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ENERGY REQUIREMENTS OF COWS AND THE EFFECT OF SEX, SELECTION, FRAME SIZE, AND ENERGY LEVEL ON PERFORMANCE OF CALVES OF FOUR GENETIC TYPES

presented by

Harold William Harpster

has been accepted towards fulfillment
of the requirements for

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Danny Hox
Major professor

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# ENERGY REQUIREMENTS OF COWS AND THE EFFECT OF SEX, SELECTION, FRAME SIZE, AND ENERGY LEVEL ON PERFORMANCE OF CALVES OF FOUR GENETIC TYPES

By

Harold William Harpster

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ABSTRACT

ENERGY REQUIREMENTS OF COWS AND THE EFFECT OF SEX, SELECTION, FRAME SIZE, AND ENERGY LEVEL ON PERFORMANCE OF CALVES OF FOUR GENETIC TYPES

By

Harold William Harpster

Cow-Calf Trials

Two cow-calf trials were conducted to examine the adequacy of energy levels recommended by the National Research Council (NRC) for cows of varying mature sizes and genetic backgrounds when maintained in unsheltered northern climatic conditions. Ten pregnant cows per cattle type were used in each trial. Types included: Unselected Hereford (USH), Selected Hereford (SH), Angus x Hereford x Charolais crossbred (AHC), and Angus x Hereford x Holstein crossbred (AHH). Body weights were recorded monthly and body condition was assessed by ultrasonic evaluation of external fat. Based on the two levels of energy fed, NRC recommendations were at least 25% too low for all types of cows maintained under harsh climatic conditions. Increasing the energy level fed to cows was not accompanied by increased efficiency to weaning (total TDN intake/calf weaning weight). However, rebreeding performance of the cows must be considered and was unacceptable for cows fed in trial 1. In both trials, the larger framed AHC and AHH cows were more efficient to weaning (TDN/calf weaning weight) than the smaller framed USH and SH types.

Metabolism Trials

Two total collection balance trials were conducted to compare the nitrogen and energy utilization of cattle of four genetic types when fed high corn silage (HS) or 80% concentrate high grain (HG) rations. Two growing steers per type (USH, SH, AHC, and AHH) received each ration in each trial. Digestibility, nitrogen retention and metabolizable energy values of the rations did not differ among the cattle types. Net protein (percentage of nitrogen intake retained) and metabolizable energy (Mcal/kg) values for the HS and HG rations were 24.2, 2.58 and 32.6, 2.96, respectively.

Feeding Trials: Steers and Heifers

The feedlot performance and carcass characteristics of 56 steer and 57 heifer calves of the four genetic types (USH, SH, AHC, and AHH) were compared (two trials). All cattle were fed a high silage ration and initial and final body composition data were obtained. Steers gained 19% faster than heifers and tended to be more efficient although feed/gain differences were small when adjusted to similar carcass fat. Carcass quality was similar when steers and heifers were compared at similar total carcass fat. Metabolizable energy required for carcass energy gain and edible portion produced were 10 and 5% greater for heifers, respectively, when both were compared at 29.2% carcass fat.

Feeding Trials: High Silage and
High Grain Steers

The influence of energy level and cattle type on the feedlot performance and carcass characteristics of 87 steers fed high silage

(HS) and 89 steers fed 71% concentrate high grain (HG) rations was examined (three trials). USH, SH, AHC, and AHH cattle types were fed in each trial. Daily carcass protein and fat gain were 30 and 25% greater, respectively, for steers fed HG. When carcass characteristics were adjusted to the same hot carcass weight within a cattle type, differences in quality grade were small. Metabolizable energy required per unit edible portion produced was 4% higher for steers fed HS and was attributed to a higher proportion of ME available for productive purposes.

The primary effect of selecting for yearling weight was to increase frame size. Daily gains of USH, SH, and AHC steers were consistent with expectations based on frame size while AHH steers gained at less than expected rates. Relative dry matter intake ($g/W_{kg}^{.75}$) was similar for all cattle types and less than predicted for AHH steers. Carcass quality of AHH steers compared favorably to the other types when all were compared at 32.3% carcass fat. Feed required per unit gain decreased with decreasing frame size. AHH steers were less efficient in converting ration protein and energy to carcass gain.

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# INTRODUCTION

Crossbreeding, selection programs, the role of the feedlot heifer, and the use of dairy breeding in beef production are topics of continuing interest to those concerned with the beef industry. Complete evaluation of these various types of cattle require analysis of both the cow-calf and feedlot phases of production. From a total industry perspective, the advantage of certain breeds or types in one phase may be offset in another phase. Dairy or dairy x beef breeds of cows typically produce more milk, are superior in lactation efficiency, and wean heavier calves than straightbred beef breeds. However, cattle of dairy breeding background may be less efficient in producing feedlot gain (Dean et al., 1976). Additionally, while cows of larger mature size typically wean heavier calves than cows of smaller mature size, the added cost of maintaining the heavier cows must be charged against the increased calf weight obtained.

Selection programs have generally emphasized growth rate; faster growing animals of larger mature size have resulted. Thus, the efficiency of production of large vs small cattle types is of considerable interest. While relatively high heritability estimates for feed efficiency have been reported, in most studies it is unclear whether animals were compared at similar finish since carcass fat was not measured. Such heritabilities would have been overestimated if

the more efficient animals were those that had gained faster but were killed at an earlier stage of growth. Few experiments have been conducted to examine the efficiency of selected vs unselected individuals originating from a common genetic base.

The assumption that larger animals are energetically more efficient than smaller types is not well founded if the animals are compared over similar initial and final body composition (Fox and Black, 1977). Numerous studies have compared large and small straightbred British breed cattle with British x Exotic and British x dairy breed crosses. Further work is needed, however, in which these types originate from a common genetic base and are compared at similar final composition.

Economic conditions prevailing in the cow-calf phase of production typically dictate that feed and shelter inputs be kept to a minimum. However, field observation have indicated that many cows wintered without shelter in harsh northern climates were of poor condition when fed levels of energy recommended by the National Research Council (NRC, 1970, 1976). Sufficient feed inputs are needed to insure acceptable preweaning calf performance and rebreeding of the cow. Few studies have examined the adequacy of NRC recommendations under harsh climatic conditions for cows of varying mature size and genetic background.

# LITERATURE REVIEW

## Effect of Cattle Type and Energy Level on Cow-Calf Performance

The beef cattle industry is characterized largely by segmented phases of production. Traits of great significance to the cow-calf producer such as fertility, longevity, and milk production may be of little direct importance to the feedlot operator who is more concerned with postweaning daily gains and efficiency of gain. Obviously, from a total industry perspective, both phases of production must be considered in complete evaluations of various cattle types. As pointed out by Gregory (1972), there has been a tendency in the past to extrapolate the results of only the growing-finishing segment of production to the entire life cycle efficiencies of various cattle types. The dangers of such conclusions are obvious when it is noted that only 35% of the total (cow + calf) nutrients required to market a 1,000 lb steer are consumed during the feedlot phase (Gregory, 1972).

While the intended market dictates, at least to a certain extent, the amount of external fat or condition required in the feedlot market animal, the amount of condition desirable in the breeding animal is rather arbitrary. Most would agree only that cows should be of "sufficient" condition to wean a calf of "acceptable" weight every 12 months. However, the level of inputs desirable may vary with

cattle type, ration, climate, and economic conditions. This section will deal with the effect of such factors on the efficiency of cow-calf production. The final topic will include consideration of the feedlot phase and briefly summarizes studies which have examined cattle type differences in efficiency from "conception to slaughter."

## Productivity to Weaning

The efficiency of beef production to weaning is of considerable interest since the industry carries two animals in the breeding herd for each animal going to slaughter (Cartwright, 1970). However, carefully designed and conducted studies are more rare in the literature than postweaning performance trials, likely due to the special problems encountered in cow-calf research. While typical feedlot conditions are relatively easy to duplicate, the same cannot be said for the cow herd where reliable measurement of feed intake typically requires the confinement of cows. Cattle type or energy level effects on reproductive performance will normally require large numbers and several years of observations. Cows which abort, fail to conceive, or lose their calf prior to weaning play havoc with experimental design and require the substitution of a replacement animal or statistical analysis with missing data. Also variation in time of calving within and between treatments may influence the factors being studied. Further observations on the problems of data analyses may be found in Jordan et al. (1977).

The relationship of cattle type and efficiency inevitably involves the significance of cow size. Klosterman (1972) has pointed

out that many problems confronting the cattle industry are of more importance than how big cattle should be. These include: feed efficiency, calving percentage, and type as related to carcass characteristics.

Increasing biological efficiency of cow-calf production by selection for a given body size is likely futile. If maintenance requirements and feed consumption are related to some fractional power of body weight (Kleiber, 1961), a size advantage in efficiency of production could be expected only if intrinsic efficiencies differ. Kleiber (1947) has stated that genetic variation dependent on body weight is irrelevant in any selection program for efficiency of production.

Reliable studies relating cow size to productivity are rather rare due to the large numbers and long periods of time required for meaningful conclusions. Knox (1957) compared compact and large type Hereford cows. Lifetime production values for calves weaned per year were 75.2% for compact and 92.5% for the large types. Weaning weights were 170 and 182 kg, respectively. A combination of these results indicated a 32% advantage of the large type cows in total calf weight weaned.

Nelson and Cartwright (1967) found a negative relationship between fertility and calf preweaning average daily gain (1,052 Angus and Hereford cow-calf pairs). A nonlinear relationship of cow weight and calf growth rate was indicated as intermediate weights of cows (570 kg for Angus and 600 kg for Hereford) gave maximal preweaning average daily gain of progeny.

Hawkins et al. (1965) studies 919 calving records from 214 Hereford cows. Cows with heaviest precalving weights had fewer calves born and/or weaned per cow mated and lower 205-day weaning weights. Conversely, cows weighing less at weaning time weaned more calves and a larger total weight of calves than heavier cows.

While a small degree of heterosis is noted in mature weight of cattle (Cundiff, 1970), it is highly responsive to selection. Brinks et al. (1962) presented a heritability estimate of approximately 0.60 for mature weight in Hereford range cows. Several thousand cow-calf records were analyzed covering a time span of 33 years. Small correlations were found between cow and calf weights with some indication of heavier cows producing heavier, faster gaining calves. Increases in cow weights over winter were also positively associated with faster gaining calves. However, increases in cow weight during lactation were negatively correlated with calves' weights and gains. Both results are consistent with several subsequent short-term studies (Jordan et al., 1977; Hironaka and Peters, 1969).

Klosterman et al. (1968a) compared the Hereford and Charolais breeds and their crosses under two systems of management. Three calf crops were produced by each of approximately 50 Hereford and 50 Charolais cows. Cows were bred to produce equal numbers of Hereford, Charolais and crossbred calves. Half the calves were creep fed and placed in the feedlot after weaning, the other half were not creep fed, wintered to gain 0.5-0.6 kg daily, grazed, and then placed in the feedlot. Records were available for 205 straightbred and 109

crossbred cows. Calves born as a percentage of cows bred was 86% for straightbred and 89% for crossbred. Values for calves weaned as a percentage of cows bred were 76 and 77% for straightbred and crossbred cows, respectively. Birth weights, 260 day weaning weights, and daily gains to weaning were (lb) 70, 518, 1.58; 83, 645, 1.99; and 77, 602, 1.85 for Hereford, Charolais, and crossbred calves, respectively. These data were adjusted for differences among years, sex, and system of management. Small but consistent evidence of hybrid vigor for these traits were thus noted (1 to 4% advantage of crossbreds over average of straightbreds).

Highly significant and positive relationships were found between weight of cow and birth and weaning weight (within breed). Fertility was not considered in that only cows with a weaned calf were included in the analysis. The total digestible nutrients supplied through creep feeding were about 10% of the total required to weaning and increased weaning weight an average 70 lb.

Carpenter et al. (1971) found that Hereford and Hereford x Brahman crossbred cows with heavier mature weights weaned heavier calves. However, relative to lighter weight cows, they exhibited longer calving intervals and produced fewer calves per unit time.

Straightbred Hereford (H) cows and calves were compared with Angus-Jersey (AJ) cows and their Charolais sired calves (Ellison et al., 1974). Weaning and yearling weights were similar while AJ cows gave birth to lighter calves (3-4 kg), produced more milk (+1.3 kg/day), and consumed less feed (-14.3%).

Lindsey et al. (1970), using records from 67 Angus, Hereford, and Shorthorn cows regressed weaning weight on cow weight/height ratio. An intermediate optimal ratio of 4.5-5.0 kg/cm was reported. Visual condition scores of cows were negatively associated with calf weaning weight.

Carpenter et al. (1972a) studied the performance of 30 Hereford and 15 Charolais cows fed to maintain a constant level of fatness. There were no significant associations between cow size and milk yield within breeds. Weight changes during the productive year and mature size were not closely related. Production efficiency on the same cows (Carpenter et al., 1972b) was examined and defined as calf weaning weight per unit feed for the cow and calf. A trend for greater efficiency of smaller cows within a breed was noted, although the trend was reversed between breeds.

Smith et al. (1976b) studied the gestation length, birth weight, dystocia level, calf mortality, and preweaning growth of 2,368 calves out of Hereford and Angus cows and by Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental sires. Charolais and Simmental crosses had faster preweaning average daily gains but also larger birth weights and more dystocia. Jersey crosses were lightest at birth and experienced considerably less dystocia than other crosses. Preweaning relative growth rate (percent increase in body weight daily) was highest for Jersey and lowest for South Devon, Limousin, Charolais, and Simmental crosses. Hereford by Angus heterosis was significant for birth weight, daily gain, and calf survival.

Past results from a continuing breeding project compari genetic types have been presented by Magee and Greathouse (1969 1971, 1972, 1973); Magee (1974); and Magee and McPeake (1975, 1 The four breeding groups were established from a common source grade Hereford cows. Groups included Unselected Hereford (USH) Selected Hereford (SH), Angus x Hereford x Charolais (AHC), and Angus x Hereford x Holstein (AHH). The mating system in the USH group was random while selection in the remaining groups was bas on yearling weight; sires were superior bulls from AI studs. A rotational crossbreeding system was used in the AHC and AHH grou

McPeake (1977) summarized the results from the 1972 thro 1976 calf crops with the following conclusions relative to cow productivity and preweaning performance:

a. Selection accounted for an 11.4% increase in actual wean weight.
b. Selection for yearling weight and crossbreeding increase cow weight.
c. Selection did not improve fertility while crossbreeding improved fertility an average 7.7% over the SH group.
d. Rotational crossbreeding increased adjusted weaning weig 13.1% and 21.4% in AHC and AHH groups, respectively.
e. The additional milk received by nursing crossbred heifer may have reduced their productivity as cows.

General effects of energy level and age of cow on rebree performance were presented by Wiltbank (1976):

| Level of feed | | | In heat by days after calving | | |
|---|---|---|---|---|---|
| Before calving | After calving | Age of cow | 50 | 70 | 90 |
| High | Moderate | Mature | 65 | 90 | 95 |
| High | Moderate | Young | 53 | 91 | 98 |
| Low | Moderate | Mature | 25 | 70 | 85 |
| Low | Moderate | Young | 28 | 68 | 87 |

It was stressed that to obtain equal response from young vs mature cows it would likely be necessary to separate the two age groups to insure adequate nutrient intake.

Wiltbank (1976) presented data from 686 cows in which the effect of body condition at calving on the onset of estrus was examined:

| | | Days after calving and % estrus | | | | | |
|---|---|---|---|---|---|---|---|
| Body condition | No. cows | 40 (%) | 50 (%) | 60 (%) | 70 (%) | 80 (%) | 90 (%) |
| Thin | 272 | 19 | 34 | 46 | 55 | 62 | 66 |
| Moderate | 364 | 21 | 45 | 61 | 79 | 88 | 92 |
| Good | 50 | 31 | 42 | 91 | 96 | 98 | 100 |

Cows were further classified as to calving time in four 20-day periods from December 20 to March 2. The 80-day breeding season extended from March 13 to June 11. In cows from the first three calving groups, 81% of the thin and 95% of the cows in good condition were pregnant after 80 days of breeding. However, only 54% of the thin and 85% of the good condition cows from the fourth calving group became pregnant.

Davis et al. (1977) studied the effect of winter nutrition on reproductive performance of Hereford cows of various ages. Three 2-year trials were conducted. Various combinations and amounts of

soybean meal, sorghum grain, and alfalfa hay were fed to cows mai on dormant range over winter. Sorghum grain (1.4 kg/day) was sup to soybean meal (0.7 kg/day) in improving weaning weight and repr tion when fed with 1.4 kg alfalfa hay. Additionally, doubling th amount of sorghum grain increased performance. Thus, energy and protein was assumed limiting for reproduction.

Delaying a portion of the winter feed until after calving decreased rebreeding performance in 2- and 3-year-old but not mat cows. Cows which rebred were generally those which lost less wei in winter and gained more weight in the subsequent grazing period

Reproductive performance of Angus (A), Brahman (B), and Charolais (C) cattle was reported by Peacock et al. (1977), in a Florida study. Cattle were straightbred and reciprocally crossed with an average of 121 matings over 11 years for each of the nine possible parent breed combinations. Pregnancy rate was described as cows pregnant of cows exposed. Survival rate was expressed as the percentage of calves surviving to weaning of cows pregnant an weaning rate was calculated as the product of pregnancy and survi rates. Pregnancy rate was influenced by breed of sire with mean of 74.4, 82.3, and 79.1% for A, B, and C sires, respectively. Ca survival was affected by breed of dam but not breed of sire (88.7 97.2, and 96.9% for A, B, and C dams, respectively). Weaning per was also affected by breed of dam (69.8, 76.5, and 75.9% for A, B C dams, respectively). A significant sire x dam interaction resu with C sire x A dam matings lowest (63.8%) and C sire x B dam mat

highest (82.2%) in weaning rate. These and other results caused the authors to conclude that large sire breeds crossed on small dam breeds may result in a net decrease for weaning rate.

Bowden (1977) compared 29 Simmental x Angus (SA), 28 Charolais x Angus (CA), 25 Hereford x Angus (HA), and 25 Jersey x Angus (JA) first-calf heifers for growth, reproductive performance, and feed utilization. All heifers were individually fed from 8 weeks postweaning until calving and were bred artificially to the same Red Poll bull. About 16 weeks after first breeding heifers were assigned to digestible energy (DE) levels sufficient for normal growth (based on mature size) or 110% of that level. Heifers fed at the latter level were heavier at calving. Body size measurements indicated the increased weight was due to additional soft tissue deposition and not skeletal growth.

Total intakes of dry matter, DE and digestible protein were higher for SA and CA vs HA and JA heifers. Heifers fed at the high DE level gained 22% faster (0.50 kg/day) than those fed low DE (0.41). Breeding performance did not differ significantly among the breed types or energy levels. Ultrasonically determined backfat depths (84 weeks of age) did not differ by energy level and averaged 8 mm. The amount of DE used per unit metabolic wt for the duration of the trial differed only slightly among the four types indicating similar relative requirements.

The introduction of dairy breeding into the beef herd typically increases milk production and calf weaning weight (Deutscher and Whiteman, 1971; Holloway et al., 1975b; Wyatt et al., 1977c).

However, the impacts of milk consumption and genetic backgrounc not been clearly delineated, since in most studies calves of si genetic composition consumed similar amounts of milk. Wyatt et (1977a) presented a study designed to examine the impact of eac

Forty Hereford and 41 Holstein cows were bred to Angus Charolais bulls, respectively. One-half of the calves born to dams (A x H) were fostered onto Holstein cows and one-half of t born to Holstein dams (C x H) were reared by Hereford cows. Ea of calf thus received low milk (4.8 to 5.5 kg/day) and high mil 11.0 kg/day) levels. High milk increased weaning weight of dry calves 19 and 22% for A x H and C x H calves, respectively. At milk level, both types of calves consumed similar amounts (with 0.2 kg) of milk suggesting little effect of potential growth ra on milk intake. Increased milk intake was associated with decr intake of creep feed. Theoretical energy requirements to produ calf gain were calculated for Hereford and Holstein cows at hig (9.8 kg) and low (5.2 kg) levels of milk production. Megacalor of digestible energy (total cow + calf) required per kg calf ga were 37.29 and 34.91 for low and high Herefords and 40.83 and 3 for low and high Holsteins, respectively. As always, economic siderations would dictate advisability of feeding for higher mi production.

A series of reports by Oklahoma workers compared the pe formance of Hereford, Hereford x Holstein, and Holstein cows as

2-year olds (Kropp et al., 1973); 3-year olds (Holloway et al., 1975a); and 4- and 5-year olds (Wyatt et al., 1977c). Cows were maintained under both range and dry lot conditions. Three levels of winter supplement (30% protein range pellet) were fed. Moderate, High, and Very High levels were the amounts necessary to effect a weight loss from fall to spring of approximately 10-15% in Hereford, Crossbred, and Holstein cows, respectively. Moderate and High levels were fed to all three groups while only the Holsteins received the Very High level. Monthly weights and subjective condition scores were obtained. Milk production was estimated monthly by the weigh-suckle-weigh technique. Reproductive performance was monitored.

Though some year to year variations in relative performance of the cows at different ages existed, some consistent trends were evident. In dry lot, increasing the level of supplement reduced winter weight losses in Hereford and crossbred cows. Within the Holstein breed group, weight losses were not significantly different between the Moderate and High levels although Very High cows lost less weight than the other groups. All cows except the Moderate and High Holsteins regained their winter losses during the summer months. Body condition scores followed weight change trends. Holsteins had lowest and Herefords highest condition scores in both dry lot and range cattle.

Milk yields increased predictably with percentage Holstein breeding. In dry lot cows the level of winter supplement did not effect the level of milk yield within breeds although yield tended to increase with increasing level of supplement. There were no

consistent effects of level of supplement on butterfat percentage within breed.

Increased calf weaning weights were associated with level of milk intake and percentage Holstein breeding, but additional feed was required to maintain the larger, heavier milking Holstein cows. Results with the 4- and 5-year old cows (Wyatt et al., 1977c) revealed that Very High Holsteins consumed 3.4 times more winter supplement and 45% more forage than Moderate Herefords.

Level of supplement had little effect on number of cows exhibiting estrus and conceiving in the Hereford and Crossbred groups. A marked effect was noted in the Holsteins, however, where reproductive performance was poor in the Moderate and High groups. The deteriorating performance of the 4- and 5-year old Holstein cows vs results at younger ages suggested an accumulative effect of low levels of supplementation.

Klosterman et al. (1968b) fed 62 mature, non-pregnant, non-lactating Hereford and Charolais cows to study the effect of cow size and condition and protein content of the ration on energy requirements for maintenance. Pelleted rations of 6.9, 9.1 or 12.0% protein were fed to cows in dry lot once daily. The low level of protein was adequate to maintain weight. The higher levels did not appear to increase the efficiency of energy utilization as gains were similar among all levels of protein when equal amounts of energy were fed. Little evidence for genetic variation in maintenance requirements was found between the two breeds.

Interesting observations on the relationship of cow condition and body weight were made. Cow condition was assessed by ultrasonic measurement and by weight to height ratio. A 0.51 ($P < .01$) within breed correlation between the two methods was reported. A significant regression of daily gain on weight to height ratio was noted. Cows with a high degree of initial finish tended to gain weight while thin cows tended to lose weight. This could be at least partially explained by the fact that the initial weight of each cow determined the amount of feed she was fed for the entire experiment. However, Lambourne and Reardon (1963) found a higher maintenance requirement per unit weight in thin vs fat sheep.

Thomas and Cartwright (1971) compared Angus-Jersey (AJ), Charolais (C), and Hereford (H) cows in a study designed to maintain them in equal condition. Crossbred cows were mated to either C or H bulls while the other cows were straightbred. AJ cows ate 22% less feed than C and 8% less than H cows although this would be influenced by the subjective evaluation of cow condition. Efficiencies of production (kg total feed/kg calf wt) at 205 days were 14.7, 16.4, and 15.6 for AJ, H, and C cows, respectively.

Melton et al. (1967) compared 26 Hereford and 14 Charolais cow-calf pairs where cows were fed to maintain body condition as equal as possible. Correlations between cow size and cow feed intake, milk yield, calf intake and gain, and total feed intake were small or negative. Efficiency at 210 days (total TDN/calf wt) favored small (8.6) over large (9.1) cows for Herefords with a similar ranking for Charolais.

Parkins et al. (1977) constructed a model to predict the total yearly ME requirements of calves and cows of various mature sizes and levels of milk production. Allowances were made for yearly maintenance requirements, pregnancy, creep feeding, and milk production. Age at weaning was assumed to be 210 days. Estimates were presented for cows of three mature weights (400, 500, 600 kg) and three levels of daily milk production (5, 10, 15 kg). One method of calculation assumed a constant calf birth weight and weaning weight within a cow size so that calf preweaning daily gains were fixed and creep feed requirements were varied by level of milk production. On this basis the total ME cost to produce a 182 kg weaned calf increased 14% for a 400 kg cow producing 15 vs 5 kg of milk daily. The increase noted for a 600 kg cow producing a 274 kg weaned calf was 13%. Efficiencies under these same conditions were calculated as total Mcal of ME required to produce 1 kg of weaned calf. Values varied from 29.4 Mcal/kg for a 600 kg cow producing 5 kg milk to 37.9 Mcal/kg for a 400 kg cow producing 15 kg milk. Low producing cows (5 kg) were the most efficient within each cow size indicating the advantage of providing creep feed to the calf vs extra feed to the cow to promote milk production. As pointed out by the authors, however, energetic and economic efficiency may differ on this point depending on the types and cost of feed fed to the cows and calves.

*Impact of Environment*

Beef cows are kept under a wide range of environments and conditions, perhaps more so than any other specie of farm animal. Facilities may vary from environmentally controlled housing to a complete lack of shelter or windbreaks. Margins of profit in the cow-calf phase of production are typically small and establishing the minimum inputs necessary (ration, housing, equipment) for acceptable performance is of interest. Since heat stress is normally of minor concern in the northern climates, this section will deal primarily with the effect of cold temperature on cow performance.

Several workers have determined the critical temperature (CT) of cattle under various conditions. The CT is defined as that air temperature below which metabolism increases to maintain body temperature (N.R.C., 1966). The conditions existing during determination should be defined since the CT varies by feeding level, species, skin covering, physical condition, humidity, and wind movement (N.R.C., 1966). Blaxter and Wainman (1961) reported a CT of 7 C for steers fed maintenance rations in respiration chambers with a 0.5 mph wind. A similar trial with four steers emphasized the impact of air movement (Blaxter and Wainman, 1964). A 1.6 mph wind increased feed requirements 6% (as measured by heat production) in cattle with winter coats maintained in freezing temperatures. Webster et al. (1970) found the CT of beef breed heifers to be closely tied to air temperature and thus changed seasonally in response to environmental conditions.

Jordan et al. (1977), in a consecutive 3-year study, examined the cow-calf performance of Shorthorn cows confined year-round to three types of shelters and fed two types of feed. Three levels of intake were fed from the start of fall feeding (September) to the late pregnancy stage (end of February). Shelters were an enclosed, ventilated barn (IN); a barn with free access to outside lots (IN-OUT); and outside lots with only windbreak fences (OUT). Types of feed were hay or grass silage and levels of intake for the indicated period were ad libitum (L1), 75% of ad libitum (L2), and 50% of ad libitum (L3). These trials were conducted in northern Ontario and average monthly temperatures (C) for the December through February months (3 yr avg) were 8, -1, and -16 C for IN, IN-OUT, and OUT environments, respectively.

There were no interactions noted among years, degree of shelter, and feed levels. Daily intakes and gains were higher for cows fed hay vs silage. The daily intake and weight loss of OUT cows were greater than the other shelter types. OUT calves were heavier than IN calves at birth but their daily gain to weaning was markedly less. Cows were naturally bred and pregnancy percentages for IN cows were 91.7 (L1), 91.7 (L2), and 75.0 (L3); IN-OUT 88.9, 88.9, and 86.1, and OUT 88.9, 80.6, and 58.3. The authors did not provide estimates of cow condition but noted that the general condition of OUT cows, especially those fed the L3 diet, was poor, and some animals died of starvation.

Ability to evaluate the three nutritional treatments is rather limited due to the experimental design where all cows were fed ad

*libitum* following calving. Digestible energy intake was highest for the OUT cows during the ad libitum period (and above NRC lactation requirements) reflecting a compensatory response. However, the calves from OUT cows gained significantly less suggesting the use of the additional energy for bodyweight gain rather than milk production. The authors concluded that cows maintained in outside climates would require year-round ad libitum feeding of roughage for maintenance of satisfactory body weight, calf production, and reproduction.

Hironaka and Peters (1969) studied the energy requirements for wintering mature Hereford cows in dry lot for three consecutive winters. Cows were fed digestible energy levels approximating 100, 80, and 60% of the NRC (1963) requirement. Cow weight changes were closely related to the average temperature, wind speed, wind chill, and blizzard conditions of the three winters. All of the cows in the low energy level group and several in the medium level had to be removed from the experiment during the second and most severe winter. Cows wintered on the low level of energy had calves of equal birth weight to the higher level cows, made greater weight gains during the summer grazing period (fall weights of all cows similar) and weaned lighter calves, all findings consistent with those of Jordan et al. (1977). The compensatory intake and weight gains (at the expense of milk production) of cows restricted during winter is apparently a common phenomenon and of important management significance.

Specific affects of cold stress were examined by Webster et al. (1970). Groups of beef breed heifers were wintered at 20 C (controls),

outdoors in open-fronted sheds (sheltered) or outdoors with no shelter (exposed). Experiments were conducted at the University of Alberta. All calves were fed individually and received 2.5 kg of barley and oats plus supplement in the evening and all the chopped alfalfa hay they could consumer in 90 min in the morning. From late October through mid-March, the mean outside temperature (C) and wind velocity (m/min) was -16 and 65 C, respectively. During this period weight gains were 102, 101, and 90 kg for control, sheltered, and exposed animals, respectively.

Resting metabolic rates were determined every 6 weeks throughout the winter months with significant increases for the sheltered group only. Tissue insulation values (determined by rectal temperature, mean skin temperature, and heat production) were not different, suggesting a lack of cold-induced changes in peripheral blood flow or fat deposition sufficient to affect heat flow through the superficial tissues of the body. Total hair cover and mean coat depth of the sheltered and exposed animals was double that of the controls although new hair growth was equal. Thus, a reduced hair shedding in the outside animals is suggested. Such insulative changes resulted in the reduction of the critical temperature of calves during the prolonged cold exposure. While the control group exhibited a small gradual decrease in still air critical temperature (CT), values for the outside groups dipped sharply in response to air temperature although there was a lag or acclimation period. The CT for the exposed group fell from 2 C in October to -14 C in February.

Specific economic data were not presented but it was concluded that physiological adaptation to cold stress was sufficient to reject the need for controlled environment buildings. Considerable benefit, however, was noted in providing simple, open-fronted shelter.

Christopherson (1976) found significant effects of cold exposure on ration digestibility and also noted different responses for cattle of various ages. All cattle were identified only as beef breeds. The first experiment consisted of two rumen fistulated cows (500 kg) fed a maintenance intake of long alfalfa-brome hay. The cows were exposed to successive 4 week periods of +20 C, -11 C, and +20 C temperatures. The second trial involved beef calves (200 to 300 kg) fed 50% hay, 50% grain rations at the rate of 1 kg feed per $W_{kg}^{0.75}$. Digestibility trials were conducted simultaneously indoors (16 to 20 C) and outside (-17 to 1 C) in pens sheltered from the wind. The final trial consisted of larger (475 kg) beef steers fed the same ration and at the same rate as the beef calves. Treatments again consisted of indoor and outdoor environments.

There were no significant differences in digestibility due to cold stress in the cow experiment. It was pointed out, however, that the 4 wk exposure period may have been too short to influence digestive function. Decreased digestibilities of 0.08 and 0.21% per degree C drop in environmental temperature were noted for the steer and calf experiments. Shorter mean retention times in the rumen and lower fiber digestibility have been shown at low vs high temperature (Warren et al., 1974). As noted in a previously cited study

(Webster et al., 1970), there were small and insignificant effects of housing on resting metabolic rate.

McDonald and Bell (1958) found an increased heart rate in lactating cows during exposure to -20 C. Similar results were found in sheep by Webster (1967). Both studies would thus suggest an increased energy expenditure as a direct consequence of cold temperatures. However, considerable physiological adaptation to cold stress occurs and adapted animals will also exhibit markedly increased heart and respiration rates when exposed to warmer temperatures (Webster et al., 1970).

The possibility of cattle type variation in response to cold stress has been considered by several workers. A size relationship can be inferred from the general principles presented in the books of Kleiber (1961) and Blaxter (1962). The body temperature of most animals is amazingly constant indicating a much higher rate of metabolism per unit weight in small vs large animals, while the rate per unit size or surface area must be fairly constant. The inference is made that animals of a larger body size should be less affected by environmental temperature. The previously cited work of Christopherson (1976) tends to support this concept with a graded response to cold temperatures among cows, steers, and calves. It becomes apparent, however, that within a species, the size relationship becomes confounded with breed. The primary climate of various breeds and the selection pressures applied to them would be expected to exert an affect independent of size. Indeed, Webster and Young (1970) presented evidence indicating

that Holstein cattle were inferior in thermal insulation to beef breeds. Warren et al. (1974) found a decrease of .30 units of digestibility per degree (C) decrease in temperature for Holstein steers weighing nearly 400 kg.

The practical problem of determining the extra energy required to overcome cold stress under a wide variety of conditions has been addressed by Young (1973). A scheme was presented for estimating the critical temperature and degree of cold stress of an animal from its thermal insulation, body weight, and metabolizable energy intake. A formula for calculating thermal insulation scores was presented based on animal type (beef and dairy), age, body condition, previous cold exposure, hair coat depth, and wind velocity.

## Conception to Slaughter Analysis

Preweaning, postweaning, and overall evaluations of cattle type may yield differing results such that the type preferences of the cow-calf, feedlot, and integrated operator are not uniform (Cartwright, 1970; Thomas and Cartwright, 1971; Klosterman, 1972). However, the importance of comparing biological types of cattle from a total industry perspective (preweaning plus postweaning phases) has been discussed by Hedrick (1972). Systematic studies including all factors associated with life cycle efficiency are extremely rare due to the obvious length of time, expense, and problems with experimental design encountered.

The infinite number of cattle type and management system combinations encountered in the industry would be hopelessly difficult

to duplicate experimentally. As a result of these problems, there is an increasing amount of effort directed toward the construction of biological models to simulate combined cow-calf performance for a variety of cattle types and management strategies. Some of the work reviewed in this section will be the result of such simulations. Most of the studies involving live animal research do not consider all factors involved in total productivity but are of value for the conditions defined.

Melton et al. (1967) compared 26 Hereford and 14 Charolais cow-calf pairs. Efficiencies (total TDN/wt) to weaning and slaughter were calculated. The extra calf weight at 365 vs 210 days was more than sufficient to offset the additional feed required, suggesting an advantage for the integrated operator.

Ellison et al. (1974) found the combined 180 day feed requirements of cow and calf per unit weight of calf to be 17% less for Angus-Jersey cows (Charolais sired calves) vs straightbred Hereford cows. The advantage of Angus-Jersey cows at 365 days was 6%. There was thus a smaller difference due to breed for integrated production vs production to weaning.

Klosterman et al. (1968a) compared efficiency of production in Hereford and Charolais cattle and their crosses. One-half of all calves were creep fed and fattened immediately while one-half were not creep fed, wintered, grazed over summer, and then placed in the feedlot. Total amounts of TDN required per unit weight at weaning were 8.01 and 7.14 for the creep system to weaning and finishing weights, respectively,

and 8.70 and 7.82 for the non-creep system. In a similar vein, Boyd and Koger (1974) found biological efficiency (kg TDN for cow and calf/kg calf) greater by 2.61 units when calves were fed to 15 months vs 9 months of age. Five different straightbred and crossbred types of cows were considered in this simulated work.

Morris and Wilton (1975), utilizing their simulation model, calculated efficiency of production as kg beef sold per combined Mcal of net energy required for cow and calf. Values of 0.0628, 0.0633, 0.0632, 0.0625, and 0.0616 were presented for cows of 400, 500, 600, 700, and 800 kg, respectively. Requirements for replacement breeding females and meat sales from cull females were included in the estimates.

Long et al. (1975) reported extensive economic data from a model developed to predict the impact of cow size and herd management on profitability. Straightbred herds of small, medium, and large mature weight were compared (430, 500, and 600 kg) under dry lot and pasture conditions. Variables included nutritional costs, fixed costs, cow size, progeny growth, attrition rates, and milk yield for cows of various ages.

Systems with small cows produced more live weight and gross income but were also more expensive to operate than systems using large cows. In dry lot, systems using large cows were more profitable while small cows were favored in pasture systems.

Joandet and Cartwright (1969) compared 118 cows from birth until they were culled from the herd. Twelve breeding groups were represented with various combinations of Brahman (B) and Hereford (H)

breeding. Numerous assumptions were used to calculate production efficiency which was defined as total TDN to produce a unit of beef. Different breeding groups showed differences in growth pattern, fertility, milk production and longevity. These factors were included in the calculated efficiencies. Optimum slaughter weights varied by breeding group from 334 to 400 kg at ages from 17 to 22 months. Optimal values for cumulative TDN required per unit postnatal live body weight varied from 9.35 (BH sire x BH dam) to 11.12 (H sire x BH [$F_2$] dam).

In a similar study, Fox and Black (1976) constructed a model to consider optimal slaughter weights for calves from various types of cows. However, cattle type was defined by mature weight and not specific breed. Optimal points were described as the weight at which total net energy consumed by the cow and calf per unit edible beef were minimal. Optimal slaughter weights for steers from 400, 500, and 600 kg cows were 360, 465, and 535 kg, respectively. Slaughter weights were similar to the point at which steers would grade high good to low choice and be of yield grade 2. The influence of cow size on efficiency was small although bigger cows resulted in a greater dilution of fixed economic costs per unit edible beef for those costs not related to weight. Increases in economic and energetic efficiency were noted from crossbreeding when 500 kg straightbred and crossbred dams were compared. Increases in fertility resulted in more edible beef produced per cow maintained.

Klosterman et al. (1974), in live animal experiments, reached conclusions similar to Fox and Black (1976). When cows were divided into three weight groups there were no significant differences in efficiencies of their calves fed to constant slaughter condition.

Carpenter et al. (1971) reported a need for compromise in later-maturing cows of heavier mature weight in terms of lifetime biological productivity. Such cows tended to wean heavier calves but have lower reproductive performance (fewer calves per unit time). Conclusions were based on records of Hereford and Hereford x Brahman crossbred cows.

Partial results of a comprehensive live animal study by Klosterman (1976) are presented in Table 1. The experiment was conducted from 1968 through 1972, with different cows used each year. Total input/output data were collected for cows and calves. As indicated, breed differences were noted for all preweaning performance traits and TDN/gain and carcass grade from the feedlot phase. Overall efficiency, expressed as the percentage of metabolizable energy fed to the cow and calf which was recovered as empty body energy in the calf at slaughter, was not significantly different among the breeds. The average efficiency value was 13.4% indicating that 86.6% of the total energy consumed was used for non-productive functions. Even this value does not reflect the total inefficiencies of beef production encountered in practical situations. The data presented were only for cow-calf pairs in which both survived to the termination of the trial. Thus, feed requirements were ignored for replacement breeding animals, bulls, open cows, etc.

Table 1. Efficiency of Beef Production Among Breeds[a]

| Item | Significance | Breed of cow | | | |
|---|---|---|---|---|---|
| | | Hereford | Hereford x Angus | Hereford x Charolais | Charolais |
| No. of cows | | 34 | 34 | 32 | 33 |
| Avg. cow wt, kg | * | 466 | 457 | 472 | 483 |
| Preweaning performance | | | | | |
| Weaning wt, kg | ** | 187.3 | 210.5 | 187.3 | 202.8 |
| 24-hr milk consump., kg | ** | 6.0 | 7.3 | 4.6 | 5.7 |
| TDN/weaning wt, kg[b] | ** | 10.1 | 8.6 | 10.0 | 9.2 |
| Feedlot performance | | | | | |
| Final wt, kg | NS | 414.6 | 421.8 | 418.7 | 431.4 |
| Gain on feed, kg | NS | 227.2 | 211.8 | 231.3 | 228.6 |
| TDN/gain | * | 5.12 | 5.40 | 5.09 | 5.32 |
| Fat thickness, cm | NS | 1.47 | 1.55 | 1.24 | 1.27 |
| Carcass grade[c] | * | 19.7 | 20.0 | 19.8 | 19.2 |
| Overall performance[d] | | | | | |
| EBE/ME fed x 100 | NS | 13.1 | 13.6 | 13.2 | 13.7 |

[a]Klosterman and Parker (1976), four-year study. Means were adjusted for differences among years, age, and weight of cow and sex of calf.

[b]TDN required by the cow plus TDN consumed by the calf as creep feed ÷ weaning weight.

[c]Low choice = 19; average choice = 20.

[d]Percentage of metabolizable energy fed to the cow and calf which was recovered as energy in the empty body of the calf at slaughter.

*Significant at $P < .05$.

**Significant at $P < .01$.

Partial results of a similar trial are presented in Table 2 (Holloway et al., 1975b). Hereford, Hereford x Holstein, and Holstein cows were fed various levels of winter supplement. The experiment included range and dry lot replicates but data are presented only for the latter. Numerous breed differences were noted in lactation efficiency, efficiency to weaning, and feedlot performance. In general, lactation efficiency and weaning weight increased and feedlot efficiency decreased as the percentage Holstein breeding increased. Overall efficiency differences were rather small, however, with Holstein cows fed Very High levels of winter supplement least efficient and significantly less than Herefords fed a moderate level.

In the previously cited Michigan breeding project where four breeding groups were developed from a common source of Hereford cows, McPeake (1977) used established biological relationships, observed productivity data and various economic assumptions to predict overall profitability. All input/output factors were considered and within the economic framework defined, returns per cow unit over "out-of-pocket" costs were $41.41, 62.47, 64.41, and 69.83 for Unselected Hereford, Selected Hereford, Angus x Hereford x Charolais, and Angus x Hereford x Holstein cows.

Table 2. Efficiency of Production of 2-Year Old Hereford, Hereford x Holstein, and Holstein Cows[a]

| Item | Breed and level of winter supplement | | | | | | |
|---|---|---|---|---|---|---|---|
| | Hereford | | Crossbred | | Holstein | | |
| | Moderate | High | Moderate | High | Moderate | High | Very high |
| **Lactation efficiency** | | | | | | | |
| DE intake during lactation, Mcal | 4,555[b] | 5,061[bc] | 5,533[cd] | 5,671[d] | 6,399 | 7,067[e] | 7,418[e] |
| Total milk produced, kg | 1,132[b] | 1,159[b] | 1,980[c] | 1,993[c] | 2,390 | 2,717 | 2,804 |
| Milk GE/DE consumed by cow x 100 | 15.6[b] | 14.6[b] | 22.7[b] | 23.3[b] | 23.5[bc] | 27.2 | 25.0[c] |
| **Efficiency to weaning** | | | | | | | |
| Weaning weight, kg | 179[b] | 196[b] | 230[c] | 229[c] | 249[cd] | 253[cd] | 261[d] |
| Kg weaning weight per Mcal DE intake by cow and calf | 0.0331[bc] | 0.0328[bc] | 0.0357[c] | 0.0352[c] | 0.0334[bc] | 0.0339[bc] | 0.0310[b] |
| **Feedlot performance** | | | | | | | |
| Carcass wt, kg | 239.7[b] | 237.5[b] | 278.2[cd] | 266.3[bd] | 284.4[cde] | 307.8[ce] | 305.6[e] |
| Kg retail cuts per Mcal DE intake by calf | 0.0189[b] | 0.0190[b] | 0.0163[bc] | 0.0160[bc] | 0.0154[c] | 0.0144[c] | 0.0148[c] |
| Carcass GE, Mcal per Mcal DE intake by calf | 0.1194[b] | 0.1214[b] | 0.1023[bc] | 0.1043[bc] | 0.0930[c] | 0.0085[c] | 0.0937[c] |
| **Overall efficiency** | | | | | | | |
| Mcal carcass GE per Mcal cow and calf DE intake | 0.0743[b] | 0.0717[bc] | 0.0670[bc] | 0.0674[bc] | 0.0611[bc] | 0.0605[c] | 0.0594[c] |

[a]Holloway et al. (1975). Cows were maintained in dry lot.

[b,c,d,e]Means on the same line with the same superscript are not significantly different ($P < .05$).

