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Myron Lindle Danner

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THE EFFECT OF FEEDING SYSTEM ON THE PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING STEERS, STEER CALVES AND HEIFER CALVES

By

Myron Lindle Danner

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ABSTRACT

THE EFFECT OF FEEDING SYSTEM ON THE PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING STEERS, STEER CALVES AND HEIFER CALVES

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Three trials were conducted to study and compare the effect of feeding system on performance, feed efficiency, economics of production and carcass composition. Trial 1 included 100 Angus x Hereford yearling steers (391 kg) while Trial 2 utilized 78 Charolais crossbred steer calves (263 kg). Feeding programs for Trials 1 and 2 included: 85% concentrates, 15% corn silage; 40% concentrates, 60% corn silage; all silage, then switched to 85% concentrates, 15% silage when approximately one-half of the expected gain was reached; all silage, then switched to 85% concentrates, 15% silage when approximately two-thirds of the expected gain had been reached; and all corn silage continuously.
In Trial 3, 180 Hereford heifer calves (190 kg) were used in a 3 x 3 factorial design to test the effects of 3 protein levels and 3 energy levels. Energy levels were: 100% corn silage (100% CS); 68% corn silage, 32% concentrates (68% CS); and 100% concentrates (100% Conc). Ration crude protein percentages within each energy level were: 100% CS (7.7, 10.9, 13.7), 68% CS (8.6, 10.9, 14.0) and 100% Conc (10.4, 11.7, 13.8). Soybean meal was used to provide supplemental nitrogen and monensin was added at 30 g/T of ration DM.

In Trials 1 and 2, performance was as expected from energy level fed except 100% silage cattle in Trial 2 performed better than expected. In Trial 3, average daily gain and feed efficiency were improved by increasing the energy content of the ration with the greatest response at the low protein level. An improved response occurred from the addition of protein to the 100% CS and 68% CS rations; however, cattle on 100% Conc rations showed no benefit from added protein.

There was a definite effect of ration on carcass composition. In Trials 1 and 3, energy level had little effect on marbling score or quality grade while increasing energy level did significantly increase fat thickness and yield grade while reducing rib eye area and percentage of retail product. In Trial 2, energy level had no effect on external fat thickness or muscling, but 100% CS rations produced carcasses with lower marbling scores and quality grades than other rations. Protein level had no effect on carcass characteristics in Trial 3.

In Trial 1, differences between treatments in metabolizable energy (ME) required/kg retail beef were small, except those fed on the mid switch program tended to be the most efficient. In Trial 2, those fed the 85% concentrate ration continuously required the least amount of ME/kg retail beef produced. Considering only adequately supplemented rations in Trial 3, those heifers fed 68% CS rations were the most efficient, followed by those fed 100% CS rations, while those fed 100% Conc rations were the least efficient.

The dry matter efficiencies and ration net energy values determined in Trial 3 indicate that the heifers performed better when fed a mixture of corn and corn silage than when each ingredient was fed separately.

In Trials 1 and 2, steers made the most economical gains when high concentrate rations were fed. In Trial 3, heifers produced the lowest cost gains on adequately supplemented high silage rations.

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INTRODUCTION

The last five years has been a period of continual and sometimes drastic change in the cattle feeding industry. Corn prices have increased from $1.50 per bushel to $4.00 and then back to $2.00. Soybean meal prices have gone from $80 per ton to $400 and back to $200. Fuel costs for raising crops and drying corn have increased dramatically. Placement of cattle in feedlots has moved up and down in an erratic manner. Demand by consumers for leaner beef has prompted the USDA to lower its quality grading standards and make yield grading mandatory. We have also witnessed the development, approval and implementation of monensin, a highly successful feed additive.

With all of these changes, the trend has been to produce leaner cattle by feeding them rations higher in roughage with a large percentage of the ration in the form of fermented feeds. Fox et al. (1977) have suggested the need for research on the impact of fermentation on protein quality. They have proposed a net protein system for predicting protein requirements and feed protein values.

As leaner cattle are produced, it is of importance to define the amount of grain required to properly finish cattle and the impact which decreasing grain in the diet has on carcass composition. Of further importance is studying the "protein sparing" effect which monensin has been suggested to have.

LITERATURE REVIEW

Introduction

Attempts at determining the most profitable feeding system are not new to cattle feeding research. Over the years, numerous experiments have been conducted to find the advantages and disadvantages of a wide array of systems. As is the way with much research, the results of these experiments have been often variable and occasionally conflicting. Due to the variety of results obtained, defining precise effects of different feeding systems across a variety of conditions would be dangerous and misleading. However careful study of past research can reveal general trends. The purpose of this review will be to establish those general trends.

Before attempting to review past research data, it is imperative to consider some of the revolutionary changes in designing and interpreting feedlot trials that have occurred since much of the data was collected. The following points should be kept in mind before attempting to apply past conclusions to current situations.

1. Calculating average daily gain (ADG) based on live weights can be deceiving since cattle on different types of rations will have different dressing percentages. Typically cattle on high roughage rations have more "fill" than cattle on high concentrate rations due to a decreased rate of flow through the gastro-intestinal tract. This

can result in an inaccurate measure of actual performance. To get a precise comparison of rate of gain, one should compare carcass ADG or adjust live weight ADG to a constant dressing percentage.

2. Dry matter (DM) required per unit of gain does not give a totally accurate measure of efficiency. It fails to take into account the variation in energy density of the ration. Therefore a better evaluation of efficiency would be to look at energy intake per unit of gain by using either metabolizable energy (ME) or total digestible nutrients (TDN) to measure energy intake. Another satisfactory method would be to compare costs per unit of gain where cost would reflect the differences in the ration energy density. One must also be sure that the composition of gain from different rations is similar.

3. Research has demonstrated that DM intake can be underestimated by up to 10% when determined by oven drying, due to loss of energy containing volatiles (Fox and Fenderson, 1976; Goodrich and Meiske, 1971; Larsen and Jones, 1973). The common tendency is to underestimate dry matter consumption of cattle fed fermented feeds. Thus, adjustments in dry matter intake should be made to correct for this. However, caution must be used when computing efficiency based on adjusted dry matter intakes. If efficiency is calculated as DM per unit gain using adjusted dry matter intakes, then care should be taken in comparing these "corrected" efficiencies to uncorrected efficiencies from other experiments. Further care should be taken if efficiency is computed using the ME system since ME values reported by NRC (1976) were likely based on oven DM values. Using these ME values from

uncorrected DM samples in conjunction with corrected DM intakes would lead to erroneous conclusions. Discretion should always be exerted in making comparisons across experiments when adjusted values are involved.

4. If cattle of a similar type are slaughtered at different weights, then one can logically expect carcass traits to differ due to differences in physiological maturity. This situation makes it difficult to determine the effect which ration had on carcass traits. One method currently being used to overcome this problem is to adjust all carcass traits to a constant weight using covariance analysis. However, earlier work was reported without this adjustment and consequently caution should be used in examining the effects which ration has on carcass composition from these data.

5. Prior to February of 1976, all cattle were graded under the "old" grading system. This system had higher marbling requirements and included compensation for conformation. Undoubtedly many cattle graded under the "old" system would be graded differently today. It remains to be determined whether the relative differences in carcass composition due to the ration fed will vary from the "old" grading system to the "new" grading system.

6. Monensin was given FDA approval in December of 1975. Since that time it has gained tremendously in popularity among cattle feeders and investigators and is now being routinely included in many research trials. Monensin is known to have an effect on the energy value of feeds and it has been suggested to affect the protein value as well. These facts should be considered in evaluating data collected without the use of monensin.

All of these modifications in cattle feeding research will undoubtedly change the applicability of past data. Whenever necessary, caution will be employed in this discussion.

The review will examine the effects and interactions which feeding systems have on the following parameters:

- Performance and carcass characteristics;
- Cattle type and sex;
- Associative effects;
- Monensin; and
- Protein requirements.

Performance and Carcass Characteristics

Published reports comparing rations of different roughage to concentrate ratios can be found dating back to the early 1950s. These early trials centered primarily on determining the corn to alfalfa hay ratio that would maximize performance. In a review of five experiments, Dowe et al. (1955) noted that in most of the feeding experiments the steers fed the ration containing the highest level of concentrate did not in all cases produce the fastest gains. Generally, the cattle fed rations containing two or three parts concentrate to one part roughage made the greatest gains.

Using ground ear corn, Dilley et al. (1959) fed yearling beef steers on three levels of nutrition to a constant slaughter weight. Most notable of his results was the fact that cattle on the most limited intake level produced carcasses with the least separable fat and fat cover but greatest marbling, indicating that level of nutrition could affect carcass composition.

Hendrickson _et al_. (1959) reached a similar conclusion when they individually fed steer calves to make gains either (a) rapidly, (b) moderately, (c) rapidly for 200 lbs and then moderately for 200 lbs, or (d) moderately for 200 lbs and then rapidly. Even though calves fed to gain moderately required about 60 days longer to reach final weight, no differences in efficiency were found. Moderate gaining calves graded lower, had less external fat and marbling, and contained about 6% more lean.

