treatment interactions, a large part of the difference in milk production was due to the extremely low milk yield of three high level Angus cows. Holtz *et al.* (1961) studying average daily gain from birth to 6 months in relation to later lactation yields, found that slower gaining Jerseys were superior producers among the Jerseys but that this difference did not exist with slower maturing Holsteins or Guernseys. This suggests that the earlier maturing Angus cows may have been influenced more by high levels of nutrition than the other breeds which mature at an older age.

Table XV shows the correlation of the difference in body weight within twin sets to the difference in their average daily milk yield. The

TABLE XV

THE DIFFERENCE IN BODY WEIGHT WITHIN TWIN SETS CORRELATED TO THE DIFFERENCE IN THEIR AVERAGE DAILY MILK YIELD

Year	Number of Observations	$\bar{x}$ Difference in Weight	$\bar{x}$ Difference in Daily Milk Yield	Correlation Coefficient
1	8	411	2.9	0.81[a]
2	8	315	2.7	0.42[a]
3	7	245	1.2	0.82[b]
Overall	23	338	2.3	0.65[c]

[a] r = 0.666 at P = 0.05 and 0.798 at P = 0.01.
[b] r = 0.707 at P = 0.05 and 0.834 at P = 0.01.
[c] r = 0.404 at P = 0.05 and 0.515 at P = 0.01.

correlation coefficients were 0.81, 0.42, and 0.82 for the first, second, and third lactations, respectively. These correlations were significant ($P \leq 0.01$) for the first and third lactations. When the 3 years data was pooled, the correlation coefficient of 0.65 was highly significant ($P < 0.01$). These correlations indicate that the degree of fatness was associated with the productivity of the cow, and that much of the within twin variation may have been due to differences in fatness and not due to a difference in susceptibility to damage from overfeeding per se.

Hansson (1956), Loosli (1957), and Crichton et al. (1960b) observed that the percentage of fat in milk tended to be slightly higher when cows were reared at a high level of nutrition. In the present experiment, level of nutrition had little effect on the fat content of the milk, although, for the first lactation high level cows produced milk with a slightly higher percentage of fat than did the moderate level cows (Table XVI). However, the moderate level cows produced more total pounds of fat because of their much greater total milk production.

The total pounds of solids and percent total solids of milk produced during a 210 day lactation is shown in Table XVII. Although total pounds of solids favored the moderate level cows due to their greater milk production, the high level cows had significantly higher percent total solids for the first ($P \simeq 0.09$) and second ($P \simeq 0.03$) lactations and when the 3 years data was pooled ($P \simeq 0.06$). Rook and Line (1961) also found that an increase in plane of energy increased the solids content of milk.

Calves nursing moderate level cows were heavier and had larger average daily gains than those nursing high level cows (Table XVIII). This is a further reflection of the higher milk yields of the moderate level cows since the amount of milk a cow provides her calf has a major influence on

TABLE XVI

AVERAGE TOTAL FAT AND AVERAGE PERCENT FAT OF MILK PRODUCED BY MODERATE AND HIGH LEVEL COWS DURING A 210 DAY LACTATION PERIOD

Lactation Number	Total Fat[a]		Percent Fat	
	Moderate	High	Moderate	High
	(lb.)	(lb.)		
1	67 ± 8[b]	57 ± 15	3.2 ± 0.2[b]	3.3 ± 0.2
2	86 ± 9	67 ± 18	3.6 ± 0.2	3.6 ± 0.2
3	56 ± 9	52 ± 15	3.0 ± 0.2	3.0 ± 0.2
Overall	70 ± 6	59 ± 9	3.3 ± 0.1	3.3 ± 0.1

[a]Based on milk production estimated by handmilking.
[b]Standard error of the mean.

TABLE XVII

AVERAGE TOTAL SOLIDS AND AVERAGE PERCENT TOTAL SOLIDS OF MILK PRODUCED BY MODERATE AND HIGH LEVEL COWS DURING A 210 DAY LACTATION PERIOD

Lactation Number	Pounds Total Solids[a]		Percent Total Solids	
	Moderate	High	Moderate	High
	(lb.)	(lb.)	(lb.)	(lb.)
1	241 ± 31[b]	213 ± 50	12.6[c] ± 0.3[b]	12.9 ± 0.2
2	296 ± 23	234 ± 55	12.5[d] ± 0.2	12.7 ± 0.2
3	223 ± 34	207 ± 51	12.0 ± 0.3	11.9 ± 0.2
Overall	255 ± 18	219 ± 29	12.4[e] ± 0.2	12.5 ± 0.2

[a]Based on milk production estimated by handmilking.
[b]Standard error of the mean.
[c]High level significantly different from moderate level at $P \simeq 0.09$.
[d]High level significantly different from moderate level at $P \simeq 0.03$.
[e]High level significantly different from moderate level at $P \simeq 0.06$.

TABLE XVIII

AVERAGE WEIGHTS AND DAILY GAINS OF CALVES AT 70, 112, AND 210 DAYS

Variable	Year of Calving	Age of Calf: 70 day Moderate (lb.)	70 day High (lb.)	112 day Moderate (lb.)	112 day High (lb.)	210 day[a] Moderate (lb.)	210 day[a] High (lb.)
Weight	1	160 ± 9[b]	143 ± 8	221[c] ± 13	199 ± 9	373 ± 21	357 ± 28
	2	177 ± 6	165 ± 6	238 ± 6	214 ± 21	394 ± 16	333 ± 34
	3	161 ± 7	150 ± 12	212 ± 10	191 ± 18	357 ± 25	325 ± 33
	Overall	165 ± 5	152 ± 5	222[d] ± 6	201 ± 9	373[e] ± 12	339 ± 17
Average Daily Gain	1	1.42[f] ± .11[b]	1.18 ± .09	1.43 ± .11	1.24 ± .08	1.48 ± .10	1.41 ± .14
	2	1.63 ± .06	1.45 ± .19	1.56 ± .04	1.35 ± .18	1.57 ± .06	1.30 ± .15
	3	1.32 ± .10	1.18 ± .15	1.29 ± .08	1.10 ± .16	1.37 ± .12	1.22 ± .15
	Overall	1.44[g] ± .06	1.25 ± .08	1.42[h] ± .06	1.22 ± .08	1.47[i] ± .06	1.32 ± .08

[a]Heifer 210 day weights corrected to bull equivalent by the methods of Koch *et al.* (1959).
[b]Standard error of the mean.
[c]Moderate level significantly different from high level at $P \simeq 0.14$
[d]Moderate level significantly different from high level at $P \simeq 0.07$
[e]Moderate level significantly different from high level at $P \simeq 0.13$
[f]Moderate level significantly different from high level at $P \simeq 0.14$
[g]Moderate level significantly different from high level at $P \simeq 0.07$
[h]Moderate level significantly different from high level at $P \simeq 0.04$
[i]Moderate level significantly different from high level at $P \simeq 0.15$

the weight of the calf. The large variation within sets of twins noted for milk production is likewise noted for calf weights and daily gain. These results are similar to those observed by Chambers et al. (1960) who found that cows full fed from 7 to 12 months weaned calves 80 pounds lighter than those reared at a lower level during this 5 month period.

Longevity

Hansson and Bonnier (1951) stated that since nutrition influences the rate of development, the process of ageing may also be affected. Although studies on the longevity of cattle have received little attention, Hansen and Steensberg (1950) and Hansson (1956) observed that cattle reared on a high plane of nutrition had a shorter life span as well as shorter productive life. Pinney (1962) reported the productive life in a herd of Hereford cows was inversely related to level of winter supplementation.

In the present study, four of the high level cows died or were removed from the experiment because of disease while all 12 of the moderate level cows remained in the herd through three lactations (Table XIX).

TABLE XIX

MORTALITY OF MODERATE AND HIGH LEVEL COWS[a]

Treatment	Number of Cows lost			
Level	Year 1	Year 2	Year 3	Overall
Moderate	0	0	0	0
High	2	1	2	5

[a]Twelve cows per group originally.

Two of the high level cows died at time of calving and two were sold, one because of mastitis and another because of a reoccurring prolapse of the uterus. One additional high level cow died midway through the third lactation when she caught her head under a fence and was unable to get up.

The effect of level of nutrition on the process of ageing cannot be accurately determined at the present time due to the lack of a critical measurement of physiological ageing. Hansson (1956) postulated that part of the difference in rate of survival might be due to increased stress which follows increased feeding.