## Performance of Feedlot Cattle

### Effect of Cattle Type on Nutrient Requirements and Utilization

Possible cattle type differences in ability to consume feed, digestive powers, requirements for body functions, and intrinsic efficiency are of obvious interest. The difficulties in delineating the impact of some of these factors undoubtedly contribute to the small number of reports found in the literature. Reid (1962) concluded that animals differ mainly in the amount of feed they will consume and in the level of feed intake at which they form appreciable body fat. He found little animal variation in digestive powers and the efficiency with which ME consumed above maintenance is utilized. Thus, selection to improve efficiency should stress the former factors.

The question of differing requirements for cattle of different size and weight but similar composition was addressed by Klosterman and Parker (1976). Weanling heifer calves (212 head) sired by Angus, Charolais, Jersey, and Brown Swiss bulls and out of Angus or Charolais dams were used in the 3-year study. One-half of each breed type (8 combinations) was fed at either 1.5 or 2.0 times their maintenance requirement where TDN for maintenance (kg) equals $0.030\ W_{kg}^{.75}$. The trial was continued for 210 days with rations adjusted based on bodyweights obtained every 14 days. Although initial weights and thus amounts of feed fed were significantly different among the various breed types, there were no significant differences among them in rate of gain. No significant interactions among breed types

and levels of feeding were noted in rate or efficiency of gain. Accurate measures of body composition were not made in this study. The authors speculated, however, that the larger type heifers were not expected to be, and did not appear to be, fatter at weaning. It was concluded that little justification existed for different energy requirements for gain of calves of different types.

Stonaker et al. (1952) compared the body size, gain, and efficiency of gain of large, intermediate, and comprest Hereford females wintered on hay. Highly significant differences were found for wither height measurements, average weight maintained, feed eaten daily, and daily gains. However, there were no differences in feed consumed per day per 1,000 lb of animal maintained or feed/gain.

Since the pathways of intermediate metabolism for converting nutrients into lipid are probably very similar in all species of homoetherms and must be identical for individuals of the same species, the energy costs of fat deposition may be considered constant. The data of Garrett (1971), however, indicates at least the possibility that the efficiency of energy use for fat deposition may differ among cattle of markedly different selection histories.

Garrett (1971) compared the net efficiency of energy utilization for maintenance and energy gained by Holstein and Hereford steers in two trials. Voluntary intake per unit metabolic body size was higher for Holsteins in both trials. Maintenance requirements were 5 and 12% higher in Holstein steers for the two trials. In trial 1, production per kg of feed consumed above maintenance was 24 g of protein and 115 g

of fat for Hereford vs 24 g of protein and 86 g of fat for Holsteins. Similar values for trial 2 were 30 g and 100 g for Herefords and 30 g and 87 g for Holsteins. The author cited his findings and evidence of other workers indicating similar energy costs for protein and fat deposition in a ruminant animal simultaneously synthesizing both. Thus, it was hypothesized that differences in energetic efficiency represented a true breed effect. The author did not attempt to identify, however, "the specific location in the complex scheme of energy metabolism at which the additional energy consumed by the Holsteins was wasted or lost."

Blaxter and Wainman (1966) determined the fasting metabolism of seven Ayrshire, two Ayrshire x Beef Shorthorn cross and eight Angus steers. Determinations were conducted at numerous times during growth on various animals. Ages during the experimental period ranged from 0.3 to 3.7 years and weights from 63 to 594 kg. Two Ayrshire steers were considerably younger and lighter in weight than the remaining cattle, thus data were summarized for cattle weighing over 300 kg. Mean fasting heat production for these animals were 90.4, 96.3, and 81.0 kcal/$W_{kg}^{.73}$ for Ayrshire, Ayrshire crossbred and Angus steers, respectively. Values for both Ayrshire groups were significantly higher than for the Angus steers. The proportion of the total energy loss from the body which arose from protein oxidation averaged 24.5% and did not differ by breed.

Hashizume et al. (1963) conducted a series of 3 balance trials with 12 Japanese Black and 18 Holstein non-pregnant dry cows. Rations

in different trials were various combinations of timothy hay, wild grass hay, rice bran, straw, and a concentrate mixture. Balance trials and heat production were determined during periods of fasting and feeding. Fasting heat production when lying was 51.5 and 73.1 kcal/$W_{kg}^{.75}$ for Japanese Black and Holstein cows, respectively. Heat production values during feeding were 89 to 108 in Japanese Black and 107 to 130 kcal/$W_{kg}^{.75}$ in Holstein cows. Calculated ME values for maintenance were 96 and 116 kcal/$W_{kg}^{.75}$ in Japanese Black and Holstein cows, respectively.

Vercoe (1970) compared the fasting metabolism of Brahman, Africander, and Hereford x Shorthorn cattle (nine animals each). All animals were bulls except one Africander and three crossbreds which were steers. Three animals per breed were used in each of 3 years with mean ages of 22, 20, and 13 months (by year). Fasting metabolism values (kcal/$W_{kg}^{.75}$) were 86.4, 102.5, and 97.4 for the Brahman, Africander, and crossbred steers, respectively. These findings were generally higher than similar values obtained by Blaxter and Wainman (1966) with steers. Several explanations were advanced for the higher estimates, the most likely thought to be the effect of intact bulls vs steers. It was stressed that a lower fasting metabolism of the Brahman cattle indicated either a lower requirement for energy to carry out the functions of basal metabolism (functions fewer or slower), or, assuming similar requirements, a more efficient use of the energy released by the biochemical processes occurring at basal conditions (less appears as heat). The second explanation was thought to be more likely. The lower heat production as an aid to thermal equilibrium in a hot environment was discussed.

In the previously cited review by Reid (1962), it was pointed out that considerable animal variation existed for the ability to consume feed and that selection for this trait would be of value. Several heritability estimates published in the literature tend to support this conclusion:

| Heritability estimate | Reference | Details |
|---|---|---|
| 0.43 | Brown and Gacula, 1964 | 201 British breed bull calves |
| 0.64 | Koch et al, 1963 | 1,324 British bull and heifer calves |
| 0.07-0.77 | Swiger et al., 1961 | 1,011 British breed bull and heifer calves |
| 0.64 | Swiger et al., 1965 | 480 British breeds and their crosses |

Bogart and England (1971) studied 290 British breed calves (bulls and heifers) of varying lines (three Hereford lines, one Angus line), years (6), and degrees of inbreeding (4 bulls from 0 to 21%+). All calves were individually fed ad libitum to a constant final bodyweight. Calves were weighed weekly and bedded with shavings. Conclusions were: (a) Heifer intakes per unit bodyweight were as high as those for bulls; (b) Lines differed in daily gain, feed consumption, and feed/gain; (c) Much of the variation in feed required per unit gain was accounted for by variations in daily gain and daily feed consumed; and (d) variation in feed intake was partly under genetic control with a heritability estimate of $0.38 \pm .15$.

In most experiments, little difference in digestive powers has been noted among cattle of varying breeds and types. Washburn

et al. (1948) found no differences in DM digestibility of a mixed ration between compact and conventional Shorthorn steers. However, Ashton (1962) found that steers of Zebu background (Bos indicus) had significantly higher dry matter and apparent nitrogen digestibilities than steers of the Bos taurus species. Brahman, Hereford, and crosses of Brahman and Africander with Shorthorns and Herefords were compared on hay diets. Dry matter digestibilities were 56.0 and 53.3% for Brahman and Herefords, respectively. French (1940) observed a trend for greater digestibility in Zebu vs Zebu-Ayrshire cattle but differences were not significant.

Hungate et al. (1960) found that the rumen fermentation rate per unit solids was greater in four Zebu vs four "mixed-breed European" cattle. A similar follow-up study was reported by Phillips et al. (1960). Mean reticulo-rumen retention times (hr), dry matter digestibilities (%), and fermentation rates (μ moles/g/hr) were: 37.3, 65, 145 and 34, 68, and 171 for European and Zebu cattle types, respectively.

Karue et al. (1972) compared Boran (a breed of Zebu type) and Hereford (75%) x Boran crossbred steers in a digestibility and nitrogen metabolism study. Trial 1 consisted of a low protein hay supplemented with vitamins and minerals. Coefficients of digestibility for DM, energy, and nitrogen were similar and not different although Boran steers consumed 23% more dry matter. Urinary nitrogen was significantly higher in the Boran steers. In trial 2 the low protein hay was supplemented with urea or cottonseed meal. Again,

coefficients of digestibility were similar and not different. Nitrogen retention was similar among breeds and differed only for supplemental nitrogen source.

Howes et al. (1963) compared the digestibility of a variety of feeds in Hereford and Brahman females. Pooled across rations, dry matter and crude protein digestibilities for Brahman vs Hereford were 63 vs 61% and 50 vs 46%, respectively, although only the latter was significantly different. Moran and Vercoe (1972) reviewed a total of 107 digestibility trials comparing various Zebu and British breeds. They concluded that Zebus had lower metabolic fecal nitrogen and slightly higher true nitrogen digestibility than British breeds although differences were small.

Reid (1962) concluded that the among-animal, within-feed variation in digestibility was so small that genetic improvement could not be expected in a reasonable period of time, even if the trait were heritable.

Feed conversion (feed/gain), at a given stage of growth, is influenced by daily energy intake, energy requirements, and the efficiency of energy utilization. Because these factors interact in the feed/gain observed, interpretation of differences due to cattle type are difficult to make under comparable conditions. Further, little work has been done to delineate the impact of component parts of feed/gain among cattle types.

Many comparisons of British and exotic breeds have shown more efficient live-weight gains for the latter in time constant trials

(National Academy of Science, 1975). Invariably, however, the larger type exotic cattle were leaner prohibiting examination of a true cattle type effect. Similar results were obtained in a comparison of British and Holstein steers (Bond et al., 1972). Two studies comparing British and Charolais steers to equal finish found no difference in feed efficiency (Klosterman et al., 1968a; Brungardt, 1972).

Cundiff (1970) reported that heterosis for feed conversion was small and not significant. However, reasonably high heritability estimates have been reported in within-breed studies (Koch et al., 1963). In most cases, it is unclear, however, whether animals were compared at similar finish since carcass fat was not measured. Such heritabilities would have been overestimated if the more efficient animals were those that had gained faster but were killed at an earlier stage of growth. In addition, animals were fed ad libitum in most trials, making it difficult to establish whether faster gaining animals simply consumed more energy above maintenance or were actually more efficient in conversion of ingested nutrients to body weight gain. However, from an economic point of view, it makes little difference which component of feed/gain is contributing to the increases observed.

## Impact of Cattle Type on Growth and Fattening Potential

In understanding observed differences in quantity and type of growth among various cattle types, it is useful to review some of the basic differences encountered at the tissue and perhaps even cellular level. Studies relating these basic differences to types, strains, or

breeds of animals are unquestionably more numerous for rodents and pigs than for cattle. However, several examples can be found for the bovine specie and are briefly reviewed in this section.

It is generally agreed that muscle cell hyperplasia is completed during fetal growth in meat animals (Joubert, 1956). Therefore, postnatal muscle growth is primarily the result of hypertrophy or increases in the size of the muscle fiber through synthesis of new protein.

Normally, the maximum adult size of various cattle types is fixed at birth since differences in size between breeds within a species are due to differences in muscle cell number, not cell size (Hedrick, 1968). As pointed out subsequently, however, differences in cell size are noted in double muscled _vs_ normal cattle. The greater accretion of lean tissue mass by large _vs_ small type cattle is thus normally due to a greater number of muscle cells rather than increases in nucleic acids or efficiency of protein synthesis at the cellular level. While few studies have actually compared cattle type differences in ability to synthesize protein (cellular level), Ashmore and Robinson (1969) found similar muscle protein/DNA and RNA/DNA ratios in "double muscled" _vs_ normal genotype cattle.

Allen _et al_. (1974) stressed the importance of examining changes in fiber type as well as size in assessing postnatal muscle growth. Genetic differences in proportions of anaerobic (white) and aerobic (red) fibers exist and relate to patterns of development, muscling, and meat quality, although cattle type comparisons have primarily involved double muscled _vs_ normal cattle (Holmes and Ashmore,

1972; West, 1974). Anaerobic fibers apparently reach full growth potential later in life or at heavier body weights and delay the onset of the "fattening phase." Thus, from a fixed number of fibers, a larger muscle mass can be produced with a higher proportion of anaerobic fibers (Allen et al., 1974). Holmes and Ashmore (1972) found a higher conversion of aerobic to anaerobic fibers in double muscled vs normal cattle. Anaerobic fibers were also larger than aerobic, reaching a greater final diameter. The significance of these observations in normal large vs small type cattle has not been fully investigated.

Guenther (1974) compared eight Angus and eight Charolais steers in a physiological maturity evaluation of the two breeds. Calves within breeds were from the same sire, were similar in age and were placed in the feedlot and fed a "standard finishing ration." Various body size measures, weights, and muscle biopsy samples were taken every 56 days for 8 consecutive sampling periods. Body weight and size measures were generally greater in the Charolais cattle for most periods. However, the Angus calves were greater in muscle fiber diameter for all periods reflecting an earlier maturation in fiber diameter.

Numerous workers have examined type variations in fat deposition. Examples for the existence of genetic variation in composition and total quantity of lipids deposited include: (a) ruminants capable of hydrogenating dietary fats while monogastrics cannot; (b) double-muscled cattle which do not deposit fat as readily as those not exhibiting this trait; (c) breeds of sheep which accumulate greater

quantities of fat over the rump; and (d) lean and fat strains of pigs (Allen et al., 1976).

Comparison of carcass characteristics among various cattle types will be more fully discussed in a subsequent section. However, basic differences in fat distribution among cattle types are noted here. Callow (1962) reported greater differences in percentage of fat in tissues of wholesale cuts attributable to breed than to nutritional level. In general, the dairy breeds appeared to have a higher proportion of kidney and pelvic fat and a smaller proportion of subcutaneous fat than beef breeds.

Callow (1961) compared the carcass characteristics of Hereford, Shorthorn, and Friesian steers. Friesians had the highest proportion of fat in the body cavity and the lowest proportion in the subcutaneous depot. This pattern was reversed in the Hereford steers and intermediate in the Shorthorns.

Cramer and Allen (1976) studied adipocyte development in the subcutaneous fat depots of Angus, Hereford, and Holstein calves from 36 to 538 days of age. Adipocyte diameter and volume were similar for all breeds. However, at the conclusion of the experiment, 12th rib fat thickness was 0.76 cm in Holstein and 1.55 cm in the Angus and Hereford breeds. Thus, the Holsteins apparently had fewer numbers of subcutaneous adipocytes since cell sizes were similar. Hood and Allen (1973), however, reported fewer and smaller sized adipocytes in Holstein vs Hereford x Angus steers.

Biochemical evidence for cattle type differences in propensity to fatten exist, although results are variable. Acetyl-CoA carboxylase (CBX) appears to be the key regulatory enzyme in fatty acid synthesis in ruminants (Pothoven and Beitz, 1975). Chakrabarty and Romans (1972) found greater CBX activity per cell in the adipose tissues of beef vs dairy breed steers. Both types had higher activities in subcutaneous vs intramuscular adipose, a result also noted in sheep by Parr (1973). Hood and Allen (1975) found higher CBX activity in the perirenal adipose tissue of 475 kg Holstien steers than in subcutaneous tissue. Similar activities were found in the two sites in Hereford x Angus steers of the same weight.

Martin and Wilson (1974) determined activities of several lipogenic enzymes necessary for NADPH generation in five Hereford and seven Holstein steers. Steers were fed a 66% TDN diet ad libitum from weaning to slaughter. Age and weight at slaughter was 397 and 357 days and 383 and 394 kg for Hereford and Holstein steers, respectively. Liver, brisket subcutaneous adipose, and perirenal adipose tissue samples were obtained at slaughter. Mean fat thickness between the 12th and 13th rib was 1.95 and 0.64 cm for Herefords and Holsteins, respectively. Overall, steers with greater adipose glucose 6-PO4 dehydrogenase (G6PD) and 6-phosphogluconate dehydrogenase (6PGD) levels gained at a slower rate and were fatter. Herefords were higher in subcutaneous 6PGD and perirenal adipose 6PGD and isocitrate dehydrogenase. There were high negative correlations between these two enzymes and average daily gains. Similar observations on these enzymes

were reported by Hood and Allen (1975) in a comparison of Holstein and Angus x Hereford steers.

## Growth and Carcass Characteristics of Feedlot Heifers

The analogy between performance differences due to sex and those due to frame size was discussed by Klosterman and Parker (1976). In support of this concept, the simulation model of Fox and Black (1977) predicts similar nutrient requirements, feed intake, and daily gains for small frame steers and average frame heifers (both expected to grade choice at 363-400 kg). Thus, differences in performance between steers and heifers are largely associated with physiological age or body composition and not sex per se. Klosterman and Parker (1976) concluded from a summary of their work that differences in maintenance requirements among sizes, breeds, and sexes of cattle were relatively small. Bogart and England (1971) found similar intakes per unit body weight for heifers and bulls in a study of 290 British breed calves.

Bose et al. (1970) studied the comparative efficiency of Hereford bulls (10), steers (9), and heifers (11). Several nutritional treatments per sex were imposed, involving a low and high energy ration. Pooled results for average daily gains were 2.36, 1.70, and 1.55 and feed/gain values were 6.4, 8.4, and 9.2 for bulls, steers, and heifers, respectively. Initial and final body composition of steers and heifers was essentially the same. $NE_m$ and $NE_g$ values of the rations were (Mcal/kg) 1.53, 1.14 and 1.51, 1.03 for steers and heifers, respectively.

Newland (1976) compared Angus steer and heifer calves finished to choice grade on either corn silage or whole shelled corn, each balanced with protein and minerals. Days on feed required to reach choice grade were 210 for steers and 183 for heifers fed all silage with gains of 2.25 and 1.90 lb per day, respectively. Similar values for the all concentrate ration were 154 days each and daily gains of 2.86 and 2.41 lb for steers and heifers, respectively. Feed/gain data were not available as steers and heifers were fed together.

Ritchie et al. (1977) found that when all heifers from a herd were compared to their steer mates, feed/gain values favored the heifers when both were compared at similar final composition. However, as noted by others (Klosterman and Parker, 1976; Cooper et al., 1972) heifers apparently had to be somewhat fatter than steers to achieve the same quality grade.

Performance data for time-constant trials was presented by Wilson et al. (1969). Data were collected from 80 steers and 94 heifers born from 1963 to 1966. Calves were the progeny of 11 different Polled Hereford bulls and $F_1$ Angus-Holstein cows. All calves were weaned at an average age of 300 days and received an ad libitum grain ration on pasture until mid-November when all calves were confined and fed 2.7 kg hay daily plus ad libitum grain. Mean values over years for steer and heifer 205 day adjusted weaning weights (kg), weight/day (kg), slaughter weight (kg), and slaughter age were 248.8, 222.9; 0.97, 0.89; 435.1, 409.8; and 447.1, 448.1, respectively. Sire x sex interactions were not important for carcass traits and were significant for 205-day weight only.

Klosterman and Parker (1976) examined the effect of sex on the net energy value of corn silage and ground ear corn when fed separately or in combination to choice quality Hereford steer and heifer calves. Steers were slaughtered at approximately 454 kg and heifers at 386 kg. The experiment was conducted in each of 2 years with 14 heifers and 14 steers assigned to the corn silage, corn silage plus corn grain, and corn grain rations. Heifers were consistently fatter than steers and consumed more dry matter per unit weight on all treatments. There was, however, very little difference in amount of dry matter required per unit gain.

Averaged over 2 years, net energy values of the rations (maintenance plus gain, Mcal/100 lb DM) for steers and heifers were: corn silage, 62.7, 73.3; corn silage plus corn grain, 69.0, 72.0; and corn grain, 71.8, 70.6. Thus, the net energy value of the corn silage ration averaged 16% higher when fed to heifers than when fed to steers. Since this difference was not observed with the other rations, it was concluded that heifers were especially adapted to a high silage program. The advantage of greater efficiency of energy conversion in heifers was questioned, however, since it appeared they had to be fed to a higher body fat content to reach the same quality grade as steers.

Bradley et al. (1966) analyzed the records of 34 Hereford and 33 Hereford-Red Poll steer and heifer calves born in two years. Calves were the progeny of two Hereford bulls, one selected for high rate of gain and efficient feed conversion (1.33 kg daily and 5.63 feed/gain) and the other for poor rate of gain and feed conversion (1.01 kg daily

and 8.28 feed/gain). One-half of the Hereford and Red Poll cows were bred to each bull. All calves were individually fed a 70% TDN, 9% digestible protein ration for 208 days (both years). Main effects of sex, sire, and breed of dam were considered since sex x sire, sex x breed of dam, and sire x breed of dam interactions were not significant. Weaning weights were adjusted to a 275 day basis. An asterisk denotes significant difference for the main effect in question.

| | Sex | | Sire | | Breed of dam | |
|---|---|---|---|---|---|---|
| Trait | Steers | Heifers | High gain | Low gain | Hereford | Red Poll |
| Preweaning ADG, kg | 0.86* | 0.80 | 0.85* | 0.81 | 0.75 | 0.91* |
| Weaning wt, kg | 269* | 252 | 267* | 254 | 237 | 284* |
| Postweaning ADG, kg | 1.01* | 0.86 | 0.99* | 0.88 | 0.95 | 0.92 |
| Final wt, kg | 479* | 431 | 473* | 436 | 434 | 475* |

A sire x sex interaction was noted in feed conversion with heifer calves sired by the high-gaining sire significantly superior to those sired by the low-gaining sire while no difference was observed in steer progeny. Rib eye area as a ratio to carcass weight was not different between steers and heifers.

Bruin et al. (1977) compared the performance of yearling Hereford heifers (319 kg initially) receiving Synovex-H (S), MGA (M), and Rumensin (R) in various combinations. All heifers were fed rations composed of 4.38 lb of corn silage dry matter, 0.91 lb supplement dry matter, and a full-feed of high moisture corn. Daily gains were

improved by S (2.84 vs 3.03 lb) and M (2.85 vs 3.02) but not by R (2.98 vs 2.89). The combination of S and R improved daily gains while R without S lowered gains. Daily intakes were predictably lowered by R but not S or M. Feed/gain was improved by S (6.28 vs 5.89), M (6.24 vs 5.92), and R (6.16 vs 6.01). Returns per head ($) for the various treatment combinations were: control (no additives) 21.93; R 13.72; M 23.49; M+R 21.08; S 17.59; S+R 21.97; S+M 23.90; S+M+R 27.12. Carcass characteristics were adjusted to similar hot carcass weight and were not appreciably influenced by treatment.

Ayala (1974) compared individually fed Holstein and Angus bulls, steers, and heifers. Approximately one-half of the animals in each sex-breed group were fed ad libitum and one-half were fed at 70% ad libitum. A pelleted ration of ground corn, soybean meal, alfalfa meal, and oat hulls was fed. One or two bull(s), steer(s), and heifer(s) per breed-intake level was slaughtered at 63, 140, and 224 days on trial. Four bulls and heifers per breed were killed initially. Results were summarized for three feeding periods: 0 to 63 days, 63 to 140 days, and 140 to 224 days. In 8 of 12 cases, steers gained more weight (2.3 to 25.6%) and were more efficient (2.6 to 23.2%) than heifers. The trends were more consistent at the ad libitum level of intake and during 0 to 63 days of growth.

Simpfendorfer (1974) compared Angus and Holstein bulls, steers, and heifers in body composition studies. Rates of increase in water, protein, and ash relative to increases in empty body weight were significantly higher in bulls than in heifers within both breeds.

Rates of fat accretion were higher in heifers vs bulls. Holstein heifers gained water, protein, and ash more rapidly, but gained fat and energy less rapidly per unit change in empty body weight than did Angus heifers.

Preston et al. (1963) compared the feedlot performance and carcass merit of 17 Friesian steers (FS), 25 crossbred Angus steers (AS), and 33 crossbred Angus heifers (AH). Dams of crossbred calves were either Ayrshires or Friesians. All calves were placed on experiment at 84 days of age and were fed a complete ground diet (one-third roughage) ad libitum. Heifers were slaughtered at 350 kg and steers at 400 kg. Initial weights were similar and days required to reach slaughter weight were 344, 356, and 354 for FS, AS, and AH groups, respectively. Feed conversion efficiency values (as 100 x gain/starch equivalent intake) were 25.6, 24.5, and 23.4 and fat content of the 10th rib (%) was 22.5, 31.2, and 36.5% for FS, AS, and AH groups, respectively. Overall "carcass quality scores" were computed for the three groups based on several chemical analyses and subjective scores of conformation, marbling, color, and firmness. Overall scores were 58, 67, and 68, respectively.

Cooper et al. (1972) compared 161 Hereford steers and 162 heifers in a 2-year study. Data were adjusted (within sex and year) by regression techniques to a carcass grade of low choice. Rations (dry matter basis) for all cattle were approximately 35% alfalfa haylage, 14% corn silage, and the remainder barley and supplement. Final weights, average daily gains, days of feeding to reach equal

grade, feed/gain, and feed cost/100 lb gain for steers and heifers were 1,038, 909 lb; 2.39, 2.02 lb; 211, 200 days; 7.45, 8.29, and $13.30, 15.14, respectively. All differences were significant at $P < .01$.

When adjusted to equal grade, heifers were fatter than steers (1.60 vs 1.78 cm), an observation also noted by Klosterman and Parker (1976). Final carcass weight, rib eye area, yield grade, and dressing percentage for steers and heifers were 290, 256 kg; 73.5, 64.5 sq cm; 3.48, 3.79; and 61.52, 63.03%, respectively.

Based on these results, extensive economic data were presented to predict the price which could be paid for feeder heifers relative to steers given various market prices. If one lot of cattle were fed per year and the lot contained equal numbers of either steers or heifers, feeder price differentials were $3.00 to $9.00 depending on the various price relationships considered.

Klosterman et al. (1968a) compared 212 Hereford, Charolais, and Hereford x Charolais steer and heifer calves under two systems of management (3 years). A portion of the calves of each breed were creep fed, fattened in dry lot, and slaughtered at 12 to 14 months of age (creep system). The remaining calves were not creep fed, wintered, grazed, fattened in dry lot, and slaughtered at 18 to 20 months of age (deferred system). Feedlot gains (lb) for steers and heifers on the creep and deferred systems were 2.24, 1.93 and 2.57, 2.41, respectively. Age of slaughter (days) was 435, 433 and 605, 607 for steers and heifers on the two systems. Carcass grades were similar between

sexes and averaged high good for creep and average good for the deferred system cattle. Sex x management system interactions were noted for rib eye area, fat trim, % edible portion, edible portion produced daily, and carcass length. In all cases differences between heifers and steers became smaller with increased age at slaughter (deferred system). There was a smaller decrease in edible portion produced daily with increasing age for heifers vs steers. Thus, heifers appeared to be more suitable than steers for deferred systems of management.

Feedlot data from previous years, where breeds and systems of management were the same but complete cutout data were not available, were pooled with the above results to give 6 years performance data (n = 281). All cattle were fed ground ear corn, soybean meal, and hay. Results by management system and breed were as follows:

| | Hereford | | Charolais | | Crossbred | |
|---|---|---|---|---|---|---|
| | Steers | Heifers | Steers | Heifers | Steers | Heifers |
| Creep system: | | | | | | |
| Final wt, lb | 838 | 797 | 1,037 | 955 | 1,022 | 891 |
| Daily gain, lb | 2.05 | 1.82 | 2.27 | 2.04 | 2.28 | 2.05 |
| Daily intake, lb | 15.9 | 15.8 | 19.0 | 18.0 | 19.1 | 16.9 |
| TDN/gain | 5.32 | 6.18 | 5.61 | 6.32 | 5.47 | 5.92 |
| Deferred system: | | | | | | |
| Final wt, lb | 978 | 949 | 1,175 | 1,073 | 1,114 | 1,037 |
| Daily gain, lb | 2.54 | 2.30 | 2.67 | 2.44 | 2.60 | 2.30 |
| Daily intake, lb | 21.7 | 21.1 | 23.6 | 23.5 | 23.7 | 22.5 |
| TDN/gain | 6.31 | 6.39 | 6.55 | 6.93 | 6.62 | 6.93 |

Hedrick et al. (1969) compared the feedlot performance and carcass characteristics of half-sib Hereford bulls, steers, and heifers. In one trial, cattle were fed a ground mixed ration (75% ear corn) ad libitum. One-half of each sex group was slaughtered when individual animals attained a live weight of approximately 400 kg (early kill) and the other half at 500 kg (late kill). Steers were 10 days younger in age at slaughter and were fed for approximately 20 days less in the feedlot. Combining kill groups, there were no differences in total gain, slaughter weight, or TDN/kg gain. The latter values were 6.08 and 6.30 for steers and heifers, respectively.

Combined over kill groups, analysis of the carcass characteristics data indicated significantly higher values for heifers vs steers in marbling score, fat thickness, percent fat trim, and ether extract in the longissimus muscle. Higher values for steers were found for percent retail yield and percent bone.

Lasley et al. (1971) compared the carcass quality characteristicsl of heifer calves of the Angus, Charolais, and Hereford breeds and their reciprocal single crosses to determine the amount of heterosis in the various traits. Data included 112 short-fed (approximately 190 days) and 106 long fed (approximately 260 days) heifers produced in the 3 years 1965, 1966, and 1967. The first calf crop was full-fed a 91% ground ear corn ration (remainder soybean meal) while calf crops 2 and 3 were fed 75% cracked corn, 15% grass hay, and 10% supplement. Heterosis effects were negligible among the various measures of carcass quality examined (carcass conformation, marbling, WB shear, quality

grade). Bull breed by cow breed interactions were significant for carcass conformation grade for short-fed heifers. The Angus x Charolais combination was superior to all other combinations in measures of carcass quality. The level of mean differences among reciprocal crosses indicated that the Charolais breed was preferable to Angus when used as the male parent. The authors thus concluded that for improvement in carcass traits it would be desirable to use Charolais sires on Angus dams and full-feed the crossbred heifer for about 6 months.

Jain et al. (1971) also reported the growth traits of heifers in the experiment previously described (Lasley et al., 1971). Breed of bull, breed of cow, and year effects existed for most of the traits considered (initial wt on full feed, feedlot average daily gain, slaughter wt, daily live wt gain, daily carcass wt gain). Interactions of breed of bull with breed of cow were highly significant for short-fed heifers. There were no significant heterosis effects in the case of long-fed heifers. Short-fed crossbred heifers were superior to straightbreds by 7 to 8% for nearly all traits. It was concluded that full utilization of heterosis would occur by placing heifers on full feed for a period of about 6 months. Comparisons of various crosses indicated the most improvement in growth would be realized with Charolais sires and Hereford dams.

It is well known that, when of comparable quality, heifers fatten at lighter weights than steers although the influence of sex on muscle to bone ratios at various stages of growth is uncertain

(Berg and Butterfield, 1968). Cahill (1964), however, quoted several studies showing a higher boneless beef to bone ratio in heifers than in steers. He thus concluded that careful marketing management of heifers might increase the relative value of their carcasses.

Suess et al. (1966) obtained palatability and quantitative carcass data on 88 Angus steer and heifer progeny from four herds representing eight sire groups. Calves were obtained at weaning and fed ad libitum a ration approaching 3:1 grain to roughage ratio. Animals were placed on test simultaneously in each of 2 years and an equal number of steers and heifers slaughtered at 386, 424, and 455 kg. There were no significant differences in percentage retail yield between steers and heifers. Significant interactions involving sex, weight group, or sire indicated that maximizing retail yield involved considerations other than the main effect of these factors. Palatability (taste panel) was not influenced by sex or weight group but interactions involving sex, weight group, or sire were significant for carcass grade. Extended feeding to increase live weight from 386 to 455 kg increased weight of retail yield with no significant change in carcass grade, marbling, or palatability.

Breidenstein et al. (1963) compared the carcass characteristics of 78 steer and 93 heifer carcasses "selected in a packing plant to be similar in characteristics presumed to be associated with retail yield." External fat was removed to an average thickness of 0.3 in and internal fat was removed as completely as possible. Bone was also removed from nearly all cuts. Means observed for steers and heifers were as follows:

Side wt (lb) 278.7, 281.2; fat thickness at 12th rib (cm) 1.34, 1.45; kidney and pelvic fat (lb) 7.87, 9.28; rib eye area (sq in) 10.94, 11.34; quality grade (19 = low choice) 19.1, 19.7; total retail product (% of side wt) 62.86, 59.95. Significant differences were noted for side wt, kidney and pelvic fat, rib-eye area, quality grade and retail yield.

Garrett and Hinman (1971) analyzed the fat content of trimmed beef muscles taken from four retail cuts. There were 36 choice and 36 good carcasses examined. Of the choice carcasses, two steers and two heifers were included in each of the yield grades 2, 3, and 4 for each of the marbling scores small, modest, and moderate. The design was identical for carcasses grading good except marbling scores were trace, slight, and small.

The amount of fat of all samples was related to quality grade, marbling score, and sex and to a lesser extent to yield grade. Comparable cuts from heifer carcasses generally averaged 0.5 to 1% higher in ether extract when compared to steer carcasses of the same quality and yield grade. Heifer carcasses were fatter based on gross carcass composition and contained more kidney fat than steers.

## Influence of Cattle Type and Ration Energy Level on Feedlot Performance and Carcass Characteristics

A consistent observation of essentially all comparative feeding trials is an increased rate of gain as energy density of the diet increases, assuming adequate protein supplementation (for example,

Jesse et al., 1976b; Prior et al., 1977). When fed various rations cattle are thought to regulate feed intake in order to maintain constant energy intake at some "set point" (Montgomery and Baumgardt, 1965). Thus, the energy density of a ration will reach a point above which energy intake is not increased. In practical terms, the levels of corn in corn-corn silage rations above which performance does not improve have been reported as 70 to 80% (Jesse, 1976a; 1976b; Fox, 1977). Thus, emphasis in this section will be placed on the effects of energy level and cattle type on the composition and efficiency of gain rather than studies reporting only gain data for cattle of a single type fed various levels of energy.

Though commonly overlooked, the importance of comparing cattle at proper endpoints is not a new concept. The impact of body size and body composition differences on efficiency of feed utilization in time or weight constant trials was recognized and discussed by Stonaker et al. (1952), Knapp and Baker (1944), and Guilbert and Gregory (1944, 1952). Even earlier, Kleiber (1936) stated that total efficiency of energy utilization was essentially independent of body size.

Smith (1975) provided data relating cattle type to feed efficiency when trials were evaluated on the basis of constant age, weight, or body composition (5% fat in longissimus muscle). A wide variety of cattle types were represented in the studies and the marked effect of trial endpoint on ranking of the breeds for feed efficiency (TDN/gain) was illustrated.

In the absence of reliable feed intake data, attempts have been made to find a proxy for feed efficiency based on some measure of growth. Average daily gain has been used but, as indicated above, is largely inappropriate for animals of varying size (Kleiber, 1936). Smith (1975) proposed the use of "relative growth rate," defined as average daily gain divided by the mean body weight during the feeding period. However, it was clear from the data presented that the relationship between relative growth rate and TDN/gain was not high when various types of cattle were compared at 5% longissimus fat ($r = 0.44$). However, within a breed or type the relationship would likely be higher. Klosterman and Parker (1976) found that "rate of maturity" (wt per day of age/slaughter wt at low choice, or more simply, 1/age at slaughter) was related to TDN required during the postweaning period ($r = -0.63$).

Hedrick (1972) pointed out an early study (Watson, 1943) where "optimality" was based on various measures of product produced. Optimal slaughter weight of full-fed steers on the basis of edible protein per unit protein intake was at 336 kg live weight (22% carcass fat). When evaluated energetically, a 680 kg weight was most efficient (carcass fat 35%). When both protein and fat were considered in relation to consumer preference, a 460 kg animal was superior (carcass fat 24%).

Not all studies reviewed in this section compared cattle types at comparable endpoints. However, the conditions under which various trials were conducted will be pointed out where possible. Although reference is made to the older literature, more recent studies will be stressed since they more adequately represent the cattle types presently fed in practice.

While "compact" and "comprest" cattle were preferred during the 1950's and early 60's, research during that time clearly indicated the superior gain ability of larger framed cattle (Stanley and McCall, 1945; Stonaker et al., 1952; Knox and Koger, 1946). It was also shown, however, that the increased rate of gain did not imply increased efficiency of feed conversion (Stonaker et al., 1952). Many of the more recent studies reviewed subsequently have supported these early observations.

Kauffman (1977) studied the relationship of muscle shape to feed efficiency in a comparative slaughter trial. Forty-eight steers were classified subjectively for degree of muscling (angular to bulging). Test animals were of Angus, Brown Swiss, Charolais, Holstein, and Longhorn breeding, with four "double-muscled" cattle included. At constant empty body weight or constant fat, muscling (shape) did not significantly effect the conversion of feed to fat-free muscle. However, muscular animals were leaner and more efficient at a given chronological age.

Brown et al. (1973, 1974) evaluated the relationships among preweaning measures of size and shape and postweaning performance of Hereford and Angus bulls. They concluded that final weight, total gain, and feed consumption were more predictable from shape and overall size than feed conversion. The simulation model of Fox and Black (1977) is in general agreement with these conclusions as differential intakes and rates of gain are predicted for cattle of varying frame size while feed conversion is constant.

Thomas and Cartwright (1971) compared Angus-Jersey (AJ), Charolais (C), and Hereford (H) calves in the feedlot. Feed conversion values were 8.1 (H), 8.6 (C), and 8.8 (AJ) although the results were difficult to evaluate since the trial was conducted on a time-constant basis. Cow-calf data (kg total feed/kg calf weaning wt) favored AJ over H over C.

Ellersieck et al. (1977) utilized records of 450 steers (6 years) of the Angus, Charolais, and Hereford breeds (and all reciprocal crosses) to determine the effects of heterosis on feed/gain. Two management systems were used in feeding out the steers. Steers in system 1 were pastured after weaning for 170 days and then placed in the feedlot (75% shelled corn) for 140 days. System 2 steers were placed in the feedlot immediately after weaning for 196 days (same ration as system 1).

Data were adjusted to a weight-constant basis. Interactions were not significant between the breed of sire and breed of dam in both management systems indicating little importance of heterosis. This was confirmed by specific and pooled comparisons of crossbreds and straightbreds.

Smith et al. (1976a) presented postweaning performance data for 1,105 steers out of Hereford and Angus cows and sired by Hereford, Polled Hereford, Angus, Jersey, South Devon, Limousin, Charolais and Simmental bulls. Differences were large in postweaning average daily gain (range = 19%) and relative growth rate (percentage change in body weight daily, range = 10%). Charolais and Simmental

crosses were fastest gaining while Jersey crosses were slowest. Breed group differences were large for feed conversion on a weight constant basis (range = 23%), but were reduced when compared on an age constant (range = 9%), or fat constant (5% longissimus fat, range = 12%) basis. Efficiencies to constant fat ranged from 20.65 Mcal ME/kg gain for Hereford x Angus crosses to 22.10 for Simmental crosses. Weights at slaughter (constant fat basis) ranged from 417 kg for Jersey crosses to 525 for Simmental crosses. Koch et al. (1976) presented the carcass characteristics of these cattle evaluated by the three slaughter end-points indicated for the performance traits. At 5% longissimus fat, fat thickness was 9.9 mm in Jersey cross steers and 13.9 mm in straight-bred British steers. Yield grades were most desirable for Charolais cross steers. Differences in relative proportions of retail product, fat trim and bone were small when cattle were compared at similar fat.

Koch and Dikeman (1977) studied the wholesale cut composition of cattle from the study described previously (Smith et al., 1976a; Koch et al., 1976). While some significant differences were found, breed group differences in percentage of retail product and bone in each cut were strikingly small. Similar observations were made by Mukhoty and Berg (1973) and Charles and Johnson (1976b).

The influence of breed of sire upon growth and carcass characteristics of 32 crossbred steers was examined by McAllister et al. (1976). Polled Hereford (PH), Charolais (C), Limousin (L), and Simmental (S) sires were bred to random groups of Angus-Holstein F1 cows. PH-sired steers were slaughtered at 476 kg with the heaviest

steers of the other breeds slaughtered the same day. On this basis slaughter ages were 427, 420, 416, and 413 days for PH, C, L, and S steers, respectively. There were no significant differences in cutability or quality grade although the latter favored PH steers. PH steers averaged less for slaughter weight per day of age (1.07, 1.16, 1.17, and 1.17 kg for PH, C, L, and S steers, respectively), rib-eye area and percentage trimmed loin but were fatter than the other steers. Edible portion produced daily was higher for C and L steers. Results of a similar study comparing steers sired by British and French breeds were in general agreement with these observations (Adams et al., 1977).

Ferrell et al. (1978) presented results of three experiments in which the influence of dietary energy, protein, and cattle type on performance and carcass traits was examined. Breed groups included Angus, Hereford, Shorthorn, crosses of these breeds, and Charolais, Dairy, Limousin, and Red Poll crosses. Overall conclusions were complicated by variations in cattle type, slaughter endpoints, and environmental conditions among the three trials.

While dry matter or metabolizable energy intake per unit metabolic weight did not differ by breeding group, weight gains so expressed slightly favored the small type steers. The authors suggested an effect of energy density of the diet upon carcass composition in that carcasses from steers fed the higher energy rations were heavier and fatter but had similar amounts of protein than carcasses from steers which received the lower energy diet. The "energy density effect" on body composition is perhaps true in the broad sense but such evaluations

should be made on equal amounts of carcass gain and over similar body weight ranges.

Feed/gain values slightly favored the small type steers. Energy or protein level interactions with breed type were not significant, a result also noted in other studies (Klosterman et al., 1968a; Freeman, 1969; Harwin et al., 1966).

Lipsey et al. (1978) compared carcass composition of 16 Main-Anjou cross (MA), 14 Gelbvieh cross (G), and 16 Hereford x Angus cross (HA) steers. All steers were fed the same ration in individual pens and slaughtered when they reached an energy coefficient endpoint of 8.0 Mcal of NE per kg gain. The unconventional method of standardizing final physiological maturity was based on the assumptions that: (a) adipose tissue weight gain is more expensive than structural tissue weight gain; (b) a strong relationship exists between partial efficiency and physiological maturity as expressed by carcass composition; and (c) the energy value of a feed used for weight gain above maintenance is constant. It was thus assumed that the use of net energy for production ($NE_p$) for weight gain should be highly related to physiological maturity as expressed by carcass composition. Fed to a common $NE_p$ efficiency of 8.0 Mcal/kg gain, MA, G, and HA steers had the following values, respectively: average daily gain, 1.09, 1.12, 0.90; feed/gain, 10.5, 9.1, 9.0; final weight (kg), 600, 601, 506; fat thickness, 1.27, 1.37, 1.80; quality grade (12 = low choice), 12.2, 11.6, 11.7. There were no significant differences in quality grade while HA steers differed from MA and G steers in all other traits.

The greater growth potential of the larger dairy breeds (primarily Holstein) vs the smaller framed British beef breeds has been reported (Kidwell and McCormick, 1956). Garcia-de-Siles (1977) fed Hereford and Holstein steers to slaughter weights of 409 and 500 kg. Weight per day of age at 280 days, 365 days, and at slaughter was 16%, 18%, and 22% greater for Holsteins than for Herefords. Holsteins reached slaughter weight at an average 83 days younger than Herefords and feed efficiency from 270 days to slaughter favored Holsteins by 13%.

Minish et al. (1966) and Hanke et al. (1964) reported faster but less efficient gains when straightbred dairy calves were compared to British breeds fed to an equal time and weight endpoint. When compared at a similar degree of finish, Wyatt et al. (1977b) found increases in daily feed intake, total feed intake, and feed/gain as percent Holstein breeding increased from 0 to 25 to 50%. Dean et al. (1976) found that progeny of Hereford and Hereford x Holstein cows gained faster (0.13 and 0.08 kg daily) than progeny of Holstein cows. Calves were sired by Angus and Charolais bulls and thus contained 0, 25, or 50% Holstein breeding. Calves of 25 and 50% Holstein breeding consumed more daily feed (4 and 11%), more total feed (14 and 43%), and required more feed/gain (9 and 27%) than beef breed calves.

Bond et al. (1972) compared Holstein, Jersey, Milking Shorthorn, Angus, and Hereford steers from 180 days of age to slaughter (55 to 60% of mature bull weight or 27 months of age if expected weight was not reached). Three rations were compared: 75% concentrate (C); 50% timothy-50% alfalfa hay (H); and the hay mix for five-sixths of the

finishing trial followed by ration C (HC). Two trials were conducted; pooled average daily gains were 0.80, 0.70, 0.58, and 0.50 kg/day for Holstein, Milking Shorthorns, beef breed, and Jersey steers, respectively. Although no breed x diet interactions were noted in the second trial, in trial 1 Holsteins and Milking Shorthorns gained at faster rates on diets C and HC than the remaining steers. Additionally, Holstein steers gained at a faster rate on the H diet than the other breeds. Breed x diet interactions for carcass fat were noted in both trials. Mean carcass fat was 31.1, 38.5, 26.0, and 20.5% for beef breed, Milking Shorthorn, Jersey, and Holstein steers, respectively. Steers fed diets C and HC were more efficient in producing carcass calories.