The use of corn silage has been a well-established practice since the late 1800s. However previous to 1960 little had been done comparing different systems of feeding silage to feedlot cattle. Prior to that time many people had believed that silage did not contain sufficient energy to be used to fatten beef cattle. However, technology in varieties, fertilization, harvesting and storing had continually improved until it was realized that cattle could be fattened on rations containing a high proportion of high quality silage.

The work of Perry _et al_. (1961, 1962) and Neuman _et al_. (1962) demonstrated that acceptable rates of gain could be obtained in steer calves and yearling steers full fed corn silage with small amounts (0.7 to 1.6 kg) of concentrates.

Hammes _et al_. (1964) used yearlings and 2 year old steers to study the nutritive value of high-forage rations for fattening beef cattle. The forages used were corn silage and alfalfa-orchard grass silage. When fed alone, grass silages produced poor feedlot performance. Rates of gain for the steers fed high corn silage rations were lower than for those fed a conventional high-grain fattening ration, but this was attributed partly to a low protein intake. Feed efficiency, expressed as pounds of dry matter or TDN per pound of gain was best for the high corn silage rations. Cattle fed the high corn silage rations produced carcasses grading high good to low choice; these grades were not significantly different from those of the carcasses from cattle fed a conventional high-grain fattening ration.

Using corn silage based rations, Young et al. (1962) compared the effects of feeding similar amounts of ground shelled corn per head by either limit-feeding on the basis of body weight continuously after weaning, or full-fed after a growing period. Differences in TDN per cwt gain were small as were differences in carcass composition.

Klosterman et al. (1965) fed either ear corn or corn silage rations during different parts of the feeding period. Cattle fed the ear corn ration gained significantly faster than those fed the silage ration. No significant differences were noted in carcass traits. Trends were similar whether cattle were fed for a time constant or a weight constant basis.

Pinney et al. (1966) also found no differences in carcass grade when they fed ground shelled corn at the rates of 0.5, 1.0 and 1.5% of body weight plus corn silage ad libitum. Further, they observed only small differences in rate of gain.

Over a period of four years Utley et al. (1975) used 32 crossbred calves and 36 crossbred yearlings in a series of trials to study high energy vs all forage diets. Their calculated returns to capital, land, labor and management were $9.66 and -$18.63 per head, respectively, for calves and yearlings fed the high energy diet compared with $55.19 and $23.97 per head, respectively, for calves and yearlings fed the all-forage diet. They also observed all-forage fed steers had less marbling, lower yield grades and less fat covering over the rib eye than steers fed the high energy diet. However carcasses for high energy cattle averaged 21 kg heavier and no corrections were made to adjust for this. Thus differences could reflect variation in physiological maturity rather than ration effect.

Perry and Beeson (1976) summarized five experiments they had conducted to compare various ratios of corn and corn silage for finishing steers. Hereford and Shorthorn steer calves and yearlings were fed corn, in addition to corn silage and supplement, in amounts ranging from 0.9 kg per head daily to 86% of the total ration dry matter. Daily gains were as expected for the energy level fed except for one experiment in which calves fed either one-third or two-thirds of a full feed of corn gained as rapidly as those fed a full feed of corn. Efficiency, expressed in TDN per unit gain, revealed that cattle fed the higher silage diets were as efficient converters of available energy to gain as were those fed the higher levels of corn in two of the experiments. In the other three, cattle on higher silage diets required less calculated TDN per pound of gain than those on the higher corn diets. When quality grades were examined, the authors concluded that calves or yearlings fed high silage diets graded similarly to those fed higher corn diets.

Guenther et al. (1965) used 36 half-sib Hereford steer calves to determine the effect of plane of nutrition on the growth and development of beef calves from weaning to slaughter weight. The experimental design permitted comparison of data on both an age and weight-constant basis. The high energy level ration contained 59% corn and 15% cottonseed hulls while the moderate energy level contained 17% corn and 55% cottonseed hulls. This experiment demonstrates two points: (1) the importance of looking at energetic efficiency rather than feed per unit of gain and (2) the importance of comparing treatments on a weight-constant basis. High plane calves required 22% less feed per kilogram of lean than the moderate plane calves when slaughtered at the same age. On a TDN basis, efficiency of lean production also favored the high-level steers over the age-constant moderate steers. However when comparisons were made on a TDN basis at a constant weight, no difference was noted. On a weight-constant basis, no significant difference was noted in the lean or fat composition of the carcasses.

Theuninck et al. (1978) observed no effect of ration on carcass characteristics when they fed four corn silage-corn grain feeding programs. However the range in energy values of the four programs was not vastly different and did not approach the extremes provided by all silage or all concentrate which had been reported in many studies.

Henderson and Britt (1974) summarized 12 experiments completed comparing the economic efficiency of an all silage ration with a ration comprised of 40% shelled corn and 60% corn silage on a DM basis. Daily gain was reduced 14%, daily DM consumption was reduced 10%, DM consumed per unit gain was increased 4%, no change in carcass grade, fat thickness over the 13th rib was reduced 0.28 cm and beef produced per acre of corn grown and fed increased 61% for the all silage ration.

Young and Kauffman (1978) used 42 yearling Hereford steers to study performance and organoleptic characteristics of the beef after they had been fed high forage diets to attain a similar carcass composition as grain fed controls. Rations included (1) 70% corn, 30% corn silage, (2) corn silage with supplement and (3) 50% corn silage, 50% haylage. Metabolizable energy (ME) intake per kilogram of carcass weight indicated that steers fed the haylage-corn silage diet were 70% as efficient in converting ME to carcass weight as steers fed grain. Expressed on a live body weight basis, forage fed steers were 92% as efficient in ME conversion due to differences in rumen fill. This agrees well with the work of Oltjen _et al_. (1971) who observed that steers fed only an all-forage diet consumed 95% the amount of metabolizable energy and were 86% as efficient in converting it to body weight as were steers fed the all-concentrate diet.

Considering the effect of ration on carcass characteristics, Young and Kauffman (1978) noted that grain fed steers had higher dressing percentages and backfat than the other two groups. Intramuscular fat estimated as marbling or percentage ether extract in the longissimus muscle was similar for all groups. With regard to organoleptic evaluation of steaks and roasts, the authors concluded that when steers are fed to a similar carcass composition, palatability of meat is comparable whether the diet is grain or forage.

Preston et al. (1975) compared all corn silage to high concentrate rations for Angus and Charolais steers. Cattle fed high concentrate gained 0.36 kg faster daily and required 122 units less DM per unit gained than cattle fed all corn silage. The authors concluded that steers could be finished satisfactorily on a corn silage ration but that a longer time on feed would be required. When the carcass data were adjusted to the mean hot carcass weight within breed, all silage fed cattle had leaner carcasses with somewhat lower marbling than high concentrate fed cattle. This suggested that ration energy level does affect carcass composition. Gill et al. (1976) and Buchanan-Smith and Alhassan (1975) also demonstrated that ration energy level influences carcass composition.

By feeding three levels of ration energy Judge et al. (1978) also noted an effect on carcass characteristics when cattle that were lighter in weight and consequently were on feed longer had higher marbling scores and quality grades. Earlier work by Ewing et al. (1961) also supports this. Feeding cattle to a constant finish at different energy levels, they observed that cattle on feed for longer periods of time had increased marbling scores and quality grades.

Similar conclusions were also reached by Dikeman et al. (1976) when they fed four combinations of low, moderate and high energy rations to growing and finishing steers. All cattle were slaughtered at similar weights with carcass merit being similar for carcasses from the

different treatments. They concluded that since steers on lower energy rations were fed longer, this affected carcass traits more than ration energy did.

Byers (1978) studied the effect of energy level on composition of growth of cattle by feeding rations _ad lib_ or 70% of _ad lib_ level of intake. Rates of protein deposition averaged 85.4 and 73.9 g/day for _ad lib_ and limit fed cattle, for a 13.6% decrease. Rates of fat deposition averaged 386.3 and 231.2 g/day for _ad lib_ and limit fed groups for a 40.1% reduction with limit feeding. Thus, the restriction in energy depressed fat deposition far more than protein deposition and at approximately equal empty body weight (358 _vs_ 350 kg) the _ad lib_ fed cattle were 15.9% fatter (30.87 _vs_ 25.97% empty body fat) than limit fed steers. These data suggest an upper limit for protein deposition, and that intake of additional energy over the requirement for protein is deposited as fat.

Byers' (1978) experiment is in direct conflict with the work of Topel _et al_. (1973). They also compared _ad lib_ feeding with restricted energy which was designed to give approximately two-thirds the average daily gain of the _ad lib_. A growing ration was fed to 363 kg and a finishing ration to 499 kg. Feed restriction had no significant effect on muscle, bone and fat content of the carcass when compared at a constant carcass weight.