Table XX summarizes the body temperature and respiration rate for the

TABLE XX

BODY TEMPERATURES AND RESPIRATION RATES
OF MODERATE AND HIGH LEVEL COWS

Date	Air Temperature	Body Temperature		Respiration Rate	
		Moderate	High	Moderate	High
April 1-11, 1961	67	102.40	102.21	26.08	29.11
June 13-24, 1961	89	102.36	102.42	39.12[a]	46.12
August 7-19, 1961	92	102.61	102.52	49.41[a]	59.66
February 1-15, 1962	54	102.60	102.59	33.74[a]	41.68
Overall	75	102.49	102.44	37.09[a]	44.15

[a]Moderate level significantly different from high level at $P < 0.01$.

the two treatment levels. The rectal temperature of all cows was quite similar regardless of treatment level. Respiration rates were higher for cows fed the high level, especially during the summer when ambient temperatures were highest. Hansson et al. (1953) stated that an increase in heart and respiration rates probably increase the strain on the heart and lungs.

Other organs and/or endocrine glands may be affected in a similar manner with increased feeding intensities. When these cows were slaughtered several of the organs were taken and are given in Table XXI, expressed as actual weight and as a percentage of the live weight. In general,

TABLE XXI

WEIGHT OF THE BRAIN, HEART, LIVER, PITUITARY GLAND AND OVARIES FROM MODERATE AND HIGH LEVEL COWS

Organ	Weight		% of live weight	
	Moderate	High	Moderate	High
Brain (gm.)	348.5	352.5	0.09	0.07
Heart (lb.)	3.6	4.2	0.40	0.36
Liver (lb.)	8.1	8.9	0.90	0.76
Ovaries (gm.)	16.9	14.2	0.004	0.003
Pituitary gland (gm.)	2.9	2.7	0.001	0.001

organs from moderate level cows made up a larger percentage of the live weight although the actual weight was less than those from high level cows.

Other data obtained at slaughter is shown in Table XXII. These

TABLE XXII

CARCASS DATA FROM MODERATE AND HIGH LEVEL COWS

Measurement	Treatment Level	
	Moderate	High
Live Grade[a]	8.1	10.3
Carcass Conformation[a]	8.9	10.4
Carcass Quality[a]	8.7	11.1
Final Carcass Grade[a]	8.7	10.7
Rib Eye Area (sq. in.)	10.85	12.17
Rib Eye Area/100 pounds Carcass Weight	2.00	1.69
Linear Fat Measurement (in.)[b]	0.68	1.34

[a]4=Low cutter, 5=Mid cutter, ... , 12= High commercial
[b]Average of three measurements over the twelfth rib, measured by methods of Malkus et al, (1961).

carcass data further emphasize the greater fatness of the high level cows, especially by the amount of fat found over the twelfth rib.

Part II. Milk Production Techniques

The milk production studies reported in this section include the following:

1. A comparison of some techniques for estimating the milk yield of beef cows.
2. A determination of the relationship between estimates made at several sampling intervals and the total milk production.
3. A determination of the relationship of the amount of milk and some milk constituents to performance of the calves.

It should be emphasized that the cows were maintained in drylot throughout the study. The calves were also kept in drylot, with the dam's milk as the only source of nutrients available to the calf to an age of 112 days and only the dam's milk plus a maintenance allowance of feed thereafter. Therefore, caution should be exercised in interpreting these data for more practical application, especially in regard to calf performance.

Records of the two treatment groups previously described were combined to study some techniques for estimating the milk production of beef cows. Records of incomplete twin sets were also included in the analysis of these data. Since the treatment level apparently influenced the milk yield of the cows, it is necessary to examine the effect of these differences upon the criteria used for estimating production.

Table XXIII summarizes the mean, standard deviation and coefficient

TABLE XXIII

THE EFFECT OF TREATMENT LEVEL ON CERTAIN MILK PRODUCTION CRITERIA

Variable	Moderate Level			High Level			Combined Levels			
	Year 2	Year 3	Overall	Year 2	Year 3	Overall	Year 1	Year 2	Year 3	Overall
	(6)[a]	(12)	(18)	(5)	(6)	(11)	(7)	(11)	(18)	(36)
Average Daily	1.53[b]	1.40	1.44	1.31	1.22	1.26	1.55	1.43	1.34	1.41
Gain	0.12[c]	0.24	0.22	0.31	0.34	0.33	0.17	0.25	0.29	0.27
	7.84[d]	17.14	15.28	23.66	27.87	26.19	10.97	17.48	21.64	19.15
210 Day Milk	11.2	10.0	10.4	9.1	8.1	8.5	11.5	10.2	9.3	10.0
Production	1.7	2.5	2.5	4.0	4.2	4.1	2.7	3.1	3.3	3.2
(Handmilk)	15.18	25.00	22.12	43.96	51.85	48.24	23.48	30.39	35.48	32.00
210 Day Milk	14.5	13.2	13.6	11.8	10.7	11.2	13.9	13.3	12.4	12.9
Production	1.6	2.4	2.2	3.2	3.7	3.5	1.8	2.8	3.1	2.9
(Weight-Change)	11.03	18.18	16.18	27.12	34.48	31.25	12.95	21.05	25.00	22.48
Percent Fat	3.4	3.0	3.2	3.3	3.0	3.1	3.2	3.4	3.0	3.2
	0.3	0.5	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.5
	8.82	16.67	15.62	15.15	13.33	16.13	15.62	11.76	16.67	15.63
Total Fat[e]	78.6	64.5	69.2	65.7	52.3	58.4	79.2	72.7	60.4	67.8
(210 Days)	13.9	21.7	20.3	34.8	34.1	35.1	28.3	26.2	27.1	28.1
	17.68	33.64	29.34	52.97	65.20	60.10	35.73	36.04	44.87	41.44
Percent Total	12.42	11.79	12.00	12.48	11.93	12.18	12.50	12.45	11.84	12.15
Solids	0.46	0.55	0.60	0.38	0.55	0.55	0.65	0.42	0.56	0.62
	3.70	4.66	5.00	3.04	4.61	4.52	5.20	3.37	4.73	5.10
Total Solids[e]	291.8	249.8	263.8	240.0	207.3	222.2	301.6	268.3	235.6	258.4
(210 Days)	41.8	67.2	63.1	109.3	114.9	113.6	79.3	84.0	88.4	89.1
	14.32	26.90	23.92	45.54	55.43	51.15	26.29	31.31	37.52	34.48

[a]Number of cows.
[b]Mean

[c]Standard deviation
[d]Coefficient of variation

[e]Based on total milk estimated by handmilking

of variation for several of these criteria for each treatment level and for the combined levels. The treatment groups were not compared the first year because sufficient numbers were not available for all criteria.

In general, the coefficient of variation for each of the criteria was larger the third lactation than the second for both levels. With the exception of percent total solids of the milk, the moderate level cows had larger means than the high level cows for each of the items measured. Although the means of the high level group were smaller for most criteria, the standard deviations were larger for this level in almost every instance. Coefficients of variation were considerably larger for the high level group. The combined levels were intermediate.

The correlation coefficients between these criteria for the moderate and high levels are given in Tables XXIV and XXV, respectively. The correlations between these milk production criteria were generally larger for high level cows than for moderate level cows due to the greater variation of the criteria meing measured. Correlations for the combined groups were intermediate between the two treatment levels (Table XXVI). Madden and McGilliard (1959) observed that the same relationship existed between part and whole production for high and low producing cows. The two treatment levels were combined for analysis of milk production data throughout the remainder of this thesis. Although correlations may not be real, due to the small numbers involved and the treatment effects discussed in Part I, they should be satisfactory for comparative purposes.

Comparison of Techniques For Estimating Milk Production

Milk production was estimated by calf weight, average daily gain of the calf, handmilking, and weight-change of the calf before and after

TABLE XXIV

CORRELATIONS BETWEEN CERTAIN MILK PRODUCTION CRITERIA OF COWS FED AT A MODERATE LEVEL OF NUTRITION

Variable		X_1	X_2	X_3	X_4	X_5	X_6	X_7
Average Daily Gain	(X_1)[a]		0.53	0.88	-.60	0.08	-.83	0.33
	- - b		0.71	0.80	0.05	0.54	-.29	0.67
	- - c		0.68	0.81	-.32	0.48	-.37	0.62
210 Day Milk Production (Handmilk)	(X_2)			0.92	0.25	0.87	0.09	0.98
				0.85	0.00	0.84	-.36	0.96
				0.91	0.20	0.87	-.08	0.98
210 Day Milk Production (Weight-Change)	(X_3)				-.29	0.50	-.76	0.70
					0.31	0.84	0.00	0.92
					0.21	0.78	-.16	0.88
Percent Fat	(X_4)					0.45	0.43	0.11
						0.69	0.77	0.42
						0.65	0.70	0.37
Total Fat[d] (210 Days)	(X_5)						0.11	0.93
							0.47	0.94
							0.39	0.94
Percent Total Solids	(X_6)							-.10
								0.23
								0.16
Total Solids[d] (210 Days)	(X_7)							

[a]Second lactation, r=0.754 at P=0.05 and 0.874 at P=0.01.
[b]Third lactation, r=0.553 at P=0.05 and 0.684 at P=0.01.
[c]Second and third lactations combined, r=0.456 at P=0.05 and 0.575 at P=0.01.
[d]Based on total milk estimated by handmilking.

