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TDN efficiency of angus and hereford cows raising straightbred and reciprocal cross calves as affected by cow and calf traits

Mike C. Crider

To the Graduate Council:

I am submitting herewith a dissertation written by Mike C. Crider entitled "TDN efficiency of angus and hereford cows raising straightbred and reciprocal cross calves as affected by cow and calf traits." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Animal Science.

Will T. Butts, Major Professor

We have read this dissertation and recommend its acceptance:

J.W. Holloway, J.B. McLaren, J.W. Philpot, D.O. Richardson

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TDN EFFICIENCY OF ANGUS AND HEREFORD COWS RAISING STRAIGHTBRED AND RECIPROCAL CROSS CALVES AS AFFECTED BY COW AND CALF TRAITS

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ABSTRACT

Mature Angus and Hereford cows raising straightbred and reciprocal cross calves were individually fed during their lactations. A total of 92 preweaning lactations and 66 postweaning growth curves were observed.

Cows were offered, ad libitum, a diet of grass silage and alfalfa pellets were added as an energy source when needed. Calves were creep fed alfalfa pellets from approximately 80 days of age until weaning. Following weaning calves were individually fed a complete growing and finishing ration until the calves were slaughtered at their maximum efficiency point (MEP).

Unit TDN was the sum of cow and calf TDN. Cow-calf unit weaning efficiency was calculated as the ratio of unit TDN to calf weaning weight. Cow-calf unit efficiency, calf age and calf weight were determined for endpoints at 12 mm fat and at MEP. Calf fat was determined at MEP. Postweaning efficiency, postweaning ADG and daily postweaning TDN were determined from weaning to 12 mm fat and MEP, respectively. Angus cow units were more efficient than were Hereford cow units (P<.001) but the effect was reduced when the covariates, milk production and calf weaning weight were added to the basic model. Crossbred calves were slightly heavier (P<.10) at weaning than straightbreds, but because of their higher calf TDN intake, they could not be declared more (P<.10) efficient. Calf weaning weight accounted for about 51 percent of the variation in cow-calf unit efficiency. Calves with improved efficiencies at weaning consumed

($P<.001$) more daily postweaning TDN. Younger calves were associated ($P<.10$) with improved postweaning ADG. When adjusted for calf weaning age crossbreds were heavier ($P<.05$) than straightbreds. Calves of Hereford sires were more efficient (P .01) than calves of Angus sires. Calf weight, at each respective endpoint, adjusted for calf weaning age, increased ($P<.05$) as cow-calf unit efficiency improved. Units with younger calves at each endpoint tended to be more efficient ($P<.10$) than units with older calves. Units with smaller cows were more efficient ($P<.05$) at MEP and ($P<.10$) at 12 mm fat than were units with larger cows.

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CHAPTER I

INTRODUCTION

Beef cattle producers have become more aware of the importance of the efficiency of converting feed into body weight as they have attempted to make profits in the difficult market situation seen in past years. Major emphasis on rate of gain as the primary criterion of selection in beef cattle implies the assumption that rapid gaining animals are more efficient converters of feed into edible beef than are slower gaining animals. Analysis of feed efficiency data calculated on the basis of feedlot performance (a ratio of feed intake by the calf to the gain produced by that intake) have shown rate of gain and efficiency of feed conversion to be positively related. However, when calculated on postweaning performance alone, this measure of efficiency does not consider such factors as mature size of the parents or preweaning influences such as level of milk production of the cow. Other studies, which examined feed efficiency of the cow-calf unit, generally indicate that overall nutritional efficiency is related to a complex set of variables associated with characteristics of the cow, calf and production system. These studies have employed feeding levels that were based on nutritional requirements or have utilized modeling techniques that were based on parameters estimated from accumulated data.

Ample research has documented that crossbred calves gain faster and produce heavier weights at weaning; thus, establishing crossbreeding as an accepted practice in the beef industry. However, little research has been conducted comparing the overall nutritional efficiency of the two mating systems. Crossbreeding is a more difficult system to incorporate into the small herds of this state and surrounding states than is straightbreeding. Comparison of the nutritional efficiency of straightbred cows raising straightbred and crossbred calves would allow producers to compare the mating systems in terms of profitability. Also, this research may determine cow-calf traits that affect production efficiency.

The purpose of this study was to compare, under unrestricted feeding levels, the nutritional efficiency at weaning and at various points postweaning of mature Angus and Hereford cows raising straightbred and crossbred calves. Secondly, this study was designed to evaluate the measurable cow-calf characteristics that may be indicative of nutritional efficiency at weaning and at various points postweaning.

CHAPTER II

REVIEW OF LITERATURE

I. Relationships Among Cattle Traits

Several studies have shown that a positive relationship exists between cow weight and calf weaning weight (Brinks et al., 1962; Neville, 1962; Christian et al., 1975; Urick et al., 1971; Marshall et al., 1976). Neville (1962) reported an increase in weaning weight of 7 pounds per 100 pound increase in cow weight. Urick et al. (1971) reported a 1.93 kg increase in 205-day weaning weight for each 45.4 kg increase in actual cow weight. Other studies have shown that calf weaning weights increase with age of dam (Brown, 1960; Brinks et al., 1967; Neville et al., 1974; Gray et al., 1978). This increase was generally noted until about seven or eight years of cow age.

Marshall et al. (1976) reported that the regression of weaning efficiency (kgs of TDN/kgs of weaning weight) on cow weight was small and nonsignificant (b = -.006). Heavier cows and their calves required more feed but also produced more weaning weight; thus, one trait appeared to counterbalance the other when combined in the efficiency ratio. Onks et al. (1975) reported a similar effect of initial weight of individually-fed Angus cows. However, Sawyer et al. (1963) found that calves from heavier cows tended to gain more rapidly, consume more feed and convert this feed more efficiently. Kress et al. (1969), Klosterman and Parker (1974) and Dinkel and Brown (1978) indicated a trend for lighter cows to be more efficient, but only

Kress and coworkers found the relationship to be statistically significant. Marshall _et al_. (1976) indicated that increased cow condition negatively affected weaning weight and efficiency. More highly conditioned cows tended to produce lighter calves at weaning and to be less efficient when cow weight and milk production were constant. Kress _et al_. (1969) also found cows with higher weight-wither height ratios to be less efficient and McCurley and McLaren (1981) also found fatter cows to produce lighter calves at weaning.

Melton _et al_. (1967) found that milk production increased with size in data from Charolais cows. Klosterman and Parker (1974) and Cartweight (1979) also noted an increase in milk production with an increase in cow body weight. Milk production has also been reported to increase with cow age (Drewry _et al_., 1959; Dawson _et al_., 1960; Williams _et al_., 1979). Robison _et al_. (1978) studied Hereford cattle and reported that total milk production increased until five years of age with little difference from five to eight years of age. Neville _et al_. (1974) reported a similar trend in daily milk productions of Hereford cows.

Several reports indicate a positive relationship between milk production and calf gain to weaning. Wistrand and Riggs (1966), observing Santa Gertrudis cows and calves, reported that a one kg increase in daily milk production resulted in a 70 gm increase in daily calf gain. This agrees with the positive correlation of 0.40 between total calf gain and total milk production reported by Melton _et al_. (1967) while observing Angus, Charolais and Hereford cows and calves. Marshall _et al_. (1976) reported that milk production had highly significant positive effects on weaning weight and efficiency.

This agrees with Robison et al. (1978) who reported correlations of weaning weight and milk production ranging from 0.44 to 0.63. The trend for greater efficiency in higher milk producing cows agrees with results of Kress et al. (1969). However, Holloway et al. (1975) using dam breeds of widely varying milking ability (Hereford, Holstein and Hereford x Holstein) reported no significant breed group variation in weaning efficiency.

Nelson and Kress (1979), observing Angus and Hereford calves, reported that weaning weight was genetically correlated with post-weaning average daily gain (ADG) and final weight .10 and .73, respectively. This agrees with Christian et al. (1965) who reported positive standard partial regressions of weaning weight on ADG from 365 days was 0.05. This author suggested that good preweaning environment handicapped early postweaning gains but enhanced later gain. The contrast of genetic versus phenotypic correlations between ADG pre-weaning and postweaning (bulls, 0.14 versus 0.15 and heifers, 0.47 versus 0.07) suggests a negative environmental correlation between pre- and postweaning ADG in heifers and a positive correlation in bulls. Dinkel and Busch (1973) reported that weaning weight was highly positively correlated with postweaning ADG and feed efficiency. In contrast, Christian et al. (1965) and Kress (1977) reported that heavier weaning calves were slightly less efficient postweaning.

Final weight has been shown to be positively correlated with postweaning ADG and feed efficiency (Dinkel and Busch, 1973 and Kress, 1977). Koch et al. (1963) reported that the genetic correlation between feed efficiency and gain was 0.79, between feed consumption and gain was 0.64 and between feed efficiency and feed consumption was 0.04. These results indicate that selecting for gain should be effective and lead to both increased feed efficiency and increased feed consumption. This work also indicates that 38% of the variation in gain could be attributed directly to genetic differences in feed efficiency and genetic differences in feed consumption accounted for 25% of the variation in gain. Fitzhugh and Cartwright (1971) reported a small phenotypic correlation for weight gain and weekly feed consumption of 0.24. They noted that when small differences in feed consumption did occur, they apparently contributed to small differences in gain. In studies from which TDN efficiency had been calculated during the postweaning phase of performance testing, Fitzhugh et al., (1967) and Joandet and Cartwright (1969) indicated that ADG was correlated negatively with feed per unit of weight gain. These studies were on a weight- or age-constant basis. According to Cundiff et al. (1971) selection of cattle based on weight per day of age calculated on a time-constant basis results in favoring cattle which reach physiological maturity at a younger age. Average daily feedlot gain was shown to increase with increasing time on feed to a high of 0.193 kg at 180 days for Hereford steers and heifers (Zinn et al., 1970). This supports the work of Smith et al. (1976) who reported that days on feed accounted for 88% of the variation in feed efficiency in weight-constant intervals.

Harrison et al. (1978) indicated that increased length of feeding period tended to increase carcass weight and marbling score. This trend for marbling score to increase with increased days on feed was also indicated by Zinn et al. (1970). In a study involving Angus, Hereford, Charolais-cross and Hereford x Angus calves, Butts et al. (1980) also indicated that increased days on feed accompanied larger carcass weight. However, the primary observation of this study was that increased wither height and decreased initial fat was associated with increased days on feed and increased carcass weight.

II. Effects of Heterosis on Cattle Traits

Several studies have indicated that preweaning ADG and weaning weight of crossbred calves were superior to straightbred calves (Gaines et al., 1966; Brinks et al., 1967; Long and Gregory, 1974; Gray et al., 1978; Gregory et al., 1978a). Cundiff (1970) reported an average estimate of 4.9% heterosis for weaning weight. Long (1980) reported average heterosis estimates of 4.0 and 5.0 percent for preweaning ADG and weaning weight, respectively. Brinks et al. (1967), working with linecross Hereford cattle, indicated that heifers exhibited 5.1 and 4.3 percent more heterosis than bulls in preweaning ADG and weaning weight, respectively.

According to Long (1980), estimates of heterosis for postweaning average daily gain across studies with varying sexes and management have ranged from 2 to 11 percent with a mean of 6 percent. Long and Gregory (1975) reported a heterosis estimate of 5.7 percent for postweaning gain and indicated that heterosis effects were higher on calves with a faster rate of gain, on calves measured at younger ages or both. Olson et al. (1978) indicated that crossbred steers grew 2.8 percent more rapidly throughout a 224-day test and had 2.9 percent heavier average weights; thus, higher average maintenance requirements on a time-constant basis, resulting in 0.8 percent less TDN per kg of gain than straightbred steers. However, on a weight-constant basis crossbred steers required less TDN per kg of gain (-1.6 percent) than did straightbred steers. Crossbreds tended to gain more rapidly than straightbreds through the weight-constant feeding period, but slowed in growth relative to their weight and to straightbreds until efficiency fell below that of straightbreds during last intervals. This supports Gregory et al. (1978b) who reported that crossbreds gained 14.5 grams less per day than straightbreds during 312 to 424 days postweaning. Smith et al. (1976), observing Angus, Hereford and reciprocal cross calves, reported the heterosis for relative gain in crossbred steers was negative; that is, the crossbred calves had a lower growth rate than either straightbred group.

Reports of units feed required per unit gain of individuals have varied with respect to interval (age-, weight- or fat-constant), measure of intake (feed weight, TDN or other measure), management of cattle and other factors (Gregory et al., 1966b; Vogt et al., 1967; Klosterman et al., 1968; Fredeen et al., 1972; Smith et al., 1976c; Ellersieck et al., 1977; Olson et al., 1978a,c). In a study involving two management systems of Angus, Hereford and reciprocal cross, (management 1--steers grazed on grasses and legumes about 170 days and then placed on full feed for 140 days; management 2--steers placed on full feed directly after weaning for 196 days) Ellersieck et al. (1977) reported heterosis of 8.0 and 5.3 percent for feed efficiency of management systems 1 and 2, respectively. Gregory et al. (1966b) reported that heterosis effects on average daily TDN consumption for 252-day postweaning feeding period were important (P<.01). However, when adjusted for the effects of midweight, the difference was small, indicating that increased TDN consumption of the crossbreds were largely the result of heavier weights. This is further revealed by the small difference (-.04 kg) between the crossbreds and straightbreds in TDN per unit of gain in the 252-day feeding period. Estimating feed efficiency as units of TDN consumed per unit of gain, Vogt et al. (1967) reported feed efficiencies of 5.91 and 5.70 for straightbred and crossbred heifers, respectively. However, this same study reported values of 7.94 and 8.09 units of TDN consumed per unit of gain for straightbred and crossbred steers, respectively.

Smith et al. (1976) reported that Hereford-Angus heterosis for efficiency of feed utilization was -2.8, 3.8 and 0.9 percent for age-, weight- and fat-constant intervals, respectively. However, none of these were significant. In the weight-constant interval, total feed requirements for maintenance were reduced for more rapidly gaining groups by a substantial reduction in days on feed. In the age-constant interval, more rapidly gaining groups were more efficient, but the advantage was tempered by a greater maintenance requirement associated with larger size throughout the time-constant period. Hence, weight-constant evaluation maximizes the advantage associated with maturity.

Cundiff (1970) stated that heterosis effects were found to be large for carcass traits associated with growth but small for most other carcass characters. This trend has been substantiated in several reports by the disappearance of heterotic effects when data were adjusted for carcass weight (Gregory et al., 1966c; Urick et al., 1974; Long and Gregory, 1975). Interactions for breed of sire by breed of dam were not significant for carcass traits as reported by Chapman et al. (1971).

Gaines et al. (1967) reported that the carcass weight of reciprocal cross Angus and Hereford steers and heifers were 13.8 and 10.5 kgs heavier than straightbred Angus and Herefords. In agreement, Gregory et al. (1966c) and Hedrick et al. (1970) reported a 13.2 and 20.8 kg advantage in carcass weight of the crossbreds, respectively. Urick et al. (1974) reported a 3.7 percent advantage in carcass weight per day of age for crossbreds.

Several studies have generally reported crossbreds to be superior in carcass rib-eye area to straightbreds (Gregory et al., 1966c; Gaines et al., 1967; Hedrick et al., 1970; Long and Gregory, 1975).

Lasley et al. (1971) reported that crossbred calves, on the whole, were not superior in carcass quality characteristics to their straightbred counterparts. Gregory et al. (1966) also reported a nonsignificant heterotic effect for slaughter grade.

Hedrick et al. (1970) reported that crossbreds were superior to straightbreds by 7 to 9 percent with respect to rib-eye area, retail cuts and carcass weight in the case of short-fed (181-198 days) heifers. However, none of these traits exhibited heterosis in the case of longfed (251-268 days) heifers which led the author to suggest that with increased age or increased length of time on feed the influence of heterosis on carcass growth traits decreases.

III. Heritabilities of Cattle Traits

Koch et al. (1973) reported heritabilities of .44, .17 and .20 for birth weight, average daily gain to weaning and weaning weight, respectively. Estimating by the paternal half-sib method, Swiger (1961) reported similar heritabilities of .22 and .25 for birth and weaning weight, respectively. In his study, an interaction of sex and age of calf was found to be important in weaning weight suggesting that males and females differ in their rate of maturing. Dinkel and Busch (1973) and Nelson and Kress (1979) reported larger heritability estimates of .40 and .35 for weaning weight; however, these estimates are based on weights taken on the producers ranches or Angus field records, respectively.

Heritability estimates for final weight have ranged from .36 to .85 (Dinkel and Busch, 1973; Koch et al., 1973; Nelson and Kress, 1979). The paternal half-sib method of estimating heritability has produced estimates of mature beef cow weight ranging from .52 to .96 (Brinks et al., 1962; Fitzhugh, 1965). Taylor and Fitzhugh (1971) reported that heritability of 0.37 for time taken to mature was only slightly reduced to 0.35 when mature weight was held constant. Moreover, only 22 percent of the genetic variation in mean time taken to mature was associated with mature weight.