Cattle Type and Sex

Using rations of corn silage, ground ear corn and a combination of the two, Klosterman and Parker (1976) determined the net energy

values of the rations for both steers and heifers in each of two years. There was little difference between the sexes in amount of dry matter required per unit of live weight gain when fed to similar quality grades. However, heifers had fatter carcasses which tended to give them higher net energy values than steers. There was an interaction among rations in this regard. The net energy value of the corn silage ration averaged 16% higher when fed to heifers than when fed to steers. There was little difference in net energy value of the ear corn ration when fed to either steers or heifers. This indicated that heifers are especially well adapted to the use of a corn silage ration.

Klosterman and Parker (1976) also compared Angus and Charolais steers when fed either corn silage or corn grain rations to a similar slaughter condition. Concentrate fed cattle averaged .36 kg higher ADG and 1.2 kg less dry matter per kg gain. When fed to equal weights, there was no difference in carcass grade between Angus steers fed silage or grain. However, Charolais steers fed silage graded two-thirds of a grade lower than those fed grain. Total carcass fat, as determined by specific gravity, was higher for both breeds when fed the concentrate ration.

Considering both sex and size together, Klosterman and Parker (1976) concluded that there were definite interactions among types of cattle and rations or feeding systems. Lower energy rations or deferred systems were best utilized by early maturing types which consume more feed per unit of weight.

Newland (1976) fed Angus steers and heifers on either corn silage or whole shelled corn. Both steers and heifers adequately finished to choice grade on all corn silage. On the all concentrates, the heifers and steers finished at the same time. On all silage, heifers required 27 days less than steers suggesting that corn silage may be more suitable for finishing heifers. Steers fed all concentrates gained 0.27 kg per day faster than all silage. Heifers fed all concentrate gained 0.23 kg per day faster. Carcass composition was similar between all silage and all concentrate rations although data were not adjusted to a constant final weight. Kilograms of beef produced per acre were 726 kg with all silage and 499 kg with all concentrate. The economics favored the all silage program which returned $40 more per head than all concentrates.

In contrast, Harpster (1978) compared steers and heifers of four genetic types (Unselected Hereford, Selected Hereford, Angus x Hereford x Charolais crossbred, and Angus x Hereford x Holstein crossbred) fed high silage rations and found that steers gained 19% faster than heifers and tended to be more efficient, although feed/gain differences were small when adjusted to similar carcass fat. However, the heifers were those rejected as herd replacements and no comparisons were made at other energy levels.

Anderson and Dinkel (1977) fed Limousin and Charolais crossbred steers on either high concentrate (83% corn) or all forage (three parts corn silage, one part alfalfa hay) rations. Steers gained 0.41 kg per day and heifers 0.36 kg per day faster on all concentrate than all forage. Forage-fed steers required 53% more TDN per kg of retail cuts than concentrate-fed steers while forage-fed heifers required 46% more TDN per kg of retail cuts than concentrate-fed heifers. Although cattle were not carried to choice quality grades, total costs per kg of retail cut favored all forage rations for both steers and heifers.

Byers et al. (1976) classified steers into large or small mature size and fed them either whole shelled corn or corn silage. Rate of gain and feed efficiencies were similar between large and small types fed corn or fed silage. The large size cattle, however, were not nearly as fat when terminated. Had the large size cattle been fed to a degree of fatness similar to the small size cattle, feed efficiency and rate of gain would have been lower than observed. When adjusted to similar carcass fat percentage within size class and between diets, small size cattle had 17% heavier carcasses and large size cattle had 34% heavier carcasses when fed corn silage than when fed corn grain diets. The authors concluded that there was a very definite effect of plane of nutrition. Large size cattle changed more markedly in composition of growth than did small size cattle when fed different energy levels. The smaller mature size cattle fattened much easier on corn silage than the larger cattle, indicating that small cattle are likely better suited for fattening on lower energy diets.

Prior et al. (1977) conducted a trial, using two types of cattle (Angus x Hereford crossbreds, small type; and three-fourths or seven-eighths Charolais and Chianina Hereford or Chianina Angus

crossbreds, large type), to evaluate their response to three dietary energy densities and three dietary levels of crude protein. The rations consisted of the following ratios of corn silage to corn plus supplement: low energy (LE), 43:57; medium energy (ME), 25:75; and high energy (HE), 11:89. Crude protein levels were LP = 10.0, MP = 11.5 and HP = 13.0% of ration dry matter.

Increasing energy intake increased ADG in both types of cattle with HE > LE. Energetic efficiency was expressed as Mcal of metabolizable energy required per kg of retail product gained. In small type cattle a more efficient utilization of energy for production of carcass retail product was obtained with the low energy ration. However, large type cattle showed only very small differences in efficiency. Carcass data were adjusted to a constant weight within type. In small type cattle quality grade, yield grade and percentage carcass fat increased as energy intake increased (LE < ME = HE). This effect was not seen in large type cattle.

Smith et al. (1977) measured growth, feed efficiency and slaughter data on 387 steers to study the effects of biological type (small vs large) and five feeding regimes: A = winter growing ration (2.18 Mcal ME/kg); summer grazing, 60% forage finishing ration (2.84 Mcal ME/kg); B = same as A, except 20% forage finishing ration (3.11 Mcal ME/kg); C = 96.6% forage ration (2.40 Mcal ME/kg); D = 96.6% forage ration switched to 60% forage ration; E = 60% forage ration.

Live weight gains were as expected from the energy density of the rations with steers receiving the highest energy rations gaining the fastest. However, feed efficiency expressed in Mcal of metabolizable energy per kg gain did not differ among rations or types. This was in contrast to the previously discussed experiment of Prior et al. (1977). For both types of cattle, composition of gain was markedly altered by regime which was readily evident when comparisons were made at equal weights. For both cattle types a similar pattern of regime effects were found for all measures of fatness (A = B < C = D < E). This ranking aligns with the major differences in ME density of the rations. The steers on the deferred-feeding regimes were leanest, followed by those on the all forage rations. Except for the lack of a difference between regime E and regimes C and D, regime effects on marbling score (A = B < C = D = E) were similar to those on measures of composition.

In another series of experiments utilizing steers of different biological types, Ferrell et al. (1978) studied the effects of differing energy levels on growth rate, feed efficiency and carcass characteristics. Unlike Prior et al. (1977) they observed no energy or protein level interactions with breed type which is consistent with the data of Smith et al. (1977). Steers having genetic potential for larger mature size grew at faster rates. However, feed intake was also higher for the larger steers; thus similar or less efficient gains resulted.

Ferrel et al. (1978) was in agreement with Prior et al. (1977) and Smith et al. (1977) in reporting that energy density of the ration did affect carcass composition in that carcasses from steers receiving the higher energy diets were heavier than carcasses from steers which

received the lower energy diets and contained greater amounts of fat but similar or less protein.

Byers (1977) discussed plane of nutrition as it affects different types of cattle. He noted that at any selected weight or age, large sized cattle will be depositing more protein and muscle and a lesser percentage fat than smaller sized cattle. Since requirements for protein and energy are directly related to the animal's tissue needs for maintenance and growth, the dietary levels provided must reflect the kind of and amount of growth which is occurring. Byers (1977) further noted that while the maximum potential for protein and muscle growth is genetically set, the expression of this potential is regulated by available energy and that energy above needs for protein deposition is stored as fat.

Hoffman et al. (1977) looked at the effect of varying ratios of corn silage and corn grain upon the feedlot performance of yearling steers. The percentage silage and grain in the ration was 93:7, 74:26, 56:44, 37:63, 19:81 and 0:100. When cattle were fed to a constant slaughter weight, the two treatments receiving either 37 or 19 percent of their energy from whole plant corn silage and the remainder from grain tended to gain the most rapidly and were more efficient in their utilization of dry matter.

In agreement with this work are Larson et al. (1976) who also looked at the influence of corn silage level on the performance and economic returns of yearling steers. The following levels of corn silage (expressed as percentage corn silage dry matter in the ration

dry matter) were fed: 0, 16.2, 29.4, 41.6, 53.8, 65.4, 76.5, 85.7 and 86.2%. Cattle fed a ration with 29.4% corn silage gained faster and had lower feed costs than cattle in other treatments.

Neuman et al. (1972) observed that yearling steers fed shelled corn rations containing 9.1 kg of corn silage daily made their gains at lower costs than those fed shelled corn rations containing 2.3 kg of corn silage.

Self and Hoffman (1977) fed three ratios of corn and corn silage to yearling steers in confinement. The percentage TDN from grain in the rations was as follows: 25, 55 and 85. When total costs, including feed costs and non-feed costs, were analyzed, cattle fed the 55% TDN from grain produced the most economical gains. Utilizing outside lots in a second trial, they again compared the 55 and 85% TDN from grain rations fed to yearling steers. The results were similar with cattle fed the 55% TDN from grain producing the most economical gains.

Associative Effects

The energy value of a ration is generally assumed to be the sum of the energy values of the dietary ingredients. However, several investigators have suggested that the energy value of an ingredient is not constant but is dependent upon the interaction with other ingredients in the ration. If this is true then the energy value of feedstuffs ought to be different when fed by themselves than when fed in a mixed ration.