The general relationship of cattle type to carcass composition was discussed by Allen et al. (1976). They reported that at similar body weight, each breed (presumably animals of similar frame size within the breed) or breed cross has a given ratio of body fat to body weight. The work of Cramer et al. (1973) was cited, indicating that about 25% of the total body fat in "chemically mature" cattle is intramuscular, regardless of breed. Therefore, animals within a breed and frame size were assumed to have a particular degree of marbling for a specified weight. They further argued that with body weight and total body fat fixed as constants within populations, carcass cutability could only be improved by changing body fat distribution. Thus, genetic selection or some other means of altering fat distribution should be utilized to decrease the percentage of total body fat deposited in waste fat depots.

Regardless of breed or type, fat is normally deposited in preferential sites during the progressing phases of growth: viscera and kidney, intermuscular, subcutaneous, intramuscular (Andrews, 1958). Palsson and Verges (1952), working with lambs, reported that the deposition of intramuscular fat was more age than plane of nutrition dependent. Similar results were reported for cattle (Lawrie and Kirton, 1956).

In a reported cattle type difference, Lawrie (1961) found beef breeds deposited intramuscular fat rapidly at 10 to 12 months of age while dairy cattle gradually marbled without a period of rapid deposition. These results were supported by the work of Berg and Butterfield (1968).

Carcass comparisons of cattle of beef vs Holstein breeding have been variable although in many cases the variability can be explained by differences in trial design. Holstein calves were found to be lower in quality and conformation grade than British breed calves when fed to equal slaughter weights (Garrett, 1971; Cole et al., 1964). However, Wyatt et al. (1977b) found marbling scores and carcass grades of Holstein progeny were as high or higher than those for Hereford progeny when cattle were fed to a similar degree of finish.

Dikeman et al. (1977) compared the carcass characteristics of light (LB) and heavy British breed (HB), and heavy Holstein (HH) breed steers. Carcass weight (kg) and fat thickness (mm) were 241, 9.7; 328, 11.2, and 325, 8.1 for LB, HB, and HH steers, respectively. HB steers had significantly more external and total fat trim than

Holsteins but less bone and no differences in total retail cuts. The LB steers had a higher percentage retail cuts, less bone, and less external fat trim from the four major wholesale cuts than HH steers. HH steers had a higher proportion of their total fat in the kidney and pelvic areas, a result also reported by Charles and Johnson (1976a).

Smith et al. (1977) compared various biological types of cattle on a wide range of feeding regimes. Cattle classified as small type (169 head) were at least five-eights British, Jersey, or Red Poll breeding. Cattle grouped as large types (218 head) were at least one-half Brown Swiss, Charolais, Chianina, Gelbvieh, Limousin, Main Anjou and/or Holstein or other large domestic dairy breeds. Five feeding regimes were examined: A = winter growing ration, summer grazing, 60% forage finishing ration; B = same as A only 20% forage finishing ration; C = 97% forage finishing ration; D = 97% forage ration switched to a 60% forage ration; E = 60% forage ration.

There were two or three slaughter groups per feeding regime from which regressions were developed to adjust data to weight- and composition-constant endpoints. Live weight gains were consistent with expectations based on the energy density of the rations although feed efficiency (Mcal ME/kg gain) did not differ by feeding regime or cattle type.

Composition of gain was markedly changed by feeding regime. Adjusted to similar carcass weight, a consistent pattern of regime effects were found for all measures of fatness ($A = B < C = D < E$). A reciprocal ranking was noted for retail product weight ($A = B > C = D > E$).

Type x regime interactions were nonsignificant for both composition and palatability traits.

Adjusted to 4% longissimus muscle fat, small and large type steers were similar in measures of fatness. A consistent trend existed for steers on regime C and D to be leaner than those on regime E while steers fed according to regimes A and B were fattest. The authors thus suggested that placing young cattle directly into the feedlot on moderate energy rations might be the best way to produce carcasses of desired quality grade with minimum fat.

Prior et al. (1977), in a comprehensive factorial experiment, studied the impact of dietary energy and protein on performance and carcass characteristics of different biological types of cattle. Two types of cattle (Angus-Hereford, small type; three-quarter or seven-eighths Charolais and Chianina Hereford or Chianina Angus, large type) were fed three energy levels (LE, 2.90; IE, 3.06; HE, 3.17 Mcal metabolizable energy/kg) at three protein levels (LP, 10%, MP, 11.5%; HP, 13%). Corn silage-corn based rations were fed to all cattle. Two of the small type cattle from each replicate (all pens replicated except LP group) were slaughtered after 196 days on experiment and the other small types after 232 days. Two of the large type cattle from each replicate were slaughtered at 232 days on experiment and the other large types at 313 days when they were expected to be of similar composition to small types slaughtered after 196 days.

There were no protein x energy interactions observed with either cattle type. Overall, dry matter intake was not influenced

by the energy density of the ration. During the first 232 days on trial, intake favored the large cattle types (8.6 vs 8.1 kg/hd/day). Energy intake was limited by bulk fill in the small but not large type cattle.

Total Mcal of metabolizable energy required to produce a kg of live weight gain was not influenced by ration energy level or type of cattle. Mcal of metabolizable energy required per kg retail product gained favored the LE groups in both cattle types. Although not pointed out by the authors, this probably indicates that sufficient energy was consumed by the LE groups of both cattle types for maximum protein synthesis. This is further supported by the fact that across the three energy levels (within a type and slaughter group) all cattle had similar amounts of total protein (kg) in their carcasses.

Predictably, live weight gain responses due to protein level occurred largely in the 0 to 63 day time period. The authors concluded that for maximum efficiency and rate of gain at lighter weights, small type cattle should receive 0.77 kg of crude protein per head daily up to 325 kg body weight. Similarly, large type cattle should be fed 0.93 kg of crude protein daily to 348 kg body weight.

Carcass composition at constant carcass weight, was altered by nutritional regime in small but not large type cattle. Adjusted to constant carcass weight, increasing dietary energy intake increased marbling score, quality grade, fat thickness, kidney and pelvic fat, and yield grade. Increasing protein percentage in the ration had no significant affect on carcass quality or composition.

Jesse et al. (1976a) studied the effect of ration energy level and slaughter weight on composition of gain in 56 Hereford steers. Corn-corn silage rations were fed in the following proportions: 30:70; 50:50; 70:30; and 80:20. Four steers from each ration were slaughtered at 341, 454, and 545 kg. The composition of empty body and carcass gain for a given weight was not affected by ration. Fat gain as a percentage of carcass gain increased from 27.5 to 48.6% as slaughter weight increased from 341 to 545 kg. However, fat as a percentage of carcass gain from 454 to 545 kg was 68.3% indicating a period of predominantly fat deposition.

It becomes obvious from the studies previously reviewed in this section that trials examining the impact of ration energy level on carcass traits have not yielded consistent results. This is also evident in the reviews of Reid et al. (1968) and Marchello and Hale (1976). Those observing effects of energy level on carcass composition include Prior et al. (1977), Fox (1977), Ferrell et al. (1978), and Smith et al. (1977). Those reporting little or no effect include Jesse et al. (1976a), Guenther et al. (1965), Reid et al. (1968), Epley et al. (1971), and Allen et al. (1976). At least a portion of the inconsistency can likely be attributed to differences in trial design such as slaughter schedule, cattle types compared, portion of the growth curve examined, degree of difference in energy level of rations compared, total energy intakes, etc. Additional factors possibly affecting results have been discussed by Fox (1977).

## OBJECTIVES

1. To examine the adequacy of energy levels recommended by the National Research Council for cows of varying mature sizes and genetic backgrounds when maintained in unsheltered northern climatic conditions.
2. To compare the efficiency of nitrogen and energy utilization of cattle of four genetic types when fed high corn silage or high corn grain rations.
3. To examine the effects of sex, selection, and crossbreeding on preweaning and postweaning performance and efficiency of growth of calves from four genetic backgrounds.
4. To examine the impact of ration energy level on composition of gain and carcass characteristics when cattle of four genetic types are fed to similar finish.
5. To compare the economics of production of steers and heifers of four genetic types when fed high corn silage and high corn grain rations.

## MATERIALS AND METHODS

### Cow-Calf Trials

#### Source and Genetic Background of Experimental Animals

Cow-calf trials were conducted from December 16, 1975 to September 9, 1976 (trial 1) and from November 23, 1976 to September 19, 1977 (trial 2). In each trial, ten pregnant cows, representative in age and weight, were obtained from each of the four genetic types maintained in a breeding project at the Lake City Experiment Station, Lake City, Michigan. Genetic groups compared were Unselected Herefords (USH), Selected Herefords (SH), Angus x Hereford x Charolais crossbred (AHC), and Angus x Hereford x Holstein crossbred (AHH).

The Lake City breeding project began in 1966 with a herd of 200 grade Hereford cows from one source. The cows were initially allotted to four groups of 50 cows each. No selection was practiced in the USH group and the mating system was random. Each year the first four USH bull calves born by different sires were retained and used as clean-up bulls the following year. At the termination of the breeding season, semen was collected from each clean-up bull, frozen, and used to inseminate cows the next year.

In the SH, AHC, and AHH groups, superior bulls from AI studs were used, selected primarily on their yearling weight. Replacement heifers in the three selected groups were retained on the basis of

their unadjusted yearling weight at a rate of 20% per year. USH replacement heifers were saved without regard to weight, but were representative of the age groups of SH, AHC, and AHH replacement heifers.

A summary of the mating systems and selection practices used in establishing each group are included in Table 3. Additional information on the source, selection, management procedures, and past performance of these herds has been presented by Magee and Greathouse (1969, 1970, 1971, 1972, 1973); Magee (1974); and Magee and McPeake (1975, 1976).

Experimental Design and Rations

The experimental design, initial weight and condition, and genetic background of cows is indicated in Table 3. Mean age of trial 1 cows was similar for all groups and each group included two first-calf heifers. AHC and AHH cows were three-breed crosses containing an average 30% Charolais or Holstein breeding, respectively. Initial weights for USH, SH, AHC, and AHH cows were 382.8, 433.6, 480.4, and 479.4 kg, respectively. Cows were in similar condition, averaging 0.36 cm external fat.

Trial 1 cows received corn silage and a soybean meal-mineral supplement (10% ration crude protein) throughout the trial. The trial was conducted concurrently with feedlot trial 2 and feed ingredients were of the same source (Table 8). Initially, levels were fed to meet the energy requirements for maintenance recommended by the National

Table 3. Experimental Design of Cow-Calf Trials (Trials 1,2)

| Trial | Cow[a] type | Nutritional[b] treatment | Initial values[c] | | | | Genetic background | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. of cows | Age, yrs | External fat, cm | Weight, kg | Selection procedure | Mating system | % Angus | % Hereford | % Charolais | % Holstein |
| 1 | USH | NRC | 10 | 4.4 | 0.25 | 382.8 | None | Random | -- | 100.0 | -- | -- |
| | SH | NRC | 10 | 4.4 | 0.43 | 433.6 | Yearling wt. | Straightbred | -- | 100.0 | -- | -- |
| | AHC | NRC | 10 | 4.4 | 0.41 | 480.4 | Yearling wt. | Crossbred | 27.5 | 42.5 | 30.0 | -- |
| | AHH | NRC | 10 | 4.4 | 0.33 | 479.4 | Yearling wt. | Crossbred | 30.0 | 40.0 | -- | 30.0 |
| 2 | USH | NRC | 5 | 4.3 | 0.79 | 437.3 | None | Random | -- | 100.0 | -- | -- |
| | | NRC25 | 5 | 5.7 | 0.71 | 444.1 | | | -- | 100.0 | -- | -- |
| | SH | NRC | 5 | 4.7 | 0.94 | 506.2 | Yearling wt. | Straightbred | -- | 100.0 | -- | -- |
| | | NRC25 | 5 | 4.9 | 0.74 | 504.2 | | | -- | 100.0 | -- | -- |
| | AHC | NRC | 5 | 3.9 | 0.76 | 534.8 | Yearling wt. | Crossbred | 45.0 | 25.0 | 30.0 | -- |
| | | NRC25 | 5 | 3.7 | 0.66 | 548.4 | | | 32.5 | 25.0 | 42.5 | -- |
| | AHH | NRC | 5 | 4.5 | 0.58 | 535.7 | Yearling wt. | Crossbred | 25.0 | 32.5 | -- | 42.5 |
| | | NRC25 | 5 | 4.9 | 0.58 | 532.1 | | | 37.5 | 32.5 | -- | 30.0 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]Corn silage plus soybean meal-mineral supplement (10% ration crude protein) fed to all cows. Trial 1, NRC: National Research Council (1970) recommended levels of energy. Trial 2, NRC: National Research Council (1976) recommended levels of energy; NRC25: 125% of recommended levels.

[c]Only data from cows with a weaned calf were included in final analyses.

Research Council (NRC, 1970). After calving, cows received the level recommended for lactation based on their pre-calving body weight. Due to the marginal condition of the cows, feed offered was increased 25% above the lactation level on April 7, 1976, corresponding to 52 days before breeding. All cows received this level for the remainder of the experiment.

Trial 2 animals included ten pregnant cows per type; eight cows from trial 1 and 32 additional cows from the Lake City herd (Table 3). Trial 2 cows were initially heavier and fatter than trial 1 cows. Average age (years), external fat (cm), and weight (kg) by type were: 5, 0.75, 440.7; 4.8, 0.84, 505.2; 3.8, 0.69, 541.6, and 4.7, 0.58, 533.9 for USH, SH, AHC, and AHH cows, respectively. AHC and AHH cows contained an average 36% Charolais or Holstein breeding, respectively.

Each group of ten cows was divided into two groups of five cows each, based on body weight and age with one first-calf heifer included in each sub-group. The sub-groups within a type received either a low (NRC) or high (NRC + 25%) energy ration based on the energy requirements recommended by the National Research Council (NRC, 1976).

The revised beef cattle requirements issued by the NRC in 1976 subdivides pregnancy requirements into the mid and late trimester of pregnancy, increasing previously recommended levels (NRC, 1970) by approximately 10%. Additionally, lactation levels were presented for cows of superior (over 10 kg milk/day) vs average milking ability. AHH cows were fed levels recommended for cows of superior milking ability; USH, SH, and AHC cows were fed at the level for average milking ability.

As in trial 1, trial 2 cows received corn silage and a soybean meal-mineral supplement (10% ration crude protein) throughout the study. The trial was conducted concurrently with feedlot trial 3 and feed ingredients were of the same source (Table 10). As indicated previously, feed amounts were based on NRC (1976) recommendations and consisted of three phases. Cows received levels for dry pregnant cows, middle third of pregnancy, for 56 days. From 56 days to calving, levels recommended for the final third of pregnancy were fed, including allowances for growth of yearling heifers. At calving, lactation levels were initiated and continued for the remainder of the trial.

Management Procedures

The corn silage and supplement was mixed in a horizontal batch mixer and fed as a complete ration once daily. Cows were group fed within type (trial 1) or within type and energy level (type 2). All cows were individually weighed every 28 days and external fat over the 12th rib was estimated using a Scanoprobe.[1] Initial and final weights were obtained after a 16 hr withdrawal from feed and water Intermediate period weights were on an off-water basis. Additionally, in trial 2, height of cows at the hooks was measured at the beginning and end of the trial and weight/height ratios were calculated as a comparative method of determining cow body condition.

Trial 1 cows were maintained separately by type in four 18.5 x 52 m dry lots without shelter or windbreaks although small

[1]Scanoprobe, model 731, Ithaco, Inc., Ithaca, New York, 48850.

shelters were provided for calves. Similar facilities for trial 2 cows were used except eight 6.1 x 46 m lots were utilized. Cows remained outside until calving was imminent at which time they were moved to a sheltered, open-fronted, calving area, again separated by type (trial 1) or by type and energy level (trial 2). When one-half of the cows in each group had calved they were returned to the dry lot and the remaining cows were placed in the sheltered calving area. Cows which lost their calves were removed from the experiment.

Newborn calves were given recommended levels of vitamin A and a vitamin E--selenium preparation. Iodine was applied to the navel of all calves and birth weights were obtained immediately. Bull calves were castrated at 2 to 3 weeks of age and calves were dehorned with caustic paste where necessary. Calving seasons extended from January 22 to April 7, 1976, for trial 1, and from January 30 to April 2, 1977, for trial 2. Weaning weights were obtained at the conclusion of each trial and adjusted to a 205 day, mature dam, bull calf basis.

Rebreeding performance was examined for trial 1 cows only. Two injections of Prostaglandin $F_2\alpha$, 11 days apart, were used to synchronize estrus. All cows were artificially inseminated 80 hr following the second injection, on May 28 and 29, 1976. Blood samples were secured from all cows immediately before breeding and were analyzed for progesterone. Cows with serum progesterone levels of 1.0 ng/ml or greater were classified as cycling. All cows were observed for estrus for 30 days post-breeding and a second AI service performed if needed.

Climatological data were collected daily at a site 275 m northwest of the trial site. Data from monthly summaries (Michigan Climatological Data, 1975-77) are presented in Table A.5 for trials 1 and 2.

## Metabolism Studies

### Experimental Animals

Two USH, SH, AHC, and AHH steers were used in each metabolism study. Trial 1 and 2 metabolism steers were representative of steers placed on feed in feedlot trials 2 and 3, respectively. Mean initial weights (kg) of trial 1 and 2 steers were 218, 269, 310, and 354 and 124, 184, 177, and 203 for USH, SH, AHC, and AHH steers, respectively.

### Trial Design, Rations, and Collection Procedures

Metabolism studies were conducted in the winter (trial 1) and fall (trial 2) of 1976 in an environmentally controlled metabolism room. Steers were confined to individual 91 x 244 cm stalls designed to allow the collection of both feces and urine. Each trial consisted of two phases in which one steer per type initially received either a high silage or a high grain ration. Rations were then switched for the second phase so that all steers received both diets.

The high silage and high grain rations and their analyses for both trials are presented in Table 4. Trial 1 and 2 steers were fed rations consistent with the initial diets fed to steer mates in feedlot trials 2 and 3, respectively, and feed ingredients were from a common

Table 4. Rations Fed to Unselected Hereford, Selected Hereford, Angus x Hereford x Charolais, and Angus x Hereford x Holstein Steers in Metabolism Studies (Trials 1, 2)[a]

| Item | Int. ref. no. | Trial 1 High silage ration, % of DM | Trial 1 High grain ration, % of DM | Trial 2 High silage ration, % of DM | Trial 2 High grain ration % of DM |
|---|---|---|---|---|---|
| Corn, aerial pt, w ears, w husks, ensiled, mature, well-eared mx 50% mn 30% dry matter | 3-08-153 | 88.00 | 20.00 | 86.00 | 20.00 |
| Corn, dent, yellow, grain, gr 2 US | 4-02-931 | | 67.40 | | 66.30 |
| Soybean, seeds, meal solv-extd | 5-04-604 | 11.04 | 10.31 | 13.05 | 11.00 |
| Limestone, grnd | 6-02-632 | 0.26 | 1.96 | 0.21 | 1.50 |
| Phosphate, deflourinated, grnd | 6-01-780 | 0.40 | | 0.45 | |
| Potassium chloride, KCl | 6-03-756 | | | | 0.91 |
| Trace mineral salt | | 0.26 | 0.29 | 0.25 | 0.25 |
| Vitamin A[b] | | 0.02 | 0.02 | 0.02 | 0.02 |
| Vitamin D[c] | | 0.02 | 0.02 | 0.02 | 0.02 |
| Percent of ration dry matter: | | | | | |
| Crude protein[d] | | 13.50 | 14.50 | 13.40 | 14.40 |
| Calcium[d] | | 0.49 | 0.80 | 0.50 | 0.69 |
| Phosphorous[e] | | 0.34 | 0.33 | 0.36 | 0.34 |
| Net energy, Mcal/kg dry matter:[e] | | | | | |
| Maintenance | | 1.59 | 2.03 | 1.60 | 2.02 |
| Gain | | 1.02 | 1.33 | 1.02 | 1.32 |

[a]Two steers per type received each ration in each of two trials.

[b]30,000 IU vitamin A per g.

[c]3,000 IU vitamin $D_3$ per g.

[d]Determined by laboratory analysis.

[e]Calculated from average nutrient composition (NRC, 1976).

source. An 18-day adaptation period was used to adjust animals to the stalls and their respective diets. Steers assigned to the high grain ration were initially offered an 85% corn silage ration (dry matter basis). The silage portion of the diet was then decreased 5% daily with a concurrent increase in the corn and supplement portion. In this manner steers were gradually adapted to a full-feed of 80% corn and supplement by day 11. The readjustment phase, in which rations were switched, was 16 days in length with an 11 day adaptation to full grain feeding as previously described.

The daily allotment for each steer was mixed in a small horizontal mixer and offered once daily. Steers were fed ad libitum and refused feed was removed daily, weighed, and recorded. Grab samples of all rations and weighbacks were secured daily, composited for each steer, and frozen. At the conclusion of each collection period, composite samples were partially thawed and thoroughly chopped in a Hobart food chopper. A 1500 g subsample was then retained for later analysis.

Urine was collected into large plastic carboys in which 200 ml of 18 N sulfuric acid was added to prevent escape of ammonia or other nitrogenous products. Carboys were emptied at least every two days and the urine collected was diluted to a total volume of 10 liters with water. A 10% aliquot was secured, composited for a given steer, and stored at 5 C until the conclusion of the collection period. A 1 liter subsample was then obtained and frozen for later analyses.

Total feces were collected in plastic-lined steel troughs behind each steer. Feces were removed at least every two days, weighed and a 10% subsample secured. Subsamples were composited for each steer and frozen until the end of the collection period. At that time the composite samples were thoroughly mixed and a 2 kg sample removed and frozen for later analyses.

Laboratory Analyses

Dry matter of rations and orts were determined by drying 100 g samples in a forced-air oven for 48 hr at 50 C. Similar procedures were used for fecal samples although a 200 g sample was used and 25 ml of 4 N sulfuric acid was mixed with the sample prior to drying.

Total nitrogen of all samples was determined with a Technicon Auto Kjeldahl System. Sample sizes were 4 g, 1 g, and 4 ml for wet rations and orts, dry feces, and urine, respectively.

Total energy was determined in an adiabatic bomb calorimeter. Wet 2 g samples of rations and orts were used with the alcohol priming method outlined by Colovos et al. (1957). One ml of 95% alcohol was added to samples immediately preceding bomb assembly. The alcohol solution used in these determinations had a caloric value of 5.27 Mcal/ml. Fecal energy was determined on dried, pelleted 1 g samples. Urine samples were prepared for combustion by adding 5 ml of urine to preweighed (approximately 350 mg) cotton balls and freeze drying for 48 hr. Energy value of the cotton was determined on triplicate samples.

Calculations

Nitrogen retention (g/day) was calculated by subtracting urinary and fecal nitrogen excretion from nitrogen intake. Retention was also expressed as a percentage of nitrogen absorbed (apparent biological value) and as a percentage of nitrogen intake.

Daily energy retained was calculated as energy intake minus fecal, urinary, and gaseous energy losses. It was necessary to estimate the latter and a factor of 8% of energy intake was used as suggested by Blaxter (1962). Metabolizable energy values of the rations were calculated as Mcal of energy retained per kg dry matter intake.

## Feedlot and Body Composition Studies

Experimental Animals

Cattle fed in three trials were 176 steer and 57 heifer calves of four genetic types (USH, SH, AHC, and AHH) from the Lake City Breeding Project which was previously described. The steers represented essentially all male calves produced in each group from the 1974 through 1976 calf crops, with the exception of those used in initial slaughter or metabolism trials. Feedlot performance data for the 1974 steer calves (trial 1) were previously presented by Crickenberger (1977).

Heifers fed were from the 1975 and 1976 calf crops and were those remaining after 50% of all heifers produced were removed as herd replacements.

As indicated previously, USH calves were the result of random matings while SH, AHC, and AHH calves were from groups where selection was practiced based on yearling weight. USH replacement heifers were thus saved without regard to weight but were representative of the age groups of the selected replacement heifers.

Trial Design and Rations

The design of feedlot trial 1 has been previously described by Crickenberger (1977) and is presented in Table 5. With the exception of the SH group, 16 steer calves per type were stratified by weight and divided into eight groupings of two steers each. One steer per group was then randomly assigned to either corn silage plus supplement (HS) or 40% corn silage plus 60% corn grain and supplement (HG), on a dry matter basis. Due to insufficient numbers of SH calves, six were fed the high silage ration and seven were fed the high grain ration.

The experimental design and rations fed in trials 2 and 3 are presented in Tables 7 and 9, respectively. Similar allotting procedures to trial 1 were used in these studies, although two changes were made in trial design. Five to eight heifers per type received a high silage ration and steers assigned to the high grain ration received 20% corn silage and 80% corn grain plus supplement. Thus with an estimated grain content of corn silage of 50%, HG steers in trial 1 received 80% concentrate rations vs 90% for trial 2 and 3 steers. High silage rations were similar across all trials with ration dry matter averaging 91% corn silage and 9% supplement.

Table 5. Experimental Design and Rations for Feedlot Trial 1

| Sex | Cattle[a] type | High silage ration: Pen no. | No. anim. | Weight, kg | | | | High grain ration: Pen no. | No. anim. | Weight, kg | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Steers | USH | 21 | 8 | To 272 | 272-318 | 318-363 | 363+ | 17 | 8 | To 272 | 272-318 | 318-363 | 363+ |
| | SH | 22 | 7 | | | | | 18 | 6 | | | | |
| | AHC | 23 | 8 | To 318 | 318-363 | 363-454 | 454+ | 19 | 8 | To 318 | 318-363 | 363-454 | 454+ |
| | AHH | 24 | 8 | | | | | 20 | 8 | | | | |
| Ingredients in ration dry matter, % | | | | | | | | | | | | | |
| Corn silage | | | | 88.7 | 92.2 | 93.3 | 95.4 | | | 41.9 | 52.0 | 39.4 | 40.3 |
| High moisture corn | | | | | | | | | | 43.3 | 36.3 | 52.7 | 55.2 |
| Supplement 174[b] | | | | 11.3 | 7.8 | 6.7 | 4.6 | | | | | | |
| Supplement 374[c] | | | | | | | | | | 14.8 | 11.7 | 7.9 | 4.5 |
| Percent of dry matter | | | | | | | | | | | | | |
| Crude protein[d] | | | | 13.1 | 11.6 | 10.7 | 9.3 | | | 14.9 | 13.7 | 12.6 | 11.2 |
| Ca[e] | | | | 0.50 | 0.43 | 0.41 | 0.36 | | | 0.64 | 0.56 | 0.39 | 0.28 |
| P[e] | | | | 0.32 | 0.29 | 0.27 | 0.25 | | | 0.34 | 0.31 | 0.32 | 0.31 |
| Net energy, Mcal/kg[e] | | | | | | | | | | | | | |
| Maintenance | | | | 1.58 | 1.57 | 1.57 | 1.57 | | | 1.90 | 1.84 | 1.95 | 1.96 |
| Gain | | | | 1.01 | 1.00 | 1.00 | 1.00 | | | 1.23 | 1.19 | 1.26 | 1.27 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]Dry matter composition: soybean meal, 92.0%; limestone, 2.2%; defluor. phosphate, 3.3%; trace mineral salt, 2.2%; vitamin A (30,000 IU/g), 0.15%; vitamin D (3,000 IU/g), 0.15%.

[c]Dry matter composition: soybean meal, 89.1%; limestone, 8.1%; trace mineral salt, 2.5%; vitamin A (30,000 IU/g), 0.15%; vitamin D (3,000 IU/g), 0.15%.

[d]Determined by laboratory analysis.

[e]Calculated from average values (NRC, 1976).

Ration ingredients were analyzed monthly and their mean nutrient composition for trials 1, 2, and 3 are presented in Tables 6, 8, and 10, respectively. All rations were adequately supplemented with calcium, phosphorous, trace mineral salt, and vitamins A and D according to the guidelines of Fox (1975) and Fox and Ritchie (1975). Supplemental potassium was added to the high grain ration fed in trial 3 due to some problems with stiffness noted in trial 2, which suggested a potassium deficiency.

A declining protein level supplementation system was followed in all trials. Crude protein requirements and ration protein levels were based primarily on the animal's stage, composition, and rate of growth and protein quality of feedstuffs as discussed by Fox et al. (1977). Specific protein requirements for cattle of various weights and frame sizes and fed various combinations of corn and corn silage have been presented by Fox and Black (1975).

Management Procedures

Each year calves were transported by truck 220 km from Lake City, Michigan to the Beef Cattle Research Center immediately after weaning. Incoming calves were vaccinated for pasteurella, IBR, BVD, and $PI_3$ and were given recommended levels of vitamins A and D intramuscularly. A starting ration of 88% corn silage and 12% soybean meal-mineral supplement was fed. The ration was balanced with calcium, phosphorous, trace mineral salt, and vitamins A and D as recommended by NRC (1970). All calves remained on the starter ration for a

Table 6. Nutrient Composition of Ration Ingredients for Feedlot Trial 1

| Ingredient | Int. ref. no. | Percent of dry matter | | | | |
|---|---|---|---|---|---|---|
| | | Dry matter[a] | Crude protein[a] | Ca[b] | P[b] | K[b] |
| Corn, aerial pt, w ears, w husks, ensiled, mature, well-eared mx 50% mn 30% dry matter | 3-08-153 | 32.50 | 8.18 | 0.28 | 0.21 | 0.95 |
| Corn, dent, yellow, grain, gr 2 US | 4-02-931 | 70.00 | 10.60 | 0.02 | 0.35 | |
| Soybean, seeds, meal solv-extd | 5-04-604 | 89.20 | 51.70 | 0.36 | 0.75 | 2.21 |
| Limestone, grnd | 6-02-632 | 100.00 | | 33.84 | 0.02 | |
| Phosphate, defluorinated, grnd | 6-01-780 | 100.00 | | 33.07 | 18.04 | 0.09 |
| Trace mineral salt | | 100.00 | | | | |
| Vitamin A[c] | | 90.00 | | | | |
| Vitamin D[d] | | 90.00 | | | | |

[a]Determined by laboratory analysis.

[b]Average nutrient composition (NRC, 1976).

[c]30,000 IU vitamin A per g.

[d]3,000 IU vitamin $D_3$ per g.

Table 7. Experimental Design and Rations for Feedlot Trial 2

| Sex | Cattle type[a] | High silage ration: Pen no. | No. anim. | Weight, kg | | | High grain ration: Pen no. | No. anim. | Weight, kg | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heifers | USH | 1 | 8 | To 218 | 218-254 | 254+ | | | | | | |
| | SH | 2 | 8 | | | | | | | | | |
| | AHC | 3 | 8 | To 263 | 263-299 | 299+ | | | | | | |
| | AHH | 4 | 8 | | | | | | | | | |
| Steers | USH | 5 | 6 | To 272 | 272-318 | 318+ | 11 | 6 | To 272 | 272-318 | 318-363 | 363+ |
| | SH | 6 | 8 | | | | 12 | 8 | | | | |
| | AHC | 9 | 8 | To 318 | 318-363 | 363+ | 13 | 8 | To 318 | 318-363 | 363-454 | 454+ |
| | AHH | 10 | 8 | | | | 14 | 8 | | | | |
| Ingredients in ration dry matter, % | | | | | | | | | | | | |
| Corn silage | | | | 88.0 | 90.4 | 92.8 | | | 20.0 | 20.0 | 20.0 | 20.0 |
| High moisture corn | | | | | | | | | 67.4 | 70.3 | 73.1 | 76.0 |
| Supplement 174[b] | | | | 12.0 | 9.6 | 7.2 | | | | | | |
| Supplement 175[c] | | | | | | | | | 12.6 | 9.7 | 6.9 | 4.0 |
| Percent of dry matter | | | | | | | | | | | | |
| Crude protein[d] | | | | 13.2 | 11.7 | 10.3 | | | 14.6 | 13.5 | 12.6 | 11.2 |
| Ca[e] | | | | 0.49 | 0.44 | 0.40 | | | 0.80 | 0.63 | 0.47 | 0.31 |
| pe | | | | 0.34 | 0.31 | 0.29 | | | 0.33 | 0.32 | 0.31 | 0.30 |
| Net energy, Mcal/kg[e] | | | | | | | | | | | | |
| Maintenance | | | | 1.59 | 1.59 | 1.48 | | | 2.03 | 2.05 | 2.07 | 2.09 |
| Gain | | | | 1.02 | 1.01 | 1.00 | | | 1.33 | 1.34 | 1.35 | 1.36 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein. Two steers (pens 10, 11) were discarded during the trial and data were completely removed.

[b]Dry matter composition: soybean meal, 92.0%; limestone, 2.2%; defluro. phosphate, 3.3%; trace mineral salt, 2.2%; vitamin A (30,000 IU/g), 0.15%; vitamin D (3,000 IU/g), 0.15%.

[c]Dry matter composition: soybean meal, 81.8%; limestone, 15.6%; trace mineral salt, 2.3%; vitamin A (30,000 IU/g), 0.15%; vitamin D (3,000 IU/g), 0.15%.

[d]Determined by laboratory analysis.

[e]Calculated from average values (NRC, 1976).

Table 8. Nutrient Composition of Ration Ingredients for Feedlot Trial 2

| Ingredient | Int. ref. no. | Percent of dry matter | | | | |
|---|---|---|---|---|---|---|
| | | Dry matter[a] | Crude protein[a] | Ca[b] | P[b] | K[b] |
| Corn, aerial pt, w ears, w husks, ensiled, mature, well-eared mx 50% mn 30% dry matter | 3-08-153 | 32.60 | 7.70 | 0.28 | 0.21 | 0.95 |
| Corn, dent, yellow, grain, gr 2 US | 4-02-931 | 69.80 | 10.58 | 0.02 | 0.35 | |
| Soybean, seeds, meal solv-extd | 5-04-604 | 90.00 | 53.56 | 0.36 | 0.75 | 2.21 |
| Limestone, grnd | 6-02-632 | 100.00 | | 33.84 | 0.02 | |
| Phosphate, defluorinated, grnd | 6-01-780 | 100.00 | | 33.07 | 18.04 | 0.09 |
| Trace mineral salt | | 100.00 | | | | |
| Vitamin A[c] | | 90.00 | | | | |
| Vitamin D[d] | | 90.00 | | | | |

[a]Determined by laboratory analysis.

[b]Average nutrient composition (NRC, 1976).

[c]30,000 IU vitamin A per g.

[d]3,000 IU vitamin $D_3$ per g.

Table 9. Experimental Design and Rations for Feedlot Trial 3

| Sex | Cattle type | High silage ration: Pen no. | No. anim. | Weight, kg | | | High grain ration: Pen no. | No. anim. | Weight, kg | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Heifers | USH | 1 | 6 | To 218 | 218-254 | 254+ | | | | | | |
| | SH | 2 | 6 | | | | | | | | | |
| | AHC | 3 | 7 | To 263 | 263-299 | 299+ | | | | | | |
| | AHH | 4 | 7 | | | | | | | | | |
| Steers | USH | 5 | 6 | To 272 | 272-318 | 318+ | 11 | 6 | To 272 | 272-318 | 318-363 | 363+ |
| | SH | 6 | 8 | | | | 12 | 8 | | | | |
| | AHC | 9 | 8 | To 318 | 318-363 | 363+ | 13 | 8 | To 318 | 318-363 | 363-454 | 454+ |
| | AHH | 10 | 8 | | | | 14 | 8 | | | | |
| Ingredients in ration dry matter, % | | | | | | | | | | | | |
| Corn silage | | | | 86.0 | 88.4 | 90.7 | | | 20.0 | 20.0 | 20.0 | 20.0 |
| High moisture corn | | | | | | | | | 66.3 | 69.2 | 72.2 | 75.1 |
| Supplement 176[b] | | | | 14.0 | 11.6 | 9.3 | | | | | | |
| Supplement 276[c] | | | | | | | | | 13.7 | 10.8 | 7.8 | 4.9 |
| Percent of dry matter | | | | | | | | | | | | |
| Crude protein[d] | | | | 13.3 | 12.3 | 11.2 | | | 14.3 | 13.5 | 12.5 | 11.5 |
| Ca[e] | | | | 0.50 | 0.46 | 0.42 | | | 0.69 | 0.56 | 0.44 | 0.31 |
| pe | | | | 0.36 | 0.34 | 0.31 | | | 0.34 | 0.33 | 0.33 | 0.32 |
| Net energy, Mcal/kg[e] | | | | | | | | | | | | |
| Maintenance | | | | 1.60 | 1.59 | 1.59 | | | 2.02 | 2.04 | 2.06 | 2.08 |
| Gain | | | | 1.02 | 1.02 | 1.01 | | | 1.32 | 1.33 | 1.35 | 1.36 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein. Two animals (pens 1, 9) were discarded during the trial and data were completely removed.

[b]Dry matter composition: soybean meal, 93.2%; limestone, 1.5%; deflour. phosphate, 3.2%; trace mineral salt, 1.8%; vitamin A (30,000 IU/g), 0.15%; vitamin D (3,000 IU/g), 0.15%.

[c]Dry matter composition: soybean meal, 80.3%; limestone, 10.9%; potassium chloride, 6.6%; trace mineral salt, 1.8%; vitamin A (30,000 IU/g), 0.20%; vitamin D (3,000 IU/g), 0.20%.

[d]Determined by laboratory analysis.

[e]Calculated from average values (NRC, 1976).

Table 10. Nutrient Composition of Ration Ingredients for Feedlot Trial 3

| Ingredient | Int. ref. no. | Percent of dry matter | | | | |
|---|---|---|---|---|---|---|
| | | Dry matter[a] | Crude protein[a] | Ca[b] | P[b] | K[b] |
| Corn, aerial pt, w ears, w husks, ensiled, mature, well-eared mx 50% mn 30% dry matter | 3-08-153 | 37.90 | 7.66 | 0.28 | 0.21 | 0.95 |
| Corn, dent, yellow, grain, gr 2 US | 4-02-931 | 72.60 | 10.60 | 0.02 | 0.35 | |
| Soybean, seeds, meal solv-extd | 5-04-604 | 90.00 | 52.40 | 0.36 | 0.75 | 2.21 |
| Limestone, grnd | 6-02-632 | 100.00 | | 33.84 | 0.02 | |
| Phosphate, defluorinated, grnd | 6-01-780 | 100.00 | | 33.07 | 18.04 | 0.09 |
| Potassium chloride, KCl | 6-03-756 | 100.00 | | | | 52.44 |
| Trace mineral salt | | 100.00 | | | | |
| Vitamin A[c] | | 90.00 | | | | |
| Vitamin D[d] | | 90.00 | | | | |

[a]Determined by laboratory analysis.

[b]Average nutrient composition (NRC, 1976).

[c]30,000 IU vitamin A per g.

[d]3,000 IU vitamin $D_3$ per g.

minimum of 30 days, were closely observed for signs of sickness and treated if necessary. When calves were healthy and consuming expected amounts of dry matter, trials were initiated. A pour-on insecticide was applied to all calves to control grubs and lice. Trial 1 calves were implanted initially with DES and reimplanted with Ralgro subject to withdrawal requirements. Trial 2 and 3 calves received Synovex-H for heifers and Synovex-S for steers at recommended intervals throughout the trials.

Cattle were fed ad libitum and received their complete ration once daily. Ration ingredients were blended in a horizontal mixer just prior to feeding. Daily feed records were kept and refused feed was periodically removed, weighed, and recorded. Samples of all feeds were secured monthly and analyzed for dry matter (50 C for 48 hr) and nitrogen (Kjeldahl on wet samples). Rations were adjusted at the beginning of each 28 day period for changes in dry matter content of ingredients.

All cattle were individually weighed at the beginning of the experiment and approximately every 28 days thereafter until removed for slaughter. Initial and final weights were obtained after a 16 hr withdrawal from feed and water. Intermediate weights were on the basis of a 16 hr withdrawal from water only.

Two steers from trial 2 and one heifer and one steer from trial 3 were removed during the course of the trials. The loss of one animal was treatment related with a high grain fed steer from trial 2 removed due to founder. The data from all four animals were

completely removed from the trials by estimating feed consumed from observed gains using the net energy requirement equations for steers and heifers as outlined by NRC (1976).

All cattle were housed, 5 to 8 per pen, in concrete, bedded lots. Approximately one-half of the floor space of each pen was covered with a roof.

Initial Slaughter Animals

All initial slaughter calves were selected to be representative of those placed on feed in the feedlot studies. Ten steer calves (two to three per genetic type) were slaughtered at the beginning of trial 2. Dressing percentage and carcass composition data from these calves were used to estimate the initial carcass weight and composition of steers fed in trials 1 and 2. Similarly, 13 steer calves (three to four per genetic type) were slaughtered at the beginning of trial 3 to estimate the initial values of their steer mates placed on experiment.

A limited number of heifers were available for initial slaughter purposes. Three USH, two AHC, and three AHH heifers from trial 2 and two SH heifers from trial 3 were used to estimate the initial carcass weight and carcass composition of heifers placed on feed in trials 2 and 3. Pre-trial nutritional and management procedures were kept as constant as possible for the three trials.

Final Slaughter Procedure and Carcass Evaluation

Trial 1 steers fed the high grain ration were slaughtered when 80% of the steers were estimated to grade choice. Steers fed

high silage were slaughtered when their mean weight was similar to the final weight of the high grain steers. All steers within a given energy level were slaughtered at one time.

Trial 2 and 3 cattle were slaughtered in three groups, again based on an estimated degree of fatness sufficient for the choice grade. Fifty percent of the high grain fed steers per cattle type were slaughtered initially followed by the remaining high grain steers and 50% of the cattle fed high silage. The final slaughter group consisted of all remaining cattle. Heifers weighed approximately 85% of their steer mates at slaughter.

All cattle killed initially and a total of 36 final slaughter steers (five high silage and four high grain steers per type) from trials 2 and 3 were slaughtered at the university meats laboratory. The pituitary gland and the semitendinosis (ST) muscle from the left side of the carcass were removed immediately after exsanguination of the 36 final slaughter steers. ST muscles were analyzed for moisture, fat, protein, nucleic acids, and muscle protein fractions and pituitary glands were assayed for total growth hormone content in studies by Eversole (1978).

All trial 1 steers and the remaining trial 2 final slaughter animals were transported 105 km to a commercial packing plant (Walters Packing Plant, Coldwater, Michigan) and processed by standard procedures. In trial 3, the remaining final slaughter animals were transported 160 km to a commercial packing plant (Dinner Bell Meats, Archbold, Ohio) for slaughter.

Carcass data were collected in a like manner regardless of slaughter location. Hot carcass weights were obtained and carcasses were chilled for a minimum of 24 hr preceding evaluation. Complete carcass quality and yield data were collected and actual fat thickness between the 12th and 13th rib was measured.

Procedures for Determining Body Composition

Body composition of all trial 1 and 2 experimental animals was determined by chemical analysis of the 9-10-11 rib cut as outlined by Hankins and Howe (1946). The rib section was removed from one side of the chilled carcass and immediately transported to the university meats laboratory for further processing. Ribs were subsequently separated into bone and soft tissue. The soft tissue was passed through a Hobart meat grinder (0.47 cm plate) five times and thoroughly mixed. A 1 kg subsample was secured and frozen for subsequent analyses. Rib tissue was analyzed for moisture by drying a 6 to 7 g sample at 100 C for 24 hr. Nitrogen determinations were conducted on wet 1 g samples with a Technicon Auto-Kjeldahl System. Ether extract was determined on dried samples with the Goldfisch procedure. Equations relating composition of the rib cut to carcass composition are presented in Table 11.

Body composition of cattle slaughtered initially in trial 3 was determined by rib analysis as previously described. The composition of final slaughter animals was determined by the specific gravity technique outlined in Garrett and Hinman (1969). Carcass

Table 11. Procedures and Equations for Determining Carcass Composition and Performance

| Trial[a] | Item | Equation[b] | References or Procedure |
|---|---|---|---|
| 1,2 | 9-10-11 rib cut | | Hankins and Howe (1946) |
| | 9-10-11 rib cut protein (x) | -- | Kjeldahl |
| | 9-10-11 rib cut fat (y) | -- | Ether extraction (Goldfisch) |
| | Carcass protein | .66x + 5.98 | Hankins and Howe (1946) |
| | Carcass fat | .77y + 2.82 | Hankins and Howe (1946) |
| 3 | Specific gravity | | |
| | SG | $\frac{\text{CW in air}}{(\text{CW in air} - \text{CW in } H_2O)(\text{Correction for water \& carcass temp.})}$ | |
| | Carcass protein | (20.0 • SG - 18.57) 6.25 | Garrett and Hinman (1969) |
| | Carcass fat | 587.86 - 530.45 • SG | Garrett and Hinman (1969) |
| 1,2,3 | Carcass performance | | |
| | Protein deposition, kg/day | $\frac{(\text{Final CW})(\%\text{ final CP}) - (\text{Initial CW})(\%\text{ initial CP})}{\text{Days on feed}}$ | |
| | Fat deposition, kg/day | $\frac{(\text{Final CW})(\%\text{ final CF}) - (\text{Initial CW})(\%\text{ initial CF})}{\text{Days on feed}}$ | |
| | Protein energy gain, Mcal/day | (Daily protein deposition, kg)(5.686 Mcal/kg) | Garrett et al. (1958) |
| | Fat energy gain, Mcal/day | (Daily fat deposition, kg)(9.367 Mcal/kg) | Garrett et al. (1958) |
| | Total energy gain, Mcal/day | Protein energy gain + fat energy gain | |

[a]The 9-10-11 rib cut procedure was used to evaluate composition of all initial slaughter cattle.