Taylor and Young (1968) estimated that heritability of maintenance to be .89, and suggested that a large additive genetic variance was associated with the efficiency of energy utilization. In 1963, Koch et al. estimated heritability of postweaning feed efficiency calculated in three different ways. The most accurate method was derived by regressing weight gain on feed consumption and produced a heritability of 0.62. The other methods, regressing feed consumption on weight and the standard ratio of gain to feed consumed, produced heritability estimates of 0.28 and 0.36, respectively.

Reports of heritability of most carcass traits have ranged from low to high (Cundiff et al., 1964; Brackelsberg et al., 1971; Cundiff et al.; 1971, Dinkel and Busch, 1973). Estimates of heritability reported of rib-eye area by Brackelsberg et al. (1971) and Dinkel and Busch (1973) were .40 and .25, respectively. These estimates are characteristic of values reported in the literature and suggest that some genetic variation exists for improving this trait.

Estimates of heritability of fat thickness have ranged from 24 percent reported by Shelby et al. (1963) to several estimates in the forties and fifties reported by Cundiff et al. (1964), Brackelsberg et al. (1971), Cundiff et al. (1971), and Dinkel and Busch (1973). Estimates of heritability of carcass grade and marbling have varied considerably, ranging from 16 to 74 percent and 17 to 73 percent, respectively (Shelby et al., 1963; Brackelsberg et al., 1971; Cundiff et al., 1971; Dinkel and Busch, 1973).

IV. Comparison of Angus with Hereford and Angus X Hereford with Hereford X Angus Cattle

Straightbred Angus calves have generally been shown to gain faster to weaning and have heavier weights at weaning than straightbred Hereford calves even though the Hereford calves were heavier at birth (Gregory et al., 1978; Gaines et al., 1966; Long and Gregory, 1974;

Gray et al., 1978). This difference was small at weaning, 1.4 and 4.5 kgs according to Gregory et al. (1965) and Gray et al. (1978), respectively. However, Gaines et al. (1966) and Long and Gregory (1974) reported differences in weaning weight of 27 lbs. and 18.9 kg, respectively, favoring Angus calves. Studies comparing Hereford x Angus calves with Angus x Hereford calves (breed of sire listed first) have indicated superiority of the Hereford x Angus in preweaning average daily gain and weaning weight (Gaines et al., 1966; Long and Gregory, 1974; Gregory et al., 1978). These results support the findings of Melton et al. (1967) and Cundiff et al. (1974) who reported that Angus cows produce more milk and provide a superior maternal preweaning environment than do Hereford cows. Contrary to this, Gray et al. (1978) reported weaning weights of 185.3 and 184.7 kgs for Angus x Hereford and Hereford x Angus calves, respectively. This data was collected under commercial conditions and not from experiment station cattle. In support of this work, Vanmiddlesworth et al. (1977) reported repeatabilities of .35 and .25 for weaning weight of the Hereford and Angus breeds, respectively. He suggests that the weaning records of a Hereford cow's early calves are more accurate indicators of her future productivity than those of Angus cows.

Long and Gregory (1975) reported 452-day weights and final weights of straightbred Angus and Hereford steers of 392 and 388 kgs and 468 and 472 kgs, respectively. The straightbred Hereford steers gained faster postweaning than did the straightbred Angus steers (difference=30 grams/day). This supports the work of Brown et al. (1972) who reported that later maturing animals eventually overtake the early maturing animals at some point prior to maturity. Long and Gregory (1975) and Gregory et al. (1978) showed superior gains of Angus x Hereford steers postweaning of 35 and 15 grams per day compared to Hereford x Angus steers, respectively. Long and Gregory (1975) suggested that superior gains enables the Angus x Hereford steers to weigh heavier at 452-day weights and adjusted final weights. However, in Gregory et al. (1978) the postweaning gain advantage of Angus x Hereford steers was not enough to overtake the advantage of the Hereford x Angus steers preweaning.

Ellersieck et al. (1977) reported feed efficiencies adjusted to 340 kg weight of straightbred Angus and Hereford and Hereford x Angus and Angus x Hereford steers for two individual postweaning management systems. In management system 1, steers were grazed about 170 days after weaning and then placed in the feedlot for 140 days; feed efficiencies were 8.90, 7.41, 7.99, and 7.01, respectively. In management system 2, steers were placed directly in the feedlot for 196 days after weaning; feed efficiencies were 7.52, 7.85, 7.26, and 7.29, respectively. Olson et al. (1978) reported postweaning time-constant feed efficiencies of straightbred Angus and Hereford and Hereford x Angus and Angus x Hereford steers of 5.80, 5.16, 5.64, and 5.26 kgs of TDN per kg of gain, respectively. These same breed groups consumed 1074, 1060, 1124, and 1074 kgs of TDN on a time-constant postweaning period basis. On a weight-constant basis, kgs of TDN per kg of gain were 5.84, 5.17, 5.55, and 5.32 for straightbred Angus and Hereford and Hereford x Angus and Angus x Hereford steers, respectively.

Gregory et al. (1978) reports that straightbred Angus steers on an age-constant basis produced heavier carcass weights (4.2 kg), higher quality grades (1.8 units) and larger rib-eye areas (3.4 cm^2) than did straightbred Herefords. This study also indicates that Angus x Hereford steers produced 2.2 kgs heavier carcass weights, 0.2 units higher quality grades and 1.8 cm^2 more rib-eye area than did Hereford x Angus steers. Long and Gregory (1975) reporting on steers placed directly in feedlot after weaning, indicated that straightbred Angus steers had higher marbling scores (0.5 units) and larger rib-eye areas (3.3 cm^2) than did straightbred Herefords at slaughter. Hereford x Angus steers also had higher marbling scores (0.9 units) and larger rib-eye areas (2.0 cm^2) than Angus x Hereford steers at slaughter.

V. Growth, Composition and Degree of Maturing of Cattle

A study by Brinks _et al._ (1962) showed that within breed correlations indicated that measures of growth in the early stages of life were positively associated with measures of lean and bone and negatively associated with measures of fat in the carcass. This is in agreement with Berg and Butterfield (1976) who found that maximum bone growth precedes that of muscle, and muscle growth precedes that of fat.

Joubert (1956) indicated that the deposition of various tissues are different but from the standpoint of the quantitative measurement of animal growth as a whole, each tissue deposition must be considered as part of the growth process. Berg and Butterfield (1976) indicated that muscles like the semitendinosus (eye of the round) and _psoas major_ (fillet) develop and complete growth earlier than other muscles.

Levan et al. (1979) indicated that although significant breed differences (Angus and Charolais steers) were noted for fat and bone content, differences in growth rate and retail lean were relatively minor when cattle were slaughtered at similar percentages of the corresponding breed average mature weight.

Zinn et al. (1970) reported that muscle and bone of steers and heifers developed at about the same proportional rate during the first 150 days of a 270-day feed trial. However, bone growth declined the last 90 days of the trial.

Cornforth et al. (1980) reported that at a constant body weight, larger heifers and steers had smaller muscle fibers and less intramuscular fat cell development than smaller framed heifers and steers, respectively.

Brown et al. (1972a) reported that Angus females had attained 53 percent of their mature weight at 12 months of age while Herefords had attained 45 percent. Angus females reached 95 percent of their maturity a year before Hereford females reached the same point. These workers also indicated that the weight of a beef animal cannot be properly evaluated in terms of projected weight or rate of maturing unless approximate physiological age is known. This was further reinforced by the fact that heavier yearling weights were associated with heavier mature weight in Herefords, while yearling weight had little relationship to mature weight in Angus. Brown et al. (1972b) indicated that Hereford females were heavier than Angus females at 40 months of age, but the opposite was true at ages prior to 40 months. Angus females exhibited growth up to 71 months of age, while

Hereford females showed growth until 85 months of age, indicating a definite earlier rate of maturity for Angus females.

CHAPTER III

EFFICIENCY OF ANGUS AND HEREFORD COWS RAISING STRAIGHTBRED AND RECIPROCAL CROSS CALVES AS AFFECTED BY COW AND CALF TRAITS AT WEANING

I. Summary

Mature Angus and Hereford cows raising straightbred and reciprocal cross calves were individually fed during their lactations over 4 years. A total of 92 lactations was observed.

Cows were offered, ad libitum, a diet of grass silage. Alfalfa pellets were added as a percentage of forage consumed, to increase the energy density of the diet to a level estimated to be sufficient to maintain cow condition equivalent to that of comparable cows on pasture. Calves were allowed access to alfalfa pellets from approximately 80 days of age until weaning. Cows and calves were weighed monthly for the first 2 years and biweekly during the remaining 2 years. Milk production was determined by the weigh-suckle-weigh method after 12-hour separation.

Cow TDN was defined as the 12-month feed consumption of the cow derived from the sum of the measured consumption during the lactation period plus an estimate of her intake throughout the remaining period. Calf TDN was calculated as the intake TDN from the creep-fed alfalfa pellets. Unit TDN was the sum of cow TDN and calf TDN. Cow-calf unit weaning efficiency was calculated as the ratio of the unit TDN to actual unadjusted calf weaning weight.

The basis models for analyses of these data included effects of year and calf breed. Year influenced all dependent variables ($P<.001$). Cow TDN increased ($P<.001$) as calf weaning weight increased. Hereford cow units consumed slightly more TDN ($P<.10$) than did Angus cow units. Calf weaning weight, adjusted for calf weaning age, was positively correlated ($P<.001$) with milk production. Angus cow units were more efficient than were Hereford cow units ($P<.001$), but the effect was reduced when the covariates, milk production and calf weaning weight, were added to the basic model. Crossbred calves were heavier ($P<.10$) at weaning than straightbreds, but because of their greater calf TDN intake, they could not be declared more ($P<.10$) efficient. Calf weaning weight accounted for 50.5% of the variation in cow-calf unit weaning efficiency.

Introduction

Many researchers have shown that crossbred calves gain more rapidly to weaning and produce heavier weaning weights than straightbred calves (Brinks et al., 1967; Gregory et al., 1978; Pahnish et al., 1969). Several studies have examined feed efficiency of the cow-calf unit or the cow-calf production system (Joandet and Cartwright, 1967; Klosterman et al., 1968; Long et al., 1975; Marshall et al., 1976). These investigators employed either direct measurement of feed intake and performance through feeding at the level of accepted nutritional requirements or utilized modeling techniques which were based on parameters estimated from accumulated data. Overall nutritional efficiency was generally indicated to be related to a complex set of variables associated with characteristics of the cow, the calf and the production regime.

In general, previous studies of weaning efficiency have been conducted by feeding cows according to their estimated nutritive requirements. However, such a nutritional environment is not typical of that provided cows in normal pasture situations. To the contrary, grazing cattle are normally presented with a certain quality of forage and the degree to which they are able to meet their requirements is dependent upon their ability to consume and utilize the forage. Cows in the study reported here were allowed to select their intake level from unrestricted amounts of feed, making the regime more nearly equivalent to that of cows on pasture. The purpose of this study was to compare, under unrestricted feeding levels, the nutritional efficiency at weaning of mature Angus and Hereford cows (fed grass silage _ad libitum_) raising straightbred and crossbred calves, and secondly, to determine measureable cow-calf characteristics that may be indicative of nutritional weaning efficiency.

Materials and Methods

Source of data. Data from 92 lactations of mature Angus and Hereford cows (4 to 13 years of age) raising straightbred and reciprocal cross calves were obtained over a four-year period. Cows were assembled from three herds of The University of Tennessee Agricultural Experiment Station and were assumed to be representative of the variation in size and maternal ability present in these herds. Angus and Hereford sires were considered to be representative of bulls used in the university herds.

Cows were calved on pasture. At the end of the calving season, each spring, twenty-four cows with male calves were selected and randomly assigned to individual feeding pens when the calves were about 6 weeks of age. Pens were designed such that the calf had access to an individual creep feeder and to the cow's feed. Cows and calves were kept in the pens during the day and in dirt exercise lots at night. Six Hereford and six Angus cows with their respective straightbred or crossbred calves were assigned to each lot. Calves were castrated about 3 weeks after cows and calves were placed in individual pens. Cows remained in the individual feeding pens until weaning of the calves. Data from four cow-calf units were deleted from the study due to death or serious illness of an animal. Calves were weaned about the same time each year at an average age of 242 days.

Cows were offered, ad libitum, diets of grass silage. The silage consisted of grass-legume mixtures. Orchardgrass (Dactylis glomerata L.), red clover (Trifolium pratense L.) and timothy (Phleum pratense L.) were the component forages of the silage and were available in varying percentages over the four-year period. The silages were quite homogeneous within year being harvested from one meadow at one time, but specie composition and maturity varied from year to year due to varying weather conditions. The basic silage diet was fortified with energy by adding alfalfa pellets (alfalfa, aerial pt, dehy grnd, pelleted, mn 17 prot, IRN 1-00-023) as a percentage of forage consumed, to a level estimated to be sufficient to maintain cow condition equivalent to that of comparable cows on pasture. Calves were allowed access to the alfalfa pellets as a creep from approximately 80 days of age until weaning.

Total digestible nutrient (TDN) content of the forages fed were calculated from NRC (1976). Hence, TDN units presented are considered to be relative and not absolute values. Representative feed samples collected periodically were evaluated by in vitro dry matter digestion trials (Tilley and Terry, 1963). TDN values derived from these trials were similar to the calculated NRC estimates.

Data collection. Cows were weighed, and fat thickness estimated (ultrasonic, between 12th and 13th rib) were taken monthly for the first 2 years and biweekly during the remaining 2 years of the study.

Daily TDN consumptions were summed over the test period (about 200 days) and averaged for each cow-calf pair. This average consumption was multiplied by age of calf to estimate the TDN consumed from birth of the calf to initiation of the trial. Consumption of the cow from weaning of her previous calf to birth of the calf on test was estimated by assuming that she was fed during the winter at a level to meet NRC requirements (1976) for maintenance during the third trimester of pregnancy. Estimates of TDN consumption during the third trimester of pregnancy were adjusted for cow weight changes (Knott et al., 1934).

Cow TDN was a 12-month estimate of yearly TDN derived as the sum of the measured consumption during lactation plus an estimate of her intake for the remainder of the year based on production requirements. Calf TDN was calculated as the feed intake from creep feeding alfalfa pellets. Unit TDN was the sum of cow TDN and calf TDN. Cow-calf unit weaning efficiency was calculated as the ratio of unit TDN to actual unadjusted calf weaning weight.

Milk production estimates were determined monthly for the first 2 years and biweekly during the remaining 2 years by the weigh-suckle-weigh method following 12 hour separation. Twelve-hour estimates were adjusted to 24-hour milk production estimates (Neville et al., 1974). Daily milk yields were regressed on number of days in lactation and the function integrated to estimate production for each cow. Milk production between calving and initiation of the trial was estimated from calf gain (NRC, 1976). These two estimates were then summed for total milk production. Average milk production was calculated as the ratio of total milk production to number of days in lactation.

Initial cow weight was taken when the cows were alloted for the test initiation in the spring. Initial cow weight was adjusted to remove variation due to differences between station herds of origin and variation due to differences in calf age.

Analyses of data. The basic models for analyses of these data included effects of year and calf breed. Calf breed, with 3 degrees of freedom, was partitioned into orthogonal contrasts comparing (1) straightbred and crossbred calves, (2) breeds of sire, and (3) breeds of cow. Additional independent variables included in the model were initial cow weight, calf weaning age, average milk production and unadjusted calf weaning weight. In view of the relatively small numbers of records available, differences between reciprocal crosses were not partitioned.

Results and Discussion

Means and standard deviations of cow and calf variables are shown in Table 1 to provide a general description of the data. Crossbred calves consumed more TDN than straightbred calves, were heavier at weaning and tended to be more efficient. Hereford cows were heavier at the initiation of the trial but produced less milk per day than did Angus cows. Calves of Angus cows were heavier at weaning and the Angus cow-calf units were more efficient than Hereford cow-calf units.

Least-squares means calculated from a model containing effects of year, calf breed and regression of the dependent variable on calf weaning age are shown in Table 2. These means reflect the orthogonal partitioning of the variation associated with the 3 degrees of freedom for calf breed into contrasts of breeds of sire, breeds of cow and crossbred versus straightbred calf. The effect of breed of sire on all dependent variables was negligible ($P<.10$) and was not tabled. Crossbred calves were heavier ($P<.10$) (206 versus 199 kg) at weaning. This indicated level of heterosis (3.8 percent) was within the range of estimates reported by Cundiff et al. (1974b), Gaines et al. (1966) and Kincaid (1962) from studies of crosses among British breeds. Crossbred calves could not be declared different from straightbreds ($P<.10$), with respect to milk intake or cow-calf unit weaning efficiency, although slight differences in absolute values of the estimates in favor of the crossbreds were noted. Angus cows weighed less (433 versus 488 kg), produced more milk (7.2 versus 6.1 kg) and weaned heavier calves (210 versus 195 kg) than did Hereford cows.