One explanation for this interaction, as proposed by Kromann (1977), is that the micro-organisms in the rumen use the most readily available carbohydrate as an energy source. Thus when a ration consisting of both high fiber and high carbohydrate sources is fed, the high fiber portion is utilized less efficiently.

Support for this theory is provided by Vance et al. (1972) who fed increasing amounts of corn grain in corn and corn silage diets. They found that ration NEm value increased linearly, indicating that the NEm value of each feed was constant. However, ration NEg value increased curvilinearly with the greatest change found when 61% to 83% corn grain (DM basis) was fed. They concluded that NEg value will vary depending upon the proportion of the feed in the total ration.

However, in subsequent work at the same station, Preston (1975) summarized three experiments and determined the NEg values for individual feeds were additive and did not depend on the relative proportions of grain and silage.

Byers et al. (1975a; 1975b) made energy determinations of corn silage and whole corn rations fed separately or in mixtures of two-thirds corn silage, one-third whole corn and one-third corn silage, two-thirds whole corn. Using the NEm and NEg values determined for corn silage and whole corn when each was fed separately, they predicted the NEm and NEg values for differing proportions of corn and corn silage. To do this they assumed a linear relationship. The observed NEm and NEg values, however, were depressed 4 to 15% below the predicted

values indicating marked feed interaction. They noted the greatest changes in digestion and metabolism of corn energy when corn was fed at levels between 50% and 90% of the diet, while for corn silage the most marked changes occurred when fed at very small amounts with the degree of change decreasing as level of silage fed increased.

Dexheimer et al. (1971) compared corn and corn silage rations fed in a constant daily amount in a two-phase system in two separate trials. Total corn silage and supplement consumption was nearly equal during the entire feeding period for both systems while those cattle fed on the two-phase system consumed 10% less shelled corn. Average daily gain was identical for the two systems while cattle fed on the two-phase system required 7% less feed per unit gain than those fed the constant amount which was a significant difference.

The work of Woody et al. (1978) agrees well with that of Dexheimer et al. (1971). Woody et al. (1978) observed that steers fed all corn silage during the growing phase and switched to an all concentrate ration had similar gains but improved in feed efficiency by 6.5% when compared to steers fed silage plus a constant amount of added grain throughout the entire feeding period.

However, the improvement in feed efficiency noted by Dexheimer et al. (1971) and Woody et al. (1978) for the two-phase system versus a continuous amount of added grain, cannot be entirely attributed to associative effects. As suggested by Fox and Black (1975) this improvement in feed efficiency could be due to compensatory gain made by cattle backgrounded on silage after they are switched to a high grain ration. Furthermore, cattle on two-phase systems would have somewhat reduced maintenance requirements since gains would have been fastest when the cattle were the heaviest.

To further complicate this subject, Goodrich et al. (1974) did a statistical and economic analysis of 17 university experiments to determine the influence of corn silage level on the performance of steer calves. They reported that the amount of feed per unit of gain increased linearly as the amount of corn silage increased. Twenty-six kilograms more feed was required per 100 kg of gain for each 10% units increase in the amount of silage dry matter in the ration.

Asplund and Harris (1971) compared differing combinations of alfalfa hay and beet pulp fed to lambs. Their data indicated that associative effects did occur, but they concluded that the magnitude was relatively small and would be of minor importance in the assessment of the value of feeds.

In another trial with lambs, Kromann et al. (1975) fed 21 diets consisting of varying proportions of dehydrated alfalfa and corn. They found no associative effects for DE, ME and NE m + p values with the various ratios of concentrate to roughage. A linear relationship between energy (DE, ME and NE m + p) and ration composition indicated that the energy values of corn and dehydrated alfalfa were additive and that no interactional effects were evident with the change in ration composition.

The extent to which associative effects occur is very difficult to define since there is much disagreement between trials. The work of

Byers et al. (1975a, 1975b) demonstrates their occurrence and is supported in part by the efforts of Dexheimer et al. (1971) and Woody et al. (1978). However the results of Preston (1975) and Goodrich et al. (1974) would argue that the impact of associative effects is not significant.

Monensin

Research with monensin fed to growing and finishing cattle has been very active during the past three to four years. Results of numerous experiments under both laboratory and feedlot conditions have been reported. The effects from feeding monensin have been very consistent in showing an increase in the amount of propionic acid, decreases in acetic and butyric but with essentially no change in total VFA production. Because acetate is used less efficiently as a source of metabolizable energy than propionate, cattle fed rations which contain monensin should gain more efficiently than cattle fed rations without monensin (Thonney, 1977).

Goodrich et al. (1976) summarized data collected from 29 university experiments involving 3,042 cattle in which monensin was fed at various levels to steers and heifers. Both calves as well as yearlings were represented. Levels of monensin fed included 5, 10, 20, 25, 30 or 40 g per ton. Daily gains of cattle fed diets that contained monensin were about equal to or greater than gains of cattle fed diets without monensin. The single exception was for cattle fed 40 g of monensin per ton of ration. These cattle had lower daily gains than those fed the control rations or any other level of monensin.

Dry matter intakes declined as the level of monensin in the diet increased. All levels of monensin required less feed per unit of gain than control cattle. Percentage improvements in feed efficiency were 6.5, 6.1, 7.4, 10.3, 8.4 and 8.5 for cattle fed rations that contained 5, 10, 20, 25, 30 and 40 g of monensin per ton. Maximum reduction in total cost (both feed and nonfeed) occurred with the addition of 25 g/ton and resulted in savings of $23 for each 272 kg gain. Carcass traits were not significantly influenced by the feeding of monensin.

In a review of six experiments, Embry (1976) summarized results by both growing periods and finishing periods. During the growing phase there was only a small effect of monensin on weight gain of the cattle in the six experiments. Weight gain was at least equal to the control group up to the 30 g/ton level. Those fed the 40 g/ton level gained at a slightly lower rate. Lowest feed requirements were obtained at the 30 g/ton level. The improvement over controls at this level amounted to 9.0% which was similar to the reduction in feed intake (9.6%) from controls. During the finishing phase, similar benefits from monensin were seen. Again the 30 g/ton level was the most efficient.

Brown et al. (1974) compiled data on quality grade and calculated cutability from 1,147 cattle fed various levels of monensin. The data showed little if any effect of monensin on carcass quality grade or percentage of cutability. Thonney (1977) in his review also concluded that monensin had no apparent consistent effect on carcass characteristics.

Since the action of monensin occurs within the rumen, the effect of growth promotants which act elsewhere may be additive to the effect of monensin. Woody and Fox (1977) observed a 5.8% improvement in feed efficiency for heifers fed monensin at the rate of 30 g/ton. A further increase of 11.5% and 6.5% in average daily gain and feed efficiency, respectively, was seen when heifers were fed monensin and implanted with Synovex H. In a review of six trials comparing various implants with and without 30 g/ton of monensin, Embry (1976) determined that the response to monensin and implants could be expected to be additive. Burroughs et al. (1976) also concluded there was an additive response to monensin and implant treatments. Legally, monensin cannot be mixed into a ration with another feed additive. Therefore, growth promotants must be implanted when used in conjunction with monensin.

An area presently under investigation concerns a possible protein sparing effect of monensin. Gates and Embry (1976) fed a corn silage ration to Hereford steer calves from 227 to 363 kg. The rations were also supplemented with protein from soybean meal or urea with all comparisons being made with and without monensin. Their results indicated that monensin improved protein utilization when fed in rations slightly deficient in protein and that it resulted in improvement in utilization of nonprotein nitrogen from urea.

In a subsequent trial reported by Gates and Embry (1977) they compared two protein levels in high concentrate rations. The protein levels were 10.4% for the unsupplemented rations and 12.7% for the rations containing soybean meal. The improvement in feed efficiency

due to monensin was observed to be greater when fed with soybean meal supplement (13.5%) than with no supplement (7.1%).

In an *in vitro* trial conducted to determine the effect of monensin on dry matter disappearance and proteolytic activity, Tolbert *et al*. (1977) determined that monensin depressed the free ammonia of sorghum plus soybean meal or sorghum plus urea. Free amino acid levels were decreased on sorghum plus soybean meal but increased on the sorghum plus urea. They concluded that monensin may exert an inhibitory effect on deamination by the rumen microflora.

Using shelled corn rations, Gill *et al*. (1977) fed various protein rations with and without monensin to yearling steers. An interaction of monensin and protein level was apparent, with monensin improving feed efficiency and rate of gain, most at the lower protein levels.

Hanson and Klopfenstein (1977) showed similar results when they fed corn silage rations supplemented with brewers' dried grains or urea. The largest response to monensin in feed efficiency occurred at the lower natural protein levels.

However, Gates *et al*. (1977) determined that monensin improved feed efficiency but that the effect was more pronounced with rations supplemented with soybean meal.