[b]Abbreviations: SG: specific gravity; CW: carcass weight, kg; CP: carcass protein, %; CF: carcass fat, %.

weights were obtained on the chilled carcass in air and under water. A steel tank, 112 cm in diameter and 183 cm in height, was fitted with a Toledo triple-beam balance. The tank was filled to near capacity with water and temperature maintained at 10 C or less with crushed ice. The front and rear quarter of one side of each carcass was alternately suspended from the balance and immersed underwater and the weight recorded. Care was taken to insure that all air pockets in the carcass were removed. Carcass and water temperatures were obtained periodically and recorded for later use in the calculation of correction factors. The equations used to relate carcass density to carcass protein and fat composition are outlined in Table 11.

Carcass Performance Calculations

Equations used to calculate carcass protein, fat, and energy gain for the three trials are presented in Table 11. The caloric values of 5.686 Mcal/kg for protein and 9.367 Mcal/kg for fat tissue presented in Garrett (1958) were used.

Economic Analysis

The procedures outlined by Black and Fox (1978) and Crickenberger and Black (1976) were followed in constructing the economic framework. Total costs per 100 kg gain were calculated based on the pooled performance results of the 2-year steer-heifer (all fed high silage) and 3-year high silage vs high grain steer comparisons.

Nonfeed costs were allocated on the basis of frame size, where applicable, and reflected current price relationships (Table 26).

Feed costs were calculated at three corn prices: $7.86, $14.73, and $21.61 per 100 kg.

The price of corn silage (ton basis) was defined as:

$$6 \text{ (price of corn grain \$/bu)} + \$3.50$$

Thus, corn silage was assumed to contain 6 bu of corn grain/ton and was priced to yield equal earnings per unit land as grain production (Woody and Black, 1978).

Historically, the price of soybeans (per bushel) has averaged 2.35 times the price of corn ($/bu). Thus, the price of soybean meal was derived from the relationships between prices of soybeans and corn and among the prices of soybeans, soybean meal, and soybean oil. The derived soybean meal price was based upon 48 lb of meal and 11 lb of oil from 60 lb (1 bushel) of soybeans:

$$\text{Soybean meal (44\%), \$/lb} = \frac{\text{Soybean price} - 11\text{ (oil price/lb)} + \text{processing charge/bu}}{48}$$

Soybean oil is priced at $0.20/lb when corn is $2/bu, increasing $0.05 per $1/bu rise in the corn price thereafter. A processing charge of $0.35/bu was assumed. The derived price was increased 10% for pricing soybean meal 49 and $30/T was added as a transport charge.

Mineral and vitamin components of the respective rations were priced at current levels. Further assumptions involved in the cost analysis are presented as footnotes to Tables 27 and 35 for the high silage steer vs heifer and high silage vs high grain steer comparisons, respectively.

## Analysis of Data

### General Statistical Procedures

Statistical tests were designed in the context of research objectives, information from previous research, and biological modeling. The two general tests utilized in testing hypotheses for all trials are outlined in this section. The specific approaches and linear models used to estimate parameters are presented subsequently for the cow-calf, metabolism, and feedlot phases of the research. Additional details describing the analytical procedures may be found in Black and Harpster (1978).

In all trials, the method of least squares (Siber, 1977; Rao and Miller, 1971; Searle, 1971) was used to estimate parameters of equations with the form:

$$Yi = \sum_{k=1}^{K} \beta_k \chi_{k,i} + e_i.$$

Cattle type (USH, SH, AHC, AHH), year, and energy level (in the case of the metabolism trials and cow-calf trial 2) were treated as 0, 1 variables, i.e., type, year, or energy level equals "1" if true, "0" otherwise. For the feedlot trials, percentage concentrate in the ration, hot carcass weight and percentage carcass fat were treated as continuous variables.

Two general types of hypotheses were tested. Tests used were:

*Test 1*

The significance of main effects and interactions (for example, cattle type) were assessed as follows:

$$H_N: \ \beta_1 = \beta_2 = \beta_3 = \beta_4$$

vs

$$H_A: \ H_N \text{ not true.}$$

Where:

$\beta_1 \ldots \beta_4$ are parameters for the USH, SH, AHC, and AHH cattle types, respectively.

Test statistic:

$$\frac{(RSSE - URSSE)/r}{URSSE/UEDF} \text{ is distributed as } F_r, \text{ UEDF.}$$

Where:

RSSE is the error sums of squares for the "restricted" model (one intercept term for all cattle types);

URSSE is the error sums of squares for the "unrestricted" model (a separate intercept term for each cattle type);

UEDF is the error degrees of freedom for the unresticted model; and

r is the number of restrictions imposed.

*Test 2*

Where a significant ($P < .10$) effect of cattle type was noted (as outlined in test 1) specific type comparisons of interest were conducted. Type comparisons included: USH vs SH; SH vs AHC, and AHC vs AHH. Hypotheses were tested as follows:

$$H_N: \sum_{k=1}^{K} C_k \beta_k = \phi$$ (for example, $\beta_1 - \beta_2 = 0$ for comparing two cattle types; i.e., $C_1 = 1$, $C_2 = -1$)

vs

$H_A$: $H_N$ not true.

Let:

$$\hat{\phi} = \Sigma C_k \hat{\beta}_k$$

$$V(\hat{\phi}) = C_1^2 V(\hat{\beta}_1) + C_2^2 V(\hat{\beta}_2) + 2C_1C_2 \, COV(\hat{\beta}_1, \hat{\beta}_2)$$

Test statistic:

$$\frac{\hat{\phi} - \phi}{\sqrt{V(\hat{\phi})}}$$ is distributed as $t\alpha$, $N - K$

Calculated levels of significance were reported in the tables for $.005 \leq P \leq .20$ as suggested by Black and Fox (1977). Values above the 10% level are presented so that other investigators can combine the results with results from similar independent experiments to permit evaluation of significance levels for the combined information.

For example, four similar independent trials, each with a significance value of .10, have a joint significance level of .03 when the results are pooled (Black and Fox, 1977). For purposes of discussion in the present studies, a "significant difference" for a given parameter was assumed if the significance level was less than .10.

Cow-Calf Trials

Experimental design of cow-calf trials 1 and 2 differed and thus data were analyzed independently. Least square means were estimated by the following linear models:

Trial 1:
Cow and calf performance parameters = f (cattle type); and

Trial 2:
Cow and calf performance parameters = f (cattle type, energy level).

Since all animals within a cattle type (trial 1) or cattle type x energy level combination (trial 2) were group fed, feed intake and efficiency of feed utilization data could not be subjected to statistical analysis.

Metabolism Studies

Metabolism trial design was consistent in each of two years and data were pooled. Least square means were estimated by the linear model:

Feed utilization parameters = f (cattle type, energy level, year).

Feedlot and Body Composition Studies

As previously outlined, USH, SH, AHC, and AHH steers were fed high silage (HS) and high grain (HG, 60% concentrate in trial 1, 80% in trials 2 and 3) rations in each of 3 years. Additionally, heifers of each cattle type were fed HS in trials 2 and 3. Data were organized in two comparisons: HS heifers vs HS steers (2 year comparison) and HS steers vs HG steers (3 year comparison).

The effects of sex on feedlot performance and carcass characteristics were examined in a comparison of HS steers vs heifers. Cattle type effects were not examined in this comparison due to the differences in selection criteria practiced for USH vs SH, AHC, and AHH heifers as described previously. Carcass data and other parameters, where appropriate, were adjusted to the mean carcass fat of all steers and heifers in the comparison (29.2%).

The effects of cattle type and ration energy level were examined by comparing HS vs HG steers. Steers were compared at similar carcass fat to examine the effect of cattle type on carcass characteristics. This adjustment was made to facilitate comparisons among types and to assess differences in fat distribution (marbling, KPH, external fat) had all steers been slaughtered at the mean carcass fat of 32.2%. Additionally, carcass data of steers was adjusted to a similar carcass weight within type to examine the influence of ration energy level on carcass characteristics. Specifically, this adjustment was made to ascertain differences in carcass fatness and quality when steers fed HS and HG are slaughtered at similar weights.

In both comparisons, equations for dry matter intake (DMI), feed/gain (F/G), and other parameters based on group data were estimated using treatment means since animals were not individually fed. Average daily gain (ADG), carcass protein gain, fat gain, and energy gain and carcass characteristic equations were estimated using individual animal data.

Analyses indicated that year x cattle type and year x energy level interactions were not significant. Thus, these parameters were not included in the final models utilized to estimate treatment means. However, an energy level x cattle type interaction was noted in the HS vs HG steer comparison for F/G. Thus, terms recognizing this interaction were included in the F/G model.

Specific linear models used to calculate treatment means were as follows:

I. HS steers vs HS heifers:

A. Dependent variables = f (cattle type, sex, year)

Where dependent variables are:

DMI
ME intake
ADG
F/G
Crude protein intake
Efficiency of crude protein utilization for carcass protein production
Efficiency of ME utilization for production of edible portion

B. Dependent variables = f (cattle type, sex, mean carcass fat, year)

Where dependent variables are:

Carcass characteristics
Carcass protein gain, fat gain, energy gain
Edible portion gained
Energetic efficiency

II. HS steers vs HG steers:

A. Dependent variables = f (cattle type, percent concentrate, year)

Where dependent variables are:

DMI
MEI
Crude protein intake
Efficiency of crude protein utilization for carcass protein production
Efficiency of ME utilization for production of edible portion

B. ADG, carcass characteristics = f (cattle type, percentage concentrate, hot carcass weight, year)

C. Feed/gain = f (cattle type, percentage concentrate for non-Holsteins, percentage concentrate for Holsteins, year)

D. Dependent variables = f (cattle type, percentage concentrate, mean carcass fat, year)

Where dependent variables are:

Carcass characteristics
Carcass protein gain, fat gain, energy gain
Edible portion gained
Energetic efficiency

In the case of the HS vs HG steer comparison, percentage concentrate in the ration was included as a continuous independent variable since three levels of concentrate were compared: 9% for HS rations, 60% concentrate and 80% concentrate (HG rations). A weighted average concentrate value (71%) was used to calculate least square means for cattle fed HG.

# RESULTS

## Cow-Calf Trial 1

### Weight and Condition of Cows

Mean weight and external fat changes of trial 1 cows are presented by weigh period (28 days) in Figure 1. Cows were placed on experiment in early December and during the adverse weather conditions encountered during the winter months, most cows lost body weight and condition. Average temperature (C) and wind speed (km/hr) for the months of December, January, and February were -2.2, 15.8; -7.2, 19.0; and 0, 20.1, respectively (Table A.5).

By early April, average weight loss was 20, 31, 51, and 68 kg for USH, SH, AHC, and AHH cows, respectively. Since the calving season extended from January 22 to April 7, 1976, part of the weight loss can be attributed to calf weight and fetal tissue loss. However, average external fat cover in early April was less than 0.25 cm for all groups, indicating a mobilization of fat stores in an attempt to meet energy requirements. All cows gained in weight and condition during subsequent months after the lactation ration offered was increased 25% on April 7, 1976 (day 112).

Mean initial, final, and amount of change values for cow weight and condition are presented in Table 12. SH cows were heavier ($P = .05$) than USH and lighter ($P = .07$) than AHC cows initially while AHC and AHH

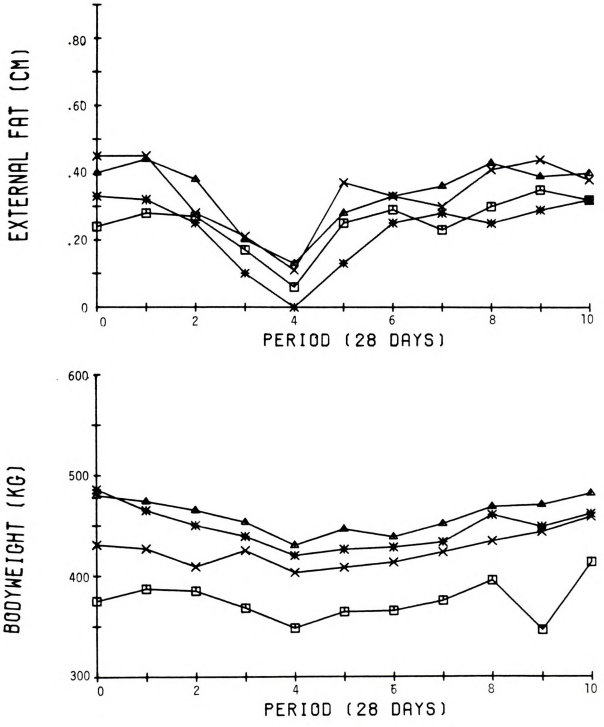



**Figure 1.** Mean weight and external fat changes of Unselected Hereford (□), Selected Hereford (×), Angus x Hereford x Charolais (△), and Angus x Hereford x Holstein (✳) cows (trial 1).

Table 12. Effect of Cattle Type on Cow and Calf Performance (Trial 1)[a]

| Item | Cattle type[b] | | | | SE | Significance level | Type comparisons[c] | | |
|---|---|---|---|---|---|---|---|---|---|
| | USH | SH | AHC | AHH | | Cattle type | USH vs SH | SH vs AHC | AHC vs AHH |
| No. of cows | 8 | 9 | 10 | 8 | | | | | |
| Cow wt initial, kg | 374.8 | 431.4 | 480.4 | 486.2 | 26.9 | <.005 | .05 | .07 | .20 |
| Cow wt final, kg | 413.3 | 457.6 | 481.3 | 460.7 | 30.7 | >.20 | NA | NA | NA |
| Cow fat initial, cm | 0.24 | 0.45 | 0.41 | 0.33 | 0.10 | .18 | NA | NA | NA |
| Cow fat final, cm | 0.32 | 0.38 | 0.41 | 0.32 | 0.10 | >.20 | NA | NA | NA |
| Cow wt change, kg[d] | 38.6 | 26.2 | 0.91 | -25.5 | 17.9 | .01 | >.20 | .17 | .17 |
| Cow fat change, cm[d] | 0.08 | -0.07 | 0.0 | -0.01 | 0.11 | >.20 | NA | NA | NA |
| Calf birth wt, kg | 29.1 | 36.4 | 39.4 | 39.5 | 3.2 | .01 | .03 | >.20 | >.20 |
| Adj. calf weaning wt, kg[e] | 161.5 | 193.8 | 208.2 | 228.9 | 19.3 | .02 | .12 | >.20 | >.20 |
| Preweaning calf ADG, kg[f] | 0.65 | 0.77 | 0.82 | 0.92 | 0.08 | .03 | .17 | >.20 | >.20 |

[a]Least square means and standard error of the difference between two means (SE). Maintenance and lactation levels of energy were based on National Research Council (1970) recommendations.

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]NA: Comparison not appropriate (main effect of cattle type not significant at $P < .10$).

[d]Final minus initial values.

[e]Adjusted for age of dam, sex of calf, 205 day basis.

[f]Based on adjusted weaning weights, 205 days.

cows were similar. Final weights did not differ ($P > .10$) by cattle type and of the specific type comparisons examined, there were no significant differences ($P > .10$) in body weight change for the 280 day trial. All cows gained weight over the duration of the trial except AHH cows, which lost an average 25.5 kg. Initial body weights of USH, SH, and AHC cows, expressed as a percentage of AHH cows, were 77, 89, and 99%, respectively. Similarly, calculated values for final weight were 90, 99, and 104%, further emphasizing the relatively poor ability of AHH cows to maintain their body weight.

Initial and final body condition, as measured by external fat cover, was not different ($P > .10$) among the four types of cows. Averaged over cattle types, initial and final values were 0.36 cm. Thus, although not noted with body weight, external fat was fully recovered during the 280 day trial.

Preweaning Calf Performance

Birth weights of SH, AHC, and AHH calves were similar (Table 12). Predictably, USH calves were lightest at birth and weaning. Adjusted 205 day weaning weights increased with increasing frame size as did preweaning calf average daily gain. There were no differences ($P > .10$) in calf weaning weight or ADG for USH vs SH, SH vs AHC, or AHC vs AHH calves. However, if the average framed British breed calves (SH) are taken as reference animals, USH calves gained 16% slower, AHC calves 6.5% faster and AHH calves 19% faster to weaning.

Cow Intake and Efficiency of Producing Calf Weaning Weight

Cows within a cattle type were group-fed and thus intake and efficiency data could not be subjected to statistical analysis. However, apparent trends will be pointed out.

Cows were fed according to requirements (NRC, 1970) based on body weight and thus TDN and dry matter intake increased with increasing cow weight (Table 13). Since maintenance requirements are a function of metabolic body size, TDN intake was also expressed on that basis. Differences were small ranging from 57.6 to 62.8 g TDN/$W_{kg}^{.75}$/day for AHC and USH cows, respectively.

It was not possible to separate calves from cows at feeding time and thus an unknown amount of feed was consumed by the calves. Nonetheless, efficiency of conversion of total TDN consumed by the cow-calf unit to calf weaning weight can be calculated. This measure of efficiency increased as cow size increased (Table 13). Trends were similar when TDN intake and TDN/calf WW were projected for a full year. This is a more realistic evaluation of the energy costs of producing calf weight since the cow must obviously be maintained throughout the year. NRC (1970) requirements for maintaining dry, pregnant cows at their off-experiment weights were used in estimating the 85 days of feed required to complete the year. Again using the average frame British breed cows (SH) as reference animals, USH cows required 14% more TDN to produce a unit of weaned calf. AHC and AHH cows required 95 and 91% as much TDN as SH cows to produce a unit of calf weaning weight.

Table 13. Mean Daily Dry Matter and Total Digestible Nutrient Intake of Trial 1 Cows and Efficiency of Feed Utilization for Production of Calf Weaning Weight[a]

| Item | Cattle type[b] | | | |
|---|---|---|---|---|
| | USH | SH | AHC | AHH |
| No. of cows | 8 | 9 | 10 | 8 |
| Trial basis, 280 days | | | | |
| Dry matter intake, kg/day | 7.93 | 8.34 | 8.44 | 9.07 |
| TDN intake, kg/day[c] | 5.55 | 5.84 | 5.91 | 6.35 |
| $Cow_{kg}^{.75}$[d] | 88.43 | 96.81 | 102.63 | 101.51 |
| TDN intake, $g/W_{kg}^{.75}$/day[e] | 62.8 | 60.3 | 57.6 | 62.6 |
| TDN/calf WW[f] | 9.62 | 8.44 | 7.95 | 7.77 |
| Yearly basis, 365 days[g] | | | | |
| TDN intake, kg/day | 5.01 | 5.29 | 5.39 | 5.68 |
| TDN/calf WW | 11.33 | 9.96 | 9.44 | 9.07 |

[a]Maintenance and lactation levels of energy were based on National Research Council (1970) recommendations. Lactation ration amounts were increased 25% on day 112 of the trial and continued for the remainder of the trial.

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Calculated ration total digestible nutrients (TDN), 70.0%.

[d]Average of initial and final values.

[e]An unknown amount of feed was consumed by the calves which were not separated from the cows.

[f]Observed total feed TDN intake of cow and calf (kg) per kg adjusted calf weaning weight (WW).

[g]Observed TDN intake plus recommended amount of TDN required to maintain dry, pregnant beef cows at their off-experiment weights for an additional 85 days.

Rebreeding Performance

As previously indicated, the amount of lactation ration offered was increased on day 112 (April 7) of the trial with cows inseminated on days 163 and 164 (May 28 and 29, 1976). Although cows were gaining weight at the time, only 15 (42%) were cycling when inseminated, as defined by serum progesterone levels greater than 1.0 ng/ml (Table 14). Fifty-three percent of all cows cycling became pregnant. The percentage of all cows cycling and the percentage bred of those cycling were, respectively: USH, 56, 80; SH, 22, 0; AHC, 30, 33, and AHH, 63, 60. Definitive conclusions concerning cattle type differences in ability to rebreed under the nutritional and environmental conditions imposed are limited due to the small number of cows per group and variation in the length of time from calving to rebreeding. For example, AHH cows tended to calve early and therefore had a greater time period to resume normal cycling.

## Cow-Calf Trial 2

Weight and Condition of Cows

In trial 2, five cows per type received a low (NRC) and five cows a high (NRC + 25%) level of energy based on the revised maintenance and lactation requirements recommended by NRC (1976). Mean 28 day body weight and external fat values for the USH, SH, AHC, and AHH cows are presented in Figures 2 to 5, respectively. External fat cover of AHH cows was lowest at the beginning of the trial and remained less than the other cattle types throughout the study, especially those fed the

Table 14. Rebreeding Data for Trial 1 Cows[a]

| Cow type | No. of cows | No. cycling[b] | No. bred[c] | Avg. days postpartum[d] |
|---|---|---|---|---|
| Unselected Hereford[e] | 9 | 5 | 4 | 86 |
| Selected Hereford | 9 | 2 | 0 | 76 |
| Angus x Hereford x Charolais | 10 | 3 | 1 | 84 |
| Angus x Hereford x Holstein | 8 | 5 | 3 | 100 |

[a]Prostaglandin $F_2\alpha$ was used to synchronize estrus.

[b]Serum progesterone levels ≥ 1.0 ng/ml.

[c]Two of the eight cows bred conceived to a return service.

[d]At time of breeding.

[e]One Unselected Hereford cow was lost after completion of the rebreeding phase of the experiment.

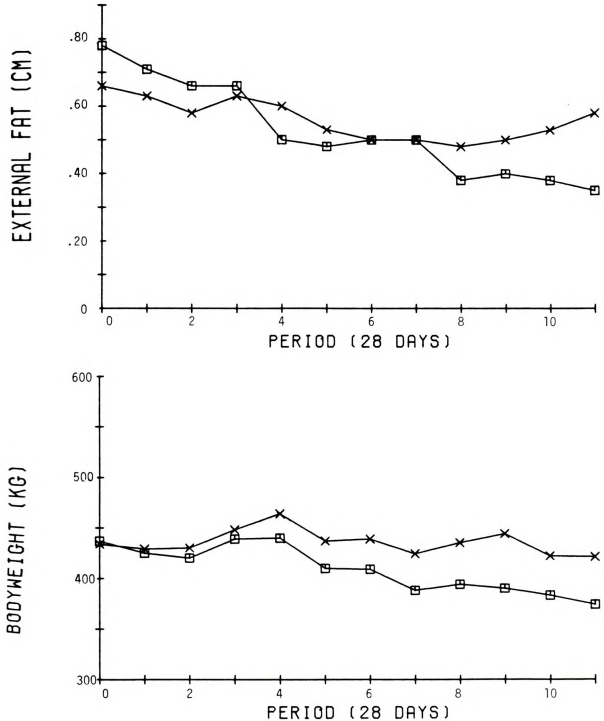



Figure 2. Mean weight and external fat changes of trial 2 Unselected Hereford cows fed two levels of energy (NRC: □; NRC + 25%: ×).

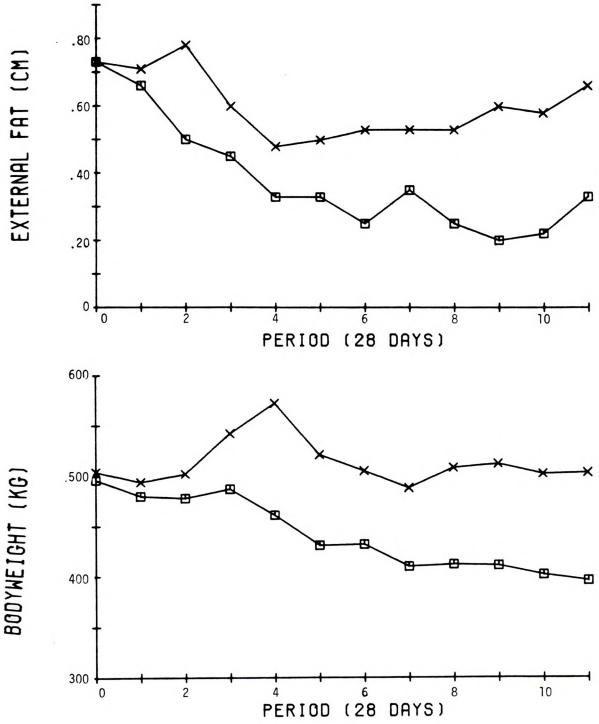



Figure 3. Mean weight and external fat changes of trial 2 Selected Hereford cows fed two levels of energy (NRC: □; NRC + 25%: ×).

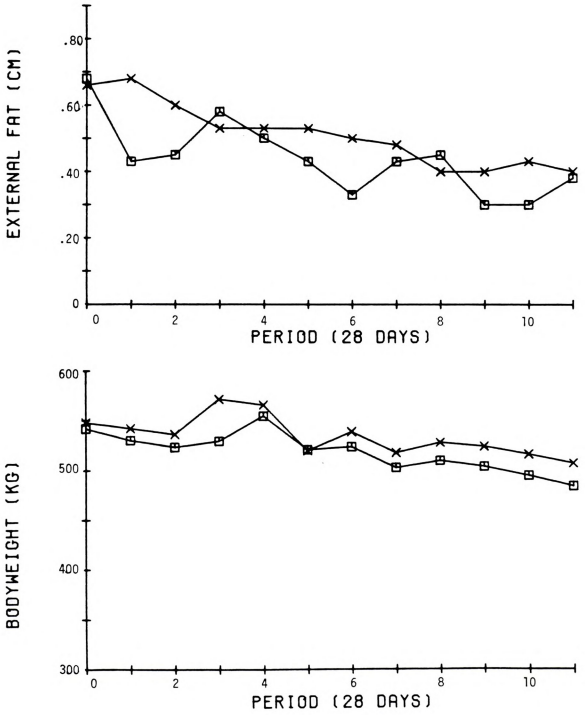



Figure 4. Mean weight and external fat changes of trial 2 Angus x Hereford x Charolais cows fed two levels of energy (NRC: □; NRC + 25%: ×).

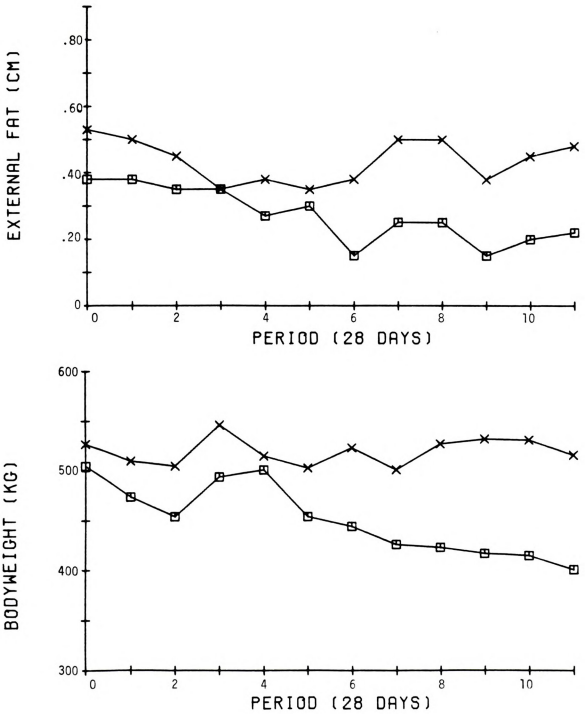



Figure 5. Mean weight and external fat changes of trial 2 Angus x Hereford x Holstein cows fed two levels of energy (NRC: □; NRC + 25%: X).

low energy level. Environmental conditions were more severe in trial 2 than trial 1. Mean temperature (C) and wind speed (m/hr) for the months of December, January, and February were -7.8, 17.2; -11.8, 19.8, and -5.3, 18.3, respectively (Table A.5). As in trial 1, cows were maintained outside without shelter although they were moved to a sheltered area for calving.

Mean body weight and external fat changes for the duration of the trial are presented in Table 15. As noted in trial 1 final body weight did not differ ($P > .10$) for USH vs SH, SH vs AHC, or AHC vs AHH cows. However, averaged across cattle types, final weights were heavier ($P < .005$) for cows fed high vs low energy (413 vs 504 kg). Cow weight change for the 301 day trial did not differ by cattle type ($P > .10$) but favored the high energy groups (-17 vs -83 kg).

Initial external fat values were similar across groups of cows fed low and high energy but averaged less ($P = .06$) for AHH vs AHC cows. Final and final minus initial fat values were not influenced by cattle type although both values were lower for cows fed low energy. In summary, cows receiving the low energy level regained 83% of their initial body weight and 48% of their initial condition. Cows receiving the high energy level regained 97% of their initial body weight and 82% of their initial condition.

Preweaning Calf Performance

Calf birth weight was not influenced ($P > .10$) by the level of energy fed to the cows (Table 15). Trends among cattle types were

Table 15. Effect of Cattle Type and Energy Level on Cow and Calf Performance (Trial 2)[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of cows | NRC | 5 | 4 | 3 | 4 | | | | | | |
| | NRC25 | 4 | 5 | 5 | 4 | | | | | | |
| Cow wt initial, kg | NRC | 432.5 | 496.6 | 541.4 | 512.9 | 30.0 | >.20 | .01 | .03 | .15 | >.20 |
| | NRC25 | 440.3 | 504.5 | 549.2 | 520.7 | | | | | | |
| Cow wt final, kg | NRC | 362.6 | 414.9 | 451.7 | 422.1 | 32.4 | <.005 | .08 | .10 | >.20 | >.20 |
| | NRC25 | 436.4 | 488.7 | 525.5 | 495.9 | | | | | | |
| Cow fat initial, cm | NRC | 0.73 | 0.73 | 0.66 | 0.46 | 0.10 | >.20 | .04 | >.20 | >.20 | .06 |
| | NRC25 | 0.74 | 0.74 | 0.67 | 0.46 | | | | | | |
| Cow fat final, cm | NRC | 0.36 | 0.39 | 0.26 | 0.24 | 0.08 | <.005 | .18 | NA | NA | NA |
| | NRC25 | 0.57 | 0.60 | 0.48 | 0.46 | | | | | | |
| Cow wt change, kg[e] | NRC | -69.9 | -81.7 | -89.7 | -90.8 | 18.9 | <.005 | >.20 | NA | NA | NA |
| | NRC25 | -3.9 | -15.8 | -23.8 | -24.9 | | | | | | |
| Cow fat change, cm[e] | NRC | -0.38 | -0.34 | -0.40 | -0.22 | 0.09 | <.005 | >.20 | NA | NA | NA |
| | NRC25 | -0.16 | -0.13 | -0.19 | -0.01 | | | | | | |
| Calf birth wt, kg | NRC | 32.4 | 41.7 | 40.9 | 41.2 | 2.8 | >.20 | <.005 | <.005 | >.20 | >.20 |
| | NRC25 | 33.2 | 42.5 | 41.7 | 42.0 | | | | | | |
| Adj. calf weaning wt, kg[f] | NRC | 158.2 | 169.3 | 201.5 | 226.8 | 14.3 | .03 | <.005 | >.20 | .03 | .09 |
| | NRC25 | 180.9 | 191.1 | 224.1 | 249.4 | | | | | | |
| Preweaning calf ADG, kg[g] | NRC | 0.61 | 0.62 | 0.78 | 0.91 | 0.07 | .04 | <.005 | >.20 | .02 | .09 |
| | NRC25 | 0.72 | 0.73 | 0.89 | 1.01 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]NRC: National Research Council (1976) recommended levels of energy for maintenance and lactation; NRC25: 125% of recommended level.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: Comparison not appropriate (main effect of cattle type not significant at $P < .10$).

[e]Final minus initial values.

[f]Adjusted for age of dam, sex of calf, 205 day basis.

[g]Based on adjusted weaning weights, 205 days.

similar to trial 1 with SH calves heavier at birth than USH calves ($P < .005$) while SH vs AHC and AHC vs AHH calves did not differ ($P > .10$). Calves from dams fed high energy were an average 12% heavier at weaning and gained 15% faster than calves from low energy dams. Comparing cattle types, adjusted calf weaning weight and pre-weaning gain increased with increasing frame size, a result consistent with trial 1. However, for USH and SH calves, these values were not different ($P > .10$).

Cow Intake and Efficiency of Producing Calf Weaning Weight

Dry matter and TDN intake were determined by cow weight and increased accordingly (Table 16). AHH cows, however, received lactation levels of energy recommended by NRC (1976) for cows of "superior milking ability." At a given body weight, approximately 25% more TDN is recommended for cows of superior vs average milking ability. Thus, TDN intake per unit metabolic body size was essentially equal for USH, SH, and AHC cows while consumption by AHH cows was greater. The lower energy intake (per unit metabolic body size) of trial 2 high energy cows (USH, SH, AHC) relative to trial 1 cows is explained by two factors. First, trial 2 was conducted over a longer period of time precalving, thus, more days on a maintenance ration. Secondly, the revised feeding standard followed in trial 2 (NRC, 1976), while increasing pregnancy requirements relative to trial 1 recommendations (NRC, 1970), actually decreased lactation levels approximately 10% for cows of average milking ability.

Table 16. Mean Daily Dry Matter and Total Digestible Nutrient Intake of Cows Fed Two Levels of Energy and Efficiency of Feed Utilization for Production of Calf Weaning Weight (Trial 2)

| Item | Energy[a] level | Cattle type[b] USH | SH | AHC | AHH |
|---|---|---|---|---|---|
| No. of cows | NRC | 5 | 4 | 3 | 4 |
| | NRC25 | 4 | 5 | 5 | 4 |
| Trial basis, 301 days | | | | | |
| Dry matter intake, kg/day | NRC | 6.01 | 6.48 | 6.80 | 7.81 |
| | NRC25 | 7.45 | 8.38 | 8.74 | 10.08 |
| TDN intake, kg/day[c] | NRC | 4.21 | 4.54 | 4.76 | 5.47 |
| | NRC25 | 5.22 | 5.87 | 6.11 | 7.06 |
| Cow $W_{kg}^{.75}$[d] | NRC | 90.36 | 97.05 | 107.71 | 98.19 |
| | NRC25 | 94.02 | 106.29 | 110.00 | 109.13 |
| TDN intake, $g/W_{kg}^{.75}$/day[e] | NRC | 46.6 | 46.8 | 44.2 | 55.7 |
| | NRC25 | 55.5 | 55.2 | 55.5 | 64.7 |
| TDN/calf WW[f] | NRC | 8.01 | 8.07 | 7.11 | 7.26 |
| | NRC25 | 8.69 | 9.25 | 8.21 | 8.52 |
| Yearly basis, 365 days[g] | | | | | |
| TDN intake, kg/day | NRC | 4.02 | 4.32 | 4.59 | 5.09 |
| | NRC25 | 5.06 | 5.70 | 5.90 | 6.70 |
| TDN/calf WW | NRC | 9.28 | 9.31 | 8.32 | 8.20 |
| | NRC25 | 10.20 | 10.89 | 9.61 | 9.80 |

[a]NRC: National Research Council (1976) recommended levels of energy for maintenance and lactation; NRC25: 125% of recommended levels. AHH cows were fed at the level recommended for cows of superior milking ability.

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Calculated ration total digestible nutrients (TDN), 70.0%.

[d]Average of initial and final values.

[e]An unknown amount of feed was consumed by the calves which were not separated from the cows.

[f]Observed total feed TDN intake of cow and calf (kg) per kg adjusted calf weaning weight (WW).

[g]Observed TDN intake plus recommended amount of TDN required to maintain dry pregnant beef cows at their off-experiment weights for an additional 64 days.

Total TDN consumed during the trial per unit calf weaning weight produced favored the larger cows (Table 16), as noted in trial 1. When projected over a full year, efficiency was highest for AHH cows and lowest for SH cows. Averaged over all cattle types, 15% more feed was required by the high vs low energy cows for production of a unit weaning weight. This was noted despite a 12% heavier weaning weight for high energy calves.

## Metabolism Studies

### Nitrogen Utilization

As indicated in Table 17, metabolism data are the pooled results of two trials. Mean initial body weights of the USH, SH, AHC, and AHH steers used in these trials were 171, 227, 243, and 278 kg, respectively.

Steers were fed ad libitum throughout the trials and nitrogen intake reflected frame size differences (Table 17). SH steers consumed more nitrogen than USH steers ($P < .005$) and AHH steers consumed more than AHC ($P = .04$). Steers fed HG rations consumed more ($P < .005$) nitrogen than those fed HS (148.5 vs 129.3 g).

There were no differences in fecal nitrogen excretion among steers fed HS vs HG rations. Coupled with the higher intakes of HG steers, this indicates a more complete digestion of the ration nitrogen for steers fed HG vs HS (66.8 vs 58.5%). Differences in digestibility due to cattle type were apparently small. Apparent digestibility of HS nitrogen for USH, SH, AHC, and AHH steers was 58.6, 57.2, 58.4, and

Table 17. Effect of Cattle Type and Ration Energy Level on Utilization of Nitrogen by Metabolism Trial Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers[e] | | 4 | 4 | 4 | 4 | | | | | | |
| Nitrogen intake, g/day | HS | 93.4 | 133.4 | 135.7 | 154.7 | 9.1 | .006 | <.005 | <.005 | >.20 | .04 |
| | HG | 112.6 | 152.6 | 155.0 | 173.9 | | | | | | |
| Fecal N excreted, g/day | HS | 38.7 | 57.1 | 56.5 | 62.2 | 4.2 | .19 | <.005 | <.005 | >.20 | .18 |
| | HG | 34.6 | 53.1 | 52.5 | 58.2 | | | | | | |
| Urine N excreted, g/day | HS | 27.4 | 46.4 | 49.3 | 54.0 | 6.9 | .13 | <.005 | .01 | >.20 | >.20 |
| | HG | 35.0 | 54.0 | 56.9 | 61.5 | | | | | | |
| Nitrogen retained, g/day | HS | 27.3 | 29.8 | 29.9 | 38.5 | 6.6 | <.005 | >.20 | NA | NA | NA |
| | HG | 43.1 | 45.6 | 45.6 | 54.2 | | | | | | |
| Percent of nitrogen intake | HS | 30.0 | 21.6 | 21.2 | 24.0 | 4.8 | .02 | >.20 | NA | NA | NA |
| | HG | 38.4 | 30.0 | 29.6 | 32.4 | | | | | | |
| Percent of nitrogen absorbed | HS | 49.2 | 37.2 | 36.3 | 40.9 | 7.5 | .15 | >.20 | NA | NA | NA |
| | HG | 57.0 | 45.0 | 44.2 | 48.7 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: comparison not appropriate (main effect of cattle type not significant at $P < .10$.

[e]Two steers per type received each ration in each of two trials.

59.8%, respectively. Similar values for steers fed HG were 69.3, 65.2, 66.1, and 66.5% for USH, SH, AHC, and AHH steers, respectively.

Urine nitrogen excretion followed the same pattern noted for nitrogen intake although there were no differences ($P > .10$) between HS and HG steers. SH steers excreted more ($P = .01$) urinary nitrogen than USH steers while remaining cattle type comparisons were not significant ($P > .10$).

While the grams of nitrogen retained daily increased with increasing steer frame size, differences were not significant ($P > .10$). Nitrogen retention expressed as a percentage of nitrogen intake or as a percentage of nitrogen absorbed, also did not differ ($P > .10$) by cattle type.

Energy level effects were noted for several measures of nitrogen retention. Steers fed HG vs HS retained more ($P < .005$) nitrogen daily (47.1 vs 31.4 g), and retained a higher ($P = .02$) percentage of nitrogen intake (32.6 vs 24.2%). Apparent biological value of the HG ration tended to be higher than the HS ration (48.7 vs 40.9%), but the difference was not significant ($P > .10$).

Energy Utilization

Daily dry matter and energy intakes increased with increasing cattle frame size (Table 18). Energy intake was higher ($P < .005$) for SH vs USH and AHH vs AHC steers ($P = .06$). Averaged across cattle types, daily energy intakes were 26.2 Mcal for steers fed HS and 28.1 Mcal for steers fed HG ($P > .10$).

Table 18. Effect of Cattle Type and Ration Energy Level on Utilization of Energy by Metabolism Trial Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparison[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers[e] | | 4 | 4 | 4 | 4 | | | | | | |
| Dry matter intake, kg/day | HS | 4.23 | 5.90 | 6.08 | 6.85 | 0.36 | .04 | <.005 | <.005 | >.20 | .04 |
| | HG | 4.79 | 6.46 | 6.64 | 7.41 | | | | | | |
| Energy intake, Mcal/day | HS | 19.31 | 26.83 | 27.58 | 31.08 | 1.80 | .15 | <.005 | <.005 | >.20 | .06 |
| | HG | 21.18 | 28.70 | 29.46 | 32.96 | | | | | | |
| Fecal energy, Mcal/day | HS | 6.43 | 8.91 | 9.21 | 10.18 | 0.58 | <.005 | <.005 | <.005 | >.20 | .10 |
| | HG | 4.28 | 6.76 | 7.06 | 8.03 | | | | | | |
| Urine energy, Mcal/day | HS | 0.38 | 0.60 | 0.62 | 0.60 | 0.04 | >.20 | <.005 | <.005 | >.20 | >.20 |
| | HG | 0.37 | 0.58 | 0.61 | 0.59 | | | | | | |
| Energy retained, Mcal/day[f] | HS | 10.95 | 15.18 | 15.55 | 17.82 | 1.39 | <.005 | <.005 | <.005 | >.20 | .11 |
| | HG | 14.84 | 19.06 | 19.44 | 21.70 | | | | | | |
| Metabolizable energy, Mcal/kg | HS | 2.65 | 2.57 | 2.53 | 2.55 | 0.09 | <.005 | >.20 | NA | NA | NA |
| | HG | 3.03 | 2.95 | 2.92 | 2.94 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: comparisons not appropriate (main effect of cattle type not significant at $P < .10$).

[e]Two steers per type received each ration in each of two trials.

[f]Energy intake minus fecal, urinary, and gaseous energy losses. Gaseous energy losses were estimated at 8% of energy intake.

Fecal energy excretion was markedly affected by energy level of the ration ($P < .005$), and averaged 8.68 Mcal/day for HS and 6.53 Mcal/day for HG steers. Apparent energy digestion coefficients were thus 66.8 and 77.0% for the HS and HG ration, respectively. SH steers excreted more ($P < .005$) fecal energy than USH steers; other type comparisons were not significant ($P > .10$). As previously noted with the nitrogen data, differences in apparent energy digestibility were small among cattle types. Coefficients for steers fed HS were 66.7, 66.8, 66.6, and 67.2%; HG values were 79.8, 76.4, 76.0, and 75.6% for USH, SH, AHC, and AHH steers, respectively.

Urinary energy excretion was similar between the two rations and for SH, AHC, and AHH steers. USH steers, however, excreted less urinary energy ($P < .005$).

Energy retention was defined as energy intake minus fecal, urinary, and estimated gaseous energy losses and did not include an estimate of heat increment. Mean values were 14.88 and 18.76 Mcal/day for the HS and HG ration, respectively ($P < .005$). Of the cattle type comparisons made, SH steers retained more ($P < .005$) energy than USH steers.

Metabolizable energy (ME) values of the respective rations were not influenced by cattle type ($P > .10$). Mean values for the HS and HG rations were 2.58 and 2.96 Mcal ME/kg ration dry matter, respectively, and were significantly different ($P < .005$).

## Feeding Trials: Steers vs Heifers

### Initial Slaughter Cattle

Steer and heifer calves fed an all silage ration in trials 2 and 3 were utilized in the steer-heifer comparison. The average weights and carcass composition of the animals slaughtered initially are presented in Table 19. A small number of heifers were available for initial slaughter purposes, and initial data were applied across trials.

The mean dressing percentage and carcass composition for each type and sex was used to estimate the initial carcass weight and composition of cattle placed on the experiments. In general, trial 3 calves were initially fatter and had higher dressing percentage than trial 2 calves.