Table 1. Means and Standard Deviations of Cow and Calf Traits by Calf Breed

Trait	Hereford[b] x Hereford		Angus x Angus		Hereford x Angus		Angus x Hereford	
N	23		23		24		22	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Annual cow TDN (kg)	2058	204	2041	142	2053	155	2112	166
Calf TDN (kg)	71	25	77	25	80	18	87	17
Unit TDN (kg)[c]	2128	215	2117	135	2133	162	2199	114
Initial cow weight (kg)[d]	492	26	434	29	452	32	489	28
Calf weaning age (days)	236	21	244	16	242	16	245	12
Milk production (kg)[e]	6.21	1.14	6.97	1.41	7.36	1.47	6.08	1.14
Calf weaning weight (kg)	189	34	207	27	216	31	201	21
Cow-calf unit weaning efficiency (kg/kg)[f]	11.67	1.97	10.39	1.27	10.06	1.41	11.08	1.15

[a]Means and standard deviations are adjusted for year differences.

[b]Sire breed x cow breed.

[c]Yearly TDN consumption of cow plus TDN consumption of the calf to weaning.

[d]Adjusted for differences in year, farm of origin and calf age.

[e]Average daily milk production.

[f]Ratio of Unit TDN to calf weaning weight.

Table 2. Least-Squares Means and Standard Errors, Comparing Straightbred Versus Crossbred Calves and Calves Nursing Hereford Versus Calves Nursing Angus Cows

Breed	Cow-calf unit weaning efficiency[b]	Calf weaning weight	Milk production[c]	Initial cow weight[d]
Straightbreds	10.99 ± .27	199 ± 4 †	6.56 ± .23	462 ± 4 *
Crossbreds	10.67 ± .27	206 ± 4	6.68 ± .23	470 ± 4
Hereford cows	11.38 ± .27 ***	195 ± 4 ***	6.09 ± .23 ***	488 ± 4 ***
Angus cows	10.28 ± .26	210 ± 4	7.15 ± .27	433 ± 4

[a] $\hat{Y}$ = Year + calf breed + calf age.

[b] Ratio of Unit TDN to calf weaning weight.

[c] Average daily milk production.

[d] Initial cow weight adjusted for differences in year, farm of origin and calf age.

† $P<.10$.

* $P<.05$.

*** $P<.001$.

Angus cow units were more efficient (10.3 versus 11.4 kg TDN/kg calf weight) in producing weaning weight than were Hereford cow units. Cundiff (1970), Gaines et al. (1966) and Pahnish et al. (1969) also reported that calves of Angus cows were similarly heavier at weaning than were calves of Hereford cows. The superiority of Angus cows over Hereford cows in milk production (18 percent) in the present study was similar to that (15 percent) reported by Melton et al. (1967). These results suggest that the larger Hereford cows used relatively more feed for maintenance than did the smaller Angus cows. Angus cows provided a more favorable maternal environment for preweaning growth than did Hereford cows.

Results from the addition of certain cow and calf variables, as covariates, to the basic model containing effects of year and calf breed in analyses of cow-calf unit weaning efficiency and components of weaning efficiency are shown in Tables 3 through 7. Year effects were important (P<.001) in all analyses of dependent variables. Year differences were assumed to include differences in samples of animals, feed and, probably, subtle changes in feeding technique over time. Interpretation of year differences was not attempted.

Models presented in Table 3 indicate that the major effect (P<.001) on cow annual TDN consumption was calf weaning weight. Milk production and initial cow weight tended to be positively correlated with cow annual TDN consumption, but the correlation was small (P<.10). Onks et al. (1975) and Marshall et al. (1976) reported similar correlations between cow weight and cow TDN consumption. Without calf weaning weight in the model, calf age was positively correlated (P<.05)

Table 3. Partial Regression Coefficients from Regression Models for Cow Annual TDN Consumption

Error df	Calf breed	Initial cow weight[b]	Calf weaning age	Milk production[c]	Calf weaning weight	R^{2d}
84	NS	.3511				2.1
84	NS		1.8852*			5.1
84	NS			12.3532		2.7
84	NS				1.9878***	10.2
83	NS	1.1230	2.4380*			6.7
83	NS	.6802			2.0656***	10.9
83	NS		.5417		1.8162**	10.4
82	NS	.9770	1.0944		1.7528**	11.6

[a] Yearly TDN consumption of the cow (including cow diet consumed by the calf).

[b] Initial cow weight adjusted for differences in year, farm of origin and calf age.

[c] Average daily milk production.

[d] All models contained a year effect accounting for 25.5% of the variation ($P<.001$) in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

NS $P>.10$.

* $P<.05$.

** $P<.01$.

*** $P<.001$.

Table 4. Partial Regression Coefficients from Regression Models for Calf TDN Consumption

Error df	Calf breed	Initial cow weight[b]	Calf weaning age	Milk production[c]	Calf weaning weight	R^{2}[d]
84	NS	-.0438				1.2
84	NS		.4162**			2.9
84	NS			2.1075		1.4
84	NS				.3348***	3.8
83	NS		.4163**	2.1117		3.1
83	NS		.2258		.2633**	4.1
83	NS			-2.3000	.3919***	4.0
82	NS		.1946	-1.3354	.3063*	4.2

[a]TDN consumed by the calf to weaning (not including cow diet consumed by calf).

[b]Initial cow weight adjusted for differences in year, farm of origin and calf age.

[c]Average daily milk production.

[d]All models contained a year effect, accounting for 79.5% of the variation (P<.001) in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

[NS]P>.10.

*P<.05.

**P<.01.

***P<.001.

Table 5. Partial Regression Coefficients from Regression Models for Unit TDN Consumption

Error df	Calf breed	Initial cow weight[b]	Calf weaning age	Milk production[c]	Calf weaning weight	R^{2}[d]
85	NS					2.2
84	NS	.3073				2.4
84	NS		2.2715*			6.2
84	NS			14.4608		3.1
84	†				2.3226***	11.7
83	NS	1.2286	2.9088**			7.8
83	NS	.6900			2.4015***	12.3
83	†		.7675		2.0795**	12.1
82	NS	1.0608	1.3676		2.0107**	13.1

[a]Yearly TDN consumption of the cow plus the TDN consumption of the calf to weaning.

[b]Initial cow weight adjusted for differences in year, farm of origin and calf age.

[c]Average daily milk production.

[d]All models contained a year effect, accounting for 33.3% of the variation ($P<.001$) in the dependent variable. R2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

NS $P>.10$.

† $P<.10$.

* $P<.05$.

** $P<.01$.

*** $P<.001$.

Table 6. Partial Regression Coefficients from Regression Models for Calf Weaning Weight

Error df	Calf breed	Initial cow weight[a]	Calf weaning age	Milk production[b]	R^{2}[c]
85	***				10.2
84	*	-.1593			11.1
84	**		.7232***		21.5
84	†			11.2368***	24.0
83	NS		.7238***	11.2539***	35.3
82	NS	.0553	.7525***	11.2163***	35.4

[a]Initial cow weight adjusted for differences in year, farm of origin and calf age.

[b]Average daily milk production.

[c]All models contained a year effect, accounting for 40.5% of variation ($P<.001$) in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

NS $P>.10$.

† $P<.10$.

* $P<.05$.

** $P<.01$.

*** $P<.001$.

Table 7. Partial Regression Coefficients from Regression Models for Cow-Calf Unit Weaning Efficiency

Error df	Calf breed	Initial cow weight[b]	Calf weaning age	Milk production[c]	Calf weaning weight	R^{2d}
85	***					12.9
84	†	.0086				13.7
84	***		-.0360***			21.8
84	†			-.6172***		26.1
84	NS				-.0490***	50.5
83	NS		-.0360***	-.6175***		35.0
83	NS		-.0007		-.0488***	50.5
83	NS			-.0910	-.0468***	50.8
82	NS		-.0032	-.1067	-.0454***	50.8

[a]Ratio of Unit TDN to calf weaning weight.

[b]Initial cow weight adjusted for differences in year, farm of origin and calf age.

[c]Average daily milk production.

[d]All models contained a year effect which accounted for 31.5% of the variation ($P<.001$) in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

[NS]$P>.10$.

[†]$P<.10$.

[***]$P<.001$.

with cow annual TDN consumption. This indicates that a major portion of the relationship between calf weaning weight and cow TDN consumption was due to length of lactation and direct consumption of cow diet by the calf and not to cow traits jointly affecting calf weaning weight and cow TDN consumption.

Calf TDN consumption (Table 4) was associated primarily with undefined differences among years. Calf weaning age and weight were associated ($P<.01$ and $P<.001$, respectively) with calf TDN consumption, but the correlation was small, accounting for only 4 percent of the variation in consumption. Small positive correlations ($P<.10$) between milk production and calf TDN consumption were noted. With calf weaning weight in the model, small negative correlations ($P<.10$) between milk production and calf TDN consumption were observed.

Results of analyses of unit TDN consumption (Table 5) differed from those of analyses of cow annual TDN and calf TDN consumption only in that slight differences ($P<.10$) between Hereford and Angus cow units were apparent in models containing regression on calf weight at weaning. Hereford cow units consumed slightly more TDN than did Angus cow units.

Calf weaning weight, adjusted for differences in calf age, was correlated positively ($P<.001$) with milk production (Table 6). Comparison of models presented in Table 6 suggests that the difference in weaning weights of calves of Hereford and Angus cows (Table 2, page 26) is attributable largely to breed differences in milk production. Marshall et al. (1976), Neville (1962) and Reynolds et al. (1978) found similar relationships between calf weaning weight and milk production. In Table 6, the small positive correlation ($P<.10$) between calf weaning weight and initial cow weight (partial b = .055) is within the range of estimates obtained from other studies. Neville (1962) and Urick et al. (1971) reported comparable values of .07 and .013, respectively, for regression of progeny weaning weight on cow weight.

Partial regression coefficients from models relating cow and calf variables to cow-calf unit weaning efficiency are shown in Table 7. Differences in calf breed were observed since Angus cow-calf units had lower efficiencies ($P<.001$) than did Hereford cow-calf units. When calf weaning weight or a combination of calf age and milk production were included in the model, the effects of calf breed were reduced ($P>.10$). Cow-calf units with older calves were more efficient ($P<.001$) than were cow-calf units with younger calves. Cow-calf unit weaning efficiency improved ($P<.001$) as milk production increased. This trend for greater efficiency in higher milk producing cows agrees with results of Kress et al. (1969) and Marshall et al. (1976). Differences in calf age and milk production, with calf breed in the model, accounted for 21.8 percent and 26.1 percent, respectively, of the variation in cow-calf unit weaning efficiency. However, with calf weaning weight in the model, milk production and calf age were less important sources of variation. Variation in calf weaning weight accounted for 50.5 percent of the variation in cow-calf unit weaning efficiency. This value is very similar to the 62 percent reported by Marshall et al. (1976) if allowance is made for the difference in feeding methods in the two studies. In the present study, animals were offered the diet *ad libitum*, whereas, in the Marshall study, animals were fed to meet estimated nutritive requirements.

CHAPTER IV

TDN EFFICIENCY OF ANGUS AND HEREFORD COWS RAISING STRAIGHTBRED AND RECIPROCAL CROSS CALVES AS AFFECTED BY COW AND CALF TRAITS AT THE MOST EFFICIENT POINT AND AT 12 MM FAT THICKNESS

I. Summary

Mature Angus and Hereford cows raising straightbred and reciprocal cross calves were individually fed during their lactations over 3 years. A total of 66 growth periods were observed. Calves were individually fed a complete growing and finishing ration postweaning. Unit TDN consumption included that consumed by the cow during the 12-month period preceding weaning and pre- and postweaning consumption of the calf. Cow-calf unit efficiency defined as the ratio of unit TDN to calf weight was determined biweekly from weaning to an age beyond the most efficient point (MEP). Cow-calf unit efficiency, calf age and calf weight were determined for endpoints of 12 mm fat cover (12th rib) and MEP. Calf fat was determined at MEP. Postweaning efficiency, postweaning ADG and daily postweaning TDN were determined from weaning to MEP and 12 mm fat, respectively.

A one-unit decrease in weaning efficiency resulted (P<.001) in a .14-unit average increase in daily post-weaning TDN at each endpoint. Younger calves were associated (P<.10) with improved postweaning ADG. Differences in postweaning efficiency due to breed of sire may actually be differences in consumption relative to calf weight. Calf age and fat at the respective endpoints were basically associated (P<.001) with undefined

differences between years. When adjusted for calf weaning age crossbreds were heavier ($P<.05$) than straightbreds, 505 versus 486 kg and 463 versus 440 kg, at MEP and 12 mm fat, respectively. Increased calf weight at each respective endpoint was associated more ($P<.10$) with calf variables at weaning than with actual sire differences.

Calves of Hereford sires were more efficient ($P<.10$) than calves of Angus sires at each respective endpoint. This difference was not explained by the addition of covariates to the model. Calf weight at each respective endpoint, adjusted for differences in calf weaning age, was negatively correlated ($P<.05$) with cow-calf unit efficiency. Cow-calf unit efficiency at each endpoint tended to improve ($P<.10$) as daily milk production increased. Younger calves at each endpoint tended to be more efficient than older calves. Calves of smaller cows were more efficient at MEP ($P<.05$) and at 12 mm fat ($P<.10$) than were calves of larger cows.

II. Introduction

Most studies of feed efficiency are reported from the post-weaning phase. Fewer studies of feed efficiency of the cow-calf pair or production system (Koch et al., 1963; Kress et al., 1969; Klosterman et al., 1968; Long et al., 1975; Onks, 1976) have been reported. These studies have generally indicated that overall nutritional efficiency is related to a complex set of variables associated with characteristics of the cow, calf and production system. These studies have employed feeding to satisfy accepted levels of nutritional requirements or have utilized modeling techniques based on parameters estimated from accumulated data.

Ample research has documented that crossbred calves gain faster and produce heavier weights than straightbreds, establishing crossbreeding as an accepted segment of the beef industry (Long and Gregory, 1975; Olson et al., 1978). Little research has been conducted comparing the overall nutritional efficiency of the two mating systems. Since crossbreeding is a more difficult system to incorporate into the small herds, the benefits of crossbreeding would need to be high enough to offset additional money and labor related to this system. Comparison of straightbred cows raising straightbred and crossbred calves beyond weaning would allow producers to compare the mating systems in overall nutritional efficiency. Also, this research may determine cow-calf traits that effect production efficiency beyond weaning.

The purpose of this study was to compare, under unrestricted feeding levels, the nutritional efficiency of mature Angus and Hereford cows raising straightbred and crossbred calves at their most efficient point and at 12 mm fat. Secondly, this study was designed to evaluate the effects of measurable cow-calf characteristics on nutritional efficiency at each respective endpoint postweaning.

III. Materials and Methods

Source of data. Data from 66 lactations of mature Angus and Hereford cows (4 to 13 years of age) raising straightbred and reciprocal cross calves were obtained over a three-year period. Cows were assembled from three herds of The University of Tennessee Agricultural

Experiment Station and were assumed to be representative of the variation in size and maternal ability present in these herds. Angus and Hereford sires were considered to be representative of bulls used in the University herds.

Cows were calved on pasture. At the end of the calving season each spring, 24 cows with male calves were selected and randomly assigned to individual feeding pens when the calves were about 6 weeks of age. Pens were designed such that the calf had access to an individual creep feeder and to the cow's feed. Cows and calves were kept in the pens during the day and in dirt exercise lots at night. Six Hereford and six Angus cows with their respective straightbred or crossbred calves were assigned to each lot. Calves were castrated about 3 weeks after cows and calves were placed in individual pens. Cows remained in the individual feeding pens until weaning of the calves. Data from six cow-calf units were deleted from the study due to death or serious illness of an animal. Calves were weaned about the same time each year at an average age of 247 days.

Cows were offered, *ad libitum*, diets of grass silage. The silage consisted of grass-legume mixtures. Orchardgrass (*Dactylis glomerata* *L.*), red clover (*Trifolium* *pratense* *L.*) and timothy (*Phleum pratense* *L.*) were the component forages of the silage and were available in varying percentages over the four-year period. The silages were quite homogeneous within year being harvested from one meadow at one time, but specie composition and maturity varied from year to year due to varying weather conditions. The basic silage diet was fortified with energy by adding alfalfa pellets (alfalfa, aerial pt, dehy grnd, pelleted, mn 17 prot, IFN 1-00-023) as a percentage of forage consumed, to a level estimated to be sufficient to maintain cow condition equivalent to that of comparable cows on pasture. Calves were allowed access to the alfalfa pellets as a creep from approximately 80 days of age until weaning.

Following weaning each year, calves were individually fed, *ad libitum* corn silage (IFN 3-08-154) and 2.73 kgs daily of a concentrate mixture composed of 86 percent corn (IFN 4-02-914) and 14 percent cottonseed meal (IFN 5-01-621) for about 160 days. At this time, the calves were individually offered *ad libitum*, a high energy growing and finishing ration. This diet was composed of: 59 percent corn (IFN 4-02-915), 10 percent cottonseed meal (IFN 5-01-621), 20 percent cottonseed hulls (IFN 1-01-599), 5 percent molasses (IFN 4-04-696), 3 percent dehydrated alfalfa pellets (IFN 6-02-632), 2 percent animal fat (IFN 4-00-409), .5 percent ground limestone (IFN 6-02-632) and .5 percent salt.

Total digestible nutrient (TDN) content of the forages and growing-finishing ration fed were calculated from NRC (1976). Hence, TDN units presented are considered to be relative and not absolute values. Representative feed samples collected periodically were evaluated by *in vitro* dry matter digestion trials (Tilley and Terry, 1963). TDN values derived from these trials were similar to the calculated NRC estimates.