In summation, monensin improves feed efficiency in feedlot cattle without affecting average daily gain. Maximum improvements of 8 to 10% can be expected when monensin is fed at levels of 25 or 30 g/ton. Monensin improves feed efficiency without changing carcass characteristics and the effect is additive with the effect of growth promotants. Less clear is the effect which monensin has on protein requirements. Evidence exists to suggest that it reduces protein requirements; however, more research is needed in this area before general recommendations can be made.

Protein Requirements

Using crossbred steer calves, Hatfield *et al*. (1971) demonstrated that in high concentrate rations, calves responded to levels of protein above 11%. Maximum ADG and feed efficiency were observed at levels of 13 to 15%. However, in high corn silage rations, optimum responses were seen at the 11% level. Yearling steers fed high-concentrate rations showed no differences in ADG or feed efficiency at 10% or 12% levels.

In agreement with this, Peterson *et al*. (1973) fed 9, 11, 13 and 15% crude protein in rations with four different energy levels and observed no increase in rates of gain when protein was increased for cattle fed high corn silage rations (86% corn silage). However, a response to increased protein was observed with the higher energy rations (43, 71 and 100% concentrate). Both of these trials suggest that energy may have been limiting in the high silage ration, whereas the higher grain rations supplied sufficient energy to allow utilization of the additional protein for growth.

Further support for this is provided by Crickenberger (1977) when he demonstrated a significant protein by energy level interaction. In his trial he used two protein systems, two energy levels and four cattle types. Cattle fed high grain rations had similar daily gains regardless of protein supplementation system. However steers fed high silage gained considerably faster when supplemented according to NRC when the crude protein level of the ration did not fall below 9.4%. In the other system ration crude protein levels fell as low as 7.4%. The author suggested that the protein quality of high grain rations was higher than of high silage rations. He further concluded that, in practice, corn silage levels should never fall below 10 to 10.5% crude protein in the latter part of the feeding period, with higher levels required at lighter weights.

In an attempt to look at the relationship of corn silage or grain diets fed during the growing phase to protein requirements during growing and finishing, Byers and Preston (1976) observed that during the finishing period cattle grown on corn silage and then fed supplemental protein during finishing gained faster than cattle grown on corn or silage and not fed supplemental protein during finishing. They concluded that urea-limestone silage averaging 13.4% crude protein may not meet protein requirements of growing calves and level of forage fed during growing or backgrounding may affect protein requirements during finishing.

Cmarik et al. (1975) observed an improvement in ADG and feed efficiency when soybean meal was added to a high concentrate ration for finishing yearling heifers. The unsupplemented ration contained 10.8% protein while the supplemented ration contained 12.2% protein.

Prior et al. (1977) in an experiment described previously, fed three dietary levels of crude protein (LP = 10, MP = 11.5 or HP = 13% of dry matter) with three energy levels to large and small type cattle. Up to about 325 kg live weight, small type cattle increased ADG and feed efficiency with no advantage for the HP compared to MP, ADG and feed efficiency increased up to 348 kg live weight in large type cattle with the HP intake compared to the LP ration. They indicated that for maximum efficiency and rate of gain at lighter live weights, small type cattle should receive at least 0.77 kg of crude protein per head per day up to approximately 325 kg of body weight; but for maximum performance large type cattle should be fed 0.93 kg of crude protein per head per day up to 348 kg of body weight.

Increasing the percentage of protein in the ration did not significantly alter carcass quality or compositional traits in small type cattle. This agrees with the findings of Epley et al. (1971) and Crickenberger (1977). However the large type cattle fed the highest crude protein ration had a higher percentage of dressed yield, fat thickness over the 12th rib and yield grade compared to those fed the LP or MP rations.

Conclusions

As was pointed out in the introduction, one must be careful in drawing conclusions because the literature on a given subject will often be conflicting. The most obvious conclusion is that as more grain is added to a corn-corn silage ration, ADG is increased and the time required to reach slaughter condition is reduced. What is less clear is the effect that increasing grain content of a ration has on efficiency. On a dry matter basis cattle are more efficient when fed a high grain ration, but on an energetic basis this advantage is not nearly as great. Interpreting past research data on efficiency is confounded by recent findings that oven drying procedures are inaccurate in determining DM content of feeds. In general, when an economic analysis was included in the feeding trials, high silage rations were favored over high concentrate rations.

It appears, with limited supporting evidence, that heifers and smaller framed cattle are better suited to high silage than high grain rations. However other evidence exists to indicate that there is no interaction between cattle type and ration, particularly in steers.

Data on the effect of ration on carcass composition have also been divergent. Prior to 1974, most research indicated that ration did not affect carcass characteristics. However since that time, an increasing number of trials have shown that when rations with extreme ranges in energy content are compared, an effect on carcass composition will be observed. At a constant weight, cattle on all silage rations will be leaner but with nearly equal quality grades to cattle on all concentrate rations. The protein content of rations has been shown to have little effect on carcass composition.

The magnitude of the impact on efficiency due to the associative effects of feeds is not well defined. The work of Byers _et al._ (1975a, 1975b), which clearly demonstrated associative effects, has not been well supported by other workers. More clear is the fact that a two-phase system is more efficient than feeding a continuous ration when both utilize the same total amount of energy.

It has been well documented that monensin will improve feed efficiency 8 to 10% with no effect on ADG or carcass characteristics. Less obvious is the effect which monensin has on protein requirements. This area needs further research along with the impact which fermentation has on protein quality.

OBJECTIVES

1. To study and compare the effect of feeding system on performance, feed efficiency and economics of production of yearling steers, steer calves and heifer calves.
2. To determine the influence of ration on carcass composition and grade determined under the new grading standards when cattle receiving different rations are fed to a constant final weight.
3. To estimate crude protein requirements of average frame British breed heifers fed monensin supplemented rations of differing energy densities.

MATERIALS AND METHODS

Experimental Animals

Trial 1 consisted of 100 Angus x Hereford crossbred yearling steers purchased in North Dakota which arrived at the Beef Cattle Research Center (B.C.R.C.) in mid-December 1975. They were a very uniform group in their type, frame and condition. Eighty steer calves purchased in Montana were used in Trial 2 which appeared to be a mixture of typical Charolais x Angus and Charolais x Hereford crosses. There was some variation in frame and type of this group of calves, but all were in similar condition. These calves arrived in late November 1975. Trial 3 consisted of 180 Hereford heifers purchased in feeder calf sales in Northern Michigan. They were extremely uniform in type, frame and condition and arrived at the B.C.R.C. in mid-October 1976.

Description of Feedlot

All three trials were conducted in open dirt lots with no windbreaks or shelter. Dirt mounds were provided which were bedded during adverse weather. Cattle were fed in a concrete fenceline feedbunk with a 10 ft concrete apron located behind it. Automatic waterers were located near the feedbunk.

Experimental Design and Rations

Trials 1 and 2 utilized three basic rations which were fed in five different systems to compare the impact of each system on performance and carcass data. Ration 1 was an all corn silage ration while ration 2 was corn silage with approximately 34% high moisture corn added. Ration 3 consisted of 78% high moisture corn with the remainder being supplement and silage. All rations were properly supplemented for protein, minerals and vitamins using the system outlined by Fox and Black (1976). Ration and supplement compositions are shown in Tables 1 and 2. This system is based upon a declining need for protein by the animal as it matures and fattens. Thus ration crude protein levels were not held constant for the entire feeding period but were adjusted each time the animals gained 45.4 kg. Protein was supplemented with soybean meal and monensin was not fed.

The feeding systems (shown in Figure 1) included: 85% concentrates, 15% corn silage; 40% concentrates, 60% corn silage; all corn silage, then switched to 85% concentrates, 15% corn silage when approximately one-half of the expected feedlot gain was reached; all corn silage, then switched to 85% concentrates, 15% corn silage when approximately two-thirds of the expected feedlot gain had been reached; and all corn silage continuously.

Trial 3 utilized a 3 x 3 factorial design in which three protein levels were factored over three energy levels for a total of nine treatments with no replicates. The three energy levels were: 100% corn silage (100% CS); 68% corn silage, 32% concentrates (68% CS);

Table 1. Ration Ingredients and Approximate Composition (DM Basis) (Trials 1 and 2)

Ingredient	Ration 1	Ration 2	Ration 3
Corn silage, %	92.5	59.0	16.0
High moisture shelled corn, %	0	34.0	78.0
Supplement, %	7.5	7.0	6.0
NEg (Mcal/kg DM)[a]	0.99	1.17	1.36
Dry matter	34.0	41.0	59.0

[a]Based on NRC (1976) values.

Table 2. Protein-Mineral Supplements (DM Basis) (Trials 1 and 2)

Ingredient	Ration[a] 1	2	3a	3b
Soybean meal (49%)	89.1	88.7	80.1	62.6
Deflorinated phosphate	4.2	1.0	0	0
Limestone	1.9	5.7	15.0	26.4
Trace mineral salt	4.6	4.3	4.7	10.5
Vitamin A[b]	0.16	0.16	0.16	0.27
Vitamin D[c]	0.16	0.16	0.16	0.27

[a]Supplement 3a was used for cattle in ration 3 that were under 800 lbs; supplement 3b was used for cattle on ration 3 that were over 800 lbs.