TABLE XXV

CORRELATIONS BETWEEN CERTAIN MILK PRODUCTION CRITERIA OF COWS FED AT A HIGH LEVEL OF NUTRITION

Variable		X_1	X_2	X_3	X_4	X_5	X_6	X_7
Average Daily Gain	(X_1)[a]		0.95	0.93	0.76	0.94	0.81	0.96
	- - b		0.97	0.96	0.60	0.96	0.74	0.97
	- - c		0.96	0.95	0.67	0.95	0.76	0.97
210 Day Milk Production (Handmilk)	(X_2)			0.99	0.72	0.99	0.70	0.99
				0.97	0.60	0.98	0.76	0.99
				0.98	0.66	0.98	0.73	0.99
210 Day Milk Production (Weight-Change)	(X_3)				0.60	0.96	0.59	0.98
					0.51	0.93	0.76	0.97
					0.54	0.94	0.70	0.97
Percent Fat	(X_4)					0.79	0.96	0.74
						0.74	0.85	0.64
						0.76	0.87	0.69
Total Fat[d] (210 Days)	(X_5)						0.75	0.99
							0.85	0.99
							0.80	0.99
Percent Total Solids	(X_6)							0.72
								0.80
								0.76
Total Solids[d] (210 Days)	(X_7)							

[a]Second lactation, r=0.811 at P=0.05 and 0.917 at P=0.01.
[b]Third lactation, r=0.754 at P=0.05 and 0.874 at P=0.01.
[c]Second and third lactations combined, r=0.576 at P=0.05 and 0.708 at P=0.01.
[d]Based on total milk estimated by handmilking.

TABLE XXVI

CORRELATIONS BETWEEN CERTAIN MILK PRODUCTION CRITERIA OF COWS FROM MODERATE AND HIGH TREATMENT LEVELS COMBINED

Variable		X_1	X_2	X_3	X_4	X_5	X_6	X_7
Average Daily Gain	$(X_1)^a$		0.50	0.56	-.21	0.29	-.40	0.43
	- - b		0.90	0.93	0.47	0.82	0.14	0.87
	- - c		0.86	0.89	0.27	0.77	0.10	0.84
	- - d		0.83	0.88	0.24	0.71	0.03	0.80
210 Day Milk Production (Handmilk)	(X_2)			0.99	0.46	0.93	0.25	0.99
				0.95	0.56	0.96	0.22	0.99
				0.95	0.38	0.94	0.34	0.99
				0.95	0.44	0.94	0.28	0.99
210 Day Milk Production (Weight-Change)	(X_3)				0.36	0.88	0.14	0.96
					0.39	0.86	-.01	0.92
					0.37	0.89	0.26	0.94
					0.36	0.86	0.17	0.93
Percent Fat	(X_4)					0.76	0.97	0.59
						0.71	0.65	0.61
						0.68	0.78	0.49
						0.70	0.80	0.54
Total Fat[e] (210 Days)	(X_5)						0.59	0.97
							0.41	0.98
							0.57	0.97
							0.54	0.97
Percent Total Solids	(X_6)							0.38
								0.33
								0.43
								0.39
Total Solids[e] (210 Days)	(X_7)							

[a]First lactation, r=0.707 at P=0.05 and 0.834 at P=0.01
[b]Second lactation, r=0.576 at P=0.05 and 0.708 at P=0.01
[c]Third lactation, r=0.456 at P=0.05 and 0.575 at P=0.01
[d]First, Second and third lactations combined, r=0.325 at P=0.05 and 0.418 at P=0.01
[e]Based on total milk estimated by handmilking

nursing. Milk production estimates by the calf-weight-change technique were based on records taken 6 days per week throughout the lactation. The seventh day of the week the cows were handmilked by the procedure previously described. Calf weight and average daily gain were calculated from the morning and afternoon weight of the calves prior to nursing. A comparison of the means, standard deviations and coefficients of variation of these techniques is presented in Table XXVII.

Some characteristics were common to each of the measurements. There was a general decrease in calf performance and milk production with each successive lactation. This decrease in performance is contrary to most research findings (Eckles and Anthony, 1956; Searle and Henderson, 1959; Dawson _et al._, 1960; Heyns, 1960a) in that yield usually increases through the third or fourth lactation. As previously described, the cows in this experiment were maintained in drylot and not handled in the manner of range cows, and this may have affected their performance. Standard deviations were larger with each successive lactation. The smaller means and larger standard deviations are reflected in larger coefficients of variation with each successive lactation.

As expected, within any single lactation average milk production decreased as the lactation progressed. The average daily gain from birth to 112 days was less than to either 70 or 210 days in each lactation. This was expected, since from birth until 112 days of age the calves received only the milk from their dams with no other source of nutrients. Therefore, a greater portion of the milk consumed would have been required to meet the maintenance requirements as the calves approached 112 days of age. The supplemental ration fed from 112 to 210 days was fed at a level calculated to provide the maintenance requirements of the calves.

TABLE XXVII

THE MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF SEVERAL ESTIMATORS OF MILK PRODUCTION

	First Year[a]			Second Year[b]			Third Year[c]			Overall[d]		
	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.
Calf Weight (210)[e]	(lb.) 388	33	8.50	(lb.) 366	59	15.99	(lb.) 352	61	17.28	(lb.) 363	58	15.83
Average daily gain (210)	1.55	0.17	10.97	1.43	0.25	17.48	1.34	0.29	21.64	1.41	0.27	19.15
Average daily gain (112)	1.42	0.16	11.27	1.44	0.27	18.75	1.28	0.29	22.66	1.35	0.27	20.00
Average daily gain (70)	1.50	0.15	10.00	1.55	0.31	20.00	1.37	0.31	22.63	1.45	0.30	20.69
Handmilk (FCM, 210)	10.3	3.1	30.10	9.3	3.1	33.33	8.0	3.2	40.00	8.9	3.3	37.08
Handmilk (210)	11.5	2.7	23.48	10.2	3.1	30.39	9.3	3.3	35.48	10.0	3.2	32.00
Handmilk (112)	12.3	2.7	21.95	11.9	3.3	27.73	10.6	3.6	33.96	11.3	3.4	30.09
Handmilk (70)	12.4	2.9	23.39	12.9	3.7	28.68	11.5	4.1	35.65	12.1	3.8	31.40
Weight-Change (FCM, 210)	12.0	2.0	16.67	12.1	2.9	23.97	10.6	3.2	30.19	11.3	3.0	26.55
Weight-Change (210)	13.9	1.8	12.95	13.3	2.8	21.05	12.4	3.1	25.00	12.9	2.9	22.48
Weight-Change (112)	14.7	1.8	12.24	14.9	2.7	18.12	13.6	3.1	22.79	14.2	2.8	19.72
Weight-Change (70)	14.7	1.4	9.52	15.3	2.5	16.34	14.0	3.2	22.86	14.5	2.8	19.31

[a] Based on 7 cows
[b] Based on 11 cows
[c] Based on 18 cows
[d] Based on 36 cows
[e] Stage of lactation (days)

Therefore, with the maintenance requirement satisfied from supplemental feed, the nutrients supplied by milk would represent a quantity available for calf gain and account for the increased calf performance for 210 days.

Handmilking had the largest coefficient of variation at each of the three stages of lactation. The coefficients of variation for milk production based on the calf-weight-change technique were approximately 10 percent lower than for handmilking and almost the same as those for average daily gain of the calf. Calf weight at 210 days had the lowest coefficient of variation of any measure used. Coefficients of variation of the magnitude reported are rather high, but with perhaps the exception of those for handmilking, are not uncommon in estimating milk production of cattle. 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.

Simple correlations between yields as estimated by each of the four methods of estimating the milk producing ability of beef cows were all highly significant ($P < 0.01$), (Table XXVIII). Under the conditions of this experiment, the simpler measures of calf weight and average daily gain appear to be competent measures of milk production. However, the observations of other investigators (Gifford, 1953; Drewery et al., 1959; Heyns, 1960b; Caldwell et al., 1962) indicate that the correlations between milk production and calf performance are not as high when the calf has access to other sources of nutrients.