Data collection. Cows were weighed, and fat thickness estimates (ultrasonic, between 12th and 13th rib) were taken monthly for the first 2 years and biweekly during the remaining 2 years of the study.

Daily TDN consumptions were summed over the test period (about 200 days) and averaged for each cow-calf pair. This average consumption was multiplied by age of calf to estimate the TDN consumed from birth of the calf to initiation of the trial. Consumption of the cow from weaning of her previous calf to birth of the calf on test was estimated by assuming that she was fed during the winter at a level to meet NRC requirements (1976) for maintenance during the third trimester of pregnancy. Estimates of TDN consumption during the third trimester of pregnancy were adjusted for cow weight changes (Knott et al., 1934).

Cow TDN was a 12-month estimate of yearly TDN derived as the sum of the measured consumption during lactation plus an estimate of her intake for the remainder of the year based on production requirements. Unit TDN was the sum of the cow TDN and calf TDN. Unit weaning efficiency was calculated as the ratio of unit TDN to actual unadjusted calf weight at weaning. Fat thickness was sonorayed (ultrasonic, 12th rib) at weaning.

Milk production estimates were determined monthly for the first 2 years and biweekly during the remaining 2 years by the weigh-suckle-weigh method following 12 hour separation. Twelve-hour milk production estimates were adjusted to 24-hour milk production estimates (Neville et al., 1974). Daily milk yields were regressed on number of days in lactation and the function integrated to estimate production for each cow. Milk production between calving and initiation of the trial was estimated from calf gain (NRC, 1976). These two estimates were then summed for total milk production. Average milk production was calculated as the ratio of total milk production to number of days in lactation.

Initial cow weight and cow height were taken when the cows were alloted for the test initiation in the spring. Each was adjusted to remove variation due to differences between station herds of origin and variation due to differences in year and calf age.

Following weaning, calves were weighed and sonorayed (ultrasonic, 12th rib) biweekly. The TDN consumption of each calf (biweekly) was added to the unit TDN consumption of the cow and calf. Biweekly estimates of feed efficiency from weaning to slaughter were calculated as the ratio of unit TDN consumption to calf weight. Calves were slaughtered when the biweekly ratios indicates that they were well beyond their point of maximum efficiency.

The most efficient point (MEP) of the individual calf was determined as the minimum of a second-order polynomial fitted through the biweekly efficiency ratios. Calf age at MEP was obtained by taking the derivative of this polynomial, setting the derivative equal to zero and solving the equation. Using calf age at MEP, second-order polynomials fitted through biweekly weights and fat thickness estimates (ultrasonic, 12th rib) were used to determine weight and fat at MEP. Age at 12 mm fat thickness of the individual calf was determined from solution of a second-order polynomial predicting fat thickness. This age was used to determine weight and efficiency at 12 mm fat thickness. Postweaning ADG was calculated as the ratio of weight gain to the number of days fed postweaning from weaning to each endpoint, respectively. Postweaning efficiency was calculated as the ratio of postweaning TDN consumed to postweaning gain from weaning to each endpoint, respectively. Daily postweaning TDN was calculated as the ratio of postweaning TDN consumed to the number of days fed postweaning from weaning to each endpoint, respectively.

Analyses of data. Preliminary analyses were performed to determine relationships of initial cow and calf variables with subsequent calf performance at the respective endpoints and to describe the sample of animals. Factor analyses were performed on a within year-calf breed basis and were used to test for redundancies among descriptive measurements and to describe the sample of animals. Multiple regression procedures were used to relate cow and calf traits to seven dependent variables at each respective endpoint: cow-calf unit efficiency, calf weight, calf fat, calf age, postweaning efficiency, postweaning ADG and daily postweaning TDN consumption. The basic models for analyses of these data included effects of year and calf breed. Calf breed, with 3 degrees of freedom, was partitioned into orthogonal contrasts comparing (1) straightbred and crossbred calves, (2) breeds of sire and (3) breeds of cow. Additional variables included as covariates in the model were calf age at weaning, calf weight at weaning, calf fat at weaning, cow weight, average milk production, unit weaning efficiency, postweaning ADG, postweaning ADG relative to metabolic calf midweight, postweaning ADG relative to metabolic cow weight, daily postweaning TDN, daily postweaning TDN, daily postweaning TDN relative to metabolic calf midweight and postweaning days on feed.

IV. Results and Discussion

Means and standard deviations of cow and calf variables are shown in Tables 8, 9, and 10 to provide a general description of the data. Crossbred calves were heavier at weaning and tended to be more efficient. Hereford cows were heavier at the initiation of the trial but produced less milk per day than did Angus cows. Calves of Angus cows were heavier at weaning and the Angus cow-calf units were more efficient than Hereford cow-calf units. There were no observable differences in the traits measured at weaning due to breed of sire. Crossbred calves were heavier at MEP, gained more postweaning, consumed more TDN to MEP and tended to be slightly more efficient as a cow-calf unit. Calves of Hereford cows were heavier, older and fatter at MEP than were calves of Angus cows. There were small differences in efficiency, gain and consumption postweaning to MEP associated with breed of cow. Calves of Hereford sires were heavier at MEP and tended to be more efficient as a cow-calf unit. Calves of Angus sires consumed more TDN, gained less and were less efficient than calves of Hereford sires postweaning. Crossbred calves were heavier and tended to be more efficient at 12 mm fat than were straightbred calves. Crossbred calves consumed more TDN and gained more postweaning to 12 mm fat than did straightbred calves. Calves of Angus cows were heavier and more efficient as a cow-calf unit at 12 mm fat than were calves of Hereford cows. Although there was no noticeable difference in gain postweaning to 12 mm fat, calves of Hereford cows consumed less TDN and were more efficient than calves of Angus cows. Calves of Hereford sires were heavier at 12 mm fat and more efficient as a cow-calf unit

Table 8. Means and Standard Deviations of Cow and Calf Traits at Weaning by Calf Breed

	Hereford x Hereford		Angus x Angus		Hereford x Angus		Angus x Hereford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Weaning efficiency (kg/kg)[c]	11.27	2.12	10.47	1.14	9.91	1.36	10.90	1.15
Weaning age (days)	243	14	249	14	248	14	250	12
Weaning weight (kg)	192	27	203	20	215	27	204	21
Weaning fat (mm)	2.8	.7	2.9	.6	2.8	.8	2.8	.6
Cow height (cm)[d]	117.2	.7	117.2	.7	117.2	.8	119.6	.9
Cow weight (kg)[d]	484	20	430	22	443	20	480	20
Milk production (kg)[e]	6.42	1.15	6.82	1.06	7.41	1.34	6.31	1.06
N	16		16		18		16	

[a]Means and standard deviations are adjusted for year differences.
[b]Sire breed x cow breed.
[c]Ratio of total TDN to calf weaning weight.
[d]Adjusted for differences in year, farm of origin and calf age.
[e]Average daily milk production.

Table 9. Means and Standard Deviations of Calf Traits at MEP and Postweaning by Calf Breed

	Hereford x Hereford[c]		Angus x Angus		Hereford x Angus		Angus x Hereford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Efficiency (kg/kg)[d]	7.47	.53	7.76	.36	7.29	.31	7.78	.43
Calf weight (kg)[d]	496	36	476	35	504	27	507	44
Calf fat (kg)[d]	17.98	5.69	17.14	5.00	15.74	4.29	18.51	3.93
Calf age (days)[d]	560	36	545	50	533	37	558	28
Postweaning ADG (kg/kg)[e]	.96	.10	.93	.09	1.01	.08	.98	.09
Postweaning efficiency (kg/kg)[e]	5.33	.74	5.88	.43	5.52	.28	5.80	.45
Daily postweaning TDN (kg)[e]	5.11	.73	5.43	.28	5.58	.34	5.66	.36

[a]Ratio of total unit TDN to calf weight at the most efficient point.

[b]Means and standard deviations are adjusted for year differences.

[c]Sire breed x cow breed.

[d]Values at MEP.

[e]Values calculated from weaning to MEP.

Table 10. Means and Standard Deviations of Calf Traits at 12 mm Fat Cover and Postweaning to 12 mm Fat Cover by Calf Breed

	Hereford x Hereford		Angus x Angus		Hereford x Angus		Angus x Hereford	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Efficiency (kg/kg)[c]	7.70	.57	7.89	.45	7.40	.34	7.96	.47
Calf weight (kg)[c]	449	34	438	38	471	30	450	26
Calf age (days)[c]	514	17	505	18	501	15	501	13
Postweaning ADG (kg/kg)[d]	.94	.10	.92	.09	1.00	.09	.97	.11
Postweaning efficiency (kg/kg)[d]	5.42	.87	5.83	.48	5.47	.39	5.68	.62
Daily postweaning TDN (kg)[d]	5.07	.71	5.33	.22	5.45	.36	5.48	.34

[a]Means and standard deviations are adjusted for year differences.

[b]Sire breed x cow breed.

[c]Values at 12 mm fat cover.

[d]Values calculated from weaning to 12 mm fat.

than were Angus sired calves. Calves of Angus sires consumed more TDN postweaning to 12 mm fat, but gained less and were less efficient.

Factor analyses were performed on a within year-calf breed basis for each endpoint group. These analyses were used to test for redundancies among descriptive measurements and to describe the sample of calves. Results from these analyses can be found in Tables 11 and 12.

Table 11 shows the rotated factor pattern for traits at weaning and MEP. The first factor of the analysis explained 53 percent of the correlation structure. Calf age at MEP, efficiency at weaning, unit consumption to MEP, postweaning gain and days on feed to MEP, and ADG postweaning relative to metabolic calf midweight received high positive loadings while calf age, weight and fat at weaning, milk production and metabolic calf midweight postweaning received high negative loadings. The second factor, explaining an additional 23 percent of the correlation structure, may be considered a factor associated with high consumption and high relative consumption unfavorably related to efficiency at MEP and postweaning efficiency. Factor 3 explained an additional 12 percent of the correlation structure with high positive loadings for calf fat at MEP, cow weight and cow height, while post-weaning ADG and relative postweaning ADG to metabolic calf midweight and cow weight received high negative loadings. Factor 4 explained an additional 10 percent of the correlation structure with a high positive loading for calf weight at MEP and a moderate negative loading for efficiency at MEP.

Table 12 is the rotated factor pattern for traits at weaning

Table 11. Rotated Factor Pattern of Cow and Calf Variables Within Year-Calf Breed Groups at MEP

	Factor loadings[a]			
Variables	1	2	3	4
Efficiency at MEP	.45	.85	-.07	-.24
Calf fat at MEP	-.51	.28	.77	.21
Calf weight at MEP	-.16	-.09	.08	.97
Calf age at MEP	.68	-.43	.53	.00
Postweaning efficiency to MEP	-.29	.89	.09	-.27
Postweaning ADG to MEP	.29	.26	-.75	.53
Daily postweaning TDN to MEP	.01	.87	-.46	.17
Calf age at weaning	-.83	.01	.51	.11
Calf weight at weaning	-.93	.05	.29	.23
Unit TDN consumption at weaning	-.21	.90	.19	.31
Efficiency at weaning	.94	.21	-.23	-.11
Calf fat at weaning	-.79	-.13	.58	.13
Cow weight	-.06	.05	.74	.63
Cow height	-.33	-.50	.75	.25
Average milk production	-.90	-.33	.29	.12
Unit TDN consumption to MEP	.77	.54	-.25	.09
Postweaning gain to MEP	.91	-.11	-.28	.27
Postweaning days to MEP	.92	-.33	.15	-.05
MCM[b]	-.79	.01	.25	.55
ADG postweaning/MCM	.68	.16	-.69	.10
ADG postweaning/MCW[c]	.23	.13	-.96	-.06
Daily postweaning TDN/MCM	.34	.78	-.51	-.09
Cumulative portion	.53	.76	.88	.98

[a]Principal axis method, varimax rotation.

[b]Metabolic calf midweight.

[c]Metabolic cow weight.

Table 12. Rotated Factor Pattern of Cow and Calf Variables Within Year-Calf Breed Groups at 12 mm Fat Cover

	Factor loadings[a]			
Variables	1	2	3	4
Efficiency at 12 mm	.28	.89	-.34	-.12
Calf weight at 12 mm	.69	-.25	.61	.29
Calf age at 12 mm	.92	-.22	.09	.28
Postweaning efficiency to 12 mm	-.34	.79	-.43	.22
Postweaning ADG to 12 mm	.41	.16	.89	.07
Daily postweaning TDN to 12 mm	.15	.84	.47	.25
Calf age at weaning	-.95	-.10	-.13	-.15
Calf weight at weaning	-.99	-.05	.06	-.13
Unit TDN consumption at weaning	-.36	.85	.00	-.39
Efficiency at weaning	.95	.29	-.07	-.04
Calf fat at weaning	-.90	-.26	-.20	-.27
Cow weight	-.30	-.06	-.11	-.95
Cow height	-.50	-.63	-.23	-.49
Average milk production	-.91	-.41	.02	-.03
Unit TDN consumption to 12 mm	.91	.09	.23	.31
Postweaning gain to 12 mm	.92	-.11	.30	.23
Postweaning days to 12 mm	.95	-.15	.11	.25
MCM[b]	-.39	-.36	.83	.19
ADG postweaning/MCM	.76	.41	.49	-.05
ADG postweaning/ MCW[c]	.44	.12	.59	.66
Daily postweaning TDN/MCM	.27	.95	.05	.15
Cumulative portion	.57	.80	.93	.99

[a]Principal axis method, varimax rotation.

[b]Metabolic calf midweight

[c]Metabolic cow weight.

and 12 mm fat. The first factor of the analysis explained 57 percent of the correlation structure. Calf weight and age at 12 mm fat, efficiency at weaning, unit consumption to 12 mm fat, postweaning gain and days on feed to 12 mm fat and ADG postweaning relative to metabolic calf midweight received high positive loadings, while calf age, weight and fat at weaning and milk production received high negative loadings. Factor 2 explained an additional 23 percent of the correlation structure and like factor 2 for the traits at weaning and MEP, described differences relating high consumption to poor efficiency. The third factor explained an additional 13 percent of the correlation structure and, like factor 4 for the traits at weaning and MEP, may be described as a weight and gain factor. Calf weight at 12 mm, postweaning ADG to 12 mm, metabolic calf midweight and ADG postweaning relative to metabolic cow weight received high positive loadings. Factor 4 explained an additional 6 percent of the correlation structure, with a high negative loading for cow weight, a moderate negative loading for cow height and a moderate positive loading for ADG postweaning relative to metabolic cow weight.

Results from the addition of certain cow and calf variables, as covariates, to the basic model containing effects of year and calf breed in analyses of efficiency and components of efficiency at each respective endpoint are shown in Tables 13 through 32. Preliminary analyses indicated no significant calf breed effects on calf age at either endpoint or on calf fat at MEP; thus, calf breed was omitted from those models.

Table 13. Partial Regression Coefficients and Least-Squares Means for Daily Postweaning TDN Consumption to MEP and 12 mm Fat Cover

	Models at endpoints									
	Most efficient point					12 mm fat cover				
Trait	1	2	3	4	5	1	2	3	4	5
Intercept	5.89	5.71	5.60	5.09	8.76	5.20	5.01	4.91	4.21	8.08
Calf weaning age	.001	-.005	-.005	.002	-.004	.002	-.004	-.004	.004	-.003
Calf weaning weight		.009**	.011***				.009***	.011***		
Calf weaning fat			-.196*					-.182*		
Milk production[b]				.089†					.111*	
Weaning efficiency[c]					-.143***					-.143***
Calf breed	*[d]	†	†	*	*					
HH	5.17	5.24	5.26	5.22	5.25	5.12	5.19	5.21	5.17	5.20
AA	5.48	5.50	5.50	5.49	5.48	5.36	5.38	5.38	5.36	5.35
HA	5.58	5.49	5.46	5.52	5.48	5.45	5.35	5.33	5.38	5.35
AH	5.64	5.68	5.66	5.69	5.70	5.47	5.51	5.49	5.53	5.53
Year	***	***	***	***	***	**	***	*	***	***
1976	5.18	5.01	5.19	5.02	5.03	5.10	4.92	5.09	4.90	4.95
1978	5.31	5.50	5.37	5.42	5.42	5.34	5.53	5.41	5.47	5.44
1979	5.91	5.93	5.85	5.99	5.99	5.61	5.62	5.56	5.71	5.69
R^2[e]	1.0	9.0	13.0	3.0	11.0	1.0	15.0	20.0	7.0	16.0

[a]Ratio of postweaning TDN consumed to days on feed postweaning at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Symbols above a mean indicate level of significance for the class of effects.

[e]All models contained terms for year and calf breed, accounting for 32 and 10 percent for MEP, respectively, and 18 and 8 percent for 12 mm fat, respectively, of variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables indcluded.

†$P<.10$; *$P<.05$; **$P<.01$; ***$P<.001$.