[b]Vitamin A contained 30,000 I.U. per gram.

[c]Vitamin D contained 3,000 I.U. per gram.

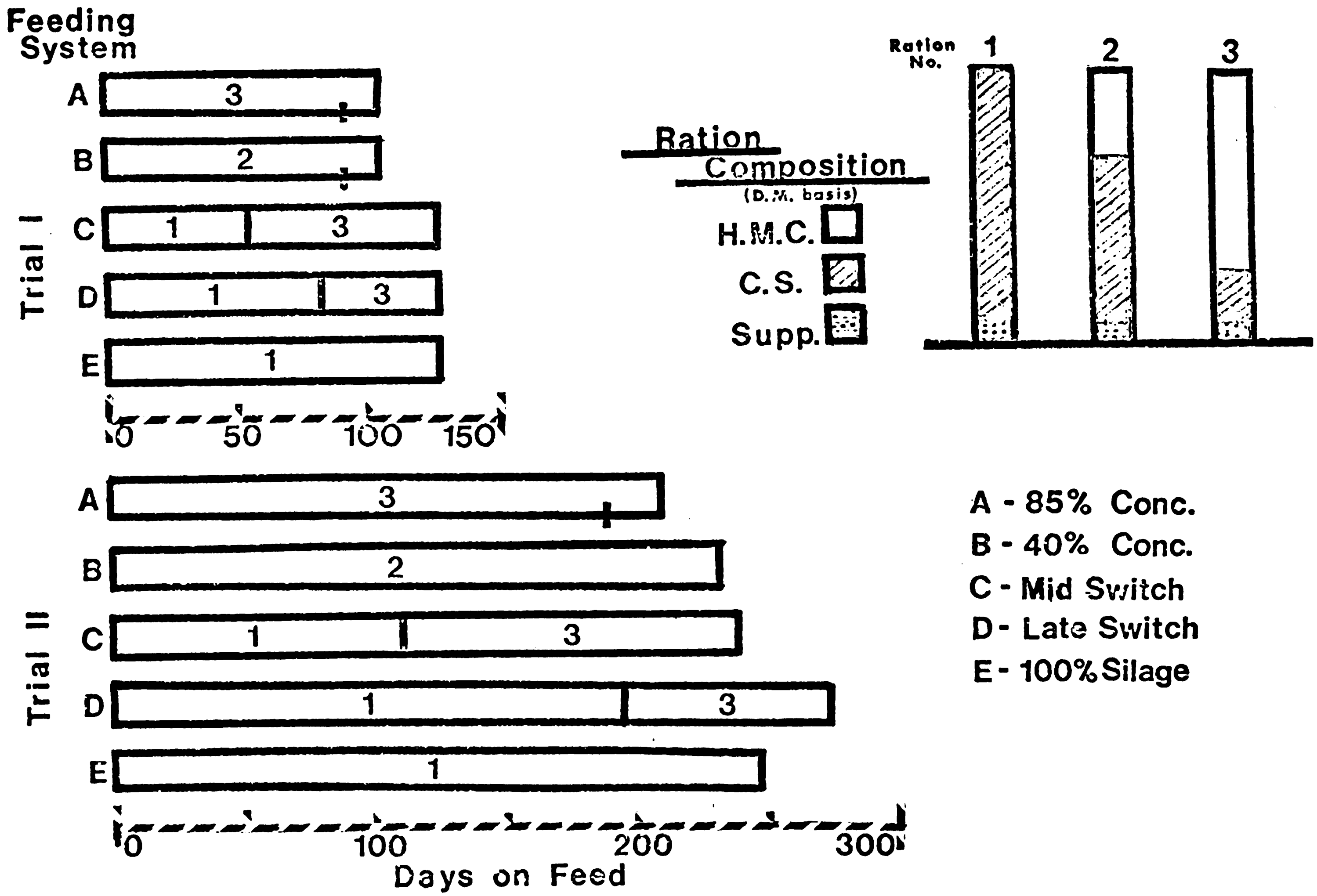


Figure 1. Experimental Design for Trials 1 and 2.

and 100% concentrates (100% Conc). These rations are shown graphically in Figure 2 along with the crude protein levels for each. Table 3 contains the exact ration composition.

All rations were balanced for mineral and vitamin requirements as outlined by Fox and Black (1976). Protein-mineral-vitamin supplements are shown in Table 4. One hundred percent Conc pens were started on 30% concentrate and then increased 5% concentrate each day for 10 days. At that point they were increased 5% concentrate every other day until they reached the 100% level. All pens received monensin, supplemented at a level of 30 g/T of ration DM.

Preliminary Treatment and Allotment Procedures

Upon arrival, all cattle were weighed, tattooed, ear-tagged, vaccinated for IBR, BVD, PI_3 and injected with Vitamins A and D. A pour-on treatment for grubs and lice was given subject to the recommended cut-off dates. Following arrival cattle were involved in trials to study different rations for starting cattle on feed. These starting experiments lasted from 28 to 43 days. The cattle were then placed on an all corn silage ration properly supplemented with soybean meal and minerals for approximately 14 days. Throughout this period of time following arrival, the cattle were observed for sickness and any abnormal cattle were removed. When the main experiments started, all cattle utilized were healthy and consuming normal amounts of dry matter. Prior to allotment, cattle were half-fed the previous day and removed from water for 16 hrs prior to weighing.

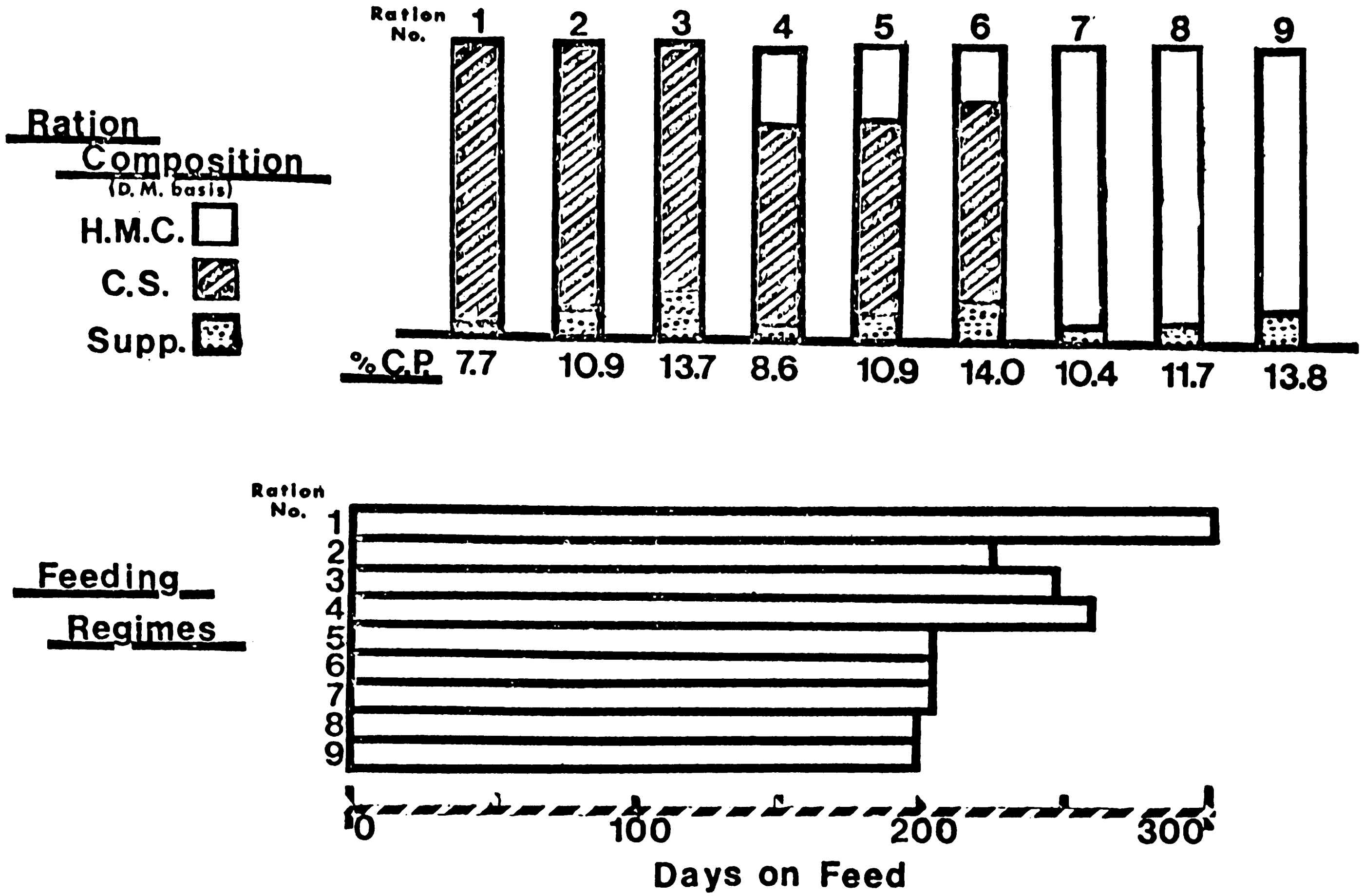


Figure 2. Experimental Design for Trial 3.