### Intake, Gain, and Feed Efficiency

Throughout discussion of the steer-heifer comparison (both fed HS), emphasis will be placed on the main effect of sex. Statistical analysis was not conducted to determine cattle type differences because differential selection procedures were utilized in retaining replacement heifers. Thus, the quality of the heifers available for the feedlot could vary. SH, AHC, and AHH replacement heifers were saved each year on the basis of their unadjusted yearling weight. USH replacements were saved without considering weight, but were in the same age groups as heifers retained in the other three groups. Thus, although differences in quality of feedlot heifers were likely

Table 19. Shrunk Weights, Carcass Weights, and Carcass Composition of Initial Slaughter Cattle (Trials 1, 2, 3)

| Trial[a] | Cattle[b] type | Sex | No. of animals | Shrunk wt, kg | Carcass wt, kg | Dressing % | Carcass protein, % | Carcass fat, % |
|---|---|---|---|---|---|---|---|---|
| 1,2 | USH | Steers | 2 | 166.7 | 86.4 | 51.8 | 18.90 | 12.90 |
| | | Heifers | 3 | 143.6 | 75.3 | 52.4 | 16.90 | 19.01 |
| | SH | Steers | 3 | 211.7 | 102.7 | 48.5 | 18.00 | 14.73 |
| | AHC | Steers | 3 | 254.0 | 131.6 | 51.8 | 18.80 | 13.33 |
| | | Heifers | 2 | 174.6 | 87.1 | 49.9 | 17.93 | 15.67 |
| | AHH | Steers | 2 | 272.2 | 139.5 | 51.2 | 18.65 | 14.10 |
| | | Heifers | 3 | 204.9 | 108.6 | 53.0 | 17.84 | 17.92 |
| 3 | USH | Steers | 3 | 160.3 | 89.5 | 55.8 | 17.84 | 18.89 |
| | SH | Steers | 3 | 196.6 | 108.7 | 55.3 | 17.88 | 19.39 |
| | | Heifers | 2 | 176.9 | 93.5 | 52.9 | 18.00 | 18.28 |
| | AHC | Steers | 3 | 245.7 | 137.0 | 55.8 | 18.30 | 17.78 |
| | AHH | Steers | 4 | 246.1 | 135.7 | 55.1 | 17.88 | 20.74 |

[a]Heifers were not fed in trial 1.

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

small among the groups, cattle type comparisons were deferred to the HS vs HG steer trials.

Daily gain, intake, and feed/gain data are presented in Table 20. Averaged across cattle types, daily gains were 1.01 kg for steers and 0.85 kg for heifers, a difference of 0.16 kg ($P < .005$). Relative gains ($g/W_{kg}^{.75}$), however, were 12.1 and 11.9 g for steers and heifers, respectively ($P > .10$).

Daily dry matter intake of steers was 13% greater than for heifers ($P < .005$); however, on a relative basis, intake was higher ($P = .02$) for the heifers. Unadjusted kg of feed required per kg of gain was 5.4% greater ($P = .02$) for heifers vs steers (8.66 vs 8.22). However, heifers were fatter than steers (30.1 vs 28.2% carcass fat) and this would affect the feed/gain differences observed. Thus, the observed feed/gain values were adjusted to the mean carcass fat (29.2%) of all cattle in the comparison using the adjustment factor outlined in Fox and Black (1977). Analysis of the adjusted values revealed no differences ($P > .10$) in feed/gain for steers vs heifers, the additional requirements of heifers being reduced to 2.3% (8.30 vs 8.49).

Carcass Characteristics

Carcass data are presented in Table 21. Adjusted to similar carcass fat (29.2%), steers and heifers did not differ ($P > .10$) in marbling score (10.4 and 10.3) or quality grade (9.4 and 9.1). Steers had greater ($P = .04$) external fat (0.97 vs 0.84). Differences in rib eye area and kidney, heart and pelvic fat were small ($P > .10$) and numerical yield grades were lower ($P < .005$) for heifers.

Table 20. Effect of Sex on Intake, Gain, and Feed Efficiency of Steers and Heifers Fed a High Silage Ration[a]

| Item | Sex | Cattle type[b] | | | | SE | Significance level |
|---|---|---|---|---|---|---|---|
| | | USH | SH | AHC | AHH | | Sex |
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| Daily gain, | | | | | | | |
| kg | Steers | 0.91 | 1.00 | 1.05 | 1.07 | 0.02 | <.005 |
| | Heifers | 0.75 | 0.84 | 0.90 | 0.91 | | |
| g per $W_{kg}^{.75}$ | Steers | 12.2 | 12.3 | 12.1 | 11.7 | 0.2 | >.20 |
| | Heifers | 12.0 | 12.1 | 11.9 | 11.5 | | |
| Daily dry matter intake,[c] | | | | | | | |
| kg | Steers | 7.12 | 8.11 | 8.65 | 9.22 | 0.14 | <.005 |
| | Heifers | 6.15 | 7.15 | 7.69 | 8.26 | | |
| g per $W_{kg}^{.75}$ | Steers | 96.0 | 99.4 | 99.1 | 100.8 | 1.7 | .02 |
| | Heifers | 99.5 | 102.8 | 102.5 | 104.3 | | |
| Feed/gain | Steers | 7.80 | 8.10 | 8.24 | 8.72 | 0.22 | .02 |
| | Heifers | 8.25 | 8.55 | 8.69 | 9.16 | | |
| Feed/gain, adjusted[d] | Steers | 7.86 | 8.28 | 8.47 | 8.57 | 0.25 | >.20 |
| | Heifers | 8.05 | 8.47 | 8.66 | 8.76 | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Intake of corn silage dry matter was increased 6.8% to adjust for errors in dry matter determination.

[d]Feed/gain values adjusted to the mean carcass fat (29.2%) of all cattle in the comparison. Adjustment factors outlined in Fox and Black (1977).

Table 21. Effects of Sex on Carcass Traits of Steers and Heifers Fed a High Silage Ration When Cattle Were Adjusted to Similar Carcass Fat[a]

| Item | Sex | Cattle type[b] USH | SH | AHC | AHH | SE | Significance level Sex |
|---|---|---|---|---|---|---|---|
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| Carcass wt, kg | Steers | 267 | 302 | 332 | 348 | | |
| | Heifers | 212 | 250 | 265 | 284 | | |
| Carcass fat, % | | 29.41 | 28.49 | 27.98 | 30.76 | | |
| Marbling[c] | Steers | 9.7 | 10.2 | 10.7 | 11.1 | 0.8 | >.20 |
| | Heifers | 9.6 | 10.1 | 10.6 | 11.0 | | |
| Quality grade[d] | Steers | 9.0 | 9.2 | 9.6 | 9.6 | 0.4 | >.20 |
| | Heifers | 8.7 | 9.0 | 9.4 | 9.3 | | |
| External fat, cm | Steers | 0.94 | 0.99 | 0.91 | 1.04 | 0.08 | .04 |
| | Heifers | 0.81 | 0.86 | 0.76 | 0.91 | | |
| Rib-eye area, sq. cm | Steers | 71.70 | 72.69 | 78.47 | 76.02 | 1.92 | >.20 |
| | Heifers | 71.86 | 72.85 | 78.63 | 76.19 | | |
| KPH, % | Steers | 2.2 | 2.3 | 2.6 | 2.6 | 0.1 | >.20 |
| | Heifers | 2.2 | 2.4 | 2.6 | 2.7 | | |
| Yield grade | Steers | 2.6 | 3.0 | 3.0 | 3.2 | 0.1 | < .005 |
| | Heifers | 2.0 | 2.4 | 2.3 | 2.6 | | |

[a]Least square means and standard error of the difference between two means (SE). Carcass traits were adjusted to the mean carcass fat of all cattle in the comparison (29.2%).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Slight+ = 9; small- =10; small = 11.

[d]High good = 9; low choice = 10.

Composition of Carcass Gain

The composition of carcass gains for steers and heifers are presented in Table 22. Adjusted to similar final carcass fat percentage, the larger framed steers deposited 16% more ($P < .005$) carcass protein and 24% more ($P < .005$) carcass fat per day than heifers. Differences in protein and fat energy gained daily would be identical to tissue gain differences since the constants 5.686 Mcal/kg protein and 9.367 Mcal/kg fat were used.

Efficiency of Carcass Production

Energetic efficiency data are presented in Table 23. Steers consumed 13% more ($P < .005$) metabolizable energy daily than heifers. Total carcass energy gained daily was 22% higher in steers vs heifers when both were compared at 29.2% carcass fat ($P < .005$). At similar composition, steers were higher in energetic efficiency (14.32 vs 13.00%, $P = .01$).

Daily crude protein intake was 13% greater ($P < .005$) for steers vs heifers (Table 24). However, efficiency of crude protein utilization for carcass protein production (%) did not differ ($P > .10$) by sex. Values were 10.7% for steers and 10.2% for heifers. These values may appear to be low, but include only the amount of protein deposited daily relative to crude protein intake. Protein required for maintenance was not included in the efficiency calculation.

Data describing edible portion gained and metabolizable energy (ME) required per kg edible portion produced are presented in Table 25.

Table 22. Effect of Sex on Carcass Gains and Energy Deposition of Steers and Heifers Fed a High Silage Ration[a]

| Item | Sex | Cattle type[b] | | | | SE | Significance level |
|---|---|---|---|---|---|---|---|
| | | USH | SH | AHC | AHH | | Sex |
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| Protein gain, g/day | Steers | 82.8 | 96.7 | 101.2 | 99.4 | 2.8 | <.005 |
| | Heifers | 69.7 | 83.6 | 88.1 | 86.3 | | |
| Fat gain, g/day | Steers | 213.7 | 240.0 | 264.9 | 263.3 | 6.8 | <.005 |
| | Heifers | 166.5 | 192.8 | 217.7 | 216.1 | | |
| Protein energy gain, kcal/day | Steers | 471.2 | 550.2 | 575.7 | 565.2 | 16.3 | <.005 |
| | Heifers | 396.8 | 475.8 | 501.3 | 490.9 | | |
| Fat energy gain, kcal/day | Steers | 2,002.0 | 2,248.2 | 2,481.3 | 2,466.4 | 63.6 | <.005 |
| | Heifers | 1,560.3 | 1,806.6 | 2,039.6 | 2,024.8 | | |

[a]Least square means and standard error of the difference between two means (SE). Data were adjusted to the mean carcass fat of all cattle in the comparison (29.2%).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

Table 23. Effect of Sex on Metabolizable Energy Intake, Carcass Energy Gain and Energetic Efficiency of Steers and Heifers Fed a High Silage Ration[a]

| Item | Sex | Cattle type[b] | | | | SE | Significance level |
|---|---|---|---|---|---|---|---|
| | | USH | SH | AHC | AHH | | Sex |
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| ME intake, Mcal/day[c] | Steers | 17.25 | 19.66 | 20.96 | 22.34 | 0.34 | <.005 |
| | Heifers | 14.92 | 17.33 | 18.64 | 20.01 | | |
| Energy gain, Mcal/day | Steers | 2.47 | 2.80 | 3.06 | 3.03 | 0.07 | <.005 |
| | Heifers | 1.96 | 2.28 | 2.54 | 2.52 | | |
| Energetic efficiency, %[d] | Steers | 14.45 | 14.43 | 14.95 | 13.45 | 0.42 | .01 |
| | Heifers | 13.13 | 13.10 | 13.62 | 12.12 | | |

[a]Least square means and standard error of the difference between two means (SE). Daily energy gain and energetic efficiency data were adjusted to the mean carcass fat of all cattle in the comparison (29.2%).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Based on a ration ME value of 2.58 Mcal/kg, as determined with the metabolism trial steers.

[d]Daily carcass energy gained, Mcal ÷ ME intake, Mcal x 100.

Table 24. Effect of Sex on Daily Crude Protein Intake and Efficiency of Protein Utilization for Carcass Protein Production of Steers and Heifers Fed a High Silage Ration[a]

| Item | Sex | Cattle type[b] | | | | SE | Significance level |
|---|---|---|---|---|---|---|---|
| | | USH | SH | AHC | AHH | | Sex |
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| Crude protein intake, kg/day | Steers | 0.788 | 0.880 | 0.944 | 0.992 | 0.000 | <.005 |
| | Heifers | 0.685 | 0.777 | 0.841 | 0.889 | | |
| ECPUCP,[c] % | Steers | 10.61 | 11.26 | 11.07 | 9.86 | 0.52 | >.20 |
| | Heifers | 10.13 | 10.78 | 10.59 | 9.39 | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Efficiency of crude protein utilization for carcass protein production (daily carcass protein gained, kg ÷ daily crude protein intake, kg x 100).

Table 25. Effect of Sex on Daily Edible Portion Gained and Efficiency of Energy Utilization for Edible Portion Production of Steers and Heifers Fed a High Silage Ration[a]

| Item | Sex | Cattle type[b] USH | SH | AHC | AHH | SE | Significance level Sex |
|---|---|---|---|---|---|---|---|
| No. of animals | Steers | 11 | 15 | 15 | 15 | | |
| | Heifers | 13 | 14 | 15 | 15 | | |
| Edible portion gained, kg/day[c] | Steers | 0.337 | 0.393 | 0.412 | 0.404 | 0.012 | <.005 |
| | Heifers | 0.284 | 0.340 | 0.358 | 0.351 | | |
| EUEP, Mcal/kg[d] | Steers | 51.62 | 49.18 | 50.25 | 57.68 | 3.13 | >.20 |
| | Heifers | 54.54 | 52.10 | 53.17 | 60.60 | | |

[a]Least square means and standard error of the difference between two means (SE). Edible portion: daily carcass protein deposited ÷ 0.246 (Fox and Black, 1976).

[b]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Adjusted to the mean carcass fat of all cattle in the comparison (29.2%).

[d]Efficiency of energy utilization for edible portion production (daily ME intake, Mcal ÷ daily edible portion gained, kg).

As noted for all measures of growth, daily edible portion gained was higher ($P < .005$) for steers vs heifers (0.378 vs 0.334 kg) when both were compared at similar carcass fat. There were no differences in ME required per kg of edible portion produced. Values were 52.18 and 55.10 Mcal ME/kg edible portion for steers and heifers, respectively.

Economics

Total costs per 100 kg gain were calculated from the observed performance of steers and heifers fed in this trial. Nonfeed costs charged to small, average, and large frame cattle are presented in Table 26. Those costs directly associated with initial and/or final body weight (yardage, marketing, interest on feeder, and death loss) were apportioned to the actual initial and final weights of the four types of steers and heifers fed in this trial.

Feed and nonfeed costs for steers and heifers, based on three prices of corn, are presented in Table 27. Averaged over all cattle types, nonfeed costs per unit gain of steers were 8% greater than those of heifers. Feed and nonfeed costs per unit gain increased with increasing mature size in both sexes. At a corn price of $7.86/100 kg, total costs as a percentage of the SH steers and heifers were 96, 95; 105, 101; and 110, 108 for the USH, AHC, and AHH steers and heifers, respectively. The spread in costs between steers and heifers widened as the price of corn and soybean meal increased.

Table 26. Nonfeed Costs for Small, Average, and Large Frame Cattle[a]

| | Frame size | | |
|---|---|---|---|
| | Small | Average | Large |
| Charge | (181-381 kg) | (227-476 kg) | (272-572 kg) |
| Yardage, $/day | 0.13 | 0.18 | 0.23 |
| Veterinary, $/head | 5.00 | 5.00 | 5.00 |
| Marketing, $/head | 16.06 | 19.13 | 22.09 |
| Interest on feeder,[b] $/head/day | 0.072 | 0.090 | 0.108 |
| Death loss, $/head[c] | 10.54 | 12.79 | 15.04 |

[a]See Black and Fox (1977) for methods of allocating nonfeed costs.

[b]Based on 10% interest/annum, and a purchase price of $143.30 per 100 kg.

[c]Based on a 2% death rate, includes 18 days of feed at $7.50/100 kg dry matter.

Table 27. Feed and Nonfeed Costs for Steers and Heifers Fed a High Silage Ration

| Cattle[a] type | No. anim. | Sex | Days on[b] feed | ADG, kg | Nonfeed cost[c] $/100 kg gain | Feed costs, $/100 kg gain[d] | | | Total costs, $/100 kg gain[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | B | C | A | B | C |
| USH | 11 | Steers | 293 | 0.91 | 37 | 52 | 88 | 125 | 89 | 126 | 163 |
| | 13 | Heifers | 299 | 0.75 | 35 | 54 | 93 | 133 | 89 | 128 | 167 |
| SH | 15 | Steers | 300 | 1.00 | 39 | 54 | 92 | 130 | 92 | 131 | 169 |
| | 14 | Heifers | 297 | 0.84 | 37 | 56 | 97 | 137 | 94 | 134 | 175 |
| AHC | 15 | Steers | 295 | 1.05 | 42 | 54 | 93 | 132 | 97 | 136 | 175 |
| | 15 | Heifers | 295 | 0.90 | 38 | 57 | 98 | 140 | 95 | 136 | 177 |
| AHH | 15 | Steers | 294 | 1.07 | 44 | 58 | 99 | 140 | 102 | 143 | 184 |
| | 15 | Heifers | 299 | 0.91 | 41 | 61 | 104 | 147 | 102 | 145 | 188 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]Weighted average for trials 2, 3.

[c]See Table 26.

[d]Price of corn and soybean meal, respectively ($/100 kg); A: 7.86, 17.67; B: 14.73, 33.40; C: 21.61, 49.18. Other prices constant ($/100 kg); limestone, 2.81; trace mineral salt, 11.42; vitamin $A_{30}$, 115.48; vitamin $D_3$, 36.20; defluor. phosphate, 26.68.

## Feeding Trials: High Silage vs High Grain Steers

Data examining the effect of cattle type and energy level on the performance and carcass characteristics of steers fed high silage (HS) and high grain (HG) rations, are presented in this section. Results from trials conducted in each of 3 years were pooled as experimental designs were similar each year. However, steers fed HG in trial 1 received a 60% concentrate ration vs 80% in trials 2 and 2. Pooled least square means for HG cattle were calculated from the weighted average percentage concentrate (71%) for the 3 years.

### Initial Slaughter Cattle

Dressing percentage and carcass composition data for the initial slaughter cattle have been previously presented (Table 19). Initial carcass weight and composition of the steers fed by Crickenberger (1977) in trial 1 was estimated from the trial 2 initial slaughter steers.

### Intake, Gain, and Feed Efficiency

Average daily gains, adjusted to the mean hot carcass weight within a cattle type, were 29% higher ($P < .005$) in HG vs HS steers (Table 28). The small framed USH steers gained at a slower rate than the remaining cattle types. Although differences were small, AHC steers gained somewhat faster than SH ($P = .01$) or AHH ($P = .08$) steers. On a relative basis ($g/W_{kg}^{.75}$) gains were highest for SH and lowest for AHH steers. There were no differences ($P > .10$) in relative gain between USH and SH steers.

Table 28. Effect of Cattle Type and Ration Energy Level on Intake, Gain and Feed Efficiency of Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Daily gain, | | | | | | | | | | | |
| kg | HS | 0.86 | 0.99 | 1.04 | 1.01 | 0.02 | <.005 | <.005 | <.005 | .01 | .08 |
| | HG | 1.14 | 1.27 | 1.32 | 1.29 | | | | | | |
| g per $W_{kg}^{.75}$ | HS | 11.8 | 12.1 | 11.4 | 10.7 | 0.3 | <.005 | <.005 | >.20 | .01 | .01 |
| | HG | 15.1 | 15.4 | 14.8 | 14.1 | | | | | | |
| Daily dry matter intake,[e] | | | | | | | | | | | |
| kg | HS | 7.18 | 8.15 | 8.81 | 9.11 | 0.18 | .16 | <.005 | <.005 | .01 | .10 |
| | HG | 7.00 | 7.96 | 8.62 | 8.93 | | | | | | |
| g per $W_{kg}^{.75}$ | HS | 96.7 | 99.5 | 98.4 | 99.9 | 1.8 | .01 | >.20 | NA | NA | NA |
| | HG | 93.0 | 95.8 | 94.8 | 96.2 | | | | | | |
| Feed/gain[f] | HS | 8.47 | 8.51 | 8.77 | 8.87 | 0.14 | -- | -- | >.20 | .09 | .01 |
| | HG | 6.09 | 6.14 | 6.39 | 7.26 | | -- | -- | -- | -- | <.005 |

[a]Least square means and standard error of the difference between two means (SE). Daily gain data were adjusted to the mean hot carcass weight within a cattle type.

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: Comparison not appropriate (main effect of cattle type not significant at $P < .10$).

[e]Intakes of corn silage and high moisture corn were increased 6.8 and 3.0%, respectively, to adjust for errors in dry matter determinations.

[f]Main effects not tested due to a cattle type x energy level interaction ($P < .05$).

Dry matter intakes were similar among steers fed HS and HG ($P > .10$). Intake increased with increasing steer frame size and intakes by AHC and AHH steers were similar ($P = .10$). Cattle type differences in intake were removed, however, when expressed on a relative basis.

A significant ($P < .05$) cattle type by energy level interaction prevented analysis of the main effects of ration and type on feed/gain. There were no energy level x type interactions for USH, SH, and AHC steers. Specific type comparisons indicated no difference ($P > .10$) in feed required per unit gain for SH vs USH steers, while feed requirements for AHC steers were greater ($P = .09$) than those of SH steers. AHH steers required only 1% more ($P = .01$) feed per unit gain than AHC steers when fed an HS ration. When fed an HG ration, however, requirements were 14% greater ($P < .005$). The relative efficiency of the Holstein crossbred steers was thus superior when fed HS vs HG rations.

Carcass Characteristics

Carcass data were adjusted to similar carcass weight within a type primarily to examine the effect of energy level on carcass traits (Table 29). In general, energy level appeared to have a marked effect on carcass fatness while effects on carcass quality were minimal. Marbling scores were slightly higher in HG steers (11.97 vs 11.19) although the difference was not significant ($P > .10$). Quality grades likewise favored ($P = .03$) HG steers (10.02 vs 9.56 where 10 equals low choice). All measures of carcass fatness were higher ($P < .005$) in

Table 29. Effect of Cattle Type and Ration Energy Level on Carcass Characteristics When Steers Within Type Were Adjusted to Similar Carcass Weights[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Hot carcass wt, kg | | 273 | 314 | 347 | 352 | | | | | | |
| Marbling[e] | HS | 10.64 | 10.23 | 11.53 | 12.37 | 0.70 | .13 | >.20 | NA | NA | NA |
| | HG | 11.41 | 11.00 | 12.31 | 13.14 | | | | | | |
| Quality grade[f] | HS | 9.37 | 9.22 | 9.71 | 9.92 | 0.29 | .03 | >.20 | NA | NA | NA |
| | HG | 9.83 | 9.68 | 10.17 | 10.38 | | | | | | |
| External fat, cm | HS | 1.05 | 1.27 | 1.04 | 1.17 | 0.09 | <.005 | <.005 | >.20 | >.20 | .15 |
| | HG | 1.37 | 1.59 | 1.36 | 1.49 | | | | | | |
| Rib eye area, $cm^2$ | HS | 73.66 | 74.84 | 82.79 | 78.67 | 1.39 | >.20 | <.005 | >.20 | <.005 | <.005 |
| | HG | 73.49 | 74.67 | 82.62 | 78.50 | | | | | | |
| KPH, % | HS | 2.48 | 2.47 | 2.82 | 2.65 | 0.12 | <.005 | >.20 | NA | NA | NA |
| | HG | 2.88 | 2.87 | 3.22 | 3.05 | | | | | | |
| Yield grade | HS | 2.71 | 3.24 | 2.93 | 3.28 | 0.14 | <.005 | <.005 | <.005 | .03 | .01 |
| | HG | 3.11 | 3.64 | 3.33 | 3.68 | | | | | | |
| Carcass fat, % | HS | 29.85 | 30.69 | 28.82 | 30.16 | 0.79 | <.005 | <.005 | >.20 | .01 | .08 |
| | HG | 34.49 | 35.32 | 33.45 | 34.80 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: comparison not appropriate (main effect of cattle type not significant at $P < .10$).

[e]Small - = 10; small = 11; small + =12.

[f]High good = 9; low choice = 10.

steers fed HG. Carcass fat, external fat, internal fat (KPH), and yield grades were 15, 28, 15, and 13% greater in HG vs HS steers, respectively. At similar carcass weight within type, there were no differences ($P > .10$) in marbling or quality grades due to cattle type.

Carcass data adjusted to the mean carcass fat of all steers (32.3%) are presented in Table 30. AHH and AHC steers tended to be superior in carcass marbling and quality grades. USH and SH steers were lower in carcass quality and did not differ ($P > .10$) from each other. Rib eye area was related to frame size although values were greater ($P = .01$) for AHC vs AHH steers and USH and SH steers did not differ significantly ($P > .10$). At similar total carcass fat, external fat was not influenced by cattle type while internal fat of AHC steers was higher than either SH ($P < .005$) or AHH ($P = .03$) steers. Yield grades were numerically highest for AHH steers but were not significantly different from AHC. SH steers had higher ($P < .005$) yield grades than USH steers but did not differ ($P > .10$) from AHC.

Composition of Carcass Gain

The chemical composition of carcass gain is presented in Table 31. Adjusted to similar final carcass fat, HG steers deposited 30% more protein and 25% more fat daily than HS steers. Differences in protein and fat energy gained were similar to the tissue gain data due to the constants used in calculating energy deposition.

Daily carcass protein gained was similar among SH, AHC, and AHH steers. The small framed USH steers, however, deposited protein

Table 30. Effect of Cattle Type and Ration Energy Level on Carcass Characteristics When Steers Were Adjusted to Similar Carcass Fat[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons[d]: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Carcass fat, % | | 32.55 | 32.90 | 31.24 | 32.54 | | | | | | |
| Marbling[e] | HS | 11.61 | 10.83 | 12.90 | 13.18 | 0.65 | .06 | <.005 | >.20 | <.005 | >.20 |
| | HG | 10.59 | 9.81 | 11.88 | 12.16 | | | | | | |
| Quality grade[f] | HS | 9.81 | 9.49 | 10.33 | 10.28 | 0.26 | .13 | <.005 | >.20 | <.005 | >.20 |
| | HG | 9.47 | 9.15 | 9.99 | 9.94 | | | | | | |
| External fat, cm | HS | 1.22 | 1.36 | 1.27 | 1.30 | 0.08 | >.20 | .17 | NA | NA | NA |
| | HG | 1.24 | 1.39 | 1.30 | 1.33 | | | | | | |
| Rib eye area, $cm^2$ | HS | 72.59 | 73.75 | 81.01 | 77.34 | 1.46 | .04 | <.005 | >.20 | <.005 | .01 |
| | HG | 75.15 | 76.32 | 83.58 | 79.90 | | | | | | |
| KPH, % | HS | 2.62 | 2.55 | 3.01 | 2.76 | 0.12 | .12 | <.005 | >.20 | <.005 | .03 |
| | HG | 2.77 | 2.71 | 3.17 | 2.92 | | | | | | |
| Yield grade | HS | 3.00 | 3.40 | 3.33 | 3.51 | 0.13 | >.20 | <.005 | <.005 | >.20 | .15 |
| | HG | 2.90 | 3.30 | 3.22 | 3.40 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE). Carcass traits were adjusted to the mean carcass fat of all steers (32.3%).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]NA: comparison not appropriate (main effect of cattle type not significant at $P < .10$).

[e]Small - = 10; small = 11; small + =12.

[f]High good = 9; low choice = 10.

Table 31. Effect of Cattle Type and Ration Energy Level on Carcass Gain and Energy Deposition of Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons: USH vs SH | Type comparisons: SH vs AHC | Type comparisons: AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Protein gain, g/day | HS | 73.8 | 92.7 | 92.9 | 91.5 | 2.8 | <.005 | <.005 | <.005 | >.20 | >.20 |
| | HG | 100.2 | 119.1 | 119.3 | 117.9 | | | | | | |
| Fat gain, g/day | HS | 258.4 | 291.2 | 324.6 | 320.5 | 8.7 | <.005 | <.005 | <.005 | <.005 | >.20 |
| | HG | 333.9 | 366.7 | 400.1 | 396.1 | | | | | | |
| Protein energy gain, kcal/day | HS | 419.6 | 527.4 | 528.2 | 520.8 | 16.1 | <.005 | <.005 | <.005 | >.20 | >.20 |
| | HG | 569.7 | 677.5 | 678.3 | 670.9 | | | | | | |
| Fat energy gain, kcal/day | HS | 2,420.3 | 2,727.8 | 3,040.8 | 3,002.9 | 81.1 | <.005 | <.005 | <.005 | <.005 | >.20 |
| | HG | 3,128.0 | 3,435.5 | 3,748.4 | 3,710.5 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE). Data were adjusted to the mean carcass fat of all steers (32.3%).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

at approximately 80% of the rate noted in the three larger types. Rate of fat deposition was similar ($P > .10$) between AHC and AHH steers. SH steers gained less ($P < .005$) fat daily than AHC steers (9%) but more ($P < .005$) than USH steers (11%).

Efficiency of Carcass Production

Energetic efficiency data are presented in Table 32. HG steers consumed 15% more ($P < .005$) metabolizable energy (ME) daily than HS steers. The larger framed AHC and AHH steers consumed similar amounts of ME (23.33 and 24.17 Mcal), while the other cattle type comparisons were significant ($P < .005$). When compared at 32.2% carcass fat, HG steers deposited 26% more ($P < .005$) carcass energy daily. As noted for ME intake, energy gains were similar ($P > .10$) between AHC and AHH steers while SH steers deposited 13% more daily carcass energy than USH steers and 8% less than AHC steers. When compared at similar carcass composition, carcass energy gained as a percentage energy consumed was greater ($P < .005$) for steers fed HG rations (17.59 vs 15.97%). There was little variation in energetic efficiency among the British and British x Charolais steers (USH, SH, and AHC). However, percentage efficiency was 5% lower in AHH steers when compared to the average of the other types.

Daily crude protein intake (Table 33) was higher ($P < .005$) in HG vs HS steers (0.974 vs 0.890 kg). Crude protein intake increased with increasing frame size although differences between AHC and AHH steers were not significant ($P > .10$). Daily carcass protein gained,

Table 32. Effect of Cattle Type and Ration Energy Level on Metabolizable Energy Intake, Carcass Energy Gain and Energetic Efficiency of Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| ME intake, Mcal/day | HS | 17.49 | 20.05 | 21.84 | 22.67 | 0.57 | <.005 | <.005 | <.005 | <.005 | .15 |
| | HG | 20.48 | 23.05 | 24.83 | 25.66 | | | | | | |
| Energy gain, Mcal/day | HS | 2.84 | 3.26 | 3.57 | 3.52 | 0.09 | <.005 | <.005 | <.005 | <.005 | >.20 |
| | HG | 3.70 | 4.11 | 4.43 | 4.38 | | | | | | |
| Energetic efficiency,[d] % | HS | 16.19 | 16.11 | 16.21 | 15.35 | 0.35 | <.005 | .05 | >.20 | >.20 | .01 |
| | HG | 17.81 | 17.73 | 17.83 | 16.97 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE). Daily energy gain and energetic efficiency data were adjusted to the mean carcass fat of all steers (32.2%).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]Daily carcass energy gained, Mcal ÷ ME intake, Mcal x 100.

Table 33. Effect of Cattle Type and Ration Energy Level on Daily Crude Protein Intake and Efficiency of Protein Utilization for Carcass Protein Production of Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons: USH vs SH | Type comparisons: SH vs AHC | Type comparisons: AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Crude protein intake, kg/day | HS | 0.779 | 0.864 | 0.942 | 0.976 | 0.030 | <.005 | <.005 | .01 | .01 | >.20 |
| | HG | 0.863 | 0.948 | 1.026 | 1.059 | | | | | | |
| ECPUCP, %[d] | HS | 10.00 | 11.09 | 10.46 | 9.77 | 0.38 | <.005 | .01 | .02 | .11 | .07 |
| | HG | 11.00 | 12.08 | 11.45 | 10.76 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]Efficiency of crude protein utilization for carcass protein production (daily carcass protein gained, kg ÷ daily crude protein intake, kg x 100.

as a percentage of protein intake, was higher for the HG steers (11.32 vs 10.33%). There were no differences in efficiency of protein use between SH and AHC steers although the other cattle type comparisons were significant ($P < .10$). Although SH, AHC, and AHH steers deposited similar quantities of carcass protein daily (Table 31), AHH steers appeared to utilize dietary protein less efficiently.

When compared at similar carcass fat, steers fed HG deposited 30% more ($P < .005$) edible portion daily than those fed HS (Table 34). Gains were similar among SH, AHC, and AHH steers. Small framed USH steers, however, deposited edible portion at a rate approximately 82% of that observed in the other cattle types. Trends were predictably similar to results noted with carcass protein gain (Table 31).

As indicated in Table 34, efficiency of ME use for production of edible portion (Mcal/kg) was not influenced by ration energy level ($P > .10$). USH steers required more ($P = .07$) ME per unit edible portion produced than SH steers. Holstein crossbred steers were highest in ME requirements but were not significantly different ($P > .10$) from AHC steers.

## Economics

Total costs per 100 kg gain were calculated from the observed performance of steers fed HS and HG rations in these trials. Nonfeed costs were allocated to cattle of various frame size as previously described (Table 26).

Table 34. Effect of Cattle Type and Ration Energy Level on Daily Edible Portion Gained and Efficiency of Energy Utilization for Edible Portion Production of Steers[a]

| Item | Energy[b] level | Cattle type[c] USH | SH | AHC | AHH | SE | Main effects: Energy level | Main effects: Cattle type | Type comparisons: USH vs SH | SH vs AHC | AHC vs AHH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of steers | HS | 19 | 22 | 23 | 23 | | | | | | |
| | HG | 19 | 22 | 24 | 24 | | | | | | |
| Edible portion gained, kg/day[d] | HS | 0.300 | 0.377 | 0.378 | 0.372 | 0.015 | <.005 | <.005 | <.005 | >.20 | >.20 |
| | HG | 0.407 | 0.484 | 0.485 | 0.479 | | | | | | |
| EUEP, Mcal/kg[e] | HS | 57.37 | 52.98 | 56.17 | 59.43 | 2.21 | .17 | .06 | .07 | .16 | .15 |
| | HG | 55.10 | 50.71 | 53.90 | 57.16 | | | | | | |

[a]Least square means and standard error of the difference between two means (SE). Edible portion: daily carcass protein deposited ÷ 0.246 (Fox and Black, 1976).

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[d]Adjusted to the mean carcass fat of all steers (32.3%).

[e]Efficiency of energy utilization for edible portion production (daily ME intake, Mcal ÷ daily edible portion gained, kg).

Feed and nonfeed costs for cattle fed in this comparison are presented in Table 35 based on three possible prices of corn. Averaged over all cattle types, nonfeed costs were 21% greater for steers fed HS vs HG rations. Feed and nonfeed costs per unit gain increased with increasing mature size for steers fed both rations. On a total cost per unit gain basis, the HS and HG rations were essentially equal for the British and British x Charolais steers (USH, SH, AHC) at a corn price of $21.61/100 kg. For AHH steers, however, this point would be reached at a corn price slightly greater than $7.86/100 kg.

Table 35. Feed and Nonfeed Costs for Steers Fed High Silage and High Grain Rations

| Cattle[a] type | No. steers | Energy[b] level | Days on[c] feed | ADG, kg | Nonfeed cost[d] $/100 kg gain | Feed costs,[e] $/100 kg gain | | | Total costs,[e] $/100 kg gain | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A | B | C | A | B | C |
| USH | 19 | HS | 291 | 0.86 | 40 | 56 | 95 | 135 | 96 | 135 | 175 |
| | 19 | HG | 236 | 1.14 | 33 | 53 | 97 | 142 | 86 | 130 | 175 |
| SH | 22 | HS | 296 | 0.99 | 41 | 56 | 96 | 135 | 97 | 136 | 176 |
| | 22 | HG | 238 | 1.27 | 34 | 54 | 98 | 143 | 88 | 132 | 177 |
| AHC | 23 | HS | 292 | 1.04 | 45 | 58 | 98 | 140 | 102 | 143 | 184 |
| | 24 | HG | 238 | 1.32 | 37 | 56 | 102 | 149 | 93 | 140 | 186 |
| AHH | 23 | HS | 292 | 1.01 | 48 | 58 | 100 | 141 | 106 | 147 | 189 |
| | 24 | HG | 238 | 1.29 | 40 | 63 | 116 | 169 | 103 | 156 | 209 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 29% corn silage plus 71% corn and supplement.

[c]Weighted average for trials 1, 2, 3.

[d]See Table 26.

[e]Price of corn and soybean meal, respectively ($/100 kg); A: 7.86, 17.67; B: 14.73, 33.40; C: 21.61, 49.18. Other prices constant ($/100 kg); limestone, 2.81; trace mineral salt, 11.42; vitamin $A_{30}$, 115.48; vitamin $D_3$, 36.20; defluor. phosphate, 26.68.

# DISCUSSION

## Cow-Calf Trials

### Energy Requirements

Cow-calf trials were not designed to define a particular energy requirement for specific types of cows. Rather the objective was to observe the adequacy of existing feeding standards (NRC, 1970 in trial 1; NRC, 1976 in trial 2) for various types of cows subjected to harsh climatic conditions.

Reliable assessment of cow body condition was of considerable concern in evaluating the energy levels fed. Klosterman et al. (1968b) has pointed out the inaccuracies of using weight as an indicator of cow body condition. He suggested weight to height (at the hooks) ratio as an alternative. In the present study condition was assessed from fatness over the 12th rib as estimated ultrasonically on a monthly basis. In the feedlot phase of the research, a simple correlation of 0.72 was found between this method of estimation and actual fat thickness in 176 steers of the four genetic types (USH, SH, AHC, and AHH). Ultrasonic estimates of fat thickness were obtained immediately preceding slaughter.

In trial 2, heighth of cows at the hooks was measured at the beginning and end of the trial and weight/height ratios were calculated as a comparative method of assessing body condition. Simple

correlations between ultrasonic fat thickness and weight/height ratios were 0.44 and 0.63 for initial and final values, respectively. Trial 2 cows averaged 0.65 cm fat initially and 0.42 cm at the end of the trial. Thus, the two methods of estimating body condition appear to be more closely related for the thinner cows.

Cow-calf trials were conducted from December 16, 1975 to September 9, 1976 (trial 1), and from November 23, 1976 to September 19, 1977 (trial 2). Three levels of TDN intake may be compared in the two cow-calf trials: (1) NRC (1970) with a 25% increase in amounts of lactation ration; (2) NRC (1976) throughout the trial, and (3) NRC (1976) plus 25% throughout the trial (trial 1). Pooled across cattle types, TDN intake was 5.91, 4.75, and 6.07 kg and percentage of initial body fat recovered at the end of the trials were 100, 51, and 83%, for systems 1, 2, and 3, respectively. Intakes were similar among cows fed system 1 and 3 due in part to differences in trial length (more days on maintenance rations for system 3 cows). The greater weight and fat recovery of system 1 vs 3 cows is likely associated with the more severe environmental conditions encountered for the latter (Table A.5). Hironaka and Peters (1969) found a close relationship between cow weight changes and average temperature and wind speed. Christopherson (1976) found significant effects of cold exposure on ration digestibility. Shorter ruminal retention times and lower fiber digestibility have also been reported at low vs high temperatures (Warren et al., 1974). Thus, TDN intake may be overestimated during the winter months when calculated from average values (NRC, 1976).

Some evidence for a differential response to the conditions imposed were noted. Trial 1 Holstein crossbred cows were the only cattle type not regaining their initial body weight and Trial 2 Holstein crosses tended to lose more weight on both rations although differences were not significant ($P > .10$). However, Kropp et al. (1973) found no treatment x breed interactions in preweaning productivity for Hereford, Hereford x Holstein, and Holstein cows fed three levels of winter supplement.

While larger cows have been assumed more "cold resistant" than small cows (Kleiber, 1961; Blaxter, 1962; Christopherson, 1976), general trends indicated the opposite in the present studies. However, the size relationship is likely confounded with breed. Webster and Young (1970) found inferior thermal insulation values for Holstein vs beef breeds.

Unfortunately, reproductive performance could only be evaluated for trial 1 cows (all cows fed the same energy level) and thus numbers were rather limited for definitive conclusions. Of 36 cows included in the comparison, 42% were cycling when inseminated and 22% became pregnant. The lactation ration was increased 25% at 52 days before breeding but energy intakes were apparently too low for acceptable reproductive performance. Jordan et al. (1977) compared Shorthorn cows fed hay or grass silage at 50, 75, and 100% of ad libitum intake during the last two-thirds of pregnancy. Pregnancy rates for cows wintered outside (northern Ontario) were 58.3, 80.6, and 88.9% for the three levels of intake, respectively. Similarly, Davis et al. (1977) found that energy and not protein limited reproductive performance of Hereford cows.

Preweaning Calf Performance

Results of trial 2 indicated little effect of precalving energy intake on birth weights of calves. In all trials birth weights were lower for the small framed USH calves while differences among the remaining types were small.

Adjusted weaning weights increased with increasing mature weight of dam, regardless of nutritional regime. Similar results were reported by Carpenter et al. (1972b), Brinks et al. (1962), and Klosterman et al. (1968a).

Preweaning calf average daily gain favored the crossbred calves (AHC and AHH). Klosterman et al. (1968a) found small but consistent evidence of hybrid vigor for weaning weight and daily gain in a comparison of Hereford, Charolais, and Hereford x Charolais crossbred calves. In trial 2, calf preweaning average daily gain (ADG) was 15% faster in calves from high vs low energy dams. Higher levels of milk production may be inferred for dams fed high energy although direct estimates were not obtained.

AHH calves were consistently higher in preweaning ADG on all nutritional regimes. Similar increases were noted in comparisons of calves of 0, 25, and 50% Holstein breeding (Holloway et al., 1975a; Wyatt et al., 1977c). Wyatt et al. (1977a) in a cross-nursing experiment, found increased weaning weights of approximately 20% for Angus x Hereford and Charolais x Holstein calves raised on Holstein vs Hereford dams. Both types of calves consumed similar amounts of milk when nursed by Holstein cows.

Efficiency of Production

Discussion of efficiency data will focus on the estimates made for a full productive year. In three of the four cattle types (SH, AHC, AHH) the total feed TDN required to produce a unit of calf weaning weight increased with increasing TDN consumption. Considering efficiency of feed conversion only, this seems to indicate the lowest energy level fed (NRC, 1976) was the most desirable. However, as discussed subsequently, other factors must be evaluated in selection of a feeding system.

Pooled over the three nutritional regimes used, total kg of TDN required per kg calf weaning weight were 10.27, 10.05, 9.12, and 9.02, for USH, SH, AHC, and AHH cows, respectively. Thus, the largest variation in values was a 14% greater requirement for USH vs AHH cows. The efficiency values observed may be compared with similar data reported by Klosterman and Parker (1976). They found efficiency of feed conversion values of 10.1, 8.6, 10.0, and 9.2 for Charolais and Hereford sired calves from Hereford, Hereford x Angus, Hereford x Charolais, and Charolais dams, respectively. Cows and calves in that study, however, had access to shelter.

While data could not be subjected to statistical analysis, in two of the three nutritional regimes compared, AHH cattle were superior in conversion of TDN to calf weaning weight. Increased milk yields and efficiency of feed use for milk production as percentage Holstein breeding increased were noted in comparisons of Hereford, Hereford x Holstein, and Holstein cows as 2-year-olds (Kropp et al.,

1973); 3-year-olds (Holloway et al., 1975a); and 4- and 5-year-olds (Wyatt et al., 1977c).

Results of the cow-calf trials indicate that current NRC (1976) requirements for energy are at least 25% too low when cows are maintained without shelter in harsh climatic conditions. Jordon et al. (1977) concluded that Shorthorn cows confined outside required year-round ad libitum feeding of roughage under severe environmental conditions.

While total TDN requirements per unit weaning weight averaged 15% higher in trial 2 cows fed NRC + 25% vs NRC, the ability of the cows to rebreed must be considered. Further, price differentials for calves of various weights and the cost of feed in relation to the sale price of the calf would have to be evaluated in determining the energy level desirable for each type.

It must be stressed that cows were exposed to extremely severe environmental conditions. Therefore, the results of these experiments are only applicable to cows maintained in a similar manner. However, the energy requirements recommended by NRC (1976) were uniformly low across all cattle types when AHH cows were fed at the "superior milking ability" level. Thus, published requirements based on cow weight and expected milking ability are likely valid under unstressed conditions.

## Metabolism Studies

### Nitrogen Utilization

The high silage (HS) and 80% high grain (HG) rations fed in the metabolism trials were supplemented with soybean meal to 13.45 and 14.45% crude protein according to the requirements outlined by Fox and Black (1975). Therefore, evaluation of protein levels *per se* was of little interest since animals were likely supplemented at or above their requirements. Holter and Kabuga (1974) found similar nitrogen utilization of high silage rations with increasing levels of crude protein above 10%.