Table 14. Analysis of Variance for Daily Postweaning TDN Consumption at MEP and 12 mm Fat Cover

Trait	Models at endpoints																			
	Most efficient point										12 mm fat cover									
	1		2		3		4		5		1		2		3		4		5	
	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	3.00***	2	3.49***	2	1.93***	2	3.21***	2	3.91***	2	1.19**	2	1.90***	2	.60*	2	1.64***	2	2.00***
Calf weaning age	1	.01	1	.27	1	.21	1	.04	1	.17	1	.05	1	.17	1	.13	1	.15	1	.08
Calf weaning weight			1	2.03**	1	2.75***							1	2.22***	1	2.87***				
Calf weaning fat					1	.87*									1	.75*				
Milk production[b]							1	.60†									1	.92*		
Weaning efficiency[c]									1	2.39***									1	2.40***
Calf breed	3	.67*	3	.48†	3	.40†	3	.58*	3	.52*	3	.41	3	.25	3	.21	3	.33	3	.29
Straightbred *vs* crossbred[d]	1	1.28*	1	.66†	1	.48	1	1.02*	1	.81*	1	.81*	1	.33	1	.21	1	.57†	1	.45†
H sire *vs* A sire	1	.55	1	.80*	1	.76*	1	.74†	1	.81*	1	.26	1	.45†	1	.42†	1	.43	1	.45†
H cow *vs* A cow	1	.27	1	.02	1	.01	1	.04	1	.00	1	.20	1	.00	1	.00	1	.00	1	.00
Residual	59	.22	58	.18	57	.17	58	.21	58	.18	59	.19	58	.16	57	.15	58	.18	58	.16

[a]Ratio of postweaning TDN consumed to days on feed postweaning at each respective endpoint.
[b]Average daily milk production.
[c]Ratio of total cow and calf TDN consumption to calf weaning weight.
[d]Orthogonal comparisons.
†P<.10; *P<.05; **P<.01; ***P<.001.

Table 15. Partial Regression Coefficients and Least-Squares Means for Postweaning ADG to MEP and 12 mm Fat Cover

	Models at endpoints									
	Most efficient point					12 mm fat cover				
Traits	1	2	3	4	5	1	2	3	4	5
Intercept	1.40	1.39	1.37	1.42	1.48	1.43	1.44	1.43	1.49	1.38
Calf weaning age	-.002†	-.002†	-.002†	-.002†	-.002†	-.002*	-.002†	-.002†	-.002*	-.002†
Calf weaning weight		.001	.001				-.000	-.000		
Calf weaning fat			-.025					-.016		
Milk production[b]				-.003					-.006	
Weaning efficiency[c]					-.004					.003
Calf breed	†[d]	†		†	*	†	†	†	†	†
HH	.96	.96	.96	.96	.96	.93	.93	.93	.93	.93
AA	.93	.93	.93	.93	.93	.92	.92	.92	.92	.92
HA	1.01	1.01	1.01	1.02	1.01	1.00	1.00	1.00	1.01	1.00
AH	.98	.99	.98	.98	.99	.98	.98	.98	.97	.98
Year										
1976	.95	.94	.97	.95	.95	.95	.95	.97	.96	.95
1978	.97	.97	.96	.96	.97	.96	.96	.95	.96	.96
1979	1.00	1.00	.99	1.00	1.00	.96	.96	.96	.96	.96
R^2[e]	4.0	5.0	7.0	4.0	4.0	6.0	6.0	7.0	7.0	6.0

[a]Ratio of postweaning gain to days on feed postweaning at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Symbols above a mean indicate level of significance for the class of effects.

[e]All models contained terms for year and calf breed, accounting for 12 and 10 percent for MEP, respectively, and 6 and 9 percent for 12 mm fat, respectively, of variation in the dependent variables. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05.

Table 16. Analysis of Variance for Postweaning ADG at MEP and 12 mm Fat Cover

	Models at endpoints																			
	Most efficient point										12 mm fat cover									
	1		2		3		4		5		1		2		3		4		5	
Traits	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	.011†	2	.012	2	.005	2	.007	2	.012	2	.001	2	.001	2	.000	2	.000	2	.000
Calf weaning age	1	.027	1	.029†	1	.027†	1	.027†	1	.029†	1	.037*	1	.028†	1	.026†	1	.039*	1	.030†
Calf weaning weight			1	.003	1	.008							1	.000	1	.000				
Calf weaning fat					1	.014									1	.006				
Milk production[b]							1	.001									1	.003		
Weaning efficiency[c]									1	.002									1	.001
Calf breed	3	.020†	3	.017†	3	.015	3	.020†	3	.018†	3	.022†	3	.021†	3	.020†	3	.023†	3	.022†
Straightbred vs crossbred[d]	1	.046*	1	.040*	1	.033*	1	.041*	1	.043*	1	.059*	1	.058*	1	.053†	1	.061*	1	.059*
H sire vs A sire	1	.012	1	.011	1	.011	1	.012	1	.011	1	.005	1	.005	1	.005	1	.006	1	.005
H cow vs A cow	1	.000	1	.000	1	.000	1	.000	1	.000	1	.001	1	.001	1	.001	1	.002	1	.001
Residual	59	.007	58	.008	57	.007	58	.008	58	.008	59	.009	58	.009	57	.009	58	.009	58	.009

[a]Ratio of postweaning gain to days on feed postweaning at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Orthogonal comparisons.

†P<.10; *P<.05.

Table 17. Partial Regression Coefficients and Least-Squares Means for Postweaning Efficiency to MEP and 12 mm Fat Cover

	Models at endpoints									
	Most efficient point					12 mm fat cover				
Trait	1	2	3	4	5	1	2	3	4	5
Intercept	3.34	3.19	.67	2.32	6.12	2.45	2.23	.25	1.04	5.91
Calf weaning age	.011*	.006	.008	.013**	.007	.014*	.006	.008	.016**	.008
Calf weaning weight		.007**	.006				.010**	.009**		
Cow weight[b]			.005					.004		
Milk production[c]				.114*					.157*	
Weaning efficiency[d]					-.138**					-.173***
Calf breed	*[e]	**	**	**	**		†	*		†
HH	5.42	5.48	5.36	5.47	5.49	5.51	5.60	5.50	5.59	5.61
AA	5.90	5.92	6.04	5.90	5.90	5.83	5.85	5.95	5.83	5.83
HA	5.52	5.43	5.51	5.44	5.42	5.47	5.35	5.42	5.36	5.35
AH	5.76	5.79	5.70	5.82	5.82	5.64	5.69	5.61	5.73	5.72
Year	**	**	***	***	***	†	**	**	**	**
1976	5.49	5.34	5.25	5.29	5.34	5.43	5.22	5.15	5.15	5.24
1978	5.52	5.68	5.77	5.65	5.62	5.57	5.79	5.86	5.76	5.70
1979	5.93	5.94	5.95	6.04	6.01	5.84	5.85	5.85	5.97	5.93
R^2 [f]	6.0	14.0	16.0	11.0	17.0	9.0	21.0	22.0	17.0	23.0

[a] Ratio of postweaning TDN consumed to postweaning gain at each respective endpoint.

[b] Adjusted for differences in year, farm of origin and calf breed.

[c] Average daily milk production.

[d] Ratio of total cow and calf TDN consumption to calf weaning weight.

[e] Symbols above a mean indicate level of significance for the class of effects.

[f] All models contained terms for year and calf breed, accounting for 13 and 15 percent at MEP, respectively, and 5 and 7 percent at 12 mm fat, respectively, of variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 18. Analysis of Variance for Postweaning Efficiency at MEP and 12 mm Fat Cover

Models at endpoints — Most efficient point

Trait	1 df	1 MS	2 df	2 MS	3 df	3 MS	4 df	4 MS	5 df	5 MS
Year	2	1.24**	2	1.48**	2	1.70***	2	1.72***	2	1.86***
Calf weaning age	1	1.31*	1	.28	1	.51	1	1.69**	1	.38
Calf weaning weight			1	1.51**	1	1.02*				
Cow weight[b]					1	.48				
Milk production[c]							1	.98*		
Weaning efficiency[d]									1	2.23**
Calf breed	3	.77*	3	.89**	3	1.05**	3	.88*	3	.90**
Straightbred vs crossbred[e]	1	.01	1	.11	1	.14	1	.05	1	.09
H sire vs A sire	1	2.13**	1	2.52***	1	2.87***	1	2.57***	1	2.59***
H cow vs A cow	1	.23	1	.02	1	.39	1	.01	1	.00
Residual	59	.23	58	.20	57	.20	58	.21	58	.19

Models at endpoints — 12 mm fat cover

Trait	1 df	1 MS	2 df	2 MS	3 df	3 MS	4 df	4 MS	5 df	5 MS
Year	2	.79†	2	1.52**	2	1.65**	2	1.67**	2	1.73**
Calf weaning age	1	2.09*	1	.36	1	.55	1	2.75**	1	.61
Calf weaning weight			1	2.94**	1	2.30**				
Cow weight[b]					1	.30				
Milk production[c]							1	1.86*		
Weaning efficiency[d]									1	3.48***
Calf breed	3	.43	3	.70†	3	.77*	3	.64	3	.68†
Straightbred vs crossbred[e]	1	.21	1	.65	1	.70	1	.43	1	.52
H sire vs A sire	1	.98†	1	1.38*	1	1.58*	1	1.43*	1	1.39*
H cow vs A cow	1	.09	1	.03	1	.10	1	.05	1	.08
Residual	59	.32	58	.28	57	.28	58	.30	58	.27

[a]Ratio of postweaning TDN consumed to postweaning gain at each respective endpoint.

[b]Adjusted for differences in year, farm of origin and calf age.

[c]Average daily milk production.

[d]Ratio of total cow and calf TDN consumption to calf weaning weight.

[e]Orthogonal comparisons.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 19. Partial Regression Coefficients and Least-Squares Means for Postweaning Efficiency at MEP and 12 mm Fat Cover

Trait	Models at endpoint									
	Most efficient point					12 mm fat cover				
	1	2	3	4	5	1	2	3	4	5
Intercept	8.83	9.85	8.67	3.24	3.03	9.89	10.88	9.61	2.62	2.01
Postweaning ADG	-2.76***					-4.11***				
Postweaning ADG/ metabolic calf midweight		-30.65***					-38.58***			
Postweaning ADG/ metabolic cow weight			-2.66***					-3.90***		
Daily postweaning TDN				.46***					.56***	
Daily postweaning TDN/ metabolic calf midweight					4.00**					5.07***
Calf breed	*[b]	*	***	*	†		†	**		
HH	5.34	5.41	5.24	5.49	5.46	5.37	5.46	5.22	5.57	5.53
AA	5.80	5.83	5.92	5.90	5.84	5.69	5.74	5.86	5.84	5.76
HA	5.63	5.60	5.69	5.46	5.51	5.64	5.52	5.72	5.40	5.51
AH	5.80	5.78	5.73	5.69	5.70	5.72	5.74	5.61	5.58	5.56
Year	***	***	***		*	*	***	**		
1976	5.51	5.33	5.42	5.74	5.84	5.46	5.39	5.34	5.71	5.76
1978	5.44	5.58	5.53	5.48	5.40	5.53	5.54	5.66	5.45	5.46
1979	5.98	6.04	5.98	5.68	5.65	5.82	5.91	5.82	5.63	5.55
R^2 [c]	5.0	18.0	6.0	1.0	1.0	26.0	42.0	26.0	3.0	4.0

[a] Ratio of postweaning TDN consumed to postweaning gain at each respective endpoint.

[b] Symbols above a mean indicate level of significance for the class of effects.

[c] All models contained terms for year and calf breed, accounting for 13 and 15 percent at MEP, respectively, and 5 and 7 percent at 12 mm fat, respectively, of variation. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

† $P<.10$; * $P<.05$; ** $P<.01$; *** $P<.001$.

Table 20. Analysis of Variance for Postweaning Efficiency at MEP and 12 mm Fat Cover

	Models at endpoint																			
	Most efficient point										12 mm fat cover									
	1		2		3		4		5		1		2		3		4		5	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	1.70***	2	2.22***	2	1.65***	2	.42	2	.99*	2	.76*	2	1.39***	2	1.13**	2	.27	2	.46
Postweaning ADG	1	3.58***									1	9.15***								
Postweaning ADG/metabolic calf midweight			1	6.27***									1	13.03***						
Postweaning ADG/metabolic cow weight					1	3.80***									1	9.03***				
Daily postweaning TDN							1	2.67***									1	3.66***		
Daily postweaning TDN/metabolic calf midweight									1	2.45**									1	3.68***
Calf breed	3	.75*	3	.58*	3	1.29***	3	.68*	3	.46†	3	.40	3	.35†	3	1.11**	3	.53	3	.22
Straightbred vs crossbred[b]	1	.31	1	.07	1	.26	1	.22	1	.04	1	.33	1	.01	1	.23	1	.66	1	.21
H sire vs A sire	1	1.56**	1	1.45**	1	2.10**	1	1.61**	1	1.23*	1	.65†	1	1.04**	1	1.14*	1	.80	1	.30
H cow vs A cow	1	.35	1	.25	1	1.54**	1	.13	1	.13	1	.22	1	.01	1	2.07**	1	.03	1	.13
Residual	59	.19	59	.14	59	.18	59	.20	59	.21	59	.20	59	.14	59	.21	59	.30	59	.30

[a]Ratio of postweaning TDN consumed to postweaning gain at each respective endpoint.

[b]Orthogonal comparisons.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 21. Partial Regression Coefficients and Least-Squares Means for Calf Age at MEP and 12 mm Fat Cover

	Models at endpoints							
	Most efficient point				12 mm fat cover			
Trait	1	2	3	4	1	2	3	4
Intercept	366	375	510	155	312	315	338	255
Calf weaning age	.695†	1.263**	.503	1.083*	.749***	.896***	.715***	.855***
Calf weaning weight		- .735**				- .190**		
Milk production[b]			-16.440***				- 2.915*	
Weaning efficiency[c]				10.286***				2.820*
Year	†[d]		†		***	***	***	***
1976	540	554	568	551	464	468	469	467
1978	567	552	549	560	557	553	554	555
1979	538	537	524	532	498	498	495	496
R^2[e]	4.0	17.0	23.0	15.0	8.0	9.0	9.0	9.0

[a]Calf age at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Symbols above a mean indicate level of significance for the class of effects.

[e]All models contained a year effect for MEP and 12 mm fat, accounting for 5 and 80 percent, respectively, of the variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 22. Analysis of Variance for Calf Age at MEP and 12 mm Fat Cover

	Models at endpoints															
	Most efficient point								12 mm fat cover							
	1		2		3		4		1		2		3		4	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	4818†	2	1631	2	6906*	2	4083†	2	35499***	2	14576***	2	23224***	2	29524***
Calf weaning age	1	5548†	1	14989**	1	2849	1	11986*	1	6440***	1	7548***	1	5767***	1	7841***
Calf weaning weight			1	16758**							1	1122**				
Milk production[b]					1	24680***										
Weaning efficiency[c]							1	14081**					1	776*	1	1058*
Residual	62	1904	61	1661	61	1531	61	1704	62	171	61	156	61	161	61	157

[a]Calf age at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 23. Partial Regression Coefficients and Least-Squares Means for Calf Fat at MEP

	Models			
	Most efficient point			
Trait	1	2	3	4
Intercept	11.73	12.51	23.08	-8.30
Calf weaning age	.024	.072	.009	.061
Calf weaning weight		- .061*		
Milk production[b]			-1.289*	
Weaning efficiency[c]				.979*
Year	*[d]	**		
1976	19.8	20.9	21.9	20.8
1978	14.2	12.9	12.8	13.6
1979	17.7	17.7	16.6	17.2
R^2 [e]	1.0	5.0	7.0	6.0

[a]Calf fat at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Symbols above a mean indicate level of significance for the class of effects.

[e]All models contained a year effect, accounting for 20% of the variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

*P<.05; **P<.01.

Table 24. Analysis of Variance for Calf Fat at MEP

	Models							
	Most efficient point							
	1		2		3		4	
Trait	df	MS	df	MS	df	MS	df	MS
Year	2	126.92*	2	184.78**	2	202.45***	2	177.10**
Calf weaning age	1	6.77	1	48.11	1	.95	1	38.27
Calf weaning weight			1	116.23*				
Milk production[b]					1	152.62*		
Weaning efficiency							1	127.67*
Residual	62	28.28	61	26.83	61	26.25	61	26.65

[a]Calf fat at the ratio of total cow and calf TDN consumption to calf weight at MEP.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

*P<.05; **P<.01; ***P<.001.

Table 25. Partial Regression Coefficients and Least-Squares Means for Calf Weight at MEP and 12 mm Fat

	Models at endpoints									
	Most efficient point					12 mm fat cover				
Trait	1	2	3	4	5	1	2	3	4	5
Intercept	483	472	463	505	610	420	403	399	345	622
Calf weaning age	.088	- .290	- .238	.052	- .130	.103	- .496†	- .472†	.223	- .242
Calf weaning weight		.523*	.677*				.830***	.901***		
Calf weaning fat			-14.824†					- 6.802		
Milk production[b]				- 2.480					8.407*	
Weaning efficiency[c]					- 6.334					-10.043***
Calf breed						*[d]	*	†	*	*
HH	496	500	502	495	499	448	455	456	452	454
AA	476	477	477	476	476	437	439	439	437	437
HA	504	488	496	506	500	471	461	461	465	464
AH	507	509	507	505	509	454	457	457	458	458
Year						***	***	***	***	***
1976	500	490	504	505	494	430	413	420	415	419
1978	493	504	495	490	498	483	501	496	493	490
1979	494	494	489	491	497	445	446	443	452	450
R^2[e]	1.0	6.0	10.0	1.0	4.0	1.0	20.0	22.0	6.0	13.0

[a]Calf weight at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Symbols above a mean indicate level of significance for the class of effects.