Table 3. Ration Ingredients and Approximate Composition (DM Basis) (Trial 3)

Ration: Energy level	100% Corn silage			68:32 (CS:Conc)			100% Concentrate		
Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Corn silage, %	98.9	92.4	85.8	69.5	67.7	65.4	0	0	0
High moisture shelled corn, %	0	0	0	29.4	26.2	21.7	98.3	95.6	91.1
Supplement, %	1.1	7.6	14.2	1.1	6.1	12.9	1.7	4.4	8.9
NEg (Mcal/kg DM)[a]	0.99	1.01	1.01	1.12	1.12	1.12	1.46	1.46	1.43
Dry matter, %	41.8	43.3	45.0	47.5	48.2	49.3	70.4	70.8	71.5

[a]Based on NRC (1976) values.

Table 4. Protein-Mineral Supplements (Trial 3)[a]

Ration — Energy level	100 % Corn silage			68:32 (CS:Conc)			100 % Concentrate		
Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Soybean meal (49%)	--	88.1	93.8	--	83.2	92.4	--	62.9	83.7
Deflorinated phosphate	69.2	7.1	2.5	39.5	5.1	1.3	--	--	--
Limestone	--	0.4	1.3	29.8	6.3	3.8	64.9	25.3	12.2
Potassium chloride	--	--	--	--	--	--	16.3	4.3	0.3
Trace mineral salt	23.6	3.3	1.8	23.4	4.0	1.9	14.4	5.7	2.8
Vitamin A[b]	1.1	0.16	0.09	1.1	0.2	0.1	0.68	0.28	0.14
Vitamin D[c]	1.1	0.16	0.09	1.1	0.2	0.1	0.68	0.28	0.14
Rumensin premix[d]	5.0	0.72	0.39	5.1	0.9	0.43	3.08	1.27	0.63

[a]Supplements were calculated based on the requirements for 190 kg heifers found in Fact Sheet 1097 of the Michigan Beef Production Manual. Figures reported are on 100% dry matter basis.

[b]Vitamin A contained 30,000 I.U. per gram.

[c]Vitamin D contained 3,000 I.U. per gram.

[d]Procured from Elanco and contained 30 g of Rumensin per lb of premix. The ration was formulated to obtain a composition of 30 g per ton of final ration dry matter.

In Trials 2 and 3, numbers of animals were such that several extremely heavy and light cattle could be removed thus making the groups more uniform in weight and giving equal numbers of animals for each treatment. Animals were blocked based on their initial weights and then allotted randomly. Twenty animals per treatment were used in Trials 1 and 3 while 16 animals per treatment were used in Trial 2. Starting dates were January 14, 1976 for Trials 1 and 2 and November 22, 1976 for Trial 3.

Feeding, Weighing and Management Procedures

The corn silage fed had been stored in either a bunker silo or an upright concrete stave silo. High moisture corn was stored in Harvestore silos. Supplements were mixed at the M.S.U. feedmill, bagged and then stored at the B.C.R.C. Rations were mixed immediately prior to feeding in a horizontal batch mixer and transported to the feedbunks with a feedtruck. The complete ration was fed once daily and supplied in amounts so that bunks were nearly cleaned up at feeding time. Daily feed consumption was recorded and periodically, unconsumed feed was removed, weighed and the amount recorded. Those cattle on high concentrate rations were started on 30% concentrate and gradually increased over periods ranging from 10 to 18 days until they reached their designated levels. The same procedure was used when cattle were switched from high silage to high concentrate rations.

Cattle in Trials 1 and 2 were implanted initially with Synovex S while those in Trial 3 received Ralgro. Cattle in Trials 2 and 3 were subsequently reimplanted at recommended intervals subject to withdrawal requirements.

Initial and final weights for all cattle were obtained after receiving one-half of normal feed the previous day and being held for 16 hrs without water. Intermediate weights were taken every 28 days after a 16 hr shrink without water. All cattle were weighed individually.

Two animals were lost in Trial 2 and one in Trial 3 due to sickness. This occurred early in the experimental period and data from these animals were removed from all analysis.

Initial Slaughter

Initially, in Trial 3, six cattle were selected at random and slaughtered to determine body composition. They were slaughtered at a packing plant located 25 miles from the B.C.R.C. where the wholesale ribs were removed and returned to campus for further analysis. Soft tissue from the 9-10-11th ribs was thoroughly ground and mixed and analyzed for moisture, fat, protein and ash. Total nitrogen of rib samples was determined using the Technicon Auto-Kjeldahl System. Water was determined by drying at 60° for 24 hrs. Ether extractable fat was determined by using the Goldfisch procedure. The following prediction equations were used for estimation of carcass chemical composition (Hankins and Howe, 1946):

$$y = .66x + 5.98$$

where: y = carcass protein,% and

x = rib protein, %.

$$y = .77x + 2.82$$

where: y = carcass fat, % and

x = rib fat, %.

Termination of Experiments

Experiments were terminated by slaughtering the cattle when the fattest pen was estimated to be 80% choice and then slaughtering the remaining pens as they reached approximately the same weight. Final weights were taken as previously discussed. All cattle were scanned using an Ithaco Ultrasonic Scanoprobe as they were weighed. Cattle from Trial 1 and pen 1 from Trial 2 were hauled 65 miles and slaughtered at Walters' Pack in Coldwater, Michigan. Due to closure of this plant, the remaining cattle in Trial 2 were hauled 25 miles and slaughtered at Charlotte Meat Company, in Charlotte, Michigan. All cattle in Trial 3 were hauled 110 miles and slaughtered at Dinner Bell Meats in Archbold, Ohio.

Carcass Data Collection

Hot carcass weights were taken and carcasses were chilled for at least 24 hrs before they were evaluated. All carcass measurements and estimations were collected by a U.S.D.A. grader except actual fat thickness. In Trial 3 specific gravity information was collected on 10 carcasses per treatment on the day following grading. Specific gravity was determined using the following format:

Specific gravity = (carcass wt in air)/(carcass wt in air minus carcass wt in water)(correction for water and carcass temperature).

The percentage of carcass fat and % carcass protein were calculated from the following equations developed by Garrett and Hinman (1969):

$$y = 587.86 - 530.45x$$

where: y = carcass fat, % and
x = specific gravity.

$$y = (20.0x - 18.57)\ (6.25)$$

where: y = carcass protein, % and
x = specific gravity.

Loss of identification during the slaughtering process occurred on one animal in both Trials 1 and 3. Therefore, carcass data from these animals was eliminated from the analysis.

<u>Cost Summary</u>

Costs were summarized for each feeding system in all trials. Non-feed costs were allocated only when they reflected variable expenses between high silage and high grain rations. Veterinary costs, marketing costs and death loss were not included since these would be the same regardless of feeding system used. The factors present in the non-feed costs were interest charges and additional facility, feeding and manure handling costs as the percentage of silage in the ration increased. The formula used was (Woody and Black, 1978):

$$\text{Non-feed cost} = \frac{.0875 + (.04 - .062(\%\ \text{corn in ration} - .50) + .06 + .01}{\text{A.D.G.}}$$

Non-feed costs of heifers were assumed to be 74% of those for steers.

Major feed ingredients (corn silage, corn and soybean meal) were priced relative to three different prices of corn: $2.00, $3.00 and $4.00 per bu. The price of corn silage (per ton, as-fed) was defined as:

$$6.72\ (\text{price of corn grain } \$/\text{bu}) + \$2.10.$$

Thus, corn silage was assumed to contain 6.72 bu of corn grain/ton and was priced to yield equal earnings per unit land as grain production (Woody and Black, 1978).

The price of soybeans has averaged about 2.35 times the price of corn ($/bu) over the years. 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:

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

Soybean oil is priced at $0.20/lb when corn is $2.00/bu, increasing $0.05 per $1.00/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/ton was added as a transport charge.

Mineral, vitamin and monensin components of the respective rations were priced at current levels as noted in Tables 13 and 14.

Data Calculations and Statistical Analysis

Average daily gain was based on final live weights after they had been adjusted to the mean dressing percentage for each trial. Dry matter consumption was adjusted using correction factors of 1.068 for corn silage and 1.03 for high moisture corn (Fox and Fenderson, 1976). Carcass and body composition data were adjusted to the mean hot carcass weight in each trial by using covariance analysis. Least squares regression analysis was used to examine main effects and interactions on performance and carcass characteristics within each trial as described by Black and Harpster (1978).