Direct estimates of milk production determined by handmilking and by calf-weight-change were highly correlated (r=0.92, 0.95 and 0.95 for 70, 112, and 210 days, respectively. The absolute values of milk

TABLE XXVIII

CORRELATIONS BETWEEN SEVERAL ESTIMATORS OF MILK PRODUCTION[a]

Variable		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Calf Weight (210)[b]	(X_1)		0.99	0.84	0.74	0.81	0.79	0.76	0.88	0.80	0.74
Average Daily Gain (210)	(X_2)			0.83	0.72	0.83	0.79	0.76	0.88	0.79	0.72
Average Daily Gain (112)	(X_3)				0.95	0.78	0.79	0.78	0.80	0.82	0.84
Average Daily Gain (70)	(X_4)					0.68	0.72	0.73	0.69	0.76	0.83
Handmilk (210)	(X_5)						0.92	0.84	0.95	0.86	0.76
Handmilk (112)	(X_6)							0.96	0.90	0.95	0.89
Handmilk (70)	(X_7)								0.84	0.92	0.92
Weight-Change (210)	(X_8)									0.93	0.82
Weight-Change (112)	(X_9)										0.95
Weight-Change (70)	(X_{10})										

[a] $r=0.325$ at $P=0.05$ and 0.418 at $P=0.01$
[b] Stage of lactation (days)

production determined by the calf-weight-change were almost 2 pounds larger for 70 days and almost 3 pounds larger for 112 and 210 days than those obtained by handmilking. This difference in absolute value was expected since calves are capable of more efficiently stripping the cows.

McCance (1959) lists three requirements for a method of estimation of milk production during a relatively short period: (1) the udder must be emptied to a comparable degree at the beginning and end of the period of observation; (2) the procedure itself must not affect production during the period of observation,and (3) production during the period of observation is the same as for other periods to which the estimate will be referred.

The degree of emptying the udder should not be an important source of error with the weight-change technique, although failure of the normal let down reflex due to unnatural conditions or the calf's limited capacity for milk may result in appreciable quantities of milk being left in the udder after each suckling. If the residual milk left in the udder is sufficient, requirements (2) and (3) cannot be met because of the effect of residual milk slowing the secretion rate (Turner, 1955). These errors mean that the weight-change technique probably gives a slightly low estimate of milk production.

The udder cannot be consistently emptied to a comparable degree by the handmilking technique. Appreciable amounts of residual milk are left in the udder, therefore, requirements (2) and (3) are not met and the estimate of actual milk production is low.

The high correlations between milk production determined by handmilking and weight-change indicate that handmilking may be a satisfactory procedure for comparing the milk yield of cows when facilities are not available for separating and weighing the calves before and after nursing. However, the weight-change technique appears to be the most precise estimator of actual milk production.

The weight of the calf also appears to be a good comparative measure of the milk producing ability of cows, especially during times when the calf is heavily dependent on the dam's milk for a source of nutrients.

Sampling Intervals

A more detailed examination of the sampling interval required to give an accurate estimate of milk production for the entire lactation was made with the handmilking and calf-weight-change techniques.

The means, standard deviation, and coefficients of variation of milk production estimated by handmilking at various sampling intervals are summarized in Table XXIX. Milk production based on samples taken at monthly intervals gave slightly higher estimates of daily milk yield than samples taken at weekly intervals. However, when estimates were made at monthly intervals, coefficients of variation were about 4 to 6 percent larger and the correlation with actual production was smaller. When the samples were taken on selected days, variation was generally decreased with each additional sample.

Correlation coefficients for these sampling intervals are shown in Table XXX. Since each sampling interval was an estimate of the average daily milk yield at different times, a certain automatic correlation exists. Therefore, these are part-whole correlations and might be expected to be high. Correlation coefficients between milk production estimated at monthly intervals and weekly intervals were 0.88 for 70 days, 0.88 for 112 days, and 0.93 for 210 days. An estimation of milk production

TABLE XXIX

THE MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF MILK PRODUCTION ESTIMATED BY HANDMILKING AT SELECTED SAMPLING INTERVALS

	First Year[a]			Second Year[b]			Third Year[c]			Overall[d]		
	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.
Weekly (FCM, 210)[e]	10.3	3.1	30.10	9.3	3.1	33.33	8.0	3.2	40.00	8.9	3.3	37.08
Weekly (210)	11.5	2.7	23.48	10.2	3.1	30.39	9.3	3.3	35.48	10.0	3.2	32.00
Weekly (112)	12.3	2.7	21.95	11.9	3.3	27.73	10.6	3.6	33.96	11.3	3.4	30.09
Weekly (70)	12.4	2.9	23.39	12.9	3.7	28.68	11.5	4.1	35.65	12.1	3.8	31.40
Monthly (210)	13.0	3.6	27.69	10.4	3.5	33.65	9.4	3.7	39.36	10.4	3.8	36.54
Monthly (112)	14.2	3.8	26.76	12.3	4.5	36.58	10.6	3.9	36.79	11.8	4.3	36.44
Monthly (70)	14.2	4.2	29.58	13.0	5.0	38.46	11.5	4.1	35.65	12.5	4.5	36.00
Day 30	11.8	3.4	28.81	13.3	5.7	42.85	11.3	4.3	38.05	12.0	4.7	39.17
Days 30, 70	12.7	3.1	24.41	13.1	4.5	34.35	10.5	4.1	39.05	11.8	4.2	35.59
Days 30, 70, 112	12.0	2.2	18.33	12.2	4.1	33.6,	10.3	3.8	36.89	11.2	3.8	33.93
Days 30, 70, 112, 210	11.3	2.4	21.24	11.0	3.7	33.64	9.4	3.6	38.30	10.2	3.5	34.31
Days 10, 30, 70, 112, 210	11.0	2.5	22.73	11.3	3.5	30.97	10.2	3.7	36.27	10.7	3.5	32.71

[a]Based on 7 cows
[b]Based on 11 cows
[c]Based on 18 cows
[d]Based on 36 cows
[e]Stage of lactation (days)

TABLE XXX

CORRELATIONS BETWEEN SELECTED SAMPLING INTERVALS FOR ESTIMATING MILK PRODUCTION BY HANDMILKING

Sampling Interval[a]		X_1	X_2	X_3	X_4
	First Lactation[b]				
Weekly (FCM, 210)	(X_1)		0.97	0.93	0.85
Weekly (210)	(X_2)			0.99	0.95
Weekly (112)	(X_3)				0.99
Weekly (70)	(X_4)				
Monthly (210)	(X_5)	0.72	0.72	0.72	0.68
Monthly (112)	(X_6)	0.71	0.71	0.71	0.68
Monthly (70)	(X_7)	0.47	0.53	0.58	0.61
Day 30	(X_8)	0.38	0.58	0.65	0.75
Days 30, 70	(X_9)	0.70	0.84	0.89	0.94
Days 30, 70, 112	(X_{10})	0.81	0.91	0.93	0.95
Days 30, 70, 112, 210	(X_{11})	0.90	0.96	0.97	0.96
Days 10, 30, 70, 112, 210	(X_{12})	0.89	0.95	0.97	0.95
	Second Lactation[c]				
	(X_1)		0.99	0.95	0.85
	(X_2)			0.93	0.95
	(X_3)				0.95
	(X_4)				
	(X_5)	0.94	0.97	0.88	0.71
	(X_6)	0.86	0.91	0.86	0.69
	(X_7)	0.89	0.86	0.93	0.92
	(X_8)	0.71	0.67	0.81	0.87
	(X_9)	0.86	0.84	0.94	0.92
	(X_{10})	0.91	0.93	0.94	0.83
	(X_{11})	0.96	0.97	0.95	0.82
	(X_{12})	0.96	0.94	0.98	0.92
	Third Lactation[d]				
	(X_1)		0.98	0.92	0.83
	(X_2)			0.89	0.84
	(X_3)				0.95
	(X_4)				
	(X_5)	0.95	0.98	0.88	0.80
	(X_6)	0.91	0.91	0.95	0.89
	(X_7)	0.75	0.79	0.89	0.94
	(X_8)	0.53	0.59	0.54	0.64
	(X_9)	0.80	0.77	0.90	0.91
	(X_{10})	0.92	0.93	0.95	0.91
	(X_{11})	0.95	0.97	0.91	0.85
	(X_{12})	0.92	0.95	0.90	0.88

TABLE XXX (Continued)

Sampling Interval[a]		X_1	X_2	X_3	X_4
------------Combined Lactations[e]-----------					
Weekly (FCM, 210)	(X_1)		0.98	0.93	0.84
Weekly (210)	(X_2)			0.92	0.84
Weekly (112)	(X_3)				0.96
Weekly (70)	(X_4)				
Monthly (210)	(X_5)	0.91	0.93	0.85	0.75
Monthly (112)	(X_6)	0.86	0.87	0.88	0.79
Monthly (70)	(X_7)	0.75	0.77	0.85	0.88
Day 30	(X_8)	0.57	0.61	0.65	0.73
Days 30, 70	(X_9)	0.80	0.80	0.91	0.91
Days 30, 70, 112	(X_{10})	0.89	0.92	0.94	0.88
Days 30, 70, 112, 210	(X_{11})	0.94	0.96	0.92	0.85
Days 10, 30, 70, 112, 210	(X_{12})	0.92	0.94	0.94	0.90

[a]Daily milk yield calculated by an average of sample(s) taken to the stage of lactation indicated in parenthesis (days).
[b]$r=0.707$ at $P=0.05$ and 0.834 at $P=0.01$
[c]$r=0.576$ at $P=0.05$ and 0.708 at $P=0.01$
[d]$r=0.456$ at $P=0.05$ and 0.575 at $P=0.01$
[e]$r=0.325$ at $P=0.05$ and 0.418 at $P=0.01$

on day 30 or on days 30 and 70 appear to be satisfactory for estimating production for the first 70 days, but it should be remembered that the variation is quite large during this stage of lactation. In general, correlations between weekly milk production and sampling on selected days increased with each additional sample taken up to 210 days. However, a sample taken very early in the lactation (10 days) tended to lower the correlation.