[e]All models contained terms for year and calfbreed, accounting for 1.0 and 7.0 percent at MEP, respectively and 33.0 and 11.0 percent at 12 mm fat respectively, of variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05; ***P<.001.

Table 26. Analysis of Variance for Calf Weight at MEP and 12 mm Fat Cover

	Models at endpoints																			
	Most efficient point										12 mm fat cover									
	1		2		3		4		5		1		2		3		4		5	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	256	2	611	2	658	2	487	2	59	2	12145***	2	21166***	2	9244***	2	9595***	2	16938***
Calf weaning age	1	85	1	763	1	512	1	29	1	167	1	117	1	2237†	1	2018†	1	534	1	581
Calf weaning weight			1	7482*	1	11093*							1	18831***	1	19631***				
Calf weaning fat					1	5000†									1	1053				
Milk production[b]							1	463									1	5322*		
Weaning efficiency[c]									1	4679									1	11764***
Calf breed	3	3082	3	2869	3	2685	3	3121	3	3204	3	3336*	3	1567*	3	1476†	3	2303*	3	2185*
Straightbred vs crossbred[d]	1	5993†	1	3334	1	2360	1	6352†	1	4465	1	6174	1	2336*	1	1933†	1	4523*	1	3873*
H sire vs A sire	1	1221	1	630	1	724	1	1442	1	759	1	3151†	1	1642†	1	1709†	1	1894	1	1971†
H cow vs A cow	1	2051	1	4355	1	4690	1	1178	1	4092	1	136	1	576	1	632	1	248	1	482
Residual	59	1934	58	1838	57	1783	58	1960	58	1887	59	876	58	566	57	558	58	799	58	688

[a]Calf weight at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Average daily milk production.

[c]Ratio of total cow and calf TDN consumption to calf weaning weight.

[d]Orthogonal comparisons.

†P<.10; *P<.05; ***P<.001.

Table 27. Partial Regression Coefficients and Least-Squares Means for Calf Weight at MEP and 12 mm Fat Cover

	Models at endpoint									
	Most efficient point					12 mm fat cover				
Trait	1	2	3	4	5	1	2	3	4	5
Intercept	258.3	290.3	197.9	.6	59.9	247.8	277.2	207.9	164.6	207.3
Postweaning ADG	242.92***			282.56***		200.86***			206.06***	
Postweaning ADG/ metabolic cow weight		214.65***			236.60***		173.96***			177.64***
Daily postweaning TDN			50.35***					41.53***		
Postweaning days				.72***	.69***				.31	.26
Calf breed		†	†		†		*	**		*
HH	497	506	510	487	496	451	457	457	447	454
AA	486	475	474	493	480	445	436	436	446	437
HA	494	490	497	504	499	462	459	466	463	460
AH	504	511	497	497	504	451	456	448	451	456
Year	†[b]	*	**	***	***	***	***	***		
1976	511	517	515	521	527	437	442	440	451	454
1978	489	482	499	473	466	477	472	483	460	457
1979	485	486	470	490	492	442	443	433	444	444
R^{2} [c]	23.0	20.0	26.0	67.0	62.0	24.0	19.0	21.0	24.0	20.0

[a]Calf weight at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Symbols above a mean indicate level of significance for the class of effects.

[c]All models contained terms for year and calf breed, accounting for 1 and 7 percent MEP, respectively, and 33 and 11 percent at 12 mm fat, respectively, of variation. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 28. Analysis of Variance for Calf Weight at MEP and 12 mm Fat Cover

	Models at endpoints																			
	Most efficient point										12 mm fat cover									
	1		2		3		4		5				2		3		4		5	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	3867†	2	6183*	2	7488**	2	11482***	2	14870***	2	10119***	2	5324***	2	15375***	2	819	2	838
Postweaning ADG	1	27624***					1	36889***			1	21840***					1	22572***		
Postweaning ADG/ metabolic cow weight			1	24823***					1	30006***			1	18016***					1	18528***
Daily postweaning TDN					1	32328***									1	19920***				
Postweaning days							1	55762***	1	51680***							1	800	1	580
Calf breed	3	888	3	3873†	3	3388†	3	768	3	1695†	3	845	3	2746*	3	2669**	3	973	3	1620*
Straightbred vs crossbred[b]	1	839	1	1412	1	397	1	1632†	1	2701*	1	1126	1	1766†	1	1602†	1	1551†	1	2182†
H sire vs A sire	1	2	1	345	1	5001†	1	6	1	543	1	1246	1	2379*	1	5904**	1	703	1	1678†
H cow vs A cow	1	1904	1	9369*	1	4946†	1	630	1	1493	1	134	1	1116	1	47	1	492	1	508
Residual	59	1467	59	1515	59	1388	58	531	58	650	59	507	59	572	59	540	58	502	58	572

[a]Calf weight at the ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.
[b]Orthogonal comparisons.
$^{\dagger}P<.10$; $^{*}P<.05$; $^{**}P<.01$; $^{***}P<.001$.

Table 29. Partial Regression Coefficients and Least-Squares Means for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints											
	Most efficient point						12 mm fat cover					
Trait	1	2	3	4	5	6	1	2	3	4	5	6
Intercept	7.27	7.38	4.13	7.55	4.99	4.87	7.26	7.39	4.56	7.77	5.48	4.58
Calf weaning age	.004	.008†	.011	.003	.005	.008*	.005	.009*	.012*	.004	.005	.009*
Calf weaning weight		-.006*	-.007**					-.006*	-.008**			
Cow weight[b]			.006*		.005†				.005†		.005	
Milk production[c]				-.031	-.061					-.057	-.084	
Weaning efficiency[a]						.120**						.133**
Calf breed	**[d]	**	**	**	**	**	**	*	**	*	**	*
HH	7.55	7.50	7.34	7.53	7.40	7.48	7.78	7.73	7.59	7.75	7.63	7.71
AA	7.81	7.79	7.96	7.81	7.95	7.81	7.94	7.93	8.07	7.94	8.07	7.95
HA	7.29	7.35	7.46	7.31	7.41	7.38	7.39	7.47	7.56	7.43	7.52	7.49
AH	7.77	7.75	7.63	7.75	7.64	7.72	7.93	7.91	7.80	7.90	7.80	7.87
Year	***	***	***	***	***	***	***	***	***	***	***	**
1976	7.19	7.30	7.18	7.24	7.17	7.31	7.41	7.54	7.44	7.51	7.45	7.56
1978	7.58	7.46	7.57	7.54	7.63	7.49	7.65	7.51	7.61	7.58	7.67	7.55
1979	8.05	8.04	8.04	8.02	8.00	7.98	8.22	8.22	8.22	8.17	8.15	8.15
R^2[e]	1.0	5.0	9.0	1.0	4.0	9.0	1.0	6.0	9.0	2.0	4.0	10.0

[a] Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b] Adjusted for differences in year, farm of origin and calf age.

[c] Average daily milk production.

[d] Symbols above a mean indicate level of significance for the class of effects.

[e] All models contained terms for year and calf breed, accounting for 34.0 and 14.0 percent at MEP, respectively, and 28.0 and 16.0 percent at 12 mm fat, respectively, of variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†$P<.10$; *$P<.05$; **$P<.01$; ***$P<.001$.

Table 30. Analysis of Variance for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints																							
	Most efficient point												12 mm fat cover											
	1		2		3		4		5		6		1		2		3		4		5		6	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	3.37***	2	2.94***	2	3.15***	2	2.11***	2	1.94***	2	1.20***	2	3.32***	2	3.20***	2	3.22***	2	2.28***	2	1.88***	2	2.29***
Calf weaning age	1	.16	1	.56†	1	.97*	1	.12	1	.22	1	.62*	1	.23	1	.78*	1	1.15*	1	.15	1	.25	1	.84*
Calf weaning weight			1	.86*	1	1.26**									1	1.12*	1	1.50**						
Cow weight[b]					1	.80*			1	.57†							1	.60†			1	.45		
Milk production[c]							1	.07	1	.25									1	.25	1	.47		
Weaning efficiency[a]											1	1.67**											1	2.08**
Calf breed	3	.96**	3	.69**	3	.87**	3	.80**	3	.91**	3	.66**	3	1.14**	3	.73*	3	.79**	3	.83*	3	.86**	3	.67*
Straightbred _vs_ crossbred[d]	1	.34	1	.14	1	.18	1	.29	1	.34	1	.15	1	.63†	1	.31	1	.35	1	.51	1	.56	1	.33
H sire _vs_ A sire	1	2.19***	1	1.87**	1	2.31***	1	2.01**	1	2.34***	1	1.79***	1	1.99***	1	1.64**	1	2.00**	1	1.71**	1	1.99**	1	1.56**
H cow _vs_ A cow	1	.19	1	.04	1	.32	1	.10	1	.16	1	.00	1	.58	1	.22	1	.09	1	.28	1	.03	1	.08
Residual	59	.18	58	.16	57	.15	58	.18	57	.17	58	.15	59	.21	58	.19	57	.19	58	.21	57	.20	58	.18

[a]Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.
[b]Adjusted for differences in year, farm of origin and calf age.
[c]Average daily milk production.
[d]Orthogonal comparisons.
†P<.10; *P<.05; **P<.01; ***P<.001.

Table 31. Partial Regression Coefficients and Least-Squares Means for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints					
	Most efficient point			12 mm fat cover		
Trait	1	2	3	1	2	3
Intercept	10.15	10.11	5.47	10.65	10.54	5.07
Postweaning ADG	-1.92**			-2.29***		
Postweaning ADG/metabolic cow weight		-1.91***			-2.22***	
Daily postweaning TDN/metabolic calf midweight			3.64***			4.39***
Calf breed	*[b]	**	**	**	**	**
HH	7.51	7.44	7.62	7.72	7.63	7.84
AA	7.73	7.82	7.74	7.86	7.96	7.88
HA	7.37	7.42	7.28	7.49	7.54	7.43
AH	7.80	7.74	7.71	7.98	7.91	7.86
Year	***	***	†	***	***	*
1976	7.16	7.09	7.43	7.40	7.32	7.61
1978	7.56	7.63	7.53	7.66	7.73	7.63
1979	8.10	8.07	7.81	8.23	8.23	8.01
R^{2}[c]	9.0	2.0	10.0	13.0	13.0	12.0

[a]Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Symbols above a mean indicate level of significance for the class of effects.

[c]All models contained terms for year and calf breed, accounting for 34 and 14 percent at MEP, respectively, and 28 and 16 percent at 12 mm fat, respectively, of variation. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 32. Analysis of Variance for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints											
	Most efficient point						12 mm fat cover					
	1		2		3		1		2		3	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	4.28***	2	4.46***	2	.44	2	3.78***	2	4.08***	2	.75*
Postweaning ADG	1	1.72**					1	2.85***				
Postweaning ADG/ metabolic cow weight			1	1.96***					1	2.94***		
Daily postweaning TDN/ metabolic calf midweight					1	2.04***					1	2.76***
Calf breed	3	.92*	3	.68**	3	.76**	3	.73**	3	.70**	3	.79**
Straightbred _vs_ rossbred[b]	1	.02	1	.03	1	.54†	1	.05	1	.07	1	.75*
H sire _vs_ A sire	1	1.62**	1	2.00***	1	1.13**	1	1.59**	1	2.00***	1	.81*
H cow _vs_ A cow	1	.17	1	.01	1	.37	1	.49†	1	.01	1	.62†
Residual	59	.15	59	.15	59	.14	59	.16	59	.16	59	.17

[a]Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Orthogonal comparisons.

†P<.10; *P<.05; **P<.01; ***P<.001.

Daily postweaning TDN. Models presented in Tables 13 and 14 (pages 50 and 52) indicate that year differences accounted for 32 and 18 percent of the variation in daily postweaning TDN to MEP and 12 mm fat, respectively. The major covariate effect (P<.001) on daily postweaning TDN was weaning efficiency to each respective endpoint. Weaning efficiency, adjusted for calf weaning age differences, accounted for 11 and 16 percent of the variation in daily postweaning TDN to MEP and 12 mm fat, respectively. Calf weaning weight, adjusted for calf weaning age differences, was positively correlated (P<.01) with daily postweaning TDN to each respective endpoint. Daily postweaning TDN tended to increase (P<.10) as daily milk production of the cow increased. Orthogonal comparisons of calf breed (Table 14, page 52) indicate that crossbreds consumed more daily postweaning TDN (P<.10) to each respective endpoint than did straightbreds, except when calf weaning weight was included in the model. This suggests that the increased consumption of crossbreds were largely the result of heavier weights and not due to heterosis effects. Gregory et al. (1966b) reported similar findings between heterosis effects and average daily postweaning TDN consumption, but before and after the adjustment for the effects of weight. Calves of Angus sires consumed (P<.10) more daily postweaning TDN to both endpoints than did calves of Hereford sires when calf weaning weight, daily milk production or weaning efficiency were added to the model. This disagrees with Olson et al. (1978) who reported 1074 and 1092 kgs of TDN consumed on a time constant postweaning basis for Angus and Hereford sired calves, respectively.

Postweaning ADG. Models presented in Tables 15 and 16 (pages 53 and 54) indicate that the major covariate effect (P<.10) on postweaning ADG was calf weaning age. Younger calves at weaning tended to have slightly higher postweaning ADG; however, the correlations were small accounting for only 4 and 6 percent of the variation in postweaning ADG to MEP and 12 mm fat, respectively. Although calf weaning weight had no appreciable effects (P<.10) on postweaning ADG, heavier calves at weaning tended to have slightly higher postweaning ADG to MEP. Christian et al. (1965), Dinkel and Busch (1973) and Nelson and Kress (1979) reported similar trends between calf weaning weight and post-weaning ADG. Observation of the orthogonal comparisons (Table 16, page 54) of most models shown indicate the superior postweaning ADG (P<.05) to each endpoint of crossbred calves. Previously, Long and Gregory (1975) and Olson et al. (1978) reported similar heterosis effects for postweaning ADG. It was noted, however, that with calf weaning age, weight and fat simultaneously added to the basic model that the effect of heterosis on postweaning ADG to 12 mm fat was reduced. Year effects accounted for 12 and 6 percent of the variation present in postweaning ADG to MEP and 12 mm fat (P<.05), respectively.

Postweaning efficiency. Models presented in Tables 17 and 18 (pages 55 and 56) indicate the effects of cow and calf covariates on postweaning efficiency (POEFF). Older calves at weaning tended to have higher (P<.05) postweaning efficiency to each respective endpoint; however, the addition of either calf weaning weight or weaning efficiency to the model reduced the effects. This suggests that the effects of age on postweaning efficiency was due largely to associated variation in weaning weight or weaning efficiency rather than to a relationship with age. Calf weaning weight was positively correlated (P<.01) with postweaning efficiency to each respective endpoint. Dinkel and Busch (1973) reported that weaning weight was highly positively correlated with feed efficiency. However, in contrast, Christian *et al*. (1965) and Kress (1977) reported that heavier weaning calves were slightly less efficient postweaning. More efficient calves at weaning were less efficient (P<.01) postweaning to each respective endpoint. A small positive correlation was noted (P<.05) between daily milk production and postweaning efficiency to both endpoints. The orthogonal comparisons (Table 18, page 56) indicate a sire difference in postweaning efficiency. Calves of Hereford sires were more efficient (P<.05) at each respective endpoint; however, this difference was greater postweaning to MEP. The covariates tended to account for more of the differences in variation in postweaning efficiency to 12 mm fat. Tables 19 and 20 (pages 57 and 58) indicate the effects of calf postweaning traits on postweaning efficiency. Postweaning ADG relative to metabolic calf midweight was negatively correlated (P<.001) with postweaning efficiency to MEP and 12 mm fat and explained an additional 18 and 42 percent, respectively, of the variation above the basic model. Although each other covariate added to the model was highly significant the correlations between them and postweaning efficiency to MEP were small accounting for less than 6 percent of the variation in each model. Both postweaning ADG and postweaning ADG relative to cow metabolic weight were negatively correlated (P<.001) with postweaning efficiency to 12 mm fat and each accounted for 26 percent of the variation. Daily postweaning TDN was positively correlated (P<.001) with postweaning efficiency to each respective endpoint. Calves of Hereford sires were more efficient (P<.01) to each respective endpoint (Table 20, page 58) than were calves of Angus sires. This agrees with findings of Ellersieck et al. (1977) when they reported feed efficiencies of 7.95 and 7.70 for Angus sired and Hereford sired calves, respectively, that grazed about 170 days after weaning and then were placed in the feedlot for 140 days. Postweaning efficiency to MEP showed no differences due to breed of sire when daily postweaning TDN or daily postweaning TDN relative to metabolic calf midweight was included in the model. This suggests that differences in postweaning efficiency due to breed of sire may actually be differences in consumption relative to calf weight. The addition of postweaning ADG relative to metabolic cow weight to the basic model of each endpoint indicated that calves of Hereford cows were more efficient (P<.01) than were calves of Angus cows.