While fecal nitrogen excretion is typically more related to nitrogen intake than source of nitrogen (Moran and Vercoe, 1972) the higher nitrogen intake of HG *vs* HS steers was associated with non-significant ($P > .10$) differences in quantity of fecal nitrogen excreted. Nitrogen digestibilities of 58.5% for HS and 66.8% for 80% concentrate (HG) rations compare with values of 66.2 and 68.9 (60% concentrate) in corn-corn silage rations fed by Crickenberger (1977). In that study, both rations were supplemented to 12.8% crude protein.

Nitrogen retention (g/day) was 50% higher in steers fed HG *vs* HS rations. Although only speculations can be made, a greater quantity of feed protein and/or microbial protein likely passed to the lower digestive tract of steers fed HG. However, Bergen *et al.* (1974) has questioned the value of corn bypass protein (Zein).

Crickenberger (1977) reported that non-ammonia nitrogen passage to the abomasum was 57.6 and 78.9 g/day on HS and HG rations, respectively. Total nitrogen intake was similar for steers fed both rations. In the present study, steers fed HS and HG rations consumed 14.84 and 18.72 Mcal of metabolizable energy (ME) daily as determined by the energy balance data. Broster (1973) noted an increase in nitrogen retention as ME intake increased.

Nitrogen retention as a percentage of absorbed nitrogen was 19% higher for the HG vs HS ration although the difference was not significant ($P > .10$). Nitrogen retention as a percentage of nitrogen intake was significantly higher in the HG vs HS ration (32.6 vs 24.2%). A "net protein" system for predicting protein requirements and feed protein values for growing and finishing cattle has been proposed by Fox et al. (1977). In that system, conversion factors (nitrogen retained as a percentage of nitrogen intake) are multiplied times feed crude protein values to obtain "net protein" values for various feeds. Preliminary conversion values of 0.30, 0.20, and 0.35 were presented by Fox et al. (1977) for high moisture corn, corn silage, and soybean meal, respectively. Calculated net protein conversion factors for the mixed rations fed in this trial would be 0.22 for the HS ration (vs 0.242 observed) and 0.28 for the HG ration (vs 0.326 observed).

Overall, variation in nitrogen utilization between steers fed HS and HG rations were more pronounced in the present study than the previously cited work of Crickenberger (1977). However, cattle fed

HS and HG in the latter study consumed similar amounts of dry matter and nitrogen while these values were markedly higher in HG steers fed in the present studies.

Several trends relative to cattle type were observed in nitrogen utilization. Intake and excretion amounts were influenced by cattle type (increasing with cattle size) while there were no differences ($P > .10$) in any measure of nitrogen retention. In comparison of steers of similar frame size (AHC and AHH) there were consistent but nonsignificant trends for a greater fecal and urinary nitrogen excretion in AHH steers. Similar patterns in Holsteins vs Angus steers have been reported (Crickenberger, 1977; Ayala, 1974). AHH steers in the present study were approximately one-third Holstein breeding.

Net protein values were not influenced by cattle type in the present study. However, all steers were young growing animals of similar physiological maturity. Net protein values need to be determined with animals fed different protein levels at different stages of maturity.

Energy Utilization

The greater digestibility of the HG vs HS ration was evident from a lower fecal energy excretion with higher dry matter ($P = .04$) and energy intakes ($P > .10$). Urine energy excretion was similar among steers fed the two rations and was expected from the nonsignificant difference in urinary nitrogen excretion. Energy retention (intake-feed-urine-gas energy), and thus metabolizable energy values, of the HG ration were predictably higher than the HS ration. Pooled across

cattle types, ME values were 2.58 and 2.96 Mcal ME/kg ration dry matter. Calculated from average published values (NRC, 1976) for the feedstuffs in the rations, the ME values were 2.56 and 3.01 Mcal/kg for the HS and HG ration, respectively. In this trial, errors in determining ME intake of the feedlot cattle would have been minimal had "book values" been used.

Cattle type differences in intake, excretion, and retention of energy were largely related to animal size. Of the specific type comparisons conducted, largest differences were noted between USH and SH steers. ME values were not influenced by cattle type.

The maximum variation in energy digestion coefficient was 0.6 units for the HS and 4.2 units for the HG ration. Most workers have found little difference in digestive powers among conventional cattle of various types (Reid, 1962; Washburn et al., 1948). However, some workers have found superior ability to digest roughages in cattle of the Bos indicus vs Bos taurus species (Ashton, 1962; Hungate et al., 1960; French, 1940; Phillips et al., 1960).

## Feeding Trials: Steers vs Heifers

### Intake, Gain, and Feed Efficiency

Adjusted to similar carcass composition, steers gained 19% faster than heifers when both were fed a high silage ration. This difference in rate of gain is similar to many values reported in the literature, although heifers fed in the present study were those remaining after herd replacements had been selected.

Establishing the expected spread in performance between steers and heifers is important in economic planning. The following studies (Table 36) selected from the literature compared steers and heifers at similar final composition. Various straightbred and crossbred comparisons are included as well as several energy levels.

Table 36. Comparative Gains of Heifers and Steers

| Study | Breed[a] | Energy level[b] | Steer ADG/ Heifer ADG |
|---|---|---|---|
| Newland (1976) | A | Low | 1.18 |
| | A | High | 1.18 |
| Bose et al. (1970) | H | Pooled High & Low | 1.10 |
| Bradley et al. (1966) | H, HX | Low | 1.17 |
| | H, HX | High | 1.18 |
| Klosterman et al. (1968a) | H, C, H x C | Low | 1.16 |
| | | High | 1.07 |

[a]A = Angus, H = Hereford, HX = Hereford x Red Poll crossbred, C = Charolais.

[b]Low = high corn silage ration or equivalent; high = high corn grain ration or equivalent.

Thus, gain differentials between steers and heifers were predominantly in the 16 to 18% range and the heifers fed in the present study appear to be consistent with that trend.

Gains expressed per unit metabolic body weight were similar for steers vs heifers (12.1 vs 11.9 g). This method of expressing daily gains (and subsequently intake) should, in effect, adjust for

frame size differences between steers and heifers. Therefore, there appears to be little effect of sex per se on gain differentials of steers and heifers. Rather, the variation is due primarily to frame size, a result consistent with the work of Klosterman and Parker (1976) and Fox and Black (1977).

Daily dry matter intake of steers was 13% greater than heifers although on a relative basis ($g/W_{kg}^{.75}$), intake was 3% higher for heifers. Bogart and England (1971) found dry matter intakes per unit of body weight of heifers were as high or higher than bulls in a comparison of 290 British breed calves. Similar observations were made by Klosterman and Parker (1976).

Since relative intake favored the heifers, relative gains were not different, and maintenance requirements are thought to be a function of metabolic body weight (Blaxter, 1962), one would predict a higher feed/gain requirement for heifers. This was observed ($P = .02$) with the unadjusted data. However, heifers were fatter than steers at slaughter (30.1 vs 28.2%) and on a weight/weight basis fat tissue deposition is more expensive than lean tissue deposition. Therefore, the adjustment factors outlined by Fox and Black (1977) were used to adjust the feed/gain data to the mean carcass fat of all cattle in the comparison (29.2%). Statistical analysis of the adjusted values revealed little evidence of a sex effect ($P > .10$) with heifers requiring only 2% more feed/gain. However, the adjusted data must be considered as an estimate only since the adjustment equations of Fox and Black (1977) have not been thoroughly tested over a wide range of cattle types, sexes, energy levels, etc.

Bose et al. (1970) found a 10% greater feed/gain value for heifers vs steers when both were compared at similar final composition. An 11% greater requirement for heifers vs steers was reported by Bradley et al. (1966). Conversely, Ritchie et al. (1977) noted more efficient gains in heifers when the entire calf crop (steers and heifers) was compared at similar finish. An energy level x sex interaction was proposed by Kosterman and Parker (1976) who found the net energy value of corn silage was 16% greater when fed to heifers vs steers.

Heifer "quality" in the present study appeared to differ in the two trials conducted. In the first steer-heifer trial, heifers required an estimated 8% more feed/gain than steers when compared at similar finish. However, the combined two-year comparison data previously discussed indicated no significant differences. Each year the heifers fed were those rejected as herd replacements. Factors causing a poor weaning weight (and culling from the herd) may include sickness, injury, or nutritional stunting as well as genetic inferiority.

Carcass Characteristics

Adjusted to similar carcass fat (29.2%) there were no differences ($P > .10$) in quality grade or rib-eye area. Steers, however, had more external fat and higher numerical yield grades. Several workers have observed a requirement for greater fatness in heifers to achieve the same quality grade of steers (Klosterman and Parker, 1976; Cooper et al., 1972; Ritchie et al., 1977). This was not apparent in the steers and heifers compared in the present study.

Composition and Efficiency of Carcass Gain

Adjusted to similar total carcass fat, the larger framed steers deposited 16% more carcass protein and 24% more carcass fat per day than the heifers. Based on the live weight gain data, however, these differences in rate would likely be minimized if calculated on a relative basis. Although not an indication of the total amounts of protein and fat gained, heifers deposited 29.3% of total (protein + fat) daily gain as protein vs 27.9% for steers.

Total carcass energy deposited daily was 22% higher for steers which also consumed 13% more ME. The higher caloric efficiency of fat deposition was evidenced by the higher unadjusted energetic efficiency values for heifers vs steers (30.1 vs 28.2% carcass fat). However, when adjusted to equal carcass fat (29.2%), daily carcass energy gained as a percentage of ME intake was 14.32 vs 13.00% for steers and heifers, respectively. Thus, when taken to similar final composition, the heifers apparently utilized ingested energy less efficiently for gain than steers. This trend existed in the adjusted feed/gain data although differences were not significant. Despite a somewhat higher proportion of tissue gain as protein in heifers vs steers, feed/gain values were 2% higher for heifers when feed conversion was adjusted to constant carcass fat. Similar trends (but greater inefficiencies for heifers vs steers) were reported by Hedrick et al. (1969).

While intake of ration crude protein differed by 13% (steers > heifers) the efficiency of prtein use for carcass protein production

was similar among steers and heifers ($P > .10$). Values of 10.7% for steers and 10.2% for heifers were considerably below the 24.2% of nitrogen intake retained in the bodies of steers fed a similar high silage ration in the metabolism studies. However, in the case of the nitrogen balance trials, retention of protein in noncarcass body tissues are accounted for. Further, steers fed in balance trials were at an early stage of growth when protein requirements were high. The lower efficiency measured over the entire trial could indicate excess dietary protein at heavier weights.

Amounts of edible portion produced daily predictably followed the trends noted for carcass protein gain (13% greater for steers *vs* heifers). ME required per unit edible portion produced was similar ($P > .10$) between steers and heifers. Since: (1) days on feed were similar for steers and heifers; (2) little evidence exists for variation in maintenance requirement due to sex (Blaxter, 1962) and (3) edible portion, by definition, contains a constant proportion of fat, little difference in efficiency of production was expected.

Suess *et al.* (1966) found no difference in percentage retail cuts between Angus crossbred steer and heifer calves. Three slaughter weights were employed and increasing live-weight from 386 to 455 kg increased retail yield of steers and heifers but there were no significant changes in carcass grade, marbling, or palatability.

Economics

The economic projections were based on an equal purchase price for steers and heifers. In most areas heifers would sell at a discount and thus, the interest charge on the heifers may be overstated.

The economic advantage in nonfeed costs per unit gain for heifers vs steers were more than offset by increased feed costs at all prices of corn greater than $7.86/100 kg. This resulted from the less efficient liveweight gains of the heifers. The cost differential between steers and heifers widened as the price of feed increased. This was caused by the higher feed/gain requirements of the heifers and became an increasing economic force as the price of grain increased.

## Feeding Trials: High Silage vs High Grain Steers

### Intake, Gain, and Feed Efficiency

Daily gain data were adjusted to the mean hot carcass weight (HCW) within a cattle type. HCW was found to be a highly significant ($P < .01$) continuous covariate in the equation estimating least square means for daily gain, while carcass fat was of less importance. This was expected when it was noted from plots of HCW vs carcass fat (within pens) that considerable frame size variation occurred (i.e., a relatively "flat" relationship), and daily gains are closely related to frame size (Fox and Black, 1977).

Average daily gains were 29% greater for cattle fed 71% concentrate high grain (HG) vs 9% concentrate high silage (HS) rations. The pooled results of cattle fed 13 and 15% crude protein rations by Hatfield et al. (1971) revealed a 33% greater gain for cattle fed a 67% high moisture corn ration vs those fed high silage. In that study, results were variable when considerably lower ration crude protein levels were fed. However, these relationships are not of concern in comparisons with the present studies since all cattle were adequately supplemented according to the system of Fox et al. (1977). First year results of USH, SH, AHC, and AHH steers fed HS and HG rations confirmed the adequacy of the protein system used throughout the 3 year study.

Fox (1977) reported that, in general, daily gain increases as the energy density of the ration increases to a level of approximately 70 to 80% corn in corn-corn silage rations. These observations were confirmed by the work of Jesse et al. (1976b) and Prior et al. (1977). Assuming a corn grain content in corn silage of 50%, cattle in the present studies received a HG ration which averaged 86% concentrate (corn grain + soybean meal-mineral-vitamin mix).

Daily gains increased with increasing frame size for the Hereford and Angus x Hereford x Charolais steers (USH, SH, AHC). A linear relationship between frame size and rate of gain is implied in the performance simulation model of Fox and Black (1977) with relationships based on an extensive review of the literature.

Holstein crossbred (AHH) steers gained at less than expected rates based on their frame size. Similar results were reported by

Crickenberger (1977) for straightbred Holstein vs Angus steers. However, Wyatt et al. (1977b) and Dean et al. (1976) observed increasing rates of gain as percentage Holstein breeding increased from 0 to 25 to 50%. Increased rates of gain for AHH vs SH steers are consistent with the results of Kidwell and McCormick (1956).

As previously explained in the steer vs heifer comparison, daily gains were expressed per unit of metabolic body weight to remove differences due to frame size as nearly as possible. Expressed on this basis, daily gains tended to favor the smaller USH and SH steers. A similar trend was noted by Ferrell et al. (1978) who compared a wide variety of beef and dairy breeds. The higher relative ADG of SH vs AHC steers was not supported in the review of literature where such differences have been small.

Daily dry matter intake did not differ for steers fed the HS and HG rations. Cattle type differences were predictably associated with cattle size. Intakes of AHH steers (approximately one-third Holstein breeding) were 3.5% greater than AHC steers. Wyatt et al. (1977b) found a 4% increased intake with steers of 25% Holstein breeding vs British x Charolais or Angus crossbreds. Intakes of steers with 50% Holstein breeding were 11% greater than the other crossbreds. Similar trends were reported by Dean et al. (1976).

The performance simulation model of Fox and Black (1977) predicts similar relative intakes ($g/W_{kg}^{.75}$) for British and British x Exotic crossbred cattle. However, relative intakes of straightbred Holstein and British x Holstein crossbreds are predicted to be 17

and 9% greater, respectively, than beef breeds. In general agreement with the simulation model (Fox and Black, 1977), Ayala (1974) found increased relative intake in straightbred Holstein vs Angus steers. In the present study, intake tended to be higher for AHH steers but differences were small. Thus, results tend to confirm the Fox and Black (1977) predictions for beef breeds while the intakes of the Holstein crossbred (AHH) steers were less than predicted.

The main effects of energy level and cattle type on feed/gain could not be assessed statistically since a cattle type x energy level interaction was noted. However, a comparison of the least square means indicated a 34% increase in feed/gain requirements for HS vs HG steers. Hatfield et al. (1971) noted a 54% increase in feed/gain for steers fed HS vs HG (67% corn) rations.

Standard analysis indicated no difference in feed/gain between SH and USH steers while some evidence existed for larger feed requirements in AHC vs SH steers ($P = .09$). The AHC vs AHH type comparison was conducted independently for the HS and HG rations due to the aforementioned interaction. Although both comparisons differed ($P = .01$, $P < .005$), Holstein feed/gain requirements as a percentage of the mean of the other types were 103 and 117% for the HS and HG ration, respectively. Thus, AHH steers performed relatively better on HS vs HG rations. Significant cattle type x energy level interactions were reported by Larson et al. (1966) and Bond et al. (1972). However, in those studies, Holsteins appeared to be more adapted to high grain rations. Nonsignificant cattle type x ration interactions were found

by Ferrell et al. (1978), Klosterman et al. (1968b), Freeman (1969), and Harwin et al. (1966).

Feed/gain was found to be independent of frame size for British and British x Exotic crossbred cattle by Fox and Black (1977), Brown et al. (1973, 1974), Smith et al. (1977), Klosterman et al. (1968a), Brungardt (1972) and Prior et al. (1977), when cattle were fed to similar final composition. However, in the present trial, there was a tendency for smaller framed cattle to be more efficient, a trend reported by Ferrell et al. (1978).

The lower relative daily gain of AHH steers, coupled with equal or greater relative intake suggests a poorer efficiency of Holstein crossbred cattle and this was apparent in the feed/gain data. Dean et al. (1976) and Wyatt et al. (1977b) found significant increases in feed required per unit gain as percentage Holstein breeding increased from 0 to 25 to 50%. The decreased efficiency of AHH steers may be attributed to a higher maintenance requirement, a poorer utilization of energy intake above maintenance for productive purposes, or a combination of the two. Higher maintenance requirements for Holstein cattle relative to beef breeds has been reported by Hashizume et al. (1963), Garrett (1971), and Ayala (1974). In addition, Garrett (1971) found increased feed requirements above maintenance per unit gain in Holstein vs Hereford steers.

Carcass Characteristics

At similar carcass weights within a cattle type, HG cattle were higher in carcass fat and external fat while there were no significant effects on carcass quality. Workers finding little effect of nutritional regime on carcass quality include Jesse et al. (1976a), Reid et al. (1968), Epley et al. (1971), and Crickenberger (1977).

Cattle types effects and patterns of fat distribution are of primary interest in the carcass data adjusted to the similar carcass fat of all steers in the comparison (32.3%). At similar carcass fat, AHH steers tended to have higher marbling scores although differences between AHC and AHH steers were not significant for marbling score or quality grade. Several earlier studies (Garrett, 1971; Cole et al., 1964) have reported inferior carcass quality for cattle of Holstein breeding. In many comparisons, however, Holstein steers were slaughtered after the same number of days on feed or at similar weights as their British breed counterparts. Therefore, they were typically leaner and had not yet deposited sufficient intramuscular fat (younger physiological age). Also Holsteins have benefited from the 1976 revision of the beef grading standards, which abolished conformation as a factor in determining quality grade. In the present study, and those reported by Wyatt et al. (1977b) and Dean et al. (1976), Holstein crossbred steers compared very favorably to beef breeds in marbling score when compared at similar final composition.

Internal fat (KPH), as a proportion of total fat, has been higher for Holstein vs beef breeds in several studies (Dikeman et al., 1977; Charles and Johnson, 1976a; Crickenberger, 1977). This was not observed for AHH steers in the present study. Highest levels of internal fat (when compared at similar carcass fat) were found in AHC steers. However due to slightly higher external fat and smaller rib-eye area in AHH steers, yield grades were not different ($P > .10$).

At similar carcass fat, differences in fat distribution in HS vs HG cattle were rather small. External fat, internal fat, and yield grades were not affected by energy level. Marbling scores, however, were 12.13 and 11.11 for HS and HG steers, respectively ($P = .06$). Lawrie and Kirton (1956) reported that intramuscular fat deposition was more age than plane of nutrition dependent. HS steers in the present study were on feed an average 55 days longer than steers fed HG.

Composition and Efficiency of Gain

Significant effects of ration energy level on the amounts of protein and fat tissue gained daily were noted. The lower daily-protein deposition of HS steers likely resulted from a lower intake of metabolizable energy. Thus, HS steers were unable to reach their maximum rate of protein deposition as outlined by Bergen (1974). Since cattle were compared at similar final body composition, and HG steers were killed after a few number of days on feed, the higher daily fat deposition of HG cattle was expected.

Daily rates of carcass protein deposition were similar among SH, AHC, and AHH steers and lowest for USH steers. Eversole (1978) presented muscle nucleic acid data for 6 steers per cattle type, selected at random (3 per energy level) from the cattle fed in this study. The concentrations (mg/g wet tissue) and total amounts (mg) of RNA in the semitendinosis muscle were 0.79, 1316; 0.93, 1783; 0.95, 2243; and 0.88, 1810 for USH, SH, AHC, and AHH steers, respectively. Thus, the smaller muscle mass of USH steers is apparent as well as less protein synthetic machinery per unit muscle weight.

The total carcass energy gained was related to the amounts of protein and fat tissue deposited as previously discussed. Compared at similar final carcass composition, the percentage of ME intake recovered as carcass energy was 15.97 and 17.58% for the HS and HG rations, respectively. The increased energetic efficiency of steers fed HG vs HS rations was likely associated with a shorter length of time on feed. A smaller proportion of the total ME intake of HG steers would be used for maintenance functions, with more ration energy available for tissue gain.

While Kleiber (1936) indicated no relationship between cattle size and energetic efficiency, breed differences exist. AHH steers were 5% less efficient than AHC steers in conversion of ration calories to carcass calories. Garrett (1971) reported increased maintenance requirements of 5 and 12% in two studies comparing Holstein and Hereford steers. Further, in that study, tissue gains per kg of feed above maintenance were 24 g of protein and 115 g of fat for

Hereford steers and 24 g of protein and 86 g of fat for Holstein steers. Thus, Holstein steers appear to expend more energy for maintenance and are less efficient in utilization of energy available for productive purposes.

The efficiency of utilization of ration crude protein for carcass protein production was higher for HG vs HS rations, a result consistent with the nitrogen balance trials. Efficiency of protein utilization was poorest for AHH steers. Crickenberger (1977) quoted the data of Ayala (1974), indicating the increased energy requirements per unit metabolic weight for Holsteins, and Smuts (1935), showing the maintenance requirement of protein was related to basal metabolism. He thus concluded that given a positive relationship between the two physiological processes, Holsteins might be expected to have a higher maintenance protein requirement than beef breeds. However, this may not be a valid explanation if the higher ME requirements of Holsteins are simply due to a higher heat loss.

Efficiency of ME use for production of edible portion was not influenced by ration energy level. AHH steers tended to have the highest requirements, and this was likely related to a greater proportion of ME intake used for maintenance. Similar observations for Holsteins relative to beef breeds were made by Larson et al. (1966), Garrett (1971), and Burroughs et al. (1969).

USH steers required more ($P = .07$) ME per kg edible portion produced than SH steers. As previously indicated, edible portion is, by definition, closely related to carcass protein production. The

lower concentration of RNA per g of muscle tissue in USH steers, coupled with similar relative intakes, may indicate an inability to more efficiently use the ingested ME for lean tissue production. However, USH steers were only 3% less efficient than AHC steers in conversion of ME to edible portion.

Economics

At a given price of corn, total costs per unit gain were higher as the frame size of the steers increased. Crickenberger and Black (1976) found a slight economic advantage for smaller framed cattle in the feedlot. They observed that increases in daily gain of larger framed cattle were not large enough to pay for the increase in nonfeed costs resulting from additional interest on the feeder and greater use of transportation and facilities. In their work, however, the variation in total costs among cattle of various frame size was smaller than noted in the present trial. This is due to the decreased feed/gain requirements with decreasing frame size in the present study, while in the work of Crickenberger and Black (1976), feed/gain was held constant.

Averaged over the USH, SH, and AHC steers, daily gain and feed/gain values were 29% higher and 28% lower, respectively, for steers fed HG vs HS. Given these observed differences, the price of corn would be $21.61/100 kg before the HS ration would be competitive. However, given the relatively poor performance of AHH steers fed HG, the corn price required to make the HS ration competitive would be only $9.82/100 kg.

# CONCLUSIONS

Based on the result of this study, the following conclusions were made:

1. National Research Council recommendations for energy were at least 25% too low for cows maintained under harsh climatic conditions, but are likely applicable to various types of cows under unstressed environments.
2. Increasing the energy level fed to cows did not increase efficiency (TDN/calf weaning weight). However, the ability of the cows to rebreed must be considered.
3. The larger framed AHC and AHH cattle types were more efficient to weaning (TDN/calf weaning weight) than the smaller framed USH and SH types.
4. Nitrogen retention and net protein (percentage of nitrogen intake retained) values were higher for an 80% concentrate vs a high silage ration.
5. Retention of ration protein and metabolizability of ration energy were similar among cattle types and differences in digestive powers were small.
6. Steers gained 19% faster than heifers when fed a high silage ration. Heifers tended to be less efficient in producing gain although differences were small when compared at similar carcass fat.

7. Carcass quality was similar when steers and heifers were compared at similar carcass fat.
8. ME requirements for producing edible beef were similar among steers and heifers.
9. Heifer quality may vary depending on the degree of culling practiced in the beef herd. Heifers were more favorable economically at lower prices of corn.
10. Average daily gains were 29% greater for steers fed a 71% concentrate (HG) ration vs those fed high silage (HS).
11. Average daily gains of USH, SH, and AHC steers were consistent with expectations based on frame size. However, Holstein crossbred steers gained at less than expected rates.
12. Relative dry matter intakes ($g/W_{kg}^{.75}$) were similar for all types of steers, and less than predicted for Holstein crossbred steers.
13. Holstein crossbred steers performed relatively better on HS vs HG rations.
14. Based on the feedlot performance data, the primary effect of selecting for yearling weight was to increase frame size.
15. Steers fed HG rations consumed more ME daily and produced heavier, fatter, higher quality carcasses.
16. At similar carcass weights within a cattle type, steers fed HG produced fatter carcasses although quality grades were similar.

17. Marbling scores of Holstein crossbred steers compared favorably to beef breeds when compared at similar carcass fat.
18. Increased rates of protein and fat deposition were noted with steers fed HG vs HS rations, and were associated with increased ME intake and a greater proportion of ME available for productive purposes.
19. Efficiency of utilization of ration protein and energy was less for Holstein crossbred steers than beef breeds.
20. Efficiency of ME use for production of edible beef was not influenced by ration energy level.

# APPENDIX

Table A.1 Individual Weight and Condition Data for Unselected and Selected Hereford Cows and Calves (Trial 1)[a]

| Pen no. | Cattle[b] type | Cow data | | | | | Calf data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. | Initial wt, kg | Final wt, kg | Initial fat, cm | Final fat, cm | No. | Sex | Birth date | Birth wt, kg | Weaning wt actual, kg | Weaning wt 205 day, kg |
| 111 | USH | 7456 | 313.0 | 319.8 | 0 | 0.25 | 205 | S | 3-14-76 | 27.2 | 108.9 | 138.3 |
| | | 7344 | 365.1 | 421.8 | 0.25 | 0.25 | 692 | H | 3-15-76 | 26.3 | 120.2 | 153.8 |
| | | 7310 | 340.2 | 403.7 | 0.25 | 0.25 | 689 | H | 2-15-76 | 23.6 | 156.5 | 180.5 |
| | | 7228 | 374.2 | 358.3 | 0.25 | 0.25 | 191 | S | 2-16-76 | 38.6 | 176.9 | 186.0 |
| | | 7240 | 385.6 | 421.8 | 0.13 | 0.25 | 200 | S | 3-08-76 | 28.1 | 108.9 | 123.4 |
| | | 7180 | 421.8 | 464.9 | 0.51 | 0.25 | 189 | S | 2-11-76 | 28.1 | 195.0 | 191.9 |
| | | 7455 | 360.6 | 406.0 | 0.25 | 0.51 | 203 | S | 3-22-76 | 32.2 | 104.3 | 136.5 |
| | | 6972 | 437.7 | 510.3 | 0.25 | 0.51 | 686 | H | 1-31-76 | 28.6 | 183.7 | 181.9 |
| 112 | SH | 7138 | 546.6 | 478.5 | 0.76 | 0.25 | 688 | H | 2-03-76 | 38.6 | 201.8 | 201.8 |
| | | 6958 | 480.8 | 530.7 | 0.76 | 0.25 | 190 | S | 2-15-76 | 36.3 | 195.0 | 194.6 |
| | | 7225 | 403.7 | 474.0 | 0.25 | 0.51 | 698 | H | 3-29-76 | 39.9 | 161.0 | 210.5 |
| | | 7244 | 435.4 | 523.9 | 0.51 | 0.51 | 206 | S | 3-26-76 | 34.5 | 176.9 | 218.2 |
| | | 7345 | 444.5 | 469.5 | 0.51 | 0.64 | 193 | S | 2-25-76 | 38.1 | 208.7 | 238.1 |
| | | 6828 | 451.3 | 435.4 | 0.25 | 0.25 | 694 | H | 3-25-76 | 38.1 | 163.3 | 199.6 |
| | | 7423 | 356.1 | 344.7 | 0.25 | 0.25 | 202 | B | 3-19-76 | 33.1 | 124.7 | 161.9 |
| | | 7363 | 396.9 | 451.3 | 0.51 | 0.25 | 207 | B | 4-05-76 | 41.7 | 140.6 | 189.1 |
| | | 7426 | 367.4 | 410.5 | 0.25 | 0.51 | 699 | H | 3-29-76 | 27.2 | 93.0 | 130.2 |

[a]Maintenance and lactation levels of energy were based on National Research Council (1970) recommendations.

[b]USH: Unselected Hereford; SH: Selected Hereford.

Table A.2 Individual Weight and Condition Data for Angus x Hereford x Charolais and Angus x Hereford×Holstein Cows and Calves (Trial 1)[a]

| | | Cow data | | | | | Calf data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pen no. | Cattle[b] type | No. | Initial wt, kg | Final wt, kg | Initial fat, cm | Final fat, cm | No. | Sex | Birth date | Birth wt, kg | Weaning wt actual, kg | Weaning wt 205 day, kg |
| 113 | AHC | 7324 | 442.3 | 444.5 | 0.25 | 0.25 | 695 | H | 3-26-77 | 39.0 | 154.2 | 208.2 |
| | | 7205 | 514.8 | 499.0 | 0.51 | 0.25 | 693 | H | 3-19-76 | 39.0 | 158.8 | 198.2 |
| | | 7479 | 390.1 | 383.3 | 0.25 | 0.25 | 196 | B | 3-05-76 | 33.6 | 99.8 | 122.5 |
| | | 7445 | 394.6 | 396.9 | 0.25 | 0.25 | 685 | H | 1-22-76 | 24.5 | 174.6 | 193.2 |
| | | 7301 | 387.8 | 381.0 | 0.25 | 0.25 | 197 | B | 3-05-76 | 34.5 | 142.9 | 168.3 |
| | | 6935 | 562.5 | 612.3 | 0.76 | 1.02 | 696 | H | 3-29-76 | 31.8 | 120.2 | 148.3 |
| | | 6846 | 571.5 | 594.2 | 1.02 | 0.76 | 292 | B | 2-22-76 | 45.4 | 231.3 | 236.8 |
| | | 7208 | 471.7 | 496.7 | 0.25 | 0.51 | 691 | H | 3-12-76 | 39.0 | 174.6 | 211.8 |
| | | 7110 | 494.4 | 464.9 | 0.25 | 0.25 | 690 | H | 2-23-76 | 40.8 | 215.5 | 232.2 |
| | | 7075 | 573.8 | 539.8 | 0.25 | 0.25 | 999[c] | B | 3-05-76 | 66.7 | 337.9 | 362.0 |
| 114 | AHH | 7230 | 480.8 | 390.1 | 0.25 | 0 | 204 | B | 3-23-76 | 40.8 | 167.8 | 204.1 |
| | | 7313 | 483.1 | 489.9 | 0.25 | 0.25 | 185 | B | 1-30-76 | 40.4 | 265.4 | 273.1 |
| | | 7029 | 494.4 | 483.1 | 0.25 | 0.25 | 288 | B | 2-10-76 | 39.5 | 258.5 | 252.2 |
| | | 6842 | 528.4 | 573.8 | 0.51 | 1.02 | 186 | B | 2-01-76 | 38.1 | 235.9 | 222.7 |
| | | 7189 | 537.5 | 449.1 | 0.25 | 0.25 | 287 | B | 2-03-76 | 38.6 | 235.9 | 224.5 |
| | | 6982 | 526.2 | 480.8 | 0.51 | 0.25 | 298 | B | 3-07-76 | 43.5 | 197.3 | 213.2 |
| | | 7305 | 399.2 | 383.3 | 0.13 | 0.25 | 201 | B | 3-15-76 | 43.5 | 176.9 | 217.7 |
| | | 7433 | 440.0 | 435.4 | 0.51 | 0.25 | 687 | H | 2-02-76 | 31.8 | 195.0 | 223.6 |

[a]Maintenance and lactation levels of energy were based on National Research Council (1970) recommendations.

[b]AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[c]Combined data for twin bull calves.

Table 3. Individual Weight and Condition Data for Unselected and Selected Hereford Cows and Calves (Trial 2)

| Pen no. | Cattle[a] type | Energy[b] level | Cow data | | | | | Calf data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | Initial wt, kg | Final wt, kg | Initial fat, cm | Final fat, cm | No. | Sex | Birth date | Birth wt, kg | Weaning wt actual, kg | Weaning wt 205 day, kg |
| 49 | USH | NRC25 | 6838 | 485.3 | 483.1 | 0.89 | 0.76 | 185 | B | 1-30-77 | 32.7 | 167.8 | 159.2 |
| | | | 7228 | 426.4 | 392.4 | 0.51 | 0.38 | 187 | B | 2-23-77 | 33.6 | 176.9 | 182.9 |
| | | | 7344 | 485.3 | 467.2 | 0.76 | 0.51 | 205 | B | 4-02-77 | 41.7 | 161.0 | 205.9 |
| | | | 7519 | 340.2 | 342.5 | 0.51 | 0.64 | 798 | H | 3-25-77 | 22.2 | 124.7 | 175.1 |
| 50 | USH | NRC | 6972 | 569.3 | 424.1 | 1.40 | 0.51 | 196 | B | 3-17-77 | 47.2 | 142.9 | 161.0 |
| | | | 7179 | 437.7 | 417.3 | 0.76 | 0.51 | 788 | H | 3-05-77 | 26.8 | 138.3 | 155.6 |
| | | | 7310 | 460.4 | 394.6 | 0.76 | 0.25 | 792 | H | 3-15-77 | 37.2 | 154.2 | 190.1 |
| | | | 7337 | 417.3 | 337.9 | 0.51 | 0.25 | 795 | H | 3-20-77 | 32.7 | 122.5 | 153.3 |
| | | | 7513 | 301.6 | 299.4 | 0.51 | 0.25 | 801 | H | 3-30-77 | 20.9 | 93.0 | 131.5 |
| 51 | SH | NRC | 6861 | 519.4 | 469.5 | 0.89 | 0.38 | 204 | B | 3-28-77 | 42.6 | 106.6 | 124.7 |
| | | | 7184 | 551.1 | 424.1 | 0.89 | 0.25 | 192 | B | 3-11-77 | 45.4 | 186.0 | 205.5 |
| | | | 7273 | 499.0 | 406.0 | 0.64 | 0.51 | 785 | H | 2-04-77 | 39.0 | 188.2 | 189.6 |
| | | | 7554 | 417.3 | 285.8 | 0.51 | 0.13 | 193 | B | 3-12-77 | 39.9 | 120.2 | 152.4 |
| 52 | SH | NRC25 | 6723 | 526.2 | 469.5 | 1.14 | 0.89 | 800 | H | 3-30-77 | 41.7 | 142.9 | 179.2 |
| | | | 7158 | 553.4 | 544.3 | 0.76 | 0.64 | 203 | B | 3-27-77 | 47.2 | 181.4 | 215.5 |
| | | | 7181 | 494.4 | 496.7 | 0.51 | 0.51 | 802 | H | 4-01-77 | 39.0 | 142.9 | 180.5 |
| | | | 7463 | 517.1 | 553.4 | 0.64 | 0.89 | 197 | B | 3-20-77 | 43.1 | 138.3 | 173.7 |
| | | | 7598 | 430.9 | 453.6 | 0.64 | 0.38 | 799 | H | 3-26-77 | 41.7 | 152.0 | 215.5 |

[a]USH: Unselected Hereford; SH: Selected Hereford.

[b]NRC: National Research Council (1976) recommended levels of energy for maintenance and lactation; NRC25: 125% of recommended levels.

Table A.4 Individual Weight and Condition Data for Angus x Hereford x Charolais and Angus x Hereford x Holstein Cows and Calves (Trial 2)

| Pen no. | Cattle[a] type | Energy[b] level | Cow data | | | | | Calf data | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | No. | Initial wt, kg | Final wt, kg | Initial fat, cm | Final fat, cm | No. | Sex | Birth date | Birth wt, kg | Weaning wt actual, kg | Weaning wt 205 day, kg |
| 53 | AHC | NRC | 7148 | 635.0 | 589.7 | 0.76 | 0.51 | 186 | B | 2-12-77 | 41.7 | 204.1 | 201.8 |
| | | | 7421 | 537.5 | 514.8 | 0.64 | 0.38 | 201 | B | 3-22-77 | 39.9 | 133.8 | 169.6 |
| | | | 7437 | 455.9 | 347.0 | 0.64 | 0.25 | 796 | H | 3-20-77 | 41.7 | 163.3 | 215.9 |
| 54 | AHC | NRC25 | 7075 | 605.5 | 567.0 | 0.64 | 0.51 | 195 | B | 3-16-77 | 51.7 | 176.9 | 199.6 |
| | | | 7242 | 582.9 | 589.7 | 0.89 | 0.64 | 189 | B | 3-04-77 | 39.9 | 172.4 | 184.6 |
| | | | 7342 | 582.9 | 496.7 | 0.76 | 0.25 | 191 | B | 3-09-77 | 33.6 | 195.0 | 224.1 |
| | | | 7483 | 485.3 | 421.8 | 0.51 | 0.25 | 793 | H | 3-16-77 | 40.8 | 195.0 | 254.0 |
| | | | 7542 | 485.3 | 455.9 | 0.51 | 0.38 | 787 | H | 2-27-77 | 41.7 | 217.7 | 275.3 |
| 55 | AHH | NRC25 | 7029 | 553.4 | 530.7 | 0.51 | 0.51 | 194 | B | 3-13-77 | 46.7 | 215.5 | 240.4 |
| | | | 7207 | 526.2 | 530.7 | 0.38 | 0.38 | 791 | H | 3-15-77 | 42.6 | 229.1 | 270.3 |
| | | | 7311 | 539.8 | 560.2 | 0.64 | 0.51 | 794 | H | 3-17-77 | 40.8 | 208.7 | 260.8 |
| | | | 7562 | 492.1 | 444.5 | 0.64 | 0.51 | 786 | H | 2-21-77 | 40.8 | 165.6 | 204.6 |
| 56 | AHH | NRC | 7313 | 582.9 | 471.7 | 0.25 | 0.25 | 790 | H | 3-10-77 | 46.3 | 224.5 | 272.2 |
| | | | 7007 | 464.9 | 369.7 | 0.25 | 0.13 | 200 | S | 3-22-77 | 33.6 | 154.2 | 178.3 |
| | | | 7410 | 474.0 | 378.7 | 0.51 | 0.25 | 797 | H | 3-23-77 | 43.5 | 154.2 | 206.4 |
| | | | 7533 | 501.2 | 385.6 | 0.51 | 0.25 | 198 | S | 3-21-77 | 38.1 | 204.1 | 271.1 |

[a]AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]NRC: National Research Council (1976) recommended levels of energy for maintenance and lactation; NRC25: 125% of recommended levels.

Table A.5 Climatic Conditions During Cow-Calf Trials (Trials 1,2)

| Trial | Year | Month | Temperature, C° | | | | | Precipitation, cm | | | | | Wind, km/hr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Max temp, no. days | | Min temp, no. days | | | Snow & sleet | | | | |
| | | | Avg | ≥32.2 | ≤0 | ≤0 | ≤-17.8 | Total | Max ground depth | No. of days ≥.25 | ≥1.27 | ≥2.54 | Avg speed |
| 1 | 1975 | Dec | -2.2 | 0 | 19 | 30 | 1 | 7.7 | 12.7 | 7 | 2 | 0 | 15.8 |
| | 1976 | Jan | -7.2 | 0 | 24 | 31 | 2 | 2.9 | 33.0 | 4 | 0 | 0 | 19.0 |
| | | Feb | 0.0 | 0 | 7 | 24 | 2 | 5.2 | 33.0 | 5 | 1 | 1 | 20.1 |
| | | March | 4.2 | 0 | 1 | 22 | 0 | 11.3 | 2.5 | 11 | 4 | 0 | 21.4 |
| | | April | 8.6 | 0 | 0 | 16 | 0 | 10.3 | 5.1 | 7 | 3 | 2 | 17.5 |
| | | May | 11.9 | 0 | 0 | 3 | 0 | 6.8 | 0.0 | 6 | 2 | 0 | 15.6 |
| | | June | 20.7 | 0 | 0 | 0 | 0 | 9.7 | 0.0 | 5 | 2 | 1 | 14.2 |
| | | July | 21.2 | 1 | 0 | 0 | 0 | 11.3 | 0.0 | 4 | 3 | 2 | 13.2 |
| | | Aug | 19.0 | 1 | 0 | 0 | 0 | 1.2 | 0.0 | 2 | 0 | 0 | 10.5 |
| | | Sept | 15.1 | 1 | 0 | 1 | 0 | 4.5 | 0.0 | 5 | 1 | 0 | 13.2 |
| 2 | 1976 | Nov | -0.4 | 0 | 6 | 29 | 0 | 2.2 | 2.5 | 2 | 1 | 0 | 16.3 |
| | | Dec | -7.8 | 0 | 23 | 31 | 4 | 1.6 | 10.2 | 2 | 0 | 0 | 17.2 |
| | 1977 | Jan | -11.8 | 0 | 31 | 31 | 12 | 2.4 | 25.4 | 3 | 0 | 0 | 19.8 |
| | | Feb | -5.3 | 0 | 18 | 27 | 3 | 1.6 | 27.9 | 3 | 0 | 0 | 18.3 |
| | | March | 4.2 | 0 | 3 | 18 | 0 | 6.7 | 10.2 | 7 | 1 | 0 | 19.3 |
| | | April | 10.1 | 0 | 0 | 10 | 0 | 9.4 | 0.0 | 8 | 4 | 0 | 15.3 |
| | | May | 17.4 | 1 | 0 | 2 | 0 | 1.0 | 0.0 | 1 | 0 | 0 | 13.5 |
| | | June | 17.8 | 0 | 0 | 0 | 0 | 9.3 | 0.0 | 6 | 2 | 2 | 13.5 |
| | | July | 22.3 | 6 | 0 | 0 | 0 | 8.6 | 0.0 | 6 | 3 | 0 | 14.3 |
| | | Aug | 19.4 | 2 | 0 | 0 | 0 | 5.2 | 0.0 | 5 | 2 | 0 | 14.0 |
| | | Sept | 17.1 | 0 | 0 | 0 | 0 | 13.4 | 0.0 | 10 | 6 | 0 | 13.2 |

Table A.6 Individual Nitrogen Balance Data for Steers Fed High Corn Silage and High Grain Rations (Trial 1)

| Cattle[a] type | Period | Anim. no. | Energy[b] level | Feed intake/day DM, kg | N intake g/day | Urine N g/day | Fecal N g/day | N retained g/day | N retained/N intake % |
|---|---|---|---|---|---|---|---|---|---|
| USH | 1 | 177 | HS | 5.33 | 116.4 | 33.7 | 40.2 | 42.5 | 36.5 |
| SH | 1 | 160 | HS | 6.83 | 145.8 | 48.9 | 60.8 | 36.1 | 24.8 |
| AHC | 1 | 174 | HS | 6.40 | 137.4 | 34.0 | 51.7 | 51.7 | 37.6 |
| AHH | 1 | 106 | HS | 8.61 | 182.0 | 52.9 | 68.0 | 61.2 | 33.6 |
| USH | 1 | 125 | HG | 3.71 | 84.1 | 31.4 | 27.1 | 25.5 | 30.4 |
| SH | 1 | 140 | HG | 5.98 | 135.3 | 44.5 | 45.5 | 45.4 | 33.5 |
| AHC | 1 | 123 | HG | 7.58 | 173.1 | 61.1 | 51.2 | 60.9 | 35.2 |
| AHH | 1 | 145 | HG | 7.30 | 165.7 | 57.0 | 50.7 | 58.0 | 35.0 |
| USH | 2 | 125 | HS | 4.33 | 101.8 | 23.2 | 44.5 | 34.1 | 33.5 |
| SH | 2 | 140 | HS | 6.72 | 158.0 | 48.6 | 81.9 | 27.5 | 17.4 |
| AHC | 2 | 123 | HS | 5.26 | 122.3 | 51.8 | 56.1 | 14.3 | 11.7 |
| AHH | 2 | 145 | HS | 6.66 | 158.9 | 61.7 | 66.5 | 30.8 | 19.4 |
| USH | 2 | 177 | HG | 5.22 | 127.7 | 48.9 | 44.4 | 34.4 | 26.9 |
| SH | 2 | 160 | HG | 7.81 | 197.6 | 77.4 | 66.2 | 54.0 | 27.3 |
| AHC | 2 | 174 | HG | 8.00 | 199.4 | 77.4 | 71.1 | 50.8 | 25.5 |
| AHH | 2 | 106 | HG | 8.71 | 214.9 | 100.7 | 59.4 | 54.8 | 25.5 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: Corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.7 Individual Energy Intake, Losses, Digestibility and Metabolizability Data for Steers Fed High Corn Silage and High Grain Rations (Trial 1)

| Cattle[a] type | Period | Anim. no. | Energy[b] level | Feed intake/day DM, kg | Feed intake/day kcal | Urine kcal/day | Methane[c] kcal/day | Feces kcal/day | Digestible energy kcal/kg | Metabolizable energy kcal/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| USH | 1 | 177 | HS | 5.53 | 26165.01 | 371.43 | 2093.20 | 6778.53 | 3.507 | 3.061 |
| SH | 1 | 160 | HS | 6.83 | 32223.03 | 477.71 | 2577.84 | 9892.63 | 3.270 | 2.822 |
| AHC | 1 | 174 | HS | 6.40 | 30172.14 | 428.57 | 2413.77 | 9532.71 | 3.223 | 2.779 |
| AHH | 1 | 106 | HS | 8.61 | 40581.22 | 616.00 | 3246.50 | 12685.72 | 3.238 | 2.790 |
| USH | 1 | 125 | HG | 3.71 | 16277.64 | 234.29 | 1302.21 | 4843.98 | 3.080 | 2.666 |
| SH | 1 | 140 | HG | 5.98 | 26395.65 | 405.71 | 2111.65 | 5748.44 | 3.453 | 3.032 |
| AHC | 1 | 123 | HG | 7.58 | 33249.79 | 365.71 | 2659.98 | 7053.72 | 3.457 | 3.057 |
| AHH | 1 | 145 | HG | 7.30 | 32121.84 | 417.14 | 2569.75 | 7244.04 | 3.409 | 3.000 |
| USH | 2 | 125 | HS | 4.33 | 19519.19 | 204.00 | 1561.54 | 6415.90 | 3.027 | 2.620 |
| SH | 2 | 140 | HS | 6.72 | 30364.53 | 627.00 | 2429.16 | 12440.41 | 2.668 | 2.213 |
| AHC | 2 | 123 | HS | 5.26 | 23710.87 | 539.43 | 1896.87 | 9056.52 | 2.785 | 2.322 |
| AHH | 2 | 145 | HS | 6.66 | 29954.96 | 428.57 | 2396.40 | 10130.16 | 2.978 | 2.554 |
| USH | 2 | 177 | HG | 5.22 | 23575.94 | 377.14 | 1886.08 | 5751.03 | 3.412 | 2.978 |
| SH | 2 | 160 | HG | 7.81 | 35455.24 | 455.71 | 2836.42 | 8826.18 | 3.411 | 2.990 |
| AHC | 2 | 174 | HG | 8.00 | 36127.36 | 557.71 | 2890.19 | 10484.74 | 3.205 | 2.774 |
| AHH | 2 | 106 | HG | 8.71 | 39314.20 | 469.43 | 3145.14 | 8111.46 | 3.584 | 3.169 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]Estimated at 8% of energy intake.