Considering accuracy of measurement and the number of samples required, an estimate of milk production by the handmilking technique on days 30, 70, 112, and 210 was seemingly satisfactory for estimating the average milk yield for a 210 day lactation. Sampling on these days gave the highest correlation (r=0.96) with weekly estimates of any sampling interval studied.

Table XXXI summarizes the means, standard deviations and coefficients of variation of milk production estimated by the calf-weight-change technique at selected sampling intervals. The means and coefficients of variation of complete records (based on 6 days per week throughout the lactation) and estimates taken at weekly intervals were quite similar. The means and coefficients of variation were slightly larger when the estimates were made at monthly intervals. With estimates obtained on selected days, those estimated from 1 days record only had the largest amount of variation.

The correlations for these sampling intervals are shown in Table XXXII. Estimates obtained at weekly intervals were very highly correlated to the total production (r=0.97, 0.98 and 0.99 at 70, 112 and 210 days, respectively, for the combined lactations). Estimates obtained at monthly sampling intervals and total milk production were also

TABLE XXXI

THE MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION OF MILK PRODUCTION ESTIMATED BY CALF-WEIGHT-CHANGE AT SELECTED SAMPLING INTERVALS

Sampling Interval	First Year[a]			Second Year[b]			Third Year[c]			Overall[d]		
	Mean	Std. Dev.	C.v.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.
Complete[e] (FCM, 210)[f]	12.0	2.0	16.67	12.1	2.9	23.97	10.6	3.2	30.19	11.3	3.0	26.55
Complete (210)	13.9	1.8	12.95	13.3	2.8	21.05	12.4	3.1	25.00	12.9	2.9	22.48
Complete (112)	14.7	1.8	12.24	14.9	2.7	18.12	13.6	3.1	22.79	14.2	2.8	19.72
Complete (70)	14.7	1.4	9.52	15.3	2.5	16.34	14.0	3.2	22.86	14.5	2.8	19.31
Weekly (210)	14.1	1.7	12.06	13.2	2.8	21.21	12.5	3.2	25.60	13.0	2.9	22.31
Weekly (112)	14.9	1.6	10.74	14.9	3.0	20.13	13.8	3.0	21.74	14.4	2.8	19.44
Weekly (70)	15.0	1.4	9.33	15.5	3.0	19.35	14.2	3.0	21.13	14.8	2.8	18.92
Monthly (210)	14.5	2.8	19.31	13.3	2.8	21.05	12.2	3.6	29.51	13.0	3.3	25.38
Monthly (112)	15.7	2.7	17.20	16.0	2.7	16.88	13.8	3.5	25.36	14.9	3.3	22.15
Monthly (70)	15.4	3.4	22.08	16.2	2.6	16.05	14.3	3.3	23.07	15.1	3.2	21.19
14th, 15th, and 16th Week	13.7	2.8	20.44	13.8	3.3	23.91	13.0	3.7	28.46	13.4	3.5	26.12
Day 30	14.9	2.9	19.46	16.7	3.4	20.36	14.5	3.6	24.83	15.2	3.6	23.68
Day 112	13.2	3.5	26.52	13.1	3.8	29.01	13.6	4.5	33.09	13.4	4.2	31.34
Day 190	13.3	2.5	18.80	10.0	3.3	33.00	10.2	4.6	45.10	10.8	4.1	37.96
Day 90 and 180	14.7	2.4	16.33	13.6	3.4	25.00	11.7	3.4	29.06	12.9	3.4	26.36
Days 30, 70	15.4	1.9	12.34	15.7	2.9	18.47	14.4	3.4	23.61	15.0	3.1	20.67
Days 30. 70, 112	14.6	2.2	15.07	14.8	2.9	19.59	14.1	3.5	24.82	14.4	3.1	21.53
Days 30, 70, 112, 210	13.9	1.9	13.67	13.9	2.7	19.42	13.0	3.5	26.92	13.4	3.1	23.13
Days 10, 30, 70, 112, 210	13.6	1.5	11.03	13.8	2.1	15.22	12.8	3.3	25.78	13.3	2.8	21.05
Days 30, 70, 112, 140, 210	13.6	2.0	14.70	13.6	2.9	21.32	12.8	3.6	28.12	13.2	3.2	24.24

[a]Based on 7 cows
[b]Based on 11 cows
[c]Based on 18 cows
[d]Based on 36 cows
[e]Milk production estimated 6 days per week
[f]Stage of lactation (days)

TABLE XXXII

CORRELATIONS BETWEEN SELECTED SAMPLING INTERVALS FOR ESTIMATING MILK PRODUCTION BY THE WEIGHT-CHANGE TECHNIQUE

Sampling Interval		X_1	X_2	X_3	X_4
		First Lactation[c]			
Complete[b] (FCM, 210)[a]	(X_1)		0.87	0.81	0.65
Complete (210)	(X_2)			0.96	0.79
Complete (112)	(X_3)				0.91
Complete (70)	(X_4)				
Weekly (210)	(X_5)	0.86	0.99	0.96	0.81
Weekly (112)	(X_6)	0.78	0.94	0.99	0.91
Weekly (70)	(X_7)	0.64	0.77	0.90	0.98
Monthly (210)	(X_8)	0.39	0.72	0.80	0.76
Monthly (112)	(X_9)	0.46	0.70	0.85	0.91
Monthly (70)	(X_{10})	0.16	0.46	0.65	0.80
14th, 15th, and 16th Week	(X_{11})	0.66	0.81	0.76	0.49
Day 30	(X_{12})	-.42	-.05	0.15	0.32
Day 112	(X_{13})	0.72	0.86	0.81	0.56
Day 190	(X_{14})	0.82	0.78	0.70	0.50
Days 90 and 180	(X_{15})	0.87	0.86	0.84	0.62
Days 30, 70	(X_{16})	0.29	0.52	0.56	0.58
Days 30, 70, 112	(X_{17})	0.55	0.76	0.75	0.62
Days 30, 70, 112, 210	(X_{18})	0.25	0.67	0.67	0.52
Days 10, 30, 70, 112, 210	(X_{19})	0.28	0.70	0.77	0.74
Days 30, 70, 112, 140, 210	(X_{20})	0.47	0.83	0.80	0.60
		Second Lactation[d]			
	(X_1)		0.98	0.94	0.83
	(X_2)			0.91	0.76
	(X_3)				0.95
	(X_4)				
	(X_5)	0.98	0.99	0.93	0.79
	(X_6)	0.93	0.90	0.99	0.92
	(X_7)	0.81	0.75	0.92	0.96
	(X_8)	0.95	0.99	0.88	0.73
	(X_9)	0.86	0.85	0.94	0.87
	(X_{10})	0.69	0.69	0.85	0.83
	(X_{11})	0.89	0.88	0.89	0.75
	(X_{12})	0.27	0.22	0.49	0.62
	(X_{13})	0.73	0.72	0.80	0.68
	(X_{14})	0.71	0.78	0.65	0.54
	(X_{15})	0.74	0.80	0.65	0.50
	(X_{16})	0.71	0.66	0.84	0.84
	(X_{17})	0.79	0.75	0.91	0.85
	(X_{18})	0.96	0.96	0.96	0.83
	(X_{19})	0.90	0.91	0.91	0.82
	(X_{20})	0.97	0.97	0.93	0.77

TABLE XXXII (Continued)