Calf age. Year differences were the major source of variation describing calf age to 12 mm fat (80 percent), but accounted for only 5 percent of the variation in calf age at MEP. Tables 21 and 22 (pages 59 and 60) indicate that older calves at weaning were older at MEP (P<.10) and at 12 mm fat (P<.001) accounting for 4 and 8 percent of the differences in variation above the basic model. Calf weaning weight was negatively correlated (P<.01) with calf age at each respective endpoint. The effect of daily milk production at each endpoint was negative; however, more of the variation in calf age at MEP was accounted for by daily milk production (17 percent versus 1 percent) than in variation at 12 mm fat. Calves with higher efficiencies at weaning were older ($P<.001$) at MEP. This same trend existed for calf age at 12 mm fat; however, the correlation was less pronounced.

Calf fat. Calf fat at MEP was associated ($P<.001$) primarily with undefined differences in year. In Tables 23 and 24 (pages 61 and 62) weaning weight and daily milk production were negatively correlated ($P<.05$) with calf fat at MEP, but the correlations were small accounting for only 4 and 6 percent of the differences in variation, respectively. A small positive correlation ($P<.05$) was noted between weaning efficiency and calf fat at MEP. This suggests that calves with higher efficiencies at weaning were fatter at MEP; however, this correlation was small accounting for about 6 percent of the variation in calf fat at MEP.

Calf weight. Models presented in Tables 25 and 26 (pages 63 and 64) indicate the effects of cow and calf covariates at each respective endpoint. Calf weaning weight, adjusted for differences in calf weaning age, was positively correlated with calf weight at MEP ($P<.05$) and with calf weight at 12 mm fat ($P<.001$). Nelson and Kress (1979), observing Angus and Hereford calves, reported that weaning weight was genetically correlated (.73) with final weight. Fatter calves at weaning, adjusted for calf weaning age and weight, tended to weigh less ($P<.10$) at MEP. Calves with lower efficiencies at weaning were heavier ($P<.001$) at 12 mm fat, accounting for about 12 percent of the variation. The same trend was noticeable between weaning efficiency and calf weight at MEP; however, the differences in variation explained was negligible (P<.10). An increase in daily milk production was associated with increased calf weight at 12 mm fat (P<.05) but not at MEP (P<.10). Crossbreds were generally heavier (P<.10) than straightbreds; however, with the addition of calf weaning weight or weaning efficiency to the model of calf weight at MEP, the differences in breed of calf were removed. This suggests that the heterosis effects are more clearly seen on younger calves and that differences in older calves are more related to relative weights and efficiencies at weaning. Long and Gregory (1975) reported that heterosis effects were higher on calves with a higher rate of gain, on calves measured at younger ages or both. Calves of Hereford sires were heavier (P<.10) at 12 mm fat than calves of Angus sires, unless daily milk production was included in the model. In Tables 27 and 28 (pages 65 and 66), all postweaning covariates included in the models were positively related (P<.001) to calf weight at MEP. Postweaning days, adjusted for differences in postweaning ADG and postweaning ADG relative to metabolic cow weight, accounted for 67 and 62 percent of the variation in calf weight at MEP, respectively. Year effects were small (P<.10) in describing calf weight at MEP. An increase in postweaning ADG resulted (P<.001) in increased calf weight at each respective endpoint. Dinkel and Busch (1973) and Kress (1977) have shown similar results between postweaning ADG and final weight. Calves of Hereford cows were heavier (P<.05) at MEP than calves of Angus cows when the model was adjusted for postweaning ADG relative to metabolic cow weight. This suggests that calves of Hereford cows gain more relative to cow weight than do calves of Angus cows. Crossbred calves were heavier (P<.10) at 12 mm fat than were straightbreds, but there were no differences in calf weights at MEP. This suggests that crossbreds were gaining faster than straightbreds until some point between 12 mm fat and MEP. Olson et al. (1978) reported that crossbreds tended to gain more rapidly than straightbreds during a weight-constant feeding period, but slowed in growth relative to their weight. Calves of Hereford sires were heavier (P<.10) at 12 mm fat than calves of Angus sires unless the model was adjusted for differences in postweaning ADG. This suggests that the advantage of the calves of Hereford sires in calf weight at 12 mm fat was due to the faster postweaning ADG of Hereford sired calves.

Cow-calf unit efficiency. Models relating cow and calf variables to cow-calf unit efficiency at the two respective endpoints are shown in Tables 29 through 34 (pp. 67-70, 78, 79). Tables 29 and 30 model 1, calves of Hereford sires (7.42 and 7.59 at MEP and 12 mm fat) were more efficient (P<.01) than calves of Angus sires (7.80 and 7.94 at MEP and 12 mm fat). This breed of sire difference was not explained by the addition of any of the covariates to the models. Ellersieck et al. (1977) reported similar results for feed efficiencies of calves of Angus and Hereford sires in a similar management system. Undefined year effects were correlated (P<.001) with cow-calf unit efficiency and accounted for 34 and 28 percent of the differences in variation at MEP and 12 mm fat, respectively. Calf weaning weight, adjusted for differences in calf weaning age, was negatively correlated (P<.05) with cow-calf unit efficiency at each respective endpoint. Calves of smaller cows were more efficient (P<.10) than calves of larger cows at each respective endpoint. Several researchers have shown this same

Table 33. Partial Regression Coefficients and Least-Squares Means for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints								
	Most efficient point					12 mm fat cover			
Trait	1	2	3	4	5	1	2	3	4
Intercept	7.98	8.96	6.57	9.97	5.61	5.98	9.18	6.48	5.35
Calf age at endpoint	.001	.004**	.005**	.002	-.001	.005	.006†	.007	.001
Calf weight at endpoint		-.006***	-.006***	-.007***			-.008***	-.009***	
Cow weight[b]			.004*					.005†	
Calf fat at endpoint				.025					
Postweaning efficiency[c]					.480***				.418***
Calf breed	**[d]	*	**	*	*	**	*	*	**
HH	7.52	7.48	7.36	7.49	7.66	7.72	7.67	7.54	7.81
AA	7.81	7.71	7.85	7.69	7.67	7.96	7.83	7.96	7.84
HA	7.30	7.41	7.49	7.41	7.34	7.41	7.57	7.65	7.45
AH	7.77	7.79	7.70	7.80	7.71	7.93	7.94	7.86	7.91
Year	***	***	***	***	***	***	***	***	***
1976	7.23	7.26	7.17	7.20	7.24	7.62	7.48	7.42	7.51
1978	7.54	7.46	7.56	7.57	7.65	7.39	7.59	7.64	7.62
1979	8.04	8.07	8.07	8.03	7.90	8.26	8.20	8.21	8.14
R^2 [e]	1.0	13.0	16.0	14.0	16.0	1.0	17.0	20.0	17.0

[a] Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b] Adjusted for differences in year, farm of origin and calf age.

[c] Ratio of postweaning TDN consumed to postweaning from weaning to each respective endpoint

[d] Symbols above a mean indicate level of significance for the class effects.

[e] All models contained terms for year and calf breed, accounting for 34.0 and 14.0 percent at MEP, respectively, and 28.0 amd 16.0 percent at 12 mm fat respectively, of variation in the dependent variable. R^2 is the additional variation in the dependent variable accounted for by the additional independent variables included.

†$P<.10$; *$P<.05$; **$P<.01$; ***$P<.001$.

Table 34. Analysis of Variance for Cow-Calf Unit Efficiency at MEP and 12 mm Fat Cover

	Models at endpoints																	
	Most efficient point										12 mm fat cover							
	1		2		3		4		5		1		2		3		4	
Trait	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS	df	MS
Year	2	3.48***	2	3.59***	2	3.86***	2	3.62***	2	2.40***	2	3.40***	2	3.12***	2	3.35***	2	2.32***
Calf age at endpoint	1	.02	1	1.23**	1	1.52**	1	.11	1	.03	1	.37	1	.54†	1	.76*	1	.02
Calf weight at endpoint			1	2.54***	1	2.78***	1	2.79***					1	3.54***	1	3.80***		
Cow weight[b]					1	.55*									1	.52†		
Calf fat at endpoint							1	.27										
Postweaning efficiency[c]									1	3.28***							1	3.49***
Calf breed	3	.95**	3	.53*	3	.62**	3	.52*	3	.49*	3	1.09**	3	.44*	3	.48*	3	.71**
Straightbred vs crossbred[d]	1	.29	1	.00	1	.00	1	.00	1	.32	1	.44	1	.00	1	.00	1	.35
H sire vs A sire	1	2.38***	1	1.49**	1	1.84***	1	1.40**	1	.51*	1	2.35**	1	1.11**	1	1.43**	1	.92*
H cow vs A cow	1	.13	1	.09	1	.13	1	.12	1	.49†	1	.31	1	.18	1	.08	1	.69*
Residual	59	.18	58	.14	57	.13	57	.14	58	.12	59	.21	58	.15	57	.14	58	.15

[a]Ratio of total cow and calf TDN consumption to calf weight at each respective endpoint.

[b]Adjusted for differences in year, farm of origin and calf age.

[c]Ratio of postweaning TDN consumed to postweaning from weaning to each respective endpoint

[d]Orthogonal comparisons.

†P<.10; *P<.05; **P<.01; ***P<.001.

trend at weaning (Kress et al., 1969; Klosterman and Parker, 1974; Onks 1976; Dinkel and Brown, 1978). Onks (1976) showed similar relationships of cow weight and unit efficiency at MEP and 12 mm fat. Cow-calf unit efficiency at each endpoint tended to improve (P<.10) as daily milk production increased. Kress et al. (1969) and Marshall et al. (1976) showed that calves of higher milking cows at weaning were more efficient. Differences in calf weaning weight and cow weight, adjusted for calf weaning age, accounted for 9 percent of the variation in cow-calf unit efficiency at each respective endpoint. However, weaning efficiency, adjusted for calf weaning age, accounted for 9 and 10 percent of the differences in variation associated with cow-calf unit efficiency at MEP and 12 mm fat, respectively. Cow weight and daily milk production in the model tended to explain about the same amount of variation as did calf weaning weight. The effects of postweaning calf traits on cow-calf unit efficiency are shown in Tables 31 and 32 (pages 69 and 70). Each postweaning covariate added to the basic model was correlated (P<.01) with cow-calf unit efficiency; however, the covariates were more successful in accounting for differences in variation in cow-calf efficiency at 12 mm fat. Daily postweaning TDN relative to metabolic calf midweight increased (P<.001) as cow-calf unit efficiency increased at each respective endpoint. This suggests that calves consuming more TDN at a constant body weight were more efficient than calves consuming less TDN at the same constant body weight. Cow-calf unit efficiency improved (P<.01) as postweaning ADG and postweaning ADG relative to metabolic cow weight increased at each respective endpoint. Koch et al. (1963) reported that the genetic correlation between feed efficiency and gain was .79. Fitzhugh <u>et al</u>. (1967) and Joandet and Cartwright (1969) indicated that ADG postweaning was negatively correlated with feed per unit of weight gain. Models presented in Tables 33 and 34 relate calf covariates at each respective endpoint to cow-calf unit efficiency at that endpoint. Older calves at each respective endpoint tended to be less efficient ($P>.10$) than younger calves. Calf weight, adjusted for calf age, accounted for 13 and 17 percent of variation in cow-calf unit efficiency at MEP and 12 mm fat, respectively. The addition of calf weight increased the importance of calf age in all cases, indicating the importance of the relationship between rate of gain and cow-calf unit efficiency. Calves of smaller cows were more efficient at MEP ($P<.05$) and at 12 mm fat ($P<.10$) than were calves of larger cows. Onks (1976) reported similar relationships among calf weight, cow weight and cow-calf unit efficiency of straightbred Angus cow-calf pairs. As postweaning efficiency improved, cow-calf unit efficiency at each respective endpoint improved (P .001). Weaning efficiency, adjusted for calf age, accounted for 16 and 17 percent of variation in cow-calf unit efficiency at MEP and 12 mm fat.

Illustrative curves of cow-calf unit efficiency, calf weight and calf fat are shown in Figure 1. Curves were plotted from 250 to 450 days according to coefficients calculated from corn silage phase (Table 39, Appendix). Curves were plotted from 450 to 650 days according to coefficients from bullfeed phase (Table 40, Appendix).

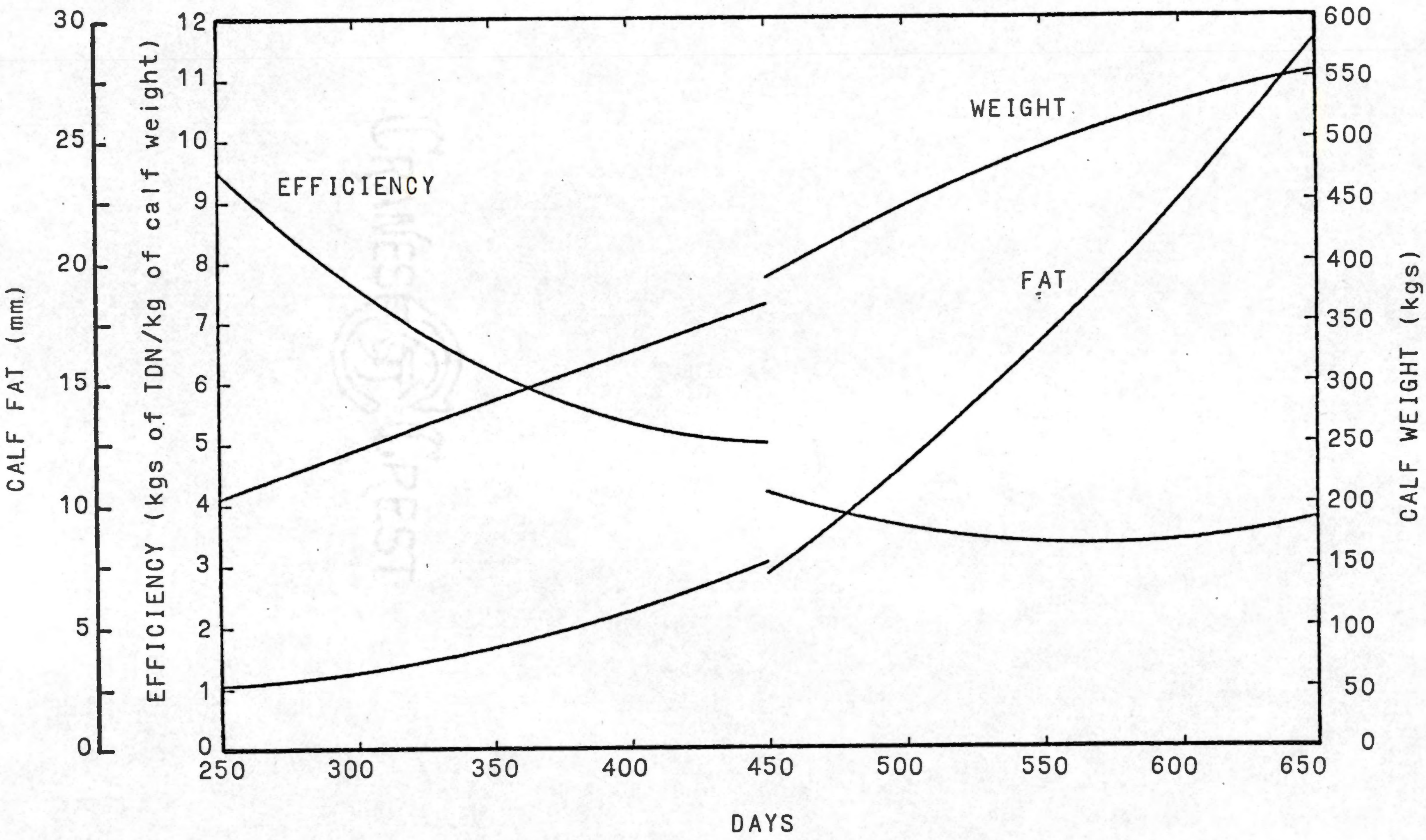

Figure 1. Relationships among calves postweaning of cow-calf unit efficiency, weight and fat thickness. Coefficients calculated postweaning (corn silage and bullfeed phase).