Table A.8 Individual Nitrogen Balance Data for Steers Fed High Corn Silage and High Grain Rations (Trial 2)

| Cattle[a] type | Period | Anim. no. | Energy[b] level | Feed intake/day DM, kg | N intake g/day | Urine N g/day | Fecal N g/day | N retained g/day | N retained/N intake % |
|---|---|---|---|---|---|---|---|---|---|
| USH | 1 | 200 | HS | 4.47 | 103.3 | 30.7 | 42.3 | 30.3 | 29.4 |
| SH | 1 | 206 | HS | 4.98 | 111.4 | 73.3 | 46.9 | -8.8 | -7.9 |
| AHC | 1 | 197 | HS | 5.71 | 129.5 | 53.3 | 56.3 | 20.0 | 15.4 |
| AHH | 1 | 201 | HS | 6.19 | 139.1 | 42.5 | 60.0 | 36.6 | 26.3 |
| USH | 1 | 203 | HG | 4.38 | 102.1 | 22.5 | 32.8 | 46.8 | 45.9 |
| SH | 1 | 207 | HG | 5.35 | 123.7 | 26.7 | 41.3 | 55.8 | 45.1 |
| AHC | 1 | 294 | HG | 6.09 | 139.6 | 42.3 | 48.3 | 49.0 | 35.1 |
| AHH | 1 | 204 | HG | 6.43 | 152.7 | 44.0 | 54.5 | 54.2 | 35.5 |
| USH | 2 | 203 | HS | 3.97 | 88.8 | 28.2 | 33.7 | 26.9 | 30.2 |
| SH | 2 | 207 | HS | 5.33 | 118.4 | 33.5 | 50.8 | 34.1 | 28.8 |
| AHC | 2 | 294 | HS | 5.51 | 121.6 | 44.9 | 46.0 | 30.6 | 25.2 |
| AHH | 2 | 204 | HS | 5.76 | 133.9 | 46.9 | 52.9 | 34.2 | 25.5 |
| USH | 2 | 200 | HG | 4.48 | 100.0 | 30.6 | 28.4 | 41.0 | 41.1 |
| SH | 2 | 206 | HG | 6.44 | 153.7 | 48.6 | 47.7 | 57.5 | 37.4 |
| AHC | 2 | 197 | HG | 6.36 | 140.1 | 60.0 | 55.4 | 24.7 | 17.6 |
| AHH | 2 | 201 | HG | 7.35 | 167.0 | 56.3 | 69.8 | 40.9 | 24.5 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.9 Individual Energy Intake, Losses, Digestibility and Metabolizability Data for Steers Fed High Corn Silage and High Grain Rations (Trial 2)

| Cattle[a] type | Period | Anim. no. | Energy[b] level | Feed intake/day DM, kg | Feed intake/day kcal | Urine kcal/day | Methane[c] kcal/day | Feces kcal/day | Digestible energy kcal/kg | Metabolizable energy kcal/kg |
|---|---|---|---|---|---|---|---|---|---|---|
| USH | 1 | 200 | HS | 4.47 | 20211.39 | 474.57 | 1616.91 | 6306.09 | 3.112 | 2.644 |
| SH | 1 | 206 | HS | 4.98 | 22667.26 | 835.71 | 1813.38 | 7455.42 | 3.053 | 2.521 |
| AHC | 1 | 197 | HS | 5.71 | 25928.99 | 736.00 | 2074.32 | 8986.53 | 2.969 | 2.477 |
| AHH | 1 | 201 | HS | 6.19 | 27926.29 | 720.00 | 2234.10 | 10158.47 | 2.870 | 2.393 |
| USH | 1 | 203 | HG | 4.38 | 18973.33 | 368.57 | 1517.87 | 4044.25 | 3.409 | 2.978 |
| SH | 1 | 207 | HG | 5.35 | 23166.44 | 587.14 | 1853.32 | 4958.98 | 3.405 | 2.949 |
| AHC | 1 | 294 | HG | 6.09 | 26477.83 | 805.71 | 2118.23 | 6150.56 | 3.340 | 2.860 |
| AHH | 1 | 204 | HG | 6.43 | 27935.17 | 728.00 | 2234.81 | 7622.79 | 3.157 | 2.696 |
| USH | 2 | 203 | HS | 3.97 | 17181.27 | 468.57 | 1374.50 | 5235.81 | 3.013 | 2.548 |
| SH | 2 | 207 | HS | 5.33 | 23093.71 | 537.14 | 1847.50 | 7726.76 | 2.882 | 2.435 |
| AHC | 2 | 294 | HS | 5.51 | 23963.33 | 711.43 | 1917.07 | 7384.00 | 3.010 | 2.533 |
| AHH | 2 | 204 | HS | 5.76 | 25548.58 | 628.57 | 2043.89 | 8700.04 | 2.926 | 2.462 |
| USH | 2 | 200 | HG | 4.48 | 20048.31 | 508.57 | 1603.86 | 3464.26 | 3.701 | 3.230 |
| SH | 2 | 206 | HG | 6.44 | 28764.60 | 792.86 | 2301.17 | 5630.84 | 3.593 | 3.112 |
| AHC | 2 | 197 | HG | 6.36 | 28544.48 | 754.29 | 2283.56 | 6419.02 | 3.476 | 2.999 |
| AHH | 2 | 201 | HG | 7.35 | 32783.97 | 780.00 | 2622.72 | 8157.55 | 3.352 | 2.889 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]Estimated at 8% of energy intake.

Table A.10 Genetic Background of Steers, Daily Intakes of Dry Matter (DM), Metabolizable Energy (ME) and Crude Protein (CP), and Efficiency of ME and CP Utilization for Carcass Production (Trial 1)

| Pen no. | No. anim. | Cattle[a] type | Energy[b] level | Genetic Background | | | | Daily Intakes[c] | | | Efficiencies[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Angus % | Hereford % | Charolais % | Holstein % | DM kg | CP kg | ME Mcal | EE % | EUEP Mcal/kg | ECPUCP % |
| 17 | 8 | USH | HG | -- | 100 | -- | -- | 7.17 | 0.856 | 21.26 | 17.90 | 58.27 | 10.66 |
| 18 | 6 | SH | HG | -- | 100 | -- | -- | 8.65 | 1.004 | 25.65 | 18.96 | 60.53 | 10.46 |
| 19 | 8 | AHC | HG | 28 | 38 | 34 | -- | 8.73 | 1.014 | 25.88 | 17.94 | 59.42 | 10.77 |
| 20 | 8 | AHH | HG | 23 | 36 | -- | 41 | 9.35 | 1.075 | 27.72 | 19.07 | 71.16 | 9.35 |
| 21 | 8 | USH | HS | -- | 100 | -- | -- | 6.90 | 0.725 | 17.57 | 16.13 | 69.58 | 8.83 |
| 22 | 7 | SH | HS | -- | 100 | -- | -- | 8.42 | 0.854 | 21.44 | 16.47 | 59.34 | 10.50 |
| 23 | 8 | AHC | HS | 36 | 33 | 31 | -- | 9.14 | 0.938 | 23.27 | 15.65 | 67.76 | 9.44 |
| 24 | 8 | AHH | HS | 28 | 33 | -- | 39 | 8.95 | 0.920 | 22.79 | 15.81 | 63.35 | 9.81 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

[c]Intake of corn silage and high moisture corn dry matter was increased by 6.8% and 3%, respectively, to adjust for errors in dry matter determination.

[d]EE (Energetic Efficiency): daily energy gained, Mcal ÷ daily ME intake, Mcal x 100; EUEP (Efficiency of Energy Utilization for Edible Portion Production): daily ME intake, Mcal ÷ daily edible portion gained, kg; ECPUCP (Efficiency of Crude Protein Utilization for Carcass Protein Production): daily carcass protein gained, kg ÷ daily CP intake, kg x 100.

Table A.11 Individual Shrunk Weights and Carcass Characteristics of Unselected Hereford Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 112 | HS | 287 | 240.4 | 455.9 | 18 | 12 | 1.02 | 3.0 | 83.2 | 2.3 |
| | 133 | | 287 | 204.1 | 390.1 | 18 | 12 | 1.78 | 3.5 | 75.5 | 3.2 |
| | 149 | | 287 | 265.4 | 480.8 | 24 | 13 | 1.78 | 3.5 | 77.4 | 3.6 |
| | 173 | | 287 | 213.2 | 474.0 | 11 | 10 | 0.76 | 2.0 | 81.3 | 2.0 |
| | 176 | | 287 | 199.6 | 430.9 | 14 | 11 | 1.78 | 3.5 | 71.0 | 3.7 |
| | 193 | | 287 | 176.9 | 376.5 | 6 | 7 | 0.64 | 1.5 | 81.3 | 1.3 |
| | 194 | | 287 | 204.1 | 430.9 | 14 | 11 | 1.14 | 2.5 | 78.1 | 2.6 |
| | 195 | | 287 | 188.2 | 412.8 | 8 | 8 | 1.27 | 2.0 | 76.1 | 2.5 |
| 17 | 108 | HG | 224 | 288.0 | 514.8 | 15 | 11 | 1.52 | 4.0 | 72.9 | 3.8 |
| | 167 | | 224 | 220.0 | 467.2 | 6 | 7 | 0.89 | 2.5 | 77.4 | 2.3 |
| | 172 | | 224 | 217.7 | 444.5 | 11 | 10 | 1.27 | 4.0 | 71.6 | 3.3 |
| | 180 | | 224 | 206.4 | 471.7 | 14 | 11 | 1.02 | 3.0 | 83.2 | 2.4 |
| | 181 | | 224 | 201.9 | 462.7 | 12 | 10 | 1.27 | 3.5 | 69.7 | 3.3 |
| | 184 | | 224 | 201.9 | 415.0 | 11 | 10 | 1.78 | 3.5 | 68.4 | 3.6 |
| | 188 | | 224 | 167.8 | 383.3 | 6 | 7 | 1.40 | 4.5 | 70.3 | 3.3 |
| | 190 | | 224 | 197.3 | 449.1 | 12 | 10 | 1.27 | 2.5 | 72.3 | 2.9 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.12 Individual Shrunk Weights and Carcass Characteristics of Selected Hereford Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 138 | HS | 287 | 288.0 | 585.1 | 12 | 10 | 2.29 | 3.5 | 74.2 | 4.8 |
| | 163 | | 287 | 263.1 | 537.5 | 12 | 10 | 2.16 | 3.5 | 78.7 | 4.3 |
| | 170 | | 287 | 240.4 | 517.1 | 9 | 9 | 1.78 | 3.0 | 89.0 | 3.1 |
| | 175 | | 287 | 224.5 | 469.5 | 11 | 10 | 0.76 | 3.5 | 81.9 | 2.3 |
| | 178 | | 287 | 244.9 | 553.4 | 12 | 10 | 2.29 | 2.5 | 89.7 | 3.8 |
| | 187 | | 287 | 226.8 | 503.5 | 13 | 10 | 1.52 | 3.5 | 72.9 | 3.7 |
| | 199 | | 287 | 186.0 | 442.3 | 7 | 7 | 1.27 | 2.0 | 74.2 | 2.7 |
| 18 | 129 | HG | 224 | 229.1 | 478.5 | 8 | 8 | 1.78 | 3.5 | 72.3 | 3.8 |
| | 143 | | 224 | 258.6 | 528.4 | 14 | 11 | 2.54 | 3.0 | 83.2 | 4.3 |
| | 153 | | 224 | 279.0 | 578.3 | 8 | 8 | 2.54 | 4.5 | 87.7 | 4.6 |
| | 160 | | 224 | 204.1 | 455.9 | 17 | 12 | 1.65 | 4.0 | 76.8 | 3.5 |
| | 162 | | 224 | 256.3 | 528.4 | 14 | 11 | 1.78 | 3.5 | 78.7 | 3.8 |
| | 192 | | 224 | 206.4 | 501.2 | 11 | 10 | 1.40 | 3.0 | 79.4 | 3.1 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.13 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Charolais Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 106 | HS | 287 | 310.7 | 655.5 | 12 | 10 | 2.41 | 3.5 | 89.7 | 4.5 |
| | 115 | | 287 | 272.2 | 521.6 | 24 | 13 | 1.52 | 3.0 | 89.0 | 3.0 |
| | 117 | | 287 | 263.1 | 478.5 | 12 | 10 | 1.52 | 3.5 | 74.8 | 3.5 |
| | 123 | | 287 | 337.9 | 632.8 | 12 | 10 | 0.76 | 3.0 | 108.4 | 1.9 |
| | 146 | | 287 | 258.6 | 578.3 | 13 | 10 | 1.65 | 3.5 | 83.2 | 3.8 |
| | 150 | | 287 | 274.4 | 569.3 | 23 | 13 | 2.29 | 4.0 | 80.0 | 4.6 |
| | 156 | | 287 | 283.5 | 594.2 | 8 | 8 | 0.64 | 3.0 | 107.1 | 1.4 |
| | 185 | | 287 | 222.3 | 464.9 | 15 | 11 | 1.27 | 3.0 | 76.8 | 2.9 |
| 19 | 102 | HG | 224 | 301.6 | 551.1 | 12 | 10 | 2.41 | 4.0 | 80.6 | 4.6 |
| | 107 | | 224 | 292.6 | 594.2 | 12 | 10 | 1.65 | 3.5 | 78.7 | 4.0 |
| | 121 | | 224 | 297.1 | 526.2 | 12 | 10 | 0.89 | 3.5 | 90.3 | 2.3 |
| | 136 | | 224 | 283.5 | 544.3 | 12 | 10 | 0.76 | 3.5 | 96.1 | 2.0 |
| | 142 | | 224 | 263.1 | 564.7 | 11 | 10 | 2.29 | 3.5 | 81.9 | 4.4 |
| | 151 | | 224 | 272.2 | 503.5 | 12 | 10 | 1.27 | 3.5 | 77.4 | 3.2 |
| | 164 | | 224 | 288.0 | 576.1 | 8 | 8 | 1.65 | 3.5 | 89.7 | 3.4 |
| | 182 | | 224 | 217.7 | 492.2 | 14 | 11 | 1.27 | 4.5 | 83.2 | 3.1 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.14 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Holstein Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 103 | HS | 287 | 344.7 | 610.1 | 14 | 11 | 2.03 | 3.5 | 89.7 | 4.0 |
| | 113 | | 287 | 317.5 | 594.2 | 9 | 8 | 0.76 | 2.0 | 89.7 | 2.2 |
| | 119 | | 287 | 306.2 | 594.2 | 13 | 10 | 1.14 | 2.0 | 81.3 | 3.0 |
| | 130 | | 287 | 299.4 | 555.7 | 18 | 12 | 2.54 | 3.5 | 65.8 | 5.4 |
| | 135 | | 287 | 294.8 | 632.8 | 15 | 11 | 1.27 | 3.5 | 89.7 | 3.3 |
| | 152 | | 287 | 294.8 | 589.7 | 12 | 10 | 0.89 | 3.0 | 94.8 | 2.3 |
| | 177 | | 287 | 285.8 | 564.7 | 12 | 10 | 2.03 | 4.0 | 75.5 | 4.5 |
| | 198 | | 287 | 213.2 | 483.1 | 13 | 10 | 0.76 | 2.5 | 77.4 | 2.3 |
| 20 | 105 | HG | 224 | 303.9 | 548.9 | 14 | 11 | 2.79 | 3.5 | 76.8 | 4.9 |
| | 114 | | 224 | 322.1 | 591.9 | 15 | 11 | 1.78 | 3.5 | 78.7 | 4.1 |
| | 116 | | 224 | 315.3 | 530.7 | 14 | 11 | 2.29 | 3.5 | 78.1 | 4.4 |
| | 125 | | 224 | 306.2 | 612.4 | 15 | 11 | 2.29 | 4.5 | 78.7 | 4.9 |
| | 126 | | 224 | 315.3 | 612.4 | 13 | 10 | 1.40 | 4.0 | 82.6 | 3.7 |
| | 155 | | 224 | 303.9 | 557.9 | 12 | 10 | 1.27 | 4.0 | 83.9 | 3.3 |
| | 165 | | 224 | 279.0 | 571.5 | 24 | 13 | 1.40 | 3.5 | 78.1 | 3.7 |
| | 179 | | 224 | 256.3 | 551.1 | 14 | 11 | 1.27 | 2.5 | 73.5 | 3.4 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.15 Individual Carcass Weight, Protein and Fat Data for Unselected Hereford Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | 112 | HS | 287 | 129.1 | 289.4 | 14.54 | 34.54 | .0616 | .2903 | .2504 | 350.2 | 2719.1 |
| | 133 | | 287 | 109.6 | 244.9 | 13.78 | 36.43 | .0454 | .2617 | .1846 | 258.1 | 2451.0 |
| | 149 | | 287 | 142.5 | 301.6 | 13.98 | 39.64 | .0531 | .3525 | .2159 | 301.9 | 3302.2 |
| | 173 | | 287 | 114.5 | 289.8 | 15.12 | 32.28 | .0773 | .2745 | .3142 | 439.3 | 2571.5 |
| | 176 | | 287 | 107.2 | 279.0 | 13.36 | 36.04 | .0593 | .3021 | .2411 | 337.3 | 2829.9 |
| | 193 | | 287 | 95.0 | 231.8 | 15.87 | 24.20 | .0656 | .1527 | .2667 | 373.0 | 1430.5 |
| | 194 | | 287 | 109.6 | 283.5 | 14.89 | 32.49 | .0749 | .2717 | .3045 | 425.7 | 2545.1 |
| | 195 | | 287 | 101.1 | 255.4 | 15.94 | 28.02 | .0752 | .2039 | .3057 | 427.7 | 1909.7 |
| 17 | 108 | HG | 224 | 154.7 | 321.1 | 14.66 | 36.52 | .0797 | .4345 | .3240 | 453.1 | 4069.8 |
| | 167 | | 224 | 118.1 | 278.5 | 15.35 | 30.57 | .0911 | .3120 | .3703 | 518.1 | 2922.5 |
| | 172 | | 224 | 116.9 | 283.9 | 14.68 | 33.05 | .0875 | .3516 | .3557 | 497.3 | 3293.7 |
| | 180 | | 224 | 110.8 | 296.7 | 15.63 | 31.49 | .1135 | .3532 | .4614 | 645.6 | 3308.3 |
| | 181 | | 224 | 108.4 | 281.7 | 14.89 | 36.52 | .0958 | .3968 | .3894 | 544.5 | 3717.0 |
| | 184 | | 224 | 108.4 | 252.7 | 14.83 | 36.10 | .0758 | .3448 | .3081 | 431.1 | 3229.6 |
| | 188 | | 224 | 90.1 | 241.8 | 14.67 | 32.99 | .0823 | .3041 | .3346 | 467.9 | 2848.7 |
| | 190 | | 224 | 106.0 | 273.5 | 15.87 | 30.39 | .1043 | .3100 | .4240 | 593.2 | 2903.9 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

Table A.16 Individual Carcass Weight, Protein and Fat Data for Selected Hereford Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain kg | Daily fat gain kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22 | 138 | HS | 287 | 149.1 | 368.3 | 13.79 | 34.29 | .0835 | .3636 | .3394 | 474.5 | 3405.8 |
| | 163 | | 287 | 136.1 | 347.5 | 15.15 | 32.89 | .0981 | .3283 | .3988 | 557.6 | 3075.5 |
| | 170 | | 287 | 124.4 | 323.4 | 15.63 | 31.52 | .0981 | .2914 | .3988 | 557.8 | 2729.5 |
| | 175 | | 287 | 116.2 | 297.6 | 14.89 | 32.34 | .0815 | .2757 | .3313 | 463.3 | 2582.4 |
| | 178 | | 287 | 126.8 | 360.6 | 14.39 | 35.25 | .1013 | .3778 | .4118 | 576.2 | 3538.8 |
| | 187 | | 287 | 117.4 | 315.2 | 14.00 | 37.92 | .0802 | .3563 | .3260 | 455.9 | 3337.2 |
| | 199 | | 287 | 96.2 | 275.8 | 15.11 | 32.63 | .0849 | .2642 | .3451 | 482.6 | 2474.7 |
| 18 | 129 | HG | 224 | 118.5 | 296.6 | 14.38 | 33.46 | .0951 | .3652 | .3866 | 340.9 | 3420.5 |
| | 143 | | 224 | 133.8 | 340.2 | 13.86 | 40.41 | .1029 | .5258 | .4183 | 585.3 | 4924.8 |
| | 153 | | 224 | 144.4 | 370.6 | 14.35 | 36.14 | .1214 | .5030 | .4935 | 690.3 | 4711.7 |
| | 160 | | 224 | 105.6 | 285.8 | 14.12 | 39.00 | .0952 | .4281 | .3870 | 541.4 | 4009.6 |
| | 162 | | 224 | 132.6 | 333.8 | 14.16 | 38.44 | .1044 | .4857 | .4244 | 593.8 | 4549.2 |
| | 192 | | 224 | 106.8 | 308.5 | 14.30 | 35.96 | .1111 | .4249 | .4516 | 631.5 | 3980.0 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

Table A.17 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Charolais Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on Feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 106 | HS | 287 | 167.0 | 411.4 | 14.39 | 34.23 | .0968 | .4131 | .3935 | 550.6 | 3869.3 |
| | 115 | | 287 | 146.3 | 337.9 | 15.08 | 31.47 | .0818 | .3026 | .3325 | 465.1 | 2834.2 |
| | 117 | | 287 | 141.4 | 305.3 | 14.06 | 39.20 | .0569 | .3513 | .2313 | 323.7 | 3290.4 |
| | 123 | | 287 | 181.6 | 413.2 | 16.42 | 21.69 | .1174 | .2279 | .4772 | 667.6 | 2134.9 |
| | 146 | | 287 | 139.0 | 370.6 | 14.42 | 36.61 | .0952 | .4081 | .3870 | 541.1 | 3823.0 |
| | 150 | | 287 | 147.5 | 363.8 | 14.12 | 39.23 | .0823 | .4287 | .3346 | 468.1 | 4015.6 |
| | 156 | | 287 | 152.4 | 367.9 | 16.14 | 26.19 | .1070 | .2649 | .4350 | 608.5 | 2481.5 |
| | 185 | | 287 | 119.5 | 291.2 | 14.73 | 33.35 | .0712 | .2829 | .2894 | 404.7 | 2650.2 |
| 19 | 102 | HG | 224 | 162.1 | 351.5 | 13.87 | 39.83 | .0816 | .5286 | .3317 | 464.0 | 4951.8 |
| | 107 | | 224 | 157.3 | 379.2 | 14.70 | 36.57 | .1168 | .5255 | .4748 | 664.3 | 4922.6 |
| | 121 | | 224 | 159.7 | 332.9 | 16.46 | 28.72 | .1107 | .3319 | .4500 | 629.4 | 3109.0 |
| | 136 | | 224 | 152.4 | 340.2 | 15.89 | 29.01 | .1134 | .3499 | .4610 | 645.0 | 3277.1 |
| | 142 | | 224 | 141.4 | 371.5 | 13.74 | 39.99 | .1091 | .5790 | .4435 | 620.5 | 5423.7 |
| | 151 | | 224 | 146.3 | 320.2 | 15.07 | 33.27 | .0927 | .3886 | .3768 | 527.3 | 3640.3 |
| | 164 | | 224 | 154.8 | 365.6 | 15.51 | 29.99 | .1233 | .3973 | .5012 | 700.9 | 3721.6 |
| | 182 | | 224 | 117.0 | 310.3 | 16.19 | 29.13 | .1260 | .3339 | .5122 | 716.6 | 3127.2 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

Table A.18 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Holstein Steers (Trial 1)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat % | Daily protein gain kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 103 | HS | 287 | 183.2 | 389.2 | 14.73 | 35.66 | .0813 | .3936 | .3305 | 462.0 | 3686.9 |
| | 113 | | 287 | 168.8 | 368.8 | 16.56 | 24.78 | .1037 | .2355 | .4215 | 598.4 | 2206.1 |
| | 119 | | 287 | 162.7 | 369.7 | 14.77 | 31.09 | .0851 | .3205 | .3459 | 483.9 | 3002.0 |
| | 130 | | 287 | 159.1 | 353.8 | 13.90 | 39.14 | .0685 | .4044 | .2785 | 398.3 | 3787.8 |
| | 135 | | 287 | 156.7 | 401.4 | 15.17 | 30.19 | .1109 | .3452 | .4508 | 630.4 | 3233.8 |
| | 152 | | 287 | 156.7 | 372.0 | 15.26 | 31.82 | .0965 | .3354 | .3923 | 548.7 | 3142.1 |
| | 177 | | 287 | 151.9 | 361.1 | 14.88 | 36.00 | .0891 | .3782 | .3622 | 506.4 | 3543.0 |
| | 198 | | 287 | 113.3 | 288.0 | 15.95 | 27.94 | .0869 | .2247 | .3533 | 494.0 | 2105.1 |
| 20 | 105 | HG | 224 | 161.5 | 337.5 | 15.82 | 31.45 | .1046 | .3721 | .4252 | 595.0 | 3485.3 |
| | 114 | | 224 | 171.2 | 372.9 | 14.79 | 36.53 | .1045 | .5004 | .4248 | 594.2 | 4686.9 |
| | 116 | | 224 | 167.6 | 337.5 | 13.09 | 44.00 | .0585 | .5574 | .2378 | 332.5 | 5221.0 |
| | 125 | | 224 | 162.7 | 385.6 | 13.77 | 41.79 | .1022 | .6168 | .4154 | 581.2 | 5777.5 |
| | 126 | | 224 | 167.6 | 381.0 | 14.64 | 37.06 | .1103 | .5249 | .4484 | 627.2 | 4916.3 |
| | 155 | | 224 | 161.5 | 348.4 | 14.18 | 39.10 | .0867 | .5064 | .3524 | 493.0 | 4743.9 |
| | 165 | | 224 | 148.3 | 366.1 | 14.72 | 35.92 | .1177 | .4936 | .4785 | 669.3 | 4623.5 |
| | 179 | | 224 | 136.2 | 345.6 | 15.05 | 35.01 | .1194 | .4545 | .4854 | 679.0 | 4257.1 |

[a]HS: corn silage plus supplement; HG: 40% corn silage plus 60% corn and supplement.

Table A.19 Genetic Background of Heifers and Steers, Daily Intakes of Dry Matter (DM), Metabolizable Energy (ME) and Crude Protein (CP), and Efficiency of ME and CP Utilization for Carcass Production (Trial 2)

| Pen no. | No. anim. | Cattle[a] type | Sex | Energy[b] level | Genetic Background | | | | Daily Intakes[d] | | | Efficiencies[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Angus % | Hereford % | Charolais % | Holstein % | DM kg | CP kg | ME Mcal | EE % | EUEP Mcal/kg | ECPUCP % |
| 1 | 8 | USH | H | HS | -- | 100 | -- | -- | 5.97 | 0.631 | 14.46 | 13.24 | 50.69 | 11.30 |
| 2 | 8 | SH | H | HS | -- | 100 | -- | -- | 6.69 | 0.692 | 16.20 | 11.96 | 53.16 | 10.97 |
| 3 | 8 | AHC | H | HS | 37 | 22 | 41 | -- | 7.22 | 0.754 | 17.48 | 12.70 | 50.44 | 11.60 |
| 4 | 8 | AHH | H | HS | 27 | 42 | -- | 31 | 8.08 | 0.831 | 19.56 | 12.92 | 66.95 | 8.87 |
| 5 | 5 | USH | S | HS | -- | 100 | -- | -- | 6.83 | 0.726 | 16.52 | 13.34 | 60.80 | 9.58 |
| 6 | 7 | SH | S | HS | -- | 100 | -- | -- | 7.93 | 0.815 | 19.21 | 14.70 | 47.20 | 12.35 |
| 9 | 8 | AHC | S | HS | 26 | 36 | 38 | -- | 8.44 | 0.872 | 20.43 | 13.98 | 52.78 | 11.26 |
| 10 | 7 | AHH | S | HS | 34 | 27 | -- | 39 | 9.10 | 0.934 | 22.03 | 14.69 | 55.61 | 10.59 |
| 11 | 5 | USH | S | HG | -- | 100 | -- | -- | 7.04 | 0.866 | 20.09 | 21.43 | 46.19 | 12.63 |
| 12 | 8 | SH | S | HG | -- | 100 | -- | -- | 7.77 | 0.915 | 22.20 | 21.82 | 42.93 | 14.14 |
| 13 | 8 | AHC | S | HG | 33 | 34 | 33 | -- | 8.72 | 1.048 | 24.94 | 19.74 | 47.99 | 12.36 |
| 14 | 8 | AHH | S | HG | 30 | 32 | -- | 38 | 9.05 | 1.093 | 25.87 | 19.02 | 55.10 | 10.67 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]Intake of corn silage and high moisture corn dry matter was increased by 6.8% and 3%, respectively, to adjust for errors in dry matter determination.

[d]EE (Energetic Efficiency): daily energy gained, Mcal ÷ daily ME intake, Mcal x 100; EUEP (Efficiency of Energy Utilization for Edible Portion Production): daily ME intake Mcal ÷ daily edible portion gained, kg; ECPUCP (Efficiency of Crude Protein Utilization for Carcass Protein Production): daily carcass protein gained, kg ÷ daily CP intake, kg x 100.

Table A.20 Individual Shrunk Weights and Carcass Characteristics of Unselected and Selected Hereford Heifers (Trial 2)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[c] | Qual[d] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 589 | HS | 253 | 154.2 | 376.5 | 9 | 9 | 0.76 | 1.5 | 67.1 | 1.9 |
| | 577 | | 253 | 156.5 | 362.9 | 18 | 12 | 1.02 | 2.0 | 69.0 | 2.1 |
| | 393 | | 253 | 129.3 | 328.9 | 5 | 6 | 0.25 | 1.0 | 60.6 | 1.5 |
| | 584 | | 253 | 147.4 | 322.1 | 8 | 8 | 0.51 | 1.0 | 62.6 | 1.4 |
| | 391 | | 336 | 99.8 | 319.8 | 9 | 9 | 0.38 | 1.0 | 65.8 | 1.5 |
| | 579 | | 336 | 129.3 | 374.2 | 7 | 7 | 0.51 | 0.5 | 68.4 | 1.5 |
| | 591 | | 336 | 133.8 | 367.4 | 7 | 7 | 0.89 | 2.5 | 73.6 | 2.0 |
| | 599 | | 336 | 115.7 | 351.5 | 11 | 10 | 0.51 | 1.5 | 69.0 | 1.7 |
| 2 | 387 | HS | 253 | 176.9 | 396.9 | 8 | 8 | 0.51 | 1.5 | 63.9 | 2.1 |
| | 544 | | 253 | 179.2 | 396.9 | 9 | 9 | 0.51 | 2.0 | 67.1 | 2.1 |
| | 532 | | 253 | 192.8 | 399.2 | 8 | 8 | 0.51 | 2.5 | 68.4 | 2.1 |
| | 511 | | 253 | 163.3 | 381.0 | 8 | 8 | 0.25 | 1.5 | 76.1 | 1.2 |
| | 541 | | 336 | 138.3 | 358.3 | 7 | 7 | 0.38 | 0.5 | 61.9 | 1.6 |
| | 594 | | 336 | 156.5 | 403.7 | 11 | 10 | 0.25 | 2.0 | 71.6 | 1.9 |
| | 543 | | 336 | 147.4 | 412.8 | 9 | 9 | 0.89 | 2.0 | 60.0 | 3.2 |
| | 581 | | 336 | 158.8 | 402.2 | 7 | 7 | 0.64 | 1.0 | 72.9 | 1.7 |

[a]Pen 1: Unselected Hereford; pen 2: Selected Hereford.

[b]HS: corn silage plus supplement.

[c]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[d]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.21 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Charolais and Angus x Hereford x Holstein Heifers (Trial 2)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[c] | Qual[d] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 572 | HS | 253 | 188.2 | 442.3 | 12 | 10 | 0.89 | 2.0 | 67.1 | 2.3 |
| | 545 | | 253 | 181.4 | 424.1 | 12 | 10 | 0.51 | 1.5 | 82.6 | 1.3 |
| | 561 | | 253 | 188.2 | 406.0 | 5 | 6 | 0.25 | 0.5 | 77.4 | 1.0 |
| | 574 | | 253 | 170.1 | 378.8 | 11 | 10 | 0.51 | 2.5 | 69.0 | 2.2 |
| | 508 | | 336 | 170.1 | 406.0 | 6 | 6 | 0.25 | 1.5 | 87.1 | 1.0 |
| | 549 | | 336 | 170.1 | 412.8 | 8 | 8 | 0.13 | 1.0 | 94.8 | 1.0 |
| | 548 | | 336 | 170.1 | 421.8 | 12 | 10 | 0.76 | 3.5 | 72.3 | 3.1 |
| | 587 | | 336 | 172.4 | 396.9 | 9 | 9 | 1.14 | 2.0 | 89.0 | 1.9 |
| 4 | 527 | HS | 253 | 229.1 | 455.9 | 12 | 10 | 0.64 | 3.0 | 71.0 | 2.3 |
| | 502 | | 253 | 217.7 | 435.5 | 14 | 11 | 1.02 | 3.0 | 64.5 | 2.7 |
| | 565 | | 253 | 222.3 | 446.8 | 8 | 8 | 0.76 | 4.0 | 74.2 | 2.6 |
| | 593 | | 253 | 195.0 | 437.7 | 14 | 11 | 1.02 | 2.0 | 71.0 | 2.3 |
| | 580 | | 336 | 204.1 | 467.2 | 12 | 10 | 1.14 | 2.0 | 76.1 | 2.9 |
| | 567 | | 336 | 172.4 | 451.3 | 7 | 7 | 0.64 | 2.0 | 67.1 | 2.7 |
| | 515 | | 336 | 181.4 | 435.5 | 14 | 11 | 0.38 | 2.0 | 75.5 | 1.9 |
| | 582 | | 336 | 224.5 | 483.1 | 12 | 10 | 1.14 | 2.5 | 62.6 | 3.6 |

[a]Pen 3: Angus x Hereford x Charolais; pen 4: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement.

[c]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[d]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.22 Individual Shrunk Weights and Carcass Characteristics of Unselected Hereford Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 159 | HS | 253 | 213.2 | 464.9 | 8 | 8 | 0.51 | 2.0 | 68.4 | 2.4 |
| | 178 | | 253 | 167.8 | 421.8 | 8 | 8 | 0.76 | 1.0 | 66.5 | 2.0 |
| | 166 | | 253 | 197.3 | 396.9 | 5 | 6 | 0.38 | 1.0 | 68.4 | 1.7 |
| | 148 | | 336 | 142.9 | 421.8 | 12 | 10 | 0.76 | 1.5 | 79.4 | 2.0 |
| | 197 | | 337 | 129.3 | 396.9 | 15 | 11 | 0.89 | 2.5 | 71.0 | 2.5 |
| 11 | 176 | HG | 204 | 179.2 | 494.4 | 9 | 9 | 1.65 | 1.5 | 68.4 | 3.8 |
| | 144 | | 204 | 224.5 | 476.3 | 11 | 10 | 1.40 | 2.5 | 81.9 | 3.2 |
| | 165 | | 204 | 163.3 | 376.5 | 9 | 9 | 1.02 | 3.5 | 65.2 | 3.0 |
| | 142 | | 253 | 154.2 | 421.8 | 14 | 11 | 1.52 | 2.5 | 69.0 | 3.2 |
| | 181 | | 253 | 108.9 | 419.6 | 14 | 11 | 1.27 | 2.5 | 72.9 | 3.0 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.23 Individual Shrunk Weights and Carcass Characteristics of Selected Hereford Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 115 | HS | 253 | 242.7 | 476.3 | 9 | 9 | 0.76 | 2.0 | 71.6 | 2.4 |
| | 118 | | 253 | 217.7 | 480.8 | 11 | 10 | 1.02 | 1.0 | 69.7 | 3.1 |
| | 111 | | 253 | 240.4 | 480.8 | 14 | 11 | 0.51 | 2.0 | 76.1 | 2.0 |
| | 150 | | 336 | 197.3 | 501.2 | 8 | 8 | 0.64 | 1.5 | 73.5 | 2.5 |
| | 190 | | 336 | 192.8 | 539.8 | 12 | 10 | 0.89 | 1.5 | 74.2 | 3.2 |
| | 188 | | 336 | 197.3 | 514.8 | 9 | 9 | 1.02 | 1.0 | 72.9 | 3.0 |
| | 113 | | 336 | 176.9 | 458.1 | 9 | 9 | 0.64 | 2.0 | 58.1 | 3.1 |
| 12 | 139 | HG | 204 | 256.3 | 499.0 | 10 | 10 | 1.02 | 2.0 | 77.4 | 2.6 |
| | 120 | | 204 | 174.6 | 519.4 | 11 | 10 | 0.89 | 1.5 | 69.7 | 2.9 |
| | 119 | | 204 | 229.1 | 519.4 | 16 | 12 | 1.52 | 2.0 | 80.6 | 3.0 |
| | 155 | | 204 | 204.1 | 492.2 | 9 | 9 | 1.14 | 2.5 | 75.5 | 3.0 |
| | 890 | | 253 | 204.1 | 533.0 | 13 | 11 | 2.54 | 1.5 | 63.9 | 4.8 |
| | 152 | | 253 | 195.0 | 501.2 | 12 | 10 | 0.89 | 1.5 | 74.2 | 3.4 |
| | 193 | | 253 | 170.1 | 485.4 | 14 | 11 | 2.03 | 3.0 | 69.7 | 4.8 |
| | 195 | | 253 | 154.2 | 460.4 | 8 | 8 | 1.52 | 1.0 | 69.0 | 3.2 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.24 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Charolais Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 122 | HS | 253 | 240.4 | 533.0 | 9 | 9 | 0.51 | 2.0 | 84.5 | 2.1 |
| | 149 | | 253 | 215.5 | 521.6 | 13 | 11 | 1.02 | 3.0 | 72.3 | 3.3 |
| | 133 | | 253 | 297.1 | 512.6 | 11 | 10 | 0.51 | 2.0 | 83.9 | 1.8 |
| | 161 | | 253 | 247.2 | 530.7 | 8 | 8 | 0.76 | 1.5 | 75.5 | 2.4 |
| | 186 | | 336 | 199.6 | 546.6 | 12 | 10 | 0.76 | 1.5 | 75.5 | 2.7 |
| | 175 | | 336 | 195.0 | 530.7 | 12 | 10 | 0.64 | 0.5 | 61.9 | 3.0 |
| | 164 | | 336 | 285.8 | 499.0 | 11 | 10 | 0.51 | 1.5 | 81.9 | 2.0 |
| | 182 | | 337 | 229.1 | 521.6 | 9 | 9 | 0.76 | 2.0 | 64.5 | 3.1 |
| 13 | 168 | HG | 204 | 251.7 | 535.2 | 10 | 10 | 1.27 | 2.0 | 81.3 | 3.4 |
| | 153 | | 204 | 285.8 | 644.1 | 11 | 10 | 1.52 | 3.0 | 77.4 | 4.4 |
| | 147 | | 204 | 301.6 | 576.1 | 10 | 10 | 0.76 | 2.0 | 75.5 | 2.8 |
| | 189 | | 204 | 226.8 | 483.1 | 10 | 10 | 2.03 | 3.0 | 76.8 | 4.0 |
| | 124 | | 253 | 251.7 | 571.5 | 12 | 10 | 1.02 | 3.5 | 85.2 | 3.3 |
| | 154 | | 253 | 213.2 | 539.8 | 15 | 11 | 1.78 | 3.0 | 64.5 | 4.8 |
| | 117 | | 253 | 249.5 | 523.9 | 12 | 10 | 0.51 | 2.0 | 74.8 | 2.5 |
| | 179 | | 253 | 188.2 | 537.5 | 15 | 11 | 1.52 | 3.0 | 80.0 | 3.6 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.25 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Holstein Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 116 | HS | 253 | 285.8 | 598.8 | 12 | 10 | 1.02 | 2.5 | 76.8 | 3.6 |
| | 121 | | 253 | 274.4 | 555.7 | 12 | 10 | 0.51 | 1.5 | 69.7 | 2.8 |
| | 130 | | 253 | 267.6 | 514.8 | 16 | 12 | 1.02 | 1.5 | 65.8 | 3.3 |
| | 109 | | 253 | 256.3 | 514.8 | 7 | 7 | 1.02 | 1.0 | 67.7 | 2.9 |
| | 167 | | 336 | 263.1 | 585.1 | 15 | 11 | 1.14 | 3.0 | 74.2 | 4.0 |
| | 169 | | 336 | 238.1 | 551.1 | 12 | 10 | 0.89 | 2.0 | 72.9 | 2.9 |
| | 114 | | 337 | 254.0 | 523.9 | 8 | 7 | 0.64 | 2.5 | 78.1 | 2.4 |
| 14 | 132 | HG | 204 | 279.0 | 551.1 | 12 | 10 | 1.52 | 2.0 | 72.3 | 3.8 |
| | 135 | | 204 | 285.8 | 557.9 | 11 | 10 | 1.65 | 2.5 | 67.7 | 4.1 |
| | 146 | | 204 | 283.5 | 580.6 | 12 | 10 | 1.02 | 2.5 | 69.7 | 3.5 |
| | 171 | | 204 | 247.2 | 533.0 | 17 | 12 | 1.27 | 3.0 | 75.5 | 3.5 |
| | 158 | | 253 | 272.2 | 594.2 | 17 | 12 | 1.78 | 3.5 | 78.7 | 4.7 |
| | 110 | | 253 | 265.4 | 555.7 | 18 | 12 | 1.78 | 2.0 | 84.5 | 3.5 |
| | 134 | | 253 | 251.7 | 526.2 | 9 | 9 | 0.76 | 1.0 | 82.6 | 2.1 |
| | 107 | | 253 | 206.4 | 444.5 | 7 | 7 | 0.51 | 0.5 | 75.5 | 1.7 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.26 Individual Carcass Weight, Protein and Fat Data for Unselected and Selected Hereford Heifers (Trial 2)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 589 | HS | 253 | 81.0 | 222.7 | 15.44 | 30.70 | .0819 | .2094 | .3329 | 465.6 | 1961.8 |
| | 577 | | 253 | 82.2 | 217.7 | 14.41 | 36.35 | .0691 | .2512 | .2808 | 392.7 | 2352.6 |
| | 393 | | 253 | 67.9 | 190.5 | 17.52 | 26.18 | .0867 | .1461 | .3523 | 492.8 | 1369.0 |
| | 584 | | 253 | 77.4 | 182.3 | 17.69 | 21.49 | .0758 | .0967 | .3080 | 430.8 | 905.9 |
| | 391 | | 336 | 52.4 | 185.5 | 15.25 | 27.31 | .0579 | .1212 | .2352 | 329.0 | 1135.2 |
| | 579 | | 336 | 67.9 | 204.1 | 16.26 | 28.33 | .0647 | .1337 | .2630 | 367.9 | 1252.6 |
| | 591 | | 336 | 70.3 | 219.1 | 16.10 | 30.57 | .0697 | .1596 | .2832 | 396.1 | 1495.0 |
| | 599 | | 336 | 60.7 | 206.8 | 15.46 | 33.42 | .0646 | .1714 | .2627 | 367.4 | 1605.1 |
| 2 | 387 | HS | 253 | 92.7 | 226.8 | 16.66 | 26.85 | .0833 | .1738 | .3387 | 473.8 | 1627.5 |
| | 544 | | 253 | 93.9 | 228.6 | 16.05 | 27.32 | .0782 | .1790 | .3179 | 444.7 | 1676.9 |
| | 532 | | 253 | 101.0 | 227.7 | 16.97 | 26.00 | .0808 | .1611 | .3284 | 459.3 | 1509.1 |
| | 511 | | 253 | 85.6 | 220.4 | 17.43 | 21.86 | .0909 | .1287 | .3697 | 517.1 | 1205.7 |
| | 541 | | 336 | 72.5 | 202.3 | 17.13 | 22.79 | .0643 | .0978 | .2614 | 365.6 | 915.7 |
| | 594 | | 336 | 82.0 | 241.8 | 15.55 | 30.43 | .0679 | .1744 | .2762 | 386.3 | 1633.3 |
| | 543 | | 336 | 77.2 | 249.0 | 14.61 | 33.37 | .0669 | .2053 | .2719 | 380.3 | 1923.3 |
| | 581 | | 336 | 83.2 | 237.2 | 16.94 | 29.85 | .0750 | .1655 | .3049 | 426.5 | 1550.2 |

[a]Pen 1: Unselected Hereford; Pen 2: Selected Hereford.