Sampling Interval	X_1	X_2	X_3	X_4
---------Third Lactation[e]---------				
(X_1)		0.96	0.92	0.83
(X_2)			0.93	0.95
(X_3)				0.95
(X_4)				
(X_5)	0.93	0.99	0.90	0.83
(X_6)	0.88	0.93	0.98	0.92
(X_7)	0.87	0.90	0.96	0.98
(X_8)	0.91	0.96	0.89	0.85
(X_9)	0.90	0.88	0.94	0.91
(X_{10})	0.84	0.83	0.90	0.91
(X_{11})	0.77	0.81	0.83	0.69
(X_{12})	0.71	0.71	0.85	0.87
(X_{13})	0.81	0.84	0.84	0.75
(X_{14})	0.74	0.79	0.64	0.59
(X_{15})	0.88	0.91	0.86	0.79
(X_{16})	0.83	0.86	0.92	0.93
(X_{17})	0.89	0.92	0.96	0.92
(X_{18})	0.87	0.93	0.87	0.83
(X_{19})	0.90	0.94	0.94	0.91
(X_{20})	0.89	0.94	0.86	0.80
------Combined Lactations[f]---------				
(X_1)		0.96	0.92	0.81
(X_2)			0.93	0.82
(X_3)				0.95
(X_4)				
(X_5)	0.94	0.99	0.91	0.82
(X_6)	0.89	0.92	0.98	0.92
(X_7)	0.83	0.84	0.94	0.97
(X_8)	0.86	0.94	0.87	0.80
(X_9)	0.83	0.84	0.92	0.89
(X_{10})	0.68	0.72	0.83	0.85
(X_{11})	0.79	0.83	0.84	0.68
(X_{12})	0.44	0.48	0.67	0.74
(X_{13})	0.77	0.81	0.82	0.70
(X_{14})	0.74	0.78	0.64	0.57
(X_{15})	0.83	0.87	0.79	0.68
(X_{16})	0.75	0.77	0.87	0.88
(X_{17})	0.82	0.85	0.92	0.88
(X_{18})	0.84	0.91	0.88	0.81
(X_{19})	0.83	0.91	0.91	0.86
(X_{20})	0.87	0.93	0.87	0.78

[a]Daily milk yield calculated by an average of sample(s) taken to the stages of lactation indicated in parenthesis (days).

[b]Milk production estimated 6 days per week for entire lactation.

[c]$r=0.707$ at $P=0.05$ and 0.834 at $P=0.01$

[d]$r=0.567$ at $P=0.05$ and 0.708 at $P=0.01$

[e]$r=0.456$ at $P=0.05$ and 0.575 at $P=0.01$

[f]$r=0.325$ at $P=0.05$ and 0.418 at $P=0.01$

highly correlated (r=0.85, 0.92 and 0.95 at 70, 112, and 210 days, respectively, for the combined lactations). Correlations between estimates obtained from one day records and total production were significant in every case, but were lower than those at the other intervals studied. These are part-whole correlations and might be expected to be high because a certain automatic correlation exists between the average daily milk yield and the yield estimated at the various sampling intervals.

Correlations based on estimates from other selected days generally increased with each additional sample taken. Total 210 day production and estimates of production on days 30, 70, 112, 140 and 210 were the most highly correlated among these intervals (r=0.93 for combined lactations). A pooled correlation of 0.87 between total production and production estimated on days 90 and 180 suggest that an estimate based on these 2 days may be useful. The average milk production estimated from the two intervals mentioned above was quite similar to that for total production and the variation was only slightly greater.

Gifford (1953) emphasized that the maximum milk production of a beef cow is probably limited by the ability of her calf to consume the quantity of milk produced. He stated that the production at any period could not exceed the daily capacity of the calf because the milk remaining in the udder would tend to slow down the secretory process. Heyns (1960b) suggested that a heavier calf at birth exerts a greater stimulation on the milk production of its dam and that this tends to continue throughout the lactation period.

The correlations between birth weight and average daily milk yield shown in Table XXXIII tend to be somewhat smaller than most of those previously reported (Drewery _et al._, 1959; Heyns, 1960b). These

TABLE XXXIII

CORRELATIONS BETWEEN BIRTH WEIGHT AND AVERAGE DAILY MILK PRODUCTION ESTIMATED BY THE WEIGHT-CHANGE TECHNIQUE

Year	Stage of Lactation			
	Day 30[a]	70 Days[b]	112 Days[b]	210 Days[b]
1[c]	0.24	-.56	-.52	-.50
2[d]	0.16	-.09	-.13	-.07
3[e]	0.56	0.40	0.33	0.14
Combined[f]	0.39	0.17	0.10	0.01

[a]One sample only
[b]Milk production estimated 6 days/week
[c]r=0.707 at P=0.05 and 0.834 at P=0.01
[d]r=0.576 at P=0.05 and 0.708 at P=0.01
[e]r=0.456 at P=0.05 and 0.575 at P=0.01
[f]r=0.325 at P=0.05 and 0.418 at P=0.01

correlations were quite variable as might be expected with the small numbers involved and with the large variation in average milk yield of the cows. Also calves in the present study were at least half-sibs in relation which would tend to make birth weight, a moderately heritable trait, less variable and thus lower the correlation. In general, the correlations between birth weight and milk production estimated on day 30 of the lactation were larger than those for later stages of lactation. The pooled correlation (r=0.39) between birth weight and milk yield on day 30 was significant ($P < 0.05$) for the 3 combined years. This may be an indication of the importance of size of calf when estimating production during the early stages of lactation, especially by the calf-weight-change technique. Heyns (1960b) found a correlation of 0.78 between birth weight and the consuming capacity of the calf for one feeding period during the first week after parturition.

Lampkin and Lampkin (1960) reported calves allowed to nurse three times daily appeared capable of taking all the milk except possibly the first 2 weeks. In the present study, calves were allowed to remain with their dams until 10 days of age and then they were separated and allowed to nurse two times daily. Residual milk was removed by hand in the event that the calves were unable to suckle the cows dry and the amount of milk obtained by handmilking was added to the milk estimated by calf-weight-change. Although it was not necessary to use this procedure to any great extent, its use would tend to lower the correlation between birth weight and average daily milk yield. Allowing the calves to remain with their dams and the removal of excess milk by handmilking would also reduce the intramammary pressure which has been reported to decrease the potential secretion rate if milk is incompletely removed from the udder (Peterson and Rigor, 1932; Turner, 1955).

Yield and Composition of Milk

The average milk yields given in Table XXVII are well within the range of milk production previously reported for beef cows. The average daily milk production of 12.9 pounds for a 210 day lactation (based on calf-weight-change, 6 days per week) in this study was quite similar to that obtained by Heyns (1960a) and Lampkin and Lampkin (1960) but was slightly higher than estimates reported by most workers (Arbuckle, 1959; Neville et al., 1960; Furr, 1962; Klett et al., 1962, Kuhlman, 1962; Montsma, 1962; Velasco, 1962). Larger yields were reported by Dawson et al. (1960) for selected Shorthorn cows. The average daily milk yield of 10.0 pounds estimated by handmilking was also slightly higher than the yield observed by Gifford (1953) using similar techniques.

The wide variety of conditions and techniques employed by the various researchers prevent an accurate, direct comparison of actual pounds produced. A number of factors, including level of nutrition, age of cow, year, season of year, breed differences and inherent differences among cows within breed may have influenced the amount of milk produced.

An attempt was made to provide adequate nutrients to allow full expression of the inherent milk producing ability of the cows in this study. This may be one explanation for the higher average daily production because in many of the previous studies large losses of body weight by the cows indicate that the feeding regimes were probably inadequate to allow full expression of their milk producing ability. A second possible explanation is that calves reared under the conditions of this experiment may offer more of a challenge to the cows, thus stimulating a higher milk yield, especially in the late stages of lactation when the calf would ordinarily be able to obtain considerable nutrients from other sources. In addition "stress conditions", which tend to lower estimates of milk yield in beef cows were minimized in the present study since the cows were well accustomed to the routine followed daily. The very high level of nutrition apparently decreased milk production in some cows as discussed in Part I. This would tend to partially offset a higher production brought about by the factors discussed above.

The normal lactation curve of dairy cattle has been described by many workers (Gowen, 1924; Nevens, 1951; Eckles and Anthony, 1956). In general there is a rapid rise in milk yield soon after parturition which becomes less and less until the maximum production is reached at approximately 2 months and then there is a steady decline after the peak production. Gifford (1953) stated that the lactation curve for beef cows did not follow the norm described for dairy cattle in that only the declining segment of the curve was represented.

The lactation curve estimated from data obtained by handmilking at weekly intervals indicates the peak production occurred at 3 weeks (Figure 3). However, the lactation curve estimated from data obtained by the calf-weight-change technique was quite similar to those described for dairy cattle. There was a rather rapid increase 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. Gifford (1953) suggested that the milk consuming capacity of the calf was one important factor which prevented the beef cow from following the normal physiological process. However, data from this study indicate that the handmilking technique and sampling interval of 1 month used by Gifford (1953) may have been important factors in determining the shape of the lactation curve.

The lactation curve obtained by use of the calf-weight-change data is in close accord with other investigators who have used this technique. Dawson *et al.* (1960), Heyns (1960a), Lampkin and Lampkin (1960) and Velasco (1962) have all reported a peak milk yield between the fourth and eighth week of lactation.