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APPENDIX

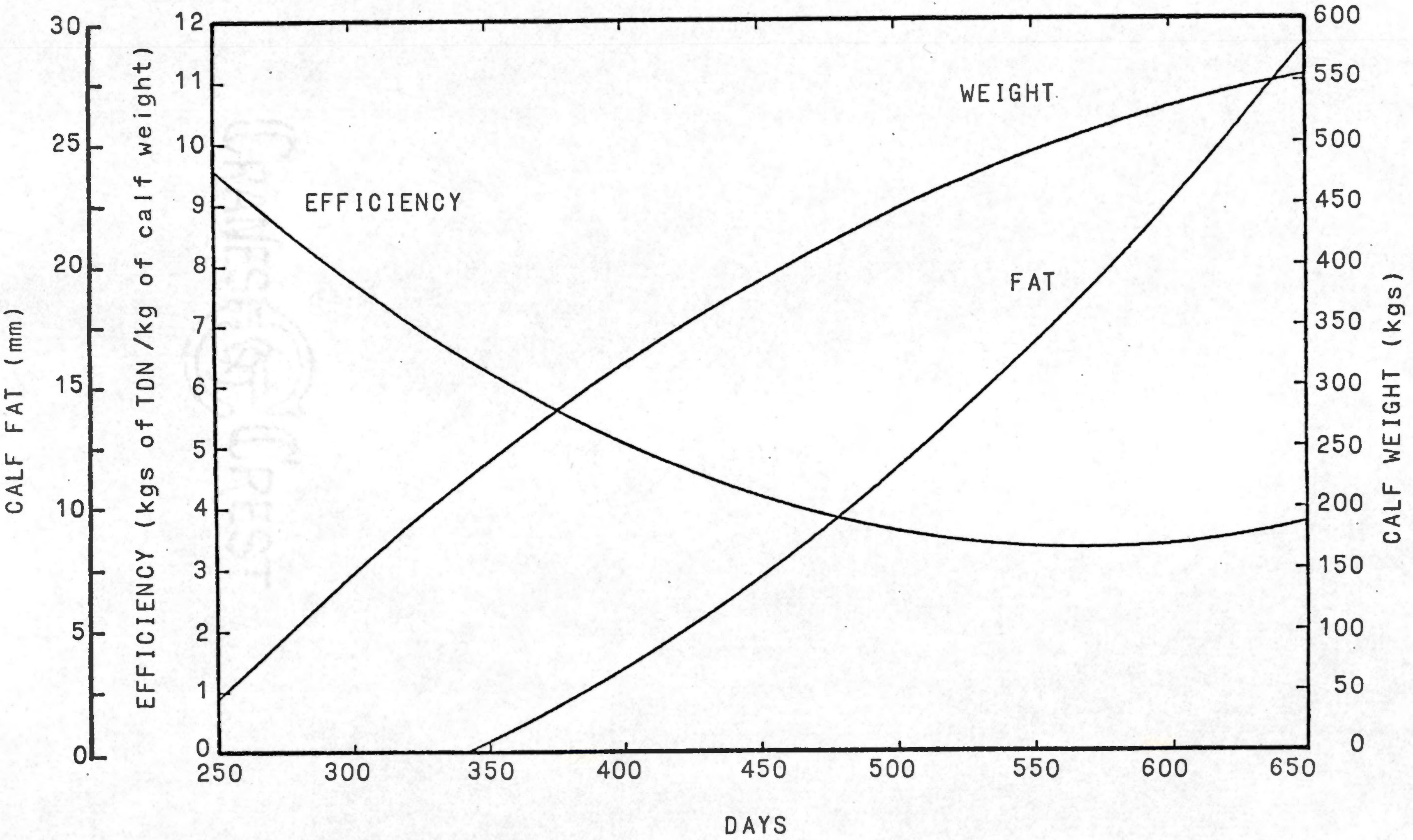

Figure 2. Relationships among calves postweaning of cow-calf unit efficiency, weight and fat thickness. Coefficients calculated postweaning (bullfeed phase).

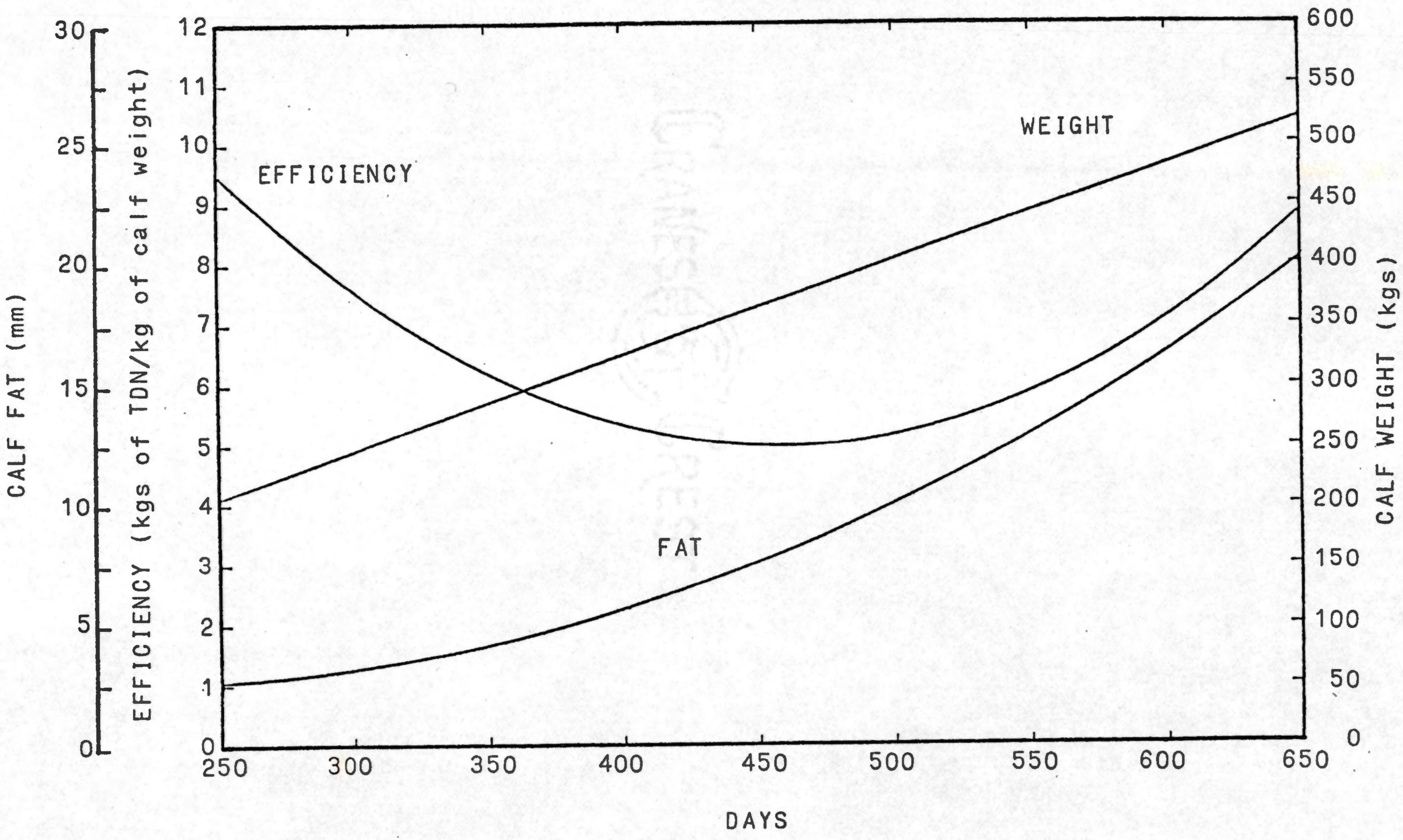

Figure 3. Relationships among calves postweaning of cow-calf unit efficiency, weight and fat thickness. Coefficients calculated postweaning (corn silage phase).

Table 35. Coefficients of Partial Regression and Least-Squares Means for the Most Efficient Point

Source	Model 1	2	3	4	5	6	7	8	9	10
Intercept	8.02	8.21	7.27	7.38	4.13	-11.22	7.55	5.99	-10.30	4.87
Weaning age (days)			.004	.008†	.011*	.015**	.003	.005	.009†	.008*
Weaning weight (kg)				-.006*	-.007**	-.006*				
Cow weight (kg)[b]					.006*			.005†		
Cow height (cm)[b]						.147*			.142*	
Milk production (kg)[c]							-.031	-.061	- .047	
Weaning efficiency (kg)[d]										.120**
Calf breed		**	**	**	**	**	**	**	**	**
HH[e]		7.53	7.55	7.50	7.34	7.30	7.53	7.40	7.34	7.48
AA		7.81	7.81	7.79	7.96	8.05	7.81	7.95	8.06	7.81
HA		7.29	7.29	7.35	7.46	7.56	7.31	7.41	7.52	7.38
AH		7.78	7.77	7.75	7.64	7.61	7.75	7.64	7.62	7.72
Year	***[f]	***	***	***	***	***	***	***	***	***
1976	7.23	7.23	7.19	7.30	7.18	6.58	7.24	7.17	6.56	7.31
1978	7.53	5.54	7.58	7.46	7.57	7.71	7.54	7.63	7.77	7.49
1979	8.02	8.03	8.05	8.04	8.04	8.62	8.02	8.00	8.56	7.98
R^2	.34	.48	.49	.53	.57	.58	.49	.52	.53	.57

[a] Ratio of total cow and calf TDN to calf weight at lowest efficiency.

[b] Cow weight and cow height adjusted for differences in eyar, farm of origin and calf age.

[c] Average daily milk production.

[d] Ratio of cow and calf TDN at weaning to calf weaning weight.

[e] Sire breed x cow breed.

[f] Symbols above a mean indicate level of significance for the class of effects.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 36. Weaning Analysis of Variance for the Most Efficient Point

Source	Model 1 df	1 MS	2 df	2 MS	3 df	3 MS	4 df	4 MS	5 df	5 MS	6 df	6 MS	7 df	7 MS	8 df	8 MS	9 df	9 MS	10 df	10 MS
Year	2	3.41***	2	3.49***	2	3.37***	2	2.94***	2	3.15***	2	1.75***	2	2.11***	2	1.94***	2	1.44***	2	1.20***
Weaning age (days)					1	.16	1	.56†	1	.97*	1	1.32**	1	.12	1	.22	1	.63	1	.62*
Weaning weight (kg)							1	.86*	1	1.26**	1	1.02*								
Cow weight (kg)[b]									1	.80*					1	.57†				
Cow height (cm)[b]											1	.89*					1	.82*		
Milk production (kg)[c]													1	.07	1	.25	1	.17		
Weaning efficiency (kg)[d]																			1	1.67**
Calf breed			3	1.00**	3	.96**	3	.69**	3	.87**	3	.91**	3	.80**	3	.91**	3	.98**	3	.66**
Straightbred vs crossbred[e]			1	.29	1	.34	1	.14	1	.18	1	.13	1	.29	1	.34	1	.27	1	.15
H sire vs A sire			1	2.42***	1	2.19***	1	1.87**	1	2.31***	1	2.39***	1	2.01**	1	2.34***	1	2.49***	1	1.79***
H cow vs A cow			1	.16	1	.19	1	.04	1	.32	1	.50†	1	.10	1	.15	1	.37	1	.00
Residual	63	.21	60	.18	59	.18	58	.16	57	.15	57	.15	58	.18	57	.17	57	.17	58	.15

[a] Ratio of total cow and calf TDN to calf weight at the lowest efficiency.
[b] Adjusted for differences in year, farm of origin and calf age.
[c] Average daily milk production.
[d] Ratio of total cow and calf TDN at weaning to calf weaning weight.
[e] Orthogonal comparisons.
†P<.10; *P<.05; **P<.01; ***P<.001.

Table 37. Postweaning Coefficients of Partial Regression and Least-Squares Means for the Most Efficient Point

Source	Model 1	2	3	4	5	6	7	8
Intercept	10.15	9.06	10.11	7.64	5.47	10.29	9.35	10.19
Postweaning ADG (kg)	-1.916***					-1.938**		
Postweaning ADG/calf wt[b]		-6.804					-7.669	
Postweaning ADG/cow wt[c]			-1.909***					-1.917***
Daily postweaning TDN				.932				
Daily postweaning TDN/calf wt[d]					3.64***			
Postweaning (days)						- .000	- .001	- .000
Calf breed	*[f]	**	**	**	**	*	**	*
HH	7.51	7.54	7.44	7.55	7.62	7.52	7.55	7.44
AA	7.73	7.79	7.82	7.81	7.74	7.73	7.79	7.82
HA	7.37	7.31	7.42	7.28	7.28	7.37	7.30	7.42
AH	7.80	7.78	7.74	7.76	7.71	7.80	7.78	7.74
Year	***	***	***	***	†	***	***	***
1976	7.16	7.17	7.09	7.26	7.43	7.15	7.15	7.09
1978	7.56	7.58	7.63	7.56	7.53	7.57	7.60	7.64
1979	8.10	8.07	8.09	7.99	7.81	8.09	8.06	8.09
R^2[g]	.57	.50	.58	.49	.58	.57	.50	.58

[a] Ratio of total cow and calf TDN to calf weight at the lowest efficiency.

[b] Postweaning average daily gain relative to metabolic calf midweight.

[c] Postweaning average daily gain relative to metabolic cow weight.

[d] Daily postweaning TDN consumption relative to metabolic calf midweight.

[e] Sire breed x cow breed.

[f] Symbols above a mean indicate level of significance for the class of effects.

[g] All models contained terms for year and calf breed, accounting for 34 and 14 percent at MEP, respectively, of variation. R^2 is the additional variation accounted for by the additional independent variables included.

†P<.10; *P<.05; **P<.01; ***P<.001.

Table 38. Postweaning Analysis of Variance for the Most Efficient Point

Source	Model 1 df	Model 1 MS	Model 2 df	Model 2 MS	Model 3 df	Model 3 MS	Model 4 df	Model 4 MS	Model 5 df	Model 5 MS	Model 6 df	Model 6 MS	Model 7 df	Model 7 MS	Model 8[a] df	Model 8[a] MS
Year	2	4.28***	2	3.40***	2	4.46***	2	2.02***	2	.44†	2	4.28***	2	3.41***	2	4.46***
Postweaning ADG (kg)	1	1.72**									1	1.74**				
Postweaning ADG/calf wt[b]			1	.31									1	.34		
Postweaning ADG/cow wt[c]					1	1.96***									1	1.97***
Daily postweaning TDN							1	.11								
Daily postweaning TDN/calf wt[d]									1	2.04***						
Postweaning (days)											1	.02	1	.04	1	.01
Calf breed	3	.92*	3	.86**	3	.68**	3	.99**	3	.76**	3	.62**	3	.87**	3	.69**
Straightbred *vs* crossbred[e]	1	.02	1	.24	1	.03	1	.38	1	.54†	1	.03	1	.25	1	.03
H sire *vs* A sire	1	1.62**	1	2.08***	1	2.00***	1	2.11***	1	1.13**	1	1.63**	1	2.06**	1	2.00***
H cow *vs* A cow	1	.17	1	.18	1	.01	1	.20	1	.37	1	.18	1	.21	1	.01
Residual	59	.15	59	.17	59	.15	59	.18	59	.14	58	.15	58	.18	58	.15

[a]Ratio of total cow and calf TDN to calf weight at the lowest efficiency.
[b]Postweaning average daily gain relative to metabolic calf midweight.
[c]Postweaning average daily gain relative to metabolic cow weight.
[d]Daily postweaning TDN consumption relative to metabolic calf midweight.
[e]Orthogonal comparisons.
†P<.10; *P<.05; **P<.01; ***P<.001.

Table 39. Coefficients of Partial Regression Calculated Postweaning (Corn Silage Phase)

Source	Cow-calf unit efficiency (kgs of TDN/ kg of calf weight)		Calf weight (kgs)		Calf fat (mm)	
Intercept	20.3137		-7.9124		6.0705	
Year						
1976	-1.4575		29.4702		3.2038	
1978	- .2895		-9.5515		- .3706	
1979	.0000		.0000		.0000	
Breed						
HH	.0237		-7.8032		- .1857	
AA	- .2045		-1.8270		.4008	
HA	- .8101		17.4369		.3809	
AH	.0000		.0000		.0000	
Age (linear)	- .0480		.8301		- .0420	
Age (quadratic)	.00005242		- .00004460		.00009550	
R^2	.53		.75		.78	
	df	MS	df	MS	df	MS
Residual	642	.7515	642	434529	620	1.4841

[a]Intercepts used in figures were adjusted for year and breed.

Table 40. Coefficients of Partial Regression Calculated Postweaning (Bullfeed Phase)

Source	Cow-calf unit efficiency (kgs of TDN/ kg of calf weight)		Calf weight (kgs)		Calf fat (mm)	
Intercept	18.1910		-624.1827		.8646	
Year						
1976	- .7999		1.4468		.7890	
1978	- .4362		- 16.2951		-5.8425	
1979	.0000		.0000		.0000	
Breed						
HH	- .1425		- 11.5792		- .4922	
AA	.0674		- 17.1354		.0671	
HA	- .5016		18.0267		.4454	
AH	.0000		.0000		.0000	
Age (linear)	- .0351		3.2511		- .0459	
Age (quadratic)	.00003094		- .00219299		.00014143	
R^2	.46		.73		.83	
	df	MS	df	MS	df	MS
Residual	839	.2446	839	1153	839	8.0514

[a]Intercepts used in figures were adjusted for year and breed.

VITA

The author, Mike Clinton Crider, son of Justin Clinton Crider and Joy Enochs Crider, was born July 7, 1954 in Milan, Tennessee in Gibson County. He attended elementary and secondary school at Clarksburg Special School District and was a 1972 high school graduate. After graduation, he attended The University of Tennessee, Martin and received the Bachelor of Science degree in Agriculture in June 1976. He then attended The University of Tennessee, Knoxville, beginning in September 1976, and received the Master of Science degree in Animal Science in December 1978. Continuing the pursuit of higher education at The University of Tennessee, Knoxville, the author received the Doctor of Philosophy degree in Animal Breeding in December 1981.