[b]HS: corn silage plus supplement.

Table A.27 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Charolais and Angus x Hereford x Holstein Heifers (Trial 2)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 572 | HS | 253 | 94.1 | 254.0 | 16.50 | 29.92 | .0990 | .2420 | .4023 | 562.7 | 2267.1 |
| | 545 | | 253 | 90.7 | 259.5 | 17.20 | 22.62 | .1121 | .1758 | .4555 | 637.1 | 1646.9 |
| | 561 | | 253 | 94.1 | 237.7 | 17.69 | 21.08 | .0994 | .1397 | .4042 | 565.4 | 1308.7 |
| | 574 | | 253 | 85.0 | 226.8 | 14.89 | 35.34 | .0732 | .2641 | .2977 | 416.4 | 2474.3 |
| | 508 | | 336 | 85.0 | 243.6 | 17.56 | 21.57 | .0820 | .1167 | .3332 | 466.1 | 1093.5 |
| | 549 | | 336 | 85.0 | 249.5 | 18.08 | 20.44 | .0889 | .1122 | .3613 | 505.4 | 1050.7 |
| | 548 | | 336 | 85.0 | 260.8 | 15.75 | 32.12 | .0769 | .2097 | .3126 | 437.3 | 1963.9 |
| | 587 | | 336 | 86.2 | 253.6 | 15.15 | 33.20 | .0683 | .2104 | .2778 | 388.6 | 1970.4 |
| 4 | 527 | HS | 253 | 120.9 | 252.2 | 15.50 | 31.40 | .0693 | .2274 | .2818 | 394.2 | 2130.1 |
| | 502 | | 253 | 115.0 | 245.9 | 13.66 | 31.16 | .0517 | .2214 | .2100 | 293.7 | 2074.3 |
| | 565 | | 253 | 117.4 | 270.8 | 15.59 | 31.95 | .0841 | .2588 | .3418 | 478.1 | 2424.3 |
| | 593 | | 253 | 103.0 | 266.7 | 15.35 | 31.43 | .0891 | .2585 | .3623 | 506.8 | 2421.2 |
| | 580 | | 336 | 107.8 | 284.4 | 14.70 | 34.61 | .0672 | .2355 | .2732 | 382.1 | 2206.3 |
| | 567 | | 336 | 91.0 | 269.0 | 15.41 | 32.77 | .0750 | .2138 | .3050 | 426.6 | 2002.6 |
| | 515 | | 336 | 95.8 | 250.8 | 16.44 | 27.04 | .0718 | .1507 | .2920 | 408.5 | 1412.0 |
| | 582 | | 336 | 118.6 | 298.9 | 16.22 | 33.34 | .0813 | .2334 | .3306 | 462.5 | 2186.2 |

[a]Pen 3: Angus x Hereford x Charolais; Pen 4: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement.

Table A.28 Individual Carcass Weight, Protein and Fat Data for Unselected Hereford Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 159 | HS | 253 | 110.4 | 281.2 | 16.30 | 26.74 | .0986 | .2410 | .4008 | 560.6 | 2257.2 |
| | 178 | | 253 | 86.9 | 240.4 | 12.86 | 26.53 | .0572 | .2077 | .2326 | 325.4 | 1945.9 |
| | 166 | | 253 | 102.2 | 236.8 | 14.85 | 24.08 | .0626 | .1733 | .2546 | 356.1 | 1623.1 |
| | 148 | | 336 | 74.0 | 249.0 | 13.51 | 25.74 | .0585 | .1623 | .2379 | 332.8 | 1520.6 |
| | 197 | | 337 | 67.0 | 241.8 | 15.11 | 28.82 | .0708 | .1811 | .2880 | 402.8 | 1696.6 |
| 11 | 176 | HG | 204 | 92.8 | 308.0 | 14.88 | 34.98 | .1386 | .4695 | .5635 | 788.2 | 4397.9 |
| | 144 | | 204 | 116.3 | 304.4 | 14.98 | 35.33 | .1157 | .4536 | .4705 | 658.1 | 4248.8 |
| | 165 | | 204 | 84.6 | 235.4 | 15.39 | 32.78 | .0993 | .3248 | .4035 | 564.3 | 3042.2 |
| | 142 | | 253 | 79.9 | 263.1 | 14.44 | 36.58 | .0905 | .3397 | .3678 | 514.4 | 3182.1 |
| | 181 | | 253 | 56.4 | 264.0 | 13.87 | 39.01 | .1026 | .3783 | .4173 | 583.6 | 3543.4 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.29 Individual Carcass Weight, Protein and Fat Data for Selected Hereford Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 115 | HS | 253 | 117.5 | 278.5 | 16.76 | 25.93 | .1009 | .2171 | .4101 | 573.6 | 2033.6 |
| | 118 | | 253 | 105.4 | 284.0 | 15.61 | 31.50 | .1002 | .2922 | .4074 | 569.9 | 2737.2 |
| | 111 | | 253 | 116.4 | 285.3 | 16.13 | 28.71 | .0991 | .2561 | .4027 | 563.3 | 2398.5 |
| | 150 | | 336 | 95.5 | 310.7 | 15.38 | 29.32 | .0911 | .2294 | .3702 | 517.8 | 2148.4 |
| | 190 | | 336 | 93.3 | 331.6 | 17.04 | 31.00 | .1182 | .2651 | .4803 | 671.9 | 2482.9 |
| | 188 | | 336 | 95.5 | 315.3 | 15.93 | 30.59 | .0982 | .2452 | .3992 | 558.4 | 2296.7 |
| | 113 | | 336 | 85.6 | 281.7 | 17.07 | 25.78 | .0970 | .1781 | .3944 | 551.6 | 1668.0 |
| 12 | 139 | HG | 204 | 124.0 | 310.7 | 16.01 | 29.79 | .1344 | .3641 | .5463 | 764.1 | 3410.3 |
| | 120 | | 204 | 84.5 | 316.2 | 15.21 | 34.37 | .1612 | .4718 | .6552 | 916.5 | 4419.2 |
| | 119 | | 204 | 110.9 | 331.6 | 14.55 | 37.75 | .1386 | .5336 | .5632 | 787.8 | 4998.3 |
| | 155 | | 204 | 98.8 | 308.9 | 15.14 | 34.31 | .1420 | .4483 | .5772 | 807.4 | 4199.0 |
| | 890 | | 253 | 98.8 | 342.9 | 13.88 | 40.97 | .1178 | .4978 | .4787 | 669.6 | 4662.4 |
| | 152 | | 253 | 94.4 | 317.5 | 15.22 | 35.04 | .1237 | .3849 | .5030 | 703.6 | 3605.6 |
| | 193 | | 253 | 82.3 | 309.4 | 13.46 | 41.09 | .1080 | .4544 | .4310 | 602.9 | 4256.7 |
| | 195 | | 253 | 74.6 | 284.0 | 14.67 | 35.33 | .1114 | .3531 | .4529 | 633.5 | 3307.3 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.30 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Charolais Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 122 | HS | 253 | 124.3 | 324.3 | 16.22 | 27.64 | .1155 | .2888 | .4696 | 656.8 | 2705.5 |
| | 149 | | 253 | 111.4 | 311.2 | 15.98 | 27.41 | .1137 | .2785 | .4620 | 646.3 | 2608.4 |
| | 133 | | 253 | 153.6 | 315.7 | 17.07 | 23.58 | .0988 | .2132 | .4016 | 561.8 | 1997.3 |
| | 161 | | 253 | 127.8 | 305.3 | 16.26 | 27.83 | .1013 | .2684 | .4118 | 576.0 | 2514.0 |
| | 186 | | 336 | 103.2 | 338.8 | 16.28 | 29.62 | .1064 | .2578 | .4327 | 605.3 | 2414.5 |
| | 175 | | 336 | 100.8 | 316.2 | 16.12 | 29.59 | .0953 | .2384 | .3875 | 542.0 | 2233.0 |
| | 164 | | 336 | 147.7 | 313.4 | 15.72 | 29.02 | .0639 | .2121 | .2598 | 363.5 | 1987.1 |
| | 182 | | 337 | 118.4 | 312.1 | 16.90 | 27.13 | .0907 | .2050 | .3686 | 515.6 | 1920.4 |
| 13 | 168 | HG | 204 | 130.2 | 336.1 | 15.50 | 31.71 | .1354 | .4374 | .5502 | 769.7 | 4096.8 |
| | 153 | | 204 | 147.7 | 407.8 | 15.15 | 35.79 | .1666 | .6190 | .6774 | 947.6 | 5798.1 |
| | 147 | | 204 | 155.9 | 352.4 | 15.21 | 35.34 | .1191 | .5087 | .4841 | 677.2 | 4764.7 |
| | 189 | | 204 | 117.3 | 313.4 | 14.88 | 36.75 | .1205 | .4881 | .4900 | 685.3 | 4572.5 |
| | 124 | | 253 | 130.2 | 372.0 | 15.77 | 30.59 | .1353 | .3812 | .5498 | 769.1 | 3570.6 |
| | 154 | | 253 | 110.2 | 337.5 | 14.77 | 35.80 | .1152 | .4194 | .4682 | 654.9 | 3928.5 |
| | 117 | | 253 | 129.0 | 341.1 | 16.47 | 27.74 | .1263 | .2656 | .5132 | 717.9 | 2488.1 |
| | 179 | | 253 | 97.3 | 341.1 | 14.10 | 37.67 | .1177 | .4566 | .4784 | 669.2 | 4276.6 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.31 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Holstein Steers (Trial 2)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 116 | HS | 253 | 146.6 | 364.7 | 15.64 | 31.95 | .1180 | .3788 | .4795 | 670.7 | 3548.1 |
| | 121 | | 253 | 140.8 | 325.7 | 16.62 | 27.86 | .1107 | .2801 | .4500 | 629.4 | 2624.1 |
| | 130 | | 253 | 137.3 | 304.8 | 15.06 | 33.76 | .0808 | .3303 | .3284 | 459.4 | 3093.6 |
| | 109 | | 253 | 131.5 | 303.9 | 16.43 | 29.43 | .1009 | .2803 | .4102 | 573.7 | 2625.8 |
| | 167 | | 336 | 135.0 | 369.7 | 15.86 | 30.16 | .1000 | .2751 | .4064 | 568.4 | 2576.8 |
| | 169 | | 336 | 122.2 | 342.9 | 15.19 | 33.82 | .0876 | .2939 | .3560 | 498.0 | 2752.7 |
| | 114 | | 337 | 130.3 | 323.9 | 17.29 | 22.41 | .0944 | .1608 | .3838 | 536.8 | 1506.3 |
| 14 | 132 | HG | 204 | 143.1 | 342.5 | 14.38 | 38.69 | .1113 | .5505 | .4523 | 632.6 | 5156.5 |
| | 135 | | 204 | 146.6 | 358.8 | 13.53 | 40.87 | .1047 | .6175 | .4254 | 595.1 | 5783.9 |
| | 146 | | 204 | 145.4 | 357.0 | 15.46 | 33.53 | .1390 | .4861 | .5649 | 790.1 | 4553.6 |
| | 171 | | 204 | 126.8 | 328.9 | 15.29 | 35.44 | .1312 | .4838 | .5333 | 746.0 | 4531.9 |
| | 158 | | 253 | 139.6 | 381.9 | 13.92 | 39.56 | .1077 | .5194 | .4378 | 612.4 | 4865.1 |
| | 110 | | 253 | 136.1 | 368.3 | 14.65 | 35.55 | .1135 | .4418 | .4612 | 645.1 | 4138.3 |
| | 134 | | 253 | 129.1 | 333.8 | 16.30 | 30.15 | .1205 | .3259 | .4899 | 685.2 | 3052.5 |
| | 107 | | 253 | 105.9 | 269.4 | 17.15 | 25.33 | .1051 | .2107 | .4272 | 597.6 | 1973.8 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.32 Genetic Background of Heifers and Steers, Daily Intakes of Dry Matter (DM), Metabolizable Energy (ME) and Crude Protein (CP), and Efficiency of ME and CP Utilization for Carcass Production (Trial 3)

| Pen no. | No anim. | Cattle[a] type | Sex | Energy[b] level | Genetic Background | | | | Daily Intakes[c] | | | Efficiencies[d] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Angus % | Hereford % | Charolais % | Holstein % | DM kg | CP kg | ME Mcal | EE % | EUEP Mcal/kg | ECPUCP % |
| 1 | 5 | USH | H | HS | -- | 100 | -- | -- | 6.16 | 0.718 | 14.96 | 15.95 | 51.52 | 10.06 |
| 2 | 6 | SH | H | HS | -- | 100 | -- | -- | 7.74 | 0.871 | 18.78 | 14.60 | 51.26 | 10.42 |
| 3 | 7 | AHC | H | HS | 27 | 50 | 23 | -- | 8.06 | 0.923 | 19.55 | 14.13 | 53.33 | 10.00 |
| 4 | 7 | AHH | H | HS | 39 | 22 | -- | 39 | 8.59 | 0.961 | 20.84 | 14.67 | 63.09 | 8.63 |
| 5 | 6 | USH | S | HS | -- | 100 | -- | -- | 7.51 | 0.863 | 18.22 | 13.56 | 51.87 | 10.10 |
| 6 | 8 | SH | S | HS | -- | 100 | -- | -- | 8.25 | 0.942 | 20.01 | 12.69 | 50.56 | 10.43 |
| 9 | 7 | AHC | S | HS | 32 | 27 | 41 | -- | 8.98 | 1.024 | 21.79 | 13.44 | 50.53 | 10.40 |
| 10 | 8 | AHH | S | HS | 29 | 30 | -- | 41 | 9.21 | 1.039 | 22.34 | 13.15 | 50.96 | 10.40 |
| 11 | 6 | USH | S | HG | -- | 100 | -- | -- | 7.23 | 0.901 | 20.68 | 20.03 | 51.69 | 11.08 |
| 12 | 8 | SH | S | HG | -- | 100 | -- | -- | 7.42 | 0.920 | 21.22 | 19.20 | 50.40 | 11.55 |
| 13 | 8 | AHC | S | HG | 23 | 39 | 38 | -- | 8.31 | 1.016 | 23.78 | 17.47 | 51.47 | 11.51 |
| 14 | 8 | AHH | S | HG | 36 | 22 | -- | 42 | 8.48 | 1.042 | 24.27 | 15.91 | 53.63 | 10.77 |

[a]USH: Unselected Hereford; SH: Selected Hereford; AHC: Angus x Hereford x Charolais; AHH: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[c]Intake of corn silage and high moisture corn dry matter was increased by 6.8% and 3%, respectively, to adjust for errors in dry matter determination.

[d]EE (Energetic Efficiency): daily energy gained, Mcal ÷ daily ME intake, Mcal x 100; EUEP (Efficiency of Energy Utilization for Edible Portion Production): daily ME intake, Mcal ÷ daily edible portion gained, kg; ECPUCP (Efficiency of Crude Protein Utilization for Carcass Protein Production): daily carcass protein gained, kg ÷ daily CP intake, kg x 100.

Table A.33 Individual Shrunk Weights and Carcass Characteristics of Unselected and Selected Hereford Heifers (Trial 3)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[c] | Qual[d] grade | Fat thickness, cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 671 | HS | 327 | 117.9 | 401.4 | 19 | 12 | 0.76 | 2.5 | 74.2 | 2.6 |
| | 672 | | 327 | 90.7 | 358.3 | 12 | 10 | 1.27 | 3.0 | 71.6 | 2.6 |
| | 681 | | 327 | 108.9 | 337.9 | 8 | 8 | 1.14 | 3.0 | 63.9 | 3.4 |
| | 686 | | 272 | 188.2 | 410.5 | 11 | 10 | 0.89 | 3.5 | 81.9 | 2.1 |
| | 689 | | 272 | 179.2 | 392.4 | 9 | 9 | 1.27 | 3.5 | 83.9 | 2.5 |
| 2 | 646 | HS | 327 | 120.2 | 430.9 | 23 | 14 | 1.78 | 3.5 | 92.9 | 2.4 |
| | 678 | | 327 | 152.0 | 496.7 | 14 | 11 | 1.27 | 3.0 | 90.3 | 2.6 |
| | 688 | | 272 | 222.3 | 471.7 | 10 | 10 | 1.40 | 3.0 | 74.8 | 3.3 |
| | 694 | | 272 | 179.2 | 451.3 | 8 | 8 | 0.76 | 3.0 | 81.3 | 2.8 |
| | 698 | | 272 | 179.2 | 437.7 | 7 | 7 | 0.76 | 3.5 | 67.7 | 2.8 |
| | 699 | | 327 | 113.4 | 455.9 | 11 | 9 | 1.02 | 3.0 | 85.8 | 2.6 |

[a]Pen 1: Unselected Hereford; pen 2: Selected Hereford.

[b]HS: corn silage plus supplement.

[c]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[d]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.34 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Charolais and Angus x Hereford x Holstein Heifers (Trial 3)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[c] | Qual[d] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 664 | HS | 327 | 147.4 | 508.0 | 6 | 5 | 0.51 | 2.5 | 79.4 | 2.3 |
| | 685 | | 327 | 199.6 | 449.1 | 9 | 9 | 1.65 | 3.5 | 73.5 | 4.2 |
| | 690 | | 272 | 235.9 | 492.2 | 15 | 11 | 1.14 | 3.5 | 83.9 | 3.0 |
| | 691 | | 272 | 199.6 | 458.1 | 12 | 10 | 0.89 | 3.0 | 84.5 | 1.9 |
| | 693 | | 272 | 183.7 | 417.3 | 11 | 10 | 1.40 | 3.5 | 69.7 | 3.1 |
| | 695 | | 272 | 179.2 | 417.3 | 10 | 10 | 0.76 | 3.0 | 77.4 | 2.8 |
| | 696 | | 327 | 145.2 | 458.1 | 10 | 10 | 0.38 | 3.0 | 66.5 | 2.9 |
| 4 | 614 | HS | 272 | 235.9 | 462.7 | 12 | 10 | 1.65 | 4.5 | 89.0 | 3.6 |
| | 624 | | 327 | 208.7 | 469.5 | 20 | 13 | 2.41 | 3.5 | 77.4 | 4.2 |
| | 641 | | 327 | 181.4 | 480.8 | 16 | 12 | 1.78 | 3.0 | 89.7 | 2.5 |
| | 652 | | 327 | 199.6 | 492.2 | 9 | 9 | 0.64 | 3.0 | 81.3 | 2.3 |
| | 666 | | 327 | 186.0 | 489.9 | 14 | 11 | 1.52 | 3.5 | 83.2 | 3.3 |
| | 675 | | 272 | 199.6 | 494.4 | 16 | 12 | 1.14 | 4.0 | 77.4 | 3.4 |
| | 687 | | 272 | 213.2 | 492.2 | 11 | 10 | 0.64 | 4.5 | 71.0 | 3.1 |

[a]Pen 3: Angus x Hereford x Charolais; pen 4: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement.

[c]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[d]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.35 Individual Shrunk Weights and Carcass Characteristics of Unselected Hereford Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 127 | HS | 327 | 186.0 | 460.4 | 9 | 9 | 1.78 | 3.5 | 66.5 | 3.8 |
| | 165 | | 327 | 181.4 | 489.9 | 9 | 9 | 1.14 | 3.5 | 81.9 | 3.0 |
| | 177 | | 272 | 165.6 | 442.3 | 8 | 8 | 1.27 | 2.5 | 85.2 | 2.2 |
| | 188 | | 271 | 172.4 | 426.4 | 6 | 7 | 0.89 | 2.5 | 71.0 | 2.5 |
| | 189 | | 272 | 210.9 | 460.4 | 11 | 11 | 1.27 | 3.0 | 74.2 | 3.2 |
| | 195 | | 327 | 154.2 | 471.7 | 10 | 10 | 1.02 | 2.5 | 72.3 | 2.8 |
| 11 | 153 | HG | 272 | 183.7 | 505.8 | 14 | 11 | 1.91 | 3.5 | 75.5 | 4.1 |
| | 167 | | 272 | 161.0 | 508.0 | 17 | 12 | 2.29 | 3.5 | 84.5 | 4.2 |
| | 175 | | 222 | 224.5 | 530.7 | 11 | 10 | 1.52 | 3.0 | 75.5 | 3.8 |
| | 184 | | 222 | 181.4 | 462.7 | 9 | 9 | 1.02 | 3.0 | 79.4 | 2.6 |
| | 191 | | 271 | 133.8 | 444.5 | 9 | 9 | 2.03 | 3.0 | 69.0 | 4.3 |
| | 194 | | 222 | 174.6 | 485.4 | 10 | 10 | 1.52 | 3.0 | 72.9 | 3.8 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.36 Individual Shrunk Weights and Carcass Characteristics of Selected Hereford Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 112 | HS | 327 | 220.0 | 535.2 | 16 | 11 | 1.78 | 3.0 | 63.9 | 4.4 |
| | 121 | | 327 | 204.1 | 542.1 | 10 | 10 | 1.27 | 3.0 | 73.5 | 3.5 |
| | 123 | | 272 | 174.6 | 462.7 | 8 | 8 | 0.76 | 3.0 | 65.8 | 2.9 |
| | 150 | | 272 | 244.9 | 512.6 | 8 | 8 | 0.64 | 2.5 | 77.4 | 2.7 |
| | 154 | | 271 | 204.1 | 467.2 | 8 | 8 | 1.02 | 2.5 | 73.5 | 2.7 |
| | 162 | | 327 | 145.2 | 485.4 | 7 | 7 | 1.27 | 2.5 | 70.3 | 3.3 |
| | 173 | | 327 | 183.7 | 535.2 | 7 | 7 | 1.02 | 3.0 | 75.5 | 3.5 |
| | 179 | | 272 | 181.4 | 478.5 | 10 | 10 | 1.14 | 3.0 | 76.8 | 3.0 |
| 12 | 130 | HG | 272 | 147.4 | 442.3 | 7 | 7 | 0.64 | 3.5 | 69.0 | 2.7 |
| | 132 | | 222 | 306.2 | 641.8 | 13 | 11 | 2.54 | 2.5 | 74.8 | 5.1 |
| | 149 | | 271 | 140.6 | 471.7 | 7 | 7 | 1.02 | 3.0 | 74.8 | 2.7 |
| | 158 | | 222 | 220.0 | 514.8 | 9 | 9 | 1.78 | 3.5 | 67.7 | 4.2 |
| | 164 | | 272 | 197.3 | 544.3 | 10 | 10 | 1.52 | 3.5 | 80.6 | 4.3 |
| | 178 | | 222 | 199.6 | 508.0 | 10 | 10 | 1.27 | 3.0 | 85.8 | 2.7 |
| | 182 | | 272 | 174.6 | 510.3 | 13 | 11 | 2.03 | 4.0 | 71.0 | 4.7 |
| | 192 | | 222 | 204.1 | 535.2 | 8 | 8 | 1.91 | 2.5 | 69.0 | 4.1 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.37 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Charolais Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat, % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 129 | HS | 327 | 222.3 | 557.9 | 9 | 9 | 1.27 | 3.5 | 76.1 | 3.6 |
| | 131 | | 272 | 244.9 | 539.3 | 14 | 11 | 0.38 | 4.0 | 92.9 | 2.2 |
| | 135 | | 272 | 276.7 | 616.9 | 8 | 8 | 0.71 | 3.5 | 87.1 | 2.7 |
| | 166 | | 272 | 256.3 | 576.1 | 10 | 10 | 0.89 | 3.5 | 78.1 | 3.5 |
| | 168 | | 271 | 224.5 | 548.9 | 8 | 8 | 0.64 | 3.0 | 83.9 | 2.3 |
| | 183 | | 327 | 222.3 | 548.9 | 9 | 9 | 1.52 | 3.5 | 85.8 | 3.3 |
| | 186 | | 327 | 229.1 | 601.0 | 15 | 11 | 1.14 | 3.0 | 73.5 | 3.9 |
| 13 | 104 | HG | 222 | 258.6 | 571.5 | 10 | 10 | 0.76 | 3.0 | 72.3 | 2.9 |
| | 110 | | 222 | 283.5 | 601.0 | 7 | 7 | 1.02 | 3.0 | 92.9 | 2.0 |
| | 125 | | 271 | 217.7 | 571.5 | 8 | 8 | 1.91 | 3.5 | 81.3 | 4.0 |
| | 128 | | 272 | 226.8 | 596.5 | 18 | 12 | 2.16 | 4.0 | 86.5 | 4.6 |
| | 145 | | 222 | 240.4 | 542.1 | 7 | 7 | 0.64 | 2.5 | 98.7 | 1.6 |
| | 147 | | 222 | 226.8 | 544.3 | 13 | 11 | 1.14 | 2.0 | 87.7 | 2.3 |
| | 163 | | 272 | 224.5 | 594.2 | 13 | 11 | 1.02 | 4.0 | 94.2 | 3.3 |
| | 169 | | 272 | 247.2 | 585.1 | 21 | 13 | 1.52 | 4.5 | 93.5 | 3.5 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.38 Individual Shrunk Weights and Carcass Characteristics of Angus x Hereford x Holstein Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial wt, kg | Final wt, kg | Marb[b] | Qual[c] grade | Fat thickness cm | KPH fat % | Rib eye area $cm^2$ | Yield grade |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 102 | | 272 | 263.1 | 621.4 | 8 | 8 | 0.25 | 3.0 | 76.8 | 2.8 |
| | 109 | | 327 | 231.3 | 619.2 | 13 | 11 | 2.03 | 2.5 | 81.3 | 3.7 |
| | 117 | | 327 | 249.5 | 596.5 | 9 | 9 | 1.52 | 3.0 | 81.9 | 3.8 |
| | 136 | | 271 | 242.7 | 562.5 | 8 | 8 | 0.76 | 2.5 | 61.3 | 3.4 |
| | 137 | | 272 | 276.7 | 589.7 | 7 | 7 | 1.14 | 3.0 | 92.9 | 2.7 |
| | 176 | | 272 | 258.6 | 578.3 | 15 | 11 | 1.02 | 3.0 | 81.9 | 3.2 |
| | 181 | | 327 | 265.4 | 628.2 | 8 | 8 | 1.14 | 3.0 | 91.6 | 3.2 |
| | 193 | | 327 | 220.0 | 582.9 | 10 | 10 | 1.02 | 3.0 | 77.4 | 3.3 |
| 14 | 103 | | 222 | 260.8 | 535.2 | 16 | 11 | 0.89 | 3.5 | 82.6 | 2.8 |
| | 114 | | 272 | 249.5 | 605.6 | 12 | 10 | 2.16 | 3.0 | 76.1 | 5.0 |
| | 119 | | 222 | 272.2 | 578.3 | 8 | 8 | 1.14 | 3.0 | 90.3 | 2.8 |
| | 124 | | 222 | 274.4 | 546.6 | 10 | 10 | 1.02 | 4.0 | 71.6 | 3.9 |
| | 138 | | 271 | 210.9 | 567.0 | 17 | 12 | 1.02 | 3.0 | 87.1 | 2.6 |
| | 141 | | 272 | 247.2 | 551.1 | 16 | 12 | 1.78 | 4.0 | 83.9 | 3.9 |
| | 151 | | 272 | 226.8 | 542.1 | 11 | 10 | 2.29 | 4.0 | 81.3 | 4.9 |
| | 170 | | 222 | 256.3 | 548.9 | 20 | 13 | 1.27 | 3.5 | 72.9 | 3.7 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

[b]Marbling scores: Sm- = 10; Sm = 11; Sm+ = 12.

[c]Quality grades: Low choice = 10; Average choice = 11; High choice = 12.

Table A.39 Individual Carcass Weight, Protein and Fat Data for Unselected and Selected Hereford Heifers (Trial 3)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 671 | HS | 327 | 61.9 | 246.3 | 15.07 | 31.38 | .0813 | .2008 | .3306 | 462.5 | 1880.9 |
| | 672 | | 327 | 47.6 | 217.7 | 14.88 | 32.18 | .0743 | .1870 | .3020 | 422.4 | 1751.9 |
| | 681 | | 327 | 57.2 | 205.9 | 14.14 | 35.32 | .0592 | .1900 | .2407 | 336.7 | 1780.0 |
| | 686 | | 272 | 98.8 | 253.6 | 14.23 | 34.94 | .0708 | .2578 | .2879 | 402.7 | 2414.5 |
| | 689 | | 272 | 94.1 | 243.6 | 15.00 | 31.68 | .0756 | .2185 | .3074 | 429.9 | 2046.7 |
| 2 | 646 | HS | 327 | 63.0 | 270.3 | 14.26 | 34.82 | .0828 | .2536 | .3366 | 470.8 | 2375.4 |
| | 678 | | 327 | 79.6 | 307.5 | 15.39 | 30.04 | .1007 | .2383 | .4093 | 572.5 | 2232.6 |
| | 688 | | 272 | 116.5 | 297.6 | 14.84 | 32.37 | .0848 | .2767 | .3448 | 482.4 | 2591.6 |
| | 694 | | 272 | 93.9 | 275.3 | 14.82 | 32.45 | .0876 | .2661 | .3559 | 497.8 | 2492.5 |
| | 698 | | 272 | 93.9 | 249.9 | 16.15 | 26.81 | .0863 | .1831 | .3507 | 490.6 | 1714.7 |
| | 699 | | 327 | 59.4 | 279.4 | 15.81 | 28.23 | .1023 | .2081 | .4160 | 581.9 | 1948.9 |

[a]Pen 1: Unselected Hereford; Pen 2: Selected Hereford.

[b]HS: corn silage plus supplement.

Table A.40 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Charolais and Angus x Hereford x Holstein Heifers (Trial 3)

| Pen[a] no. | Heifer no. | Energy[b] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 664 | HS | 327 | 73.7 | 311.2 | 16.78 | 24.13 | .1194 | .1937 | .4854 | 679.0 | 1814.8 |
| | 685 | | 327 | 99.8 | 286.2 | 14.24 | 34.91 | .0694 | .2588 | .2823 | 394.8 | 2424.0 |
| | 690 | | 272 | 117.9 | 312.5 | 15.22 | 30.75 | .0969 | .2858 | .3940 | 551.1 | 2677.3 |
| | 691 | | 272 | 99.8 | 279.4 | 15.44 | 29.84 | .0926 | .2494 | .3765 | 526.7 | 2335.7 |
| | 693 | | 272 | 91.9 | 254.5 | 15.34 | 30.26 | .0827 | .2305 | .3364 | 470.5 | 2158.9 |
| | 695 | | 272 | 89.6 | 259.9 | 15.76 | 28.44 | .0915 | .2203 | .3719 | 520.2 | 2063.3 |
| | 696 | | 327 | 72.6 | 285.8 | 15.24 | 30.68 | .0932 | .2337 | .3787 | 529.7 | 2189.3 |
| 4 | 614 | HS | 272 | 124.5 | 307.5 | 12.90 | 40.60 | .0631 | .3793 | .2566 | 359.0 | 3553.0 |
| | 624 | | 327 | 110.2 | 314.8 | 13.59 | 37.67 | .0700 | .3038 | .2846 | 398.1 | 2845.8 |
| | 641 | | 327 | 95.8 | 300.7 | 15.31 | 30.37 | .0884 | .2272 | .3592 | 502.5 | 2128.0 |
| | 652 | | 327 | 105.4 | 294.4 | 16.33 | 26.06 | .0896 | .1766 | .3640 | 509.2 | 1654.1 |
| | 666 | | 327 | 98.2 | 301.2 | 14.80 | 32.54 | .0824 | .2466 | .3350 | 468.6 | 2310.0 |
| | 675 | | 272 | 105.4 | 312.5 | 14.10 | 35.52 | .0922 | .3401 | .3750 | 524.5 | 3186.1 |
| | 687 | | 272 | 112.6 | 299.4 | 15.33 | 30.28 | .0948 | .2595 | .3852 | 538.8 | 2430.6 |

[a]Pen 3: Angus x Hereford x Charolais; Pen 4: Angus x Hereford x Holstein.

[b]HS: corn silage plus supplement.

Table A.41 Individual Carcass Weight, Protein and Fat Data for Unselected Hereford Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 127 | HS | 327 | 103.4 | 287.1 | 15.03 | 31.57 | .0753 | .2179 | .3059 | 427.9 | 2041.2 |
| | 165 | | 327 | 100.9 | 313.0 | 15.03 | 31.54 | .0886 | .2442 | .3602 | 503.9 | 2287.2 |
| | 177 | | 272 | 92.1 | 263.5 | 15.82 | 28.19 | .0929 | .2092 | .3776 | 528.2 | 1959.8 |
| | 188 | | 271 | 95.8 | 254.0 | 16.16 | 26.78 | .0883 | .1841 | .3590 | 502.2 | 1724.2 |
| | 189 | | 272 | 117.3 | 284.0 | 14.89 | 32.13 | .0783 | .2546 | .3182 | 445.1 | 2385.2 |
| | 195 | | 327 | 85.7 | 283.5 | 16.90 | 23.64 | .0998 | .1548 | .4059 | 567.7 | 1449.6 |
| 11 | 153 | HG | 272 | 102.1 | 331.1 | 12.73 | 41.33 | .0869 | .4349 | .3532 | 494.1 | 4073.5 |
| | 167 | | 272 | 89.5 | 327.0 | 13.47 | 38.17 | .1024 | .3988 | .4162 | 582.2 | 3735.4 |
| | 175 | | 222 | 124.8 | 327.5 | 13.86 | 36.51 | .1032 | .4344 | .4197 | 587.0 | 4069.4 |
| | 184 | | 222 | 100.9 | 279.9 | 15.32 | 30.31 | .1119 | .2968 | .4548 | 636.1 | 2780.5 |
| | 191 | | 271 | 74.4 | 279.4 | 12.82 | 40.94 | .0823 | .3724 | .3345 | 467.9 | 3488.4 |
| | 194 | | 222 | 97.1 | 289.9 | 14.63 | 33.26 | .1124 | .3528 | .4568 | 639.0 | 3304.9 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.42 Individual Carcass Weight, Protein and Fat Data for Selected Hereford Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 112 | HS | 327 | 121.2 | 322.5 | 16.17 | 26.73 | .0932 | .1916 | .3787 | 529.8 | 1794.4 |
| | 121 | | 327 | 112.5 | 338.4 | 16.15 | 26.80 | .1057 | .2104 | .4295 | 600.8 | 1970.8 |
| | 123 | | 272 | 96.2 | 270.8 | 16.18 | 26.70 | .0973 | .1970 | .3977 | 556.3 | 1845.5 |
| | 150 | | 272 | 135.0 | 313.0 | 16.31 | 26.14 | .0989 | .2043 | .4022 | 562.6 | 1913.7 |
| | 154 | | 271 | 112.5 | 281.2 | 15.25 | 30.62 | .0838 | .2378 | .3407 | 476.6 | 2227.5 |
| | 162 | | 327 | 80.0 | 297.6 | 16.68 | 24.55 | .1082 | .1755 | .4398 | 615.1 | 1643.6 |
| | 173 | | 327 | 101.2 | 327.5 | 16.53 | 25.20 | .1103 | .1919 | .4484 | 627.2 | 1797.5 |
| | 179 | | 272 | 100.0 | 287.6 | 14.56 | 33.55 | .0878 | .2844 | .3569 | 499.2 | 2664.4 |
| 12 | 130 | HG | 272 | 81.2 | 263.1 | 14.48 | 33.90 | .0862 | .2710 | .3503 | 490.0 | 2538.1 |
| | 132 | | 222 | 168.7 | 401.0 | 13.33 | 38.75 | .1036 | .5557 | .4212 | 589.1 | 5205.0 |
| | 149 | | 271 | 77.5 | 280.3 | 15.63 | 29.02 | .1104 | .2449 | .4487 | 627.7 | 2294.2 |
| | 158 | | 222 | 121.2 | 313.0 | 13.74 | 37.05 | .0951 | .4185 | .3866 | 540.8 | 3919.8 |
| | 164 | | 272 | 108.7 | 342.9 | 14.24 | 34.89 | .1075 | .3638 | .4371 | 611.4 | 3408.1 |
| | 178 | | 222 | 110.0 | 308.4 | 15.62 | 29.04 | .1284 | .3075 | .5218 | 729.9 | 2880.7 |
| | 182 | | 272 | 96.2 | 321.6 | 12.54 | 42.12 | .0839 | .4321 | .3412 | 477.2 | 4047.9 |
| | 192 | | 222 | 112.5 | 332.0 | 15.11 | 31.23 | .1350 | .3695 | .5490 | 767.9 | 3461.5 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.43 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Charolais Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 129 | HS | 327 | 124.0 | 343.4 | 16.50 | 25.34 | .1039 | .1982 | .4222 | 590.5 | 1856.4 |
| | 131 | | 272 | 136.7 | 332.5 | 15.16 | 31.02 | .0931 | .2905 | .3783 | 529.1 | 2720.7 |
| | 135 | | 272 | 154.4 | 370.6 | 15.59 | 29.18 | .1083 | .2969 | .4403 | 615.8 | 2781.2 |
| | 166 | | 272 | 143.0 | 354.3 | 15.43 | 29.84 | .1046 | .2956 | .4252 | 594.8 | 2768.5 |
| | 168 | | 271 | 125.3 | 329.3 | 15.86 | 28.02 | .1081 | .2583 | .4393 | 614.5 | 2419.5 |
| | 183 | | 327 | 124.0 | 342.0 | 17.30 | 21.91 | .1119 | .1607 | .4549 | 636.3 | 1505.3 |
| | 186 | | 327 | 127.8 | 376.9 | 16.24 | 26.43 | .1157 | .2349 | .4703 | 657.9 | 2200.5 |
| 13 | 104 | HG | 222 | 144.3 | 353.4 | 15.09 | 31.31 | .1208 | .3836 | .4909 | 686.6 | 3593.6 |
| | 110 | | 222 | 158.2 | 359.3 | 15.50 | 29.57 | .1202 | .3521 | .4884 | 683.2 | 3298.4 |
| | 125 | | 271 | 121.3 | 357.4 | 16.07 | 27.14 | .1300 | .2782 | .5284 | 739.1 | 2605.6 |
| | 128 | | 272 | 126.6 | 390.5 | 13.93 | 36.24 | .1139 | .4396 | .4630 | 647.6 | 4116.7 |
| | 145 | | 222 | 134.1 | 342.0 | 16.05 | 27.24 | .1367 | .3121 | .5556 | 777.1 | 2923.3 |
| | 147 | | 222 | 126.6 | 326.1 | 15.02 | 31.59 | .1160 | .3635 | .4714 | 659.3 | 3405.1 |
| | 163 | | 272 | 125.3 | 379.7 | 14.83 | 32.39 | .1223 | .3713 | .4972 | 695.4 | 3477.6 |
| | 169 | | 272 | 137.9 | 367.4 | 12.58 | 41.95 | .0758 | .4796 | .3083 | 431.2 | 4492.1 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

Table A.44 Individual Carcass Weight, Protein and Fat Data for Angus x Hereford x Holstein Steers (Trial 3)

| Pen no. | Steer no. | Energy[a] level | Days on feed | Initial carcass wt, kg | Final carcass wt, kg | Carcass protein, % | Carcass fat, % | Daily protein gain, kg | Daily fat gain, kg | Daily edible portion gain, kg | Daily protein energy, kcal | Daily fat energy, kcal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 102 | HS | 272 | 144.7 | 349.3 | 15.77 | 28.43 | .1072 | .2549 | .4357 | 609.5 | 2387.4 |
| | 109 | | 327 | 127.2 | 385.6 | 15.65 | 28.94 | .1143 | .2608 | .4668 | 652.9 | 2442.6 |
| | 117 | | 327 | 137.2 | 362.9 | 15.88 | 27.94 | .1011 | .2231 | .4110 | 574.8 | 2089.5 |
| | 136 | | 271 | 133.5 | 325.7 | 16.61 | 24.84 | .1118 | .1957 | .4545 | 635.7 | 1833.3 |
| | 137 | | 272 | 152.2 | 362.9 | 15.29 | 30.46 | .1036 | .2908 | .4213 | 589.3 | 2724.1 |
| | 176 | | 272 | 142.2 | 358.3 | 14.77 | 32.67 | .1007 | .3230 | .4093 | 572.6 | 3025.3 |
| | 181 | | 327 | 145.9 | 391.0 | 16.12 | 26.93 | .1129 | .2293 | .4589 | 641.9 | 2147.6 |
| | 193 | | 327 | 121.0 | 357.4 | 16.34 | 25.99 | .1125 | .2071 | .4574 | 639.8 | 1939.6 |
| 14 | 103 | HG | 222 | 143.5 | 323.0 | 15.21 | 30.78 | .1054 | .3144 | .4286 | 599.5 | 2944.6 |
| | 114 | | 272 | 137.2 | 389.6 | 13.86 | 36.51 | .1075 | .4204 | .4369 | 611.1 | 3937.8 |
| | 119 | | 222 | 149.7 | 355.6 | 16.00 | 27.45 | .1357 | .2996 | .5518 | 771.8 | 2806.8 |
| | 124 | | 222 | 150.9 | 342.9 | 14.28 | 34.75 | .0982 | .3974 | .3990 | 558.1 | 3722.3 |
| | 138 | | 271 | 116.0 | 340.2 | 15.83 | 28.18 | .1220 | .2650 | .4961 | 694.0 | 2482.2 |
| | 141 | | 272 | 136.0 | 362.9 | 14.63 | 33.24 | .1054 | .3410 | .4283 | 599.1 | 3194.0 |
| | 151 | | 272 | 124.7 | 361.5 | 14.25 | 34.86 | .1067 | .3697 | .4338 | 606.8 | 3463.2 |
| | 170 | | 222 | 141.0 | 338.4 | 15.15 | 31.03 | .1170 | .3421 | .4757 | 665.3 | 3204.0 |

[a]HS: corn silage plus supplement; HG: 20% corn silage plus 80% corn and supplement.

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