There was a considerable variation among individual cows in the time required to reach maximum production. Several factors may have a role in influencing the time required to reach the peak of lactation including capacity of the calf, management and nutrition. The latter factor is well illustrated in this study (Part I, Figure II) with high level cows reaching the peak of lactation much earlier than moderate level cows.

The means, standard deviations, and coefficients of variation for

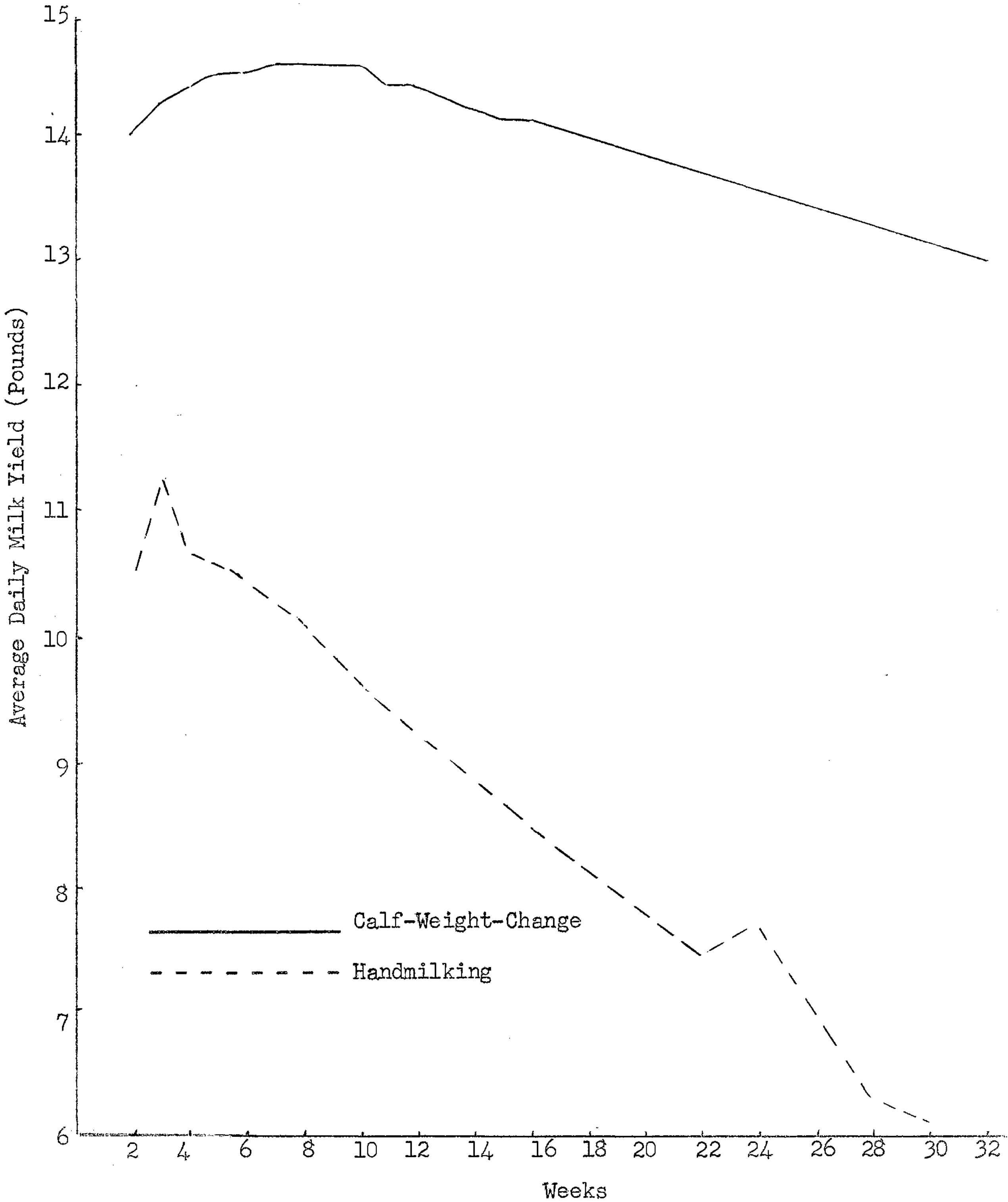


Figure 3. Average Daily Milk Production in Relation to Stage of Lactation

total fat, percent fat, total solids and percent total solids are shown in Table XXXIV. The percent fat varied from 3.0 to 3.5 percent with an overall average for the three years of 3.2 percent. These fat levels compare favorably with the 3.08 percent fat reported by Gifford (1953) and the 2.82 percent fat for Afrikaner cows reported by Heyns (1960a). In each of these studies, as well as the present study, the fat content may not be representative because of incomplete letdown of milk with the procedures used in collecting samples. Cole and Johansson (1933) and Dawson et al. (1960) found the average percent fat of milk from beef cows was approximately 4 percent when they were managed as dairy cows. Caldwell et al. (1962), using oxytocin to facilitate complete milk letdown found an average percent fat of 4.44 for mixed beef cows. These findings are in accord with the observation of Eckles and Anthony (1956) that first drawn milk is low in fat and the strippings are extremely rich.

The total pounds of fat produced was influenced to a large extent by the total pounds of milk. A coefficient of variation of about 15 percent was noted for percent fat compared to slightly over 40 percent for total pounds of fat because of the wide variation in total milk yield.

The percent total solids of the milk ranged from 12.50 percent the first year to 11.84 percent the third year. with an overall average of 12.15 percent. These percentages generally agree with those reported by Klett et al. (1962), but are approximately 1.00 percent less than those reported by Heyns (1960a) and Caldwell et al. (1962). The inability to completely strip the cows in this study, with the procedures used, was probably a contributing factor to the low percentage of total solids since strippings are high in total solids (Eckles and Anthony, 1956). The percent total solids was quite constant between cows as indicated by

TABLE XXXIV

THE MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF VARIATION FOR TOTAL FAT, PERCENT FAT, TOTAL SOLIDS AND PERCENT TOTAL SOLIDS[a]

Variable	First Year[b]			Second Year[c]			Third Year[d]			Overall[e]		
	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.	Mean	Std. Dev.	C.V.
Total Fat (210)[f]	79.2	28.3	35.73	72.7	26.2	36.04	60.4	27.1	44.87	67.8	28.1	41.44
Total Fat (112)	46.4	15.5	33.40	48.7	14.9	30.60	35.0	17.2	49.14	41.4	17.4	42.03
Total Fat (70)	29.5	10.8	36.61	34.5	11.0	31.88	23.1	12.1	52.38	27.8	12.6	45.32
Percent Fat[g]	3.5	0.5	15.62	3.4	0.4	11.76	3.0	0.5	16.67	3.2	0.5	15.63
Total Solids (210)	301.6	79.3	26.29	268.3	84.0	31.31	235.6	88.4	37.52	258.4	89.1	34.48
Total Solids (112)	173.6	40.7	23.44	168.6	47.6	28.23	141.3	51.0	36.09	155.9	50.3	32.26
Total Solids (70)	110.1	27.2	24.70	116.8	35.2	30.14	93.3	35.4	37.94	103.4	35.6	34.43
Percent Total Solids[g]	12.50	0.65	5.20	12.45	0.42	3.37	11.84	0.56	4.73	12.15	0.62	5.10

[a]Based on total milk estimated by handmilking
[b]Based on 7 cows
[c]Based on 11 cows
[d]Based on 18 cows
[e]Based on 36 cows
[f]Stage of lactation (days)
[g]Average percentage for 210 days

coefficients of variation of about 5.0 percent. The total amount of solids produced during the lactation was quite variable due to the wide differences in total milk production.

The relationships between production of milk, fat, and total solids are shown in Table XXXV. As expected, both total fat and total solids were highly correlated with milk production. The correlations between average daily milk yield and percent fat and percent total solids were much lower.

Correlation coefficients between average daily gain of the calf and average daily milk yield of the dam (based on calf-weight-change 6 days per week) were 0.83, 0.82, and 0.88 at 70, 112, and 210 days, respectively (Table XXXVI). These correlations are generally higher than most of those reported by previous workers (Gifford, 1953; Drewery et al., 1959; Heyns, 1960b; Caldwell et al., 1962; Neville, 1962; Velasco, 1962). With non-milk nutrients provided only after 112 days and then limited to the maintenance requirements of the calf, these correlations between milk yield and calf gain were expected to be high. Furr (1962), using fall calving cows, and Montsma (1960), studying cows existing under extreme drought conditions, reported very high correlations between milk yield and average daily gain, indicating a high relationship when other nutrients available to the calf are limited.

The pounds of milk required per pound of calf gain are shown in Table XXXVII. These values are well within the range found by other workers (Drewery et al., 1959; Lampkin and Lampkin, 1960; Klett et al., 1962; Montsma, 1962; Neville, 1962). The large amount of milk required per pound of gain to 112 days is due to a complete lack of non-milk nutrients during the 112 day period, under the conditions of this experiment. Disregarding this stage, there was a general decrease in the

TABLE XXXV

CORRELATIONS BETWEEN MILK PRODUCTION AND SOME MILK CONSTITUENTS[a]

Variable		X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Milk Production[b] (210 Handmilking)	(X_1)		0.95	0.94	0.78	0.71	0.44	0.99	0.88	0.82	0.28
Milk Production[c] (210 weight-change)	(X_2)			0.86	0.75	0.70	0.36	0.93	0.86	0.81	0.17
Total Fat (210)	(X_3)				0.88	0.80	0.70	0.97	0.92	0.84	0.54
Total Fat (112)	(X_4)					0.97	0.76	0.82	0.96	0.91	0.56
Total Fat (70)	(X_5)						0.68	0.75	0.94	0.94	0.51
Percent Fat	(X_6)							0.54	0.65	0.55	0.80
Total Solids (210)	(X_7)								0.91	0.84	0.39
Total Solids (112)	(X_8)									0.96	0.46
Total Solids (70)	(X_9)										0.40
Percent Total Solids	(X_{10})										

[a] $r = 0.325$ at $P = 0.05$ and 0.418 at $P = 0.01$
[b] Milk Production estimated by handmilking one day per week
[c] Milk Production estimated by calf-weight-change 6 days per week

TABLE XXXVI

CORRELATIONS BETWEEN AVERAGE DAILY GAIN OF THE CALF AND AVERAGE DAILY MILK PRODUCTION BY THE DAM AT THREE STAGES OF LACTATION[a,b]

Variable		X_1	X_2	X_3	X_4	X_5	X_6
Average Daily Gain (70)	(X_1)		0.95	0.72	0.83	0.76	0.69
Average Daily Gain (112)	(X_2)			0.83	0.84	0.82	0.80
Average Daily Gain (210)	(X_3)				0.72	0.79	0.88
Milk Production (70)	(X_4)					0.95	0.82
Milk Production (112)	(X_5)						0.93
Milk Production (210)	(X_6)						

[a]Milk production estimated by calf-weight-change 6 days per week.
[b]$r=0.325$ at $P=0.05$ and 0.418 at $P=0.01$

TABLE XXXVII

POUNDS OF MILK REQUIRED PER POUND OF CALF GAIN AT THREE PERIODS OF LACTATION

Lactation Number	Period of Lactation	Total Milk[a] (lb.)	Total Gain (lb.)	Milk/Pound of Calf Gain (lb.)
1	70 days	1026	105	9.78
	112 days	1645	159	10.35
	210 days	2916	327	8.94
2	70 days	1071	109	9.85
	112 days	1668	161	10.36
	210 days	2789	300	9.30
3	70 days	982	96	10.23
	112 days	1518	143	10.62
	210 days	2592	281	9.22
Combined	70 days	1018	103	10.08
	112 days	1589	154	10.45
	210 days	2715	303	9.17

[a]Milk production determined by calf-weight-change 6 days per week.

pounds of milk required per pound of calf gain as the calf grew older. This is in general agreement with Drewery et al. (1959), although differences in the amount of milk used for maintenance may still be a factor.

The 36 complete lactation records were broken into three levels of production and the amount of milk required per pound of calf gain calculated for each level of production (Table XXXVIII). Calves receiving

TABLE XXXVIII

POUNDS OF MILK REQUIRED PER POUND OF CALF GAIN AT THREE LEVELS OF PRODUCTION

Level of Milk Production	Period of Lactation	Total Milk[a]	Total Gain	Milk/Pound of Calf Gain
Low	70 days	828	84	9.88
	112 days	1249	122	10.26
	210 days	2020	226	8.95
Medium	70 days	1059	110	9.66
	112 days	1619	161	10.04
	210 days	2777	320	8.69
High	70 days	1168	111	10.52
	112 days	1899	172	11.02
	210 days	3350	341	9.81

[a]Milk production determined by calf-weight-change 6 days per week.

low and medium amounts of milk were quite similar in the conversion of milk to calf gain. Calves with larger milk intakes were not as efficient in converting milk to gain as calves receiving less milk, perhaps because more of the calf gain was as fat. Similar results were obtained by Klett et al. (1962) who also found the calves from higher yielding dams were less efficient in converting milk to gain. On the other hand, Montsma

(1960) found calves from high yielding dams had better conversion rates. However, breed differences were involved in the comparisons in each of these two studies and may have influenced the conversion rates reported.

SUMMARY

Twelve sets of twin beef females, nine of which were monozygotic, were used to study the influence of moderate vs. very high levels of nutrition on growth, reproductive ability, and production. Extensive data were obtained on milk production, including an appraisal of techniques for estimating the milk yield, sampling intervals, and the relationship of the amount of milk and milk constituents to calf performance.

One member of each set was fed a high energy ration to achieve maximum possible gain and to maintain the cow at a high degree of body fatness. The second member of the set was fed a ration adequate in all nutrients but containing a moderate level of energy. Moderate level cows were fed to make average daily gains of one-half to two-thirds pounds prior to first parturition and to maintain a healthy, thrifty condition thereafter. All of the cows were kept in drylot and fed individually in stanchions to facilitate accurate feed intake data and to control weight.

The maximum differences in body weight between the two levels occurred just prior to the first parturition or at an average age of approximately 3 years. High level cows averaged 295, 483, 342, and 273 pounds heavier than the moderate level cows at first mating and at first, second and third parturition, respectively. In general, differences in body measurements were correspondent to the differences in weight, but smaller differences in measurements indicated that much of the difference in body weight was due to fat.

A high energy intake, which resulted in excessive body fatness, had little influence on breeding efficiency but increased calving difficulty and decreased survival rates of both cows and calves.

Although the variation within twin sets was rather large, the average milk production of the moderate level cows was usually higher. Some high level cows had an extremely low milk production while others equaled or surpassed their moderate level mates. A pooled correlation coefficient ($r=0.65$) between the difference in body weight within twin sets and the difference in their average daily milk yield was highly significant ($P < 0.01$), and indicates that the degree of fatness influences the productivity of the cow. There may also be individual differences in susceptibility to damage from excessive fattening. Little difference was noted in the fat percentage of the milk but high level cows produced milk with a significantly higher ($P \simeq 0.06$) percent total solids.

Birth weight of calves from high level cows was slightly higher. Weight and average daily gain of the calves were correspondent to the milk yield of their dams.

Body temperature of all cows was similar regardless of treatment level. Respiration rates were higher for cows fed the high level of energy, especially when ambient temperatures were highest.

Data from combined treatment levels were used to evaluate calf weight, average daily gain of the calf, handmilking, and weight-change of the calf before and after nursing to estimate the amount of milk produced by beef cows. Correlations between each of the four methods of estimating milk yield were high. However, because of the small numbers and the experimental conditions involved, these correlations may not be real. However, they should be satisfactory for comparative purposes. Handmilking had the largest coefficient of variation, followed in order of decreasing variation by calf-weight-change, average daily gain and calf weight.

The weight-change technique appears to be the most precise estimator of actual production but handmilking and the simpler measures of calf weight and average daily gain appear to be good comparative measures of the milk producing ability of beef cows, especially during times when the calf is heavily dependent on the dam's milk for a source of nutrients. The average daily milk yield for a 210 day lactation was 12.9 and 10.0 pounds as estimated by the calf-weight-change and handmilking techniques, respectively. Both estimates are probably lower than the actual yield. The milk averaged 3.2 percent fat and 12.15 percent total solids. The total pounds of fat and solids produced during a lactation were directly proportional to the total milk yield.

Handmilking and calf-weight-change techniques were examined further to determine the accuracy of selected sampling intervals for estimating the actual milk production.

With the handmilking technique, variation was generally decreased and the correlation between weekly milk production and estimates taken on selected days generally increased with each additional sample taken. Considering accuracy of measurement and the number of samples required, an estimate of milk production by the handmilking technique on days 30, 70, 112 and 210 was apparently satisfactory for estimating the average milk yield for a 210 day lactation.

Milk yield determined 6 days per week by the calf-weight-change technique 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-weight-change technique.

Correlations between birth weight of the calf and estimated milk yield at various stages of lactation indicate that size of the calf may be an important consideration when estimating the milk yield during early stages of lactation by the calf-weight-change technique.

Correlations between average daily milk yield and average daily gain were high since non-milk nutrients were limited to the maintenance requirements of the calf. An average of 9.17 pounds of milk was required per pound of calf gain for a 210 day lactation. Calves from dams producing larger amounts of milk were less efficient in converting milk to gain.

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