RESULTS AND DISCUSSION

Feedlot Performance

The performance of the yearling steers is given in Table 5. The performance for both phases is given along with the overall performance. In both phases, those fed the high grain ration had the fastest rate of gain and had the least feed requirement/unit gain, as expected. Those cattle on the mid-switch and late switch programs gained slower after being switched from silage to corn. This is somewhat puzzling and perhaps indicates that if cattle are to be on feed for relatively short periods of time (100 to 120 days), they should be fed the same ration continuously. Possibly they did not have time to fully adapt to the new ration before being switched.

Those yearlings fed 100% silage performed very poorly during Phase II, and had disasterous feed efficiency (15.8 units feed/unit gain).

Table 6 shows the performance of the calves fed each of the five systems. Again, those fed high grain had fastest gains and lowest DM requirements/unit gain. However, the difference in gain between the 85% concentrate and all silage was not as great as in the yearlings. The 100% silage cattle were not as well finished (25% choice) and had they been fed to the same degree of fatness their feed conversion would have dropped.

Table 5. Feedlot Performance (Trial 1)[a]

	85% Conc	40% Conc	Mid-Switch	Late Switch	100% Silage
			Phase I Performance		
Initial wt, kg[b]	391	391	391	391	391
Days on feed	56	56	56	84	56
Avg. daily gain, kg	1.39	1.38	1.18	1.08	1.20
Avg. daily DM, kg[e]					
Corn silage	2.2	7.3	9.9	10.1	10.4
HM corn	8.0	4.1	--	--	--
Supplement	0.5	0.7	0.6	0.6	0.6
Total	10.7	12.1	10.5	10.7	11.0
DM/unit gain	7.70	8.77	8.90	9.91	9.17
			Phase II Performance		
Initial wt, kg[c]	469	468	457	482	458
Days on feed	44	44	62	44	72
Avg. daily gain, kg	1.41	1.10	1.03	1.02	0.67
Avg. daily DM, kg[e]					
Corn silage	1.6	6.9	2.0	2.1	9.8
HM corn	8.7	3.8	7.9	8.2	--
Supplement	0.3	0.6	0.3	0.3	0.8
Total	10.6	11.3	10.2	10.6	10.6
DM/unit gain	7.52	10.27	9.90	10.39	15.82
			Overall Performance		
Final wt, kg[d]	531	517	521	527	506
Days on feed	100	100	118	128	128
Avg daily gain, kg	1.40	1.26	1.10	1.06	0.90
Avg. daily DM, kg[e]					
Corn silage	1.9	7.2	5.8	7.3	10.1
HM corn	8.3	3.9	4.2	2.8	0
Supplement	0.5	0.6	0.4	0.5	0.7
Total	10.7	11.7	10.4	10.7	10.8
DM/unit gain	7.64	9.29	9.45	10.09	12.00
Dressing %	60.7	60.3	59.7	60.0	59.0
% Grading choice	90	80	80	85	75

[a]Twenty steers/treatment.

[b]Initial wt on experiment taken after 16 hrs without feed and water.

[c]Intermediate weights taken after 16 hrs without water only and adjusted to normal shrunk wt (98% of actual wt).

[d]Final weight = carc wt/.5994 x 100.

[e]Dry matter of corn silage and high moisture corn was adjusted using the correction factors determined by Fox and Fenderson (1976) to account for errors in oven drying procedures. Corn silage - 1.068. HM corn - 1.03.

Table 6. Feedlot Performance (Trial 2)[a]

	85% Conc	40% Conc	Mid-Switch	Late Switch	100% Silage
			Phase I Performance		
Initial wt, kg[b]	264	264	263	262	262
Days on feed	112	112	112	196	112
Avg. daily gain, kg	1.38	1.16	1.06	1.10	1.15
Avg. daily DM, kg[e]					
Corn silage	1.6	5.0	7.5	7.9	7.6
HM corn	6.1	2.9	--	--	--
Supplement	0.7	0.7	0.7	0.8	0.7
Total	8.4	8.6	8.2	8.7	8.3
DM/unit gain	6.09	7.41	7.74	7.91	7.22
			Phase II Performance		
Initial wt, kg[c]	418	393	382	478	391
Days on feed	89	121	128	79	135
Avg. daily gain, kg	1.42	1.16	1.26	0.99	1.02
Avg. daily DM, kg[e]					
Corn silage	1.5	6.6	1.7	2.0	9.6
HM corn	8.4	3.7	8.5	8.0	--
Supplement	0.4	0.7	0.4	0.3	1.0
Total	10.3	11.0	10.6	10.3	10.6
DM/unit gain	7.25	9.48	8.41	10.40	10.39
			Overall Performance		
Final wt, kg[d]	545	534	543	556	528
Days on feed	202	233	240	275	247
Avg. daily gain, kg	1.39	1.16	1.17	1.07	1.08
Avg. daily DM, kg[e]					
Corn silage	1.5	5.8	4.4	6.2	8.7
HM corn	7.1	3.3	4.5	2.3	0
Supplement	0.5	0.7	0.5	0.6	0.9
Total	9.1	9.8	9.4	9.1	9.6
DM/unit gain	6.55	8.45	8.03	8.50	8.89
Dressing %	64.1	63.3	63.5	62.5	62.6
% Grading choice	67	87	56	50	25

[a]Sixteen steers/treatment, except 15 head for 85% and 40% Conc due to death losses.

[b]Initial wt on experiment taken after 16 hrs without feed and water.

[c]Intermediate weights taken after 16 hrs without water only and adjusted to normal shrunk wt (98% of actual wt).

[d]Final weight = carc. wt/.632 x 100.

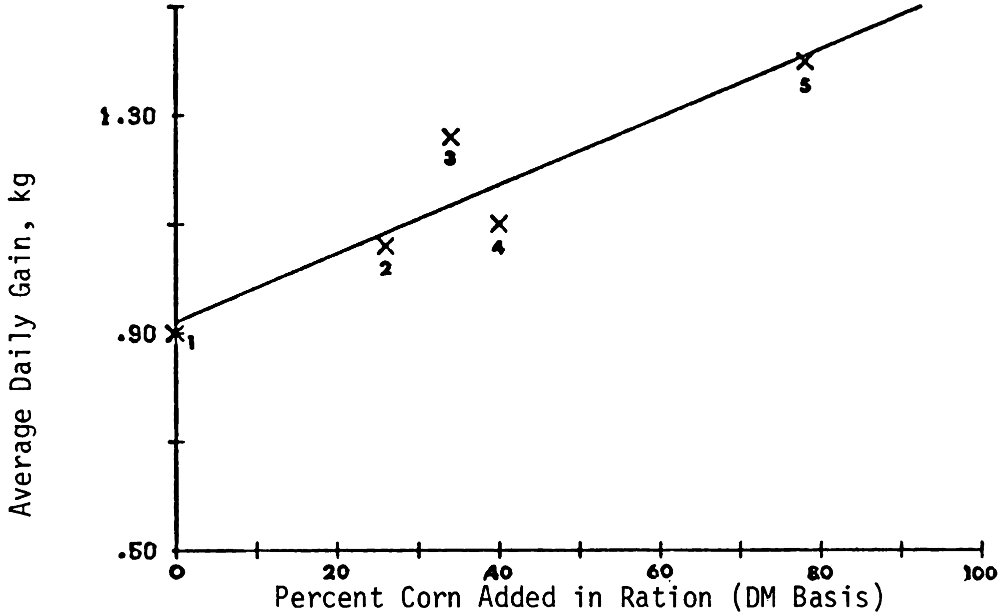
[e]Dry matter of corn silage and high moisture corn was adjusted using the correction factors determined by Fox and Fenderson (1976) to account for errors in oven drying procedures. Corn silage - 1.068. HM corn - 1.03.

Average daily gain and feed efficiency (feed/gain) for Trials 1 and 2 are plotted in Figures 3 and 4 by the average percentage of corn added in the ration. The regression lines have also been drawn. In both trials the slope of the regression line for A.D.G. was significant ($P < .005$) indicating that energy level affected gains.

Woody (1978) observed that steers fed all corn silage during the growing phase and switched to an all concentrate ration had similar gains but improved feed efficiency by 6.5% when compared to steers fed silage plus a constant amount of added grain throughout the entire feeding period. Similar results were obtained by Dexheimer et al. (1971).

A similar comparison may be made in Trials 1 and 2 by comparing the gains and feed efficiency of the 40% concentrate cattle to the mid-switch cattle. In yearling steers, cattle on the continuous 40% concentrate ration gained faster and were more efficient in feed conversion by 2% than cattle on the mid-switch program. The opposite relationship existed in Trial 2. Charolais crossbred calves fed on a mid-switch program gained equal to and were 5% more efficient in feed conversion than calves fed a 40% concentrate ration continuously although total corn consumption was greater on the mid-switch program. The results of Trial 2 agree well with those of Woody (1978) and Dexheimer et al. (1971).

Performance of the heifers is summarized in Table 7. As would be expected average daily gain improved with increasing corn in the ration across all protein levels. The greatest response to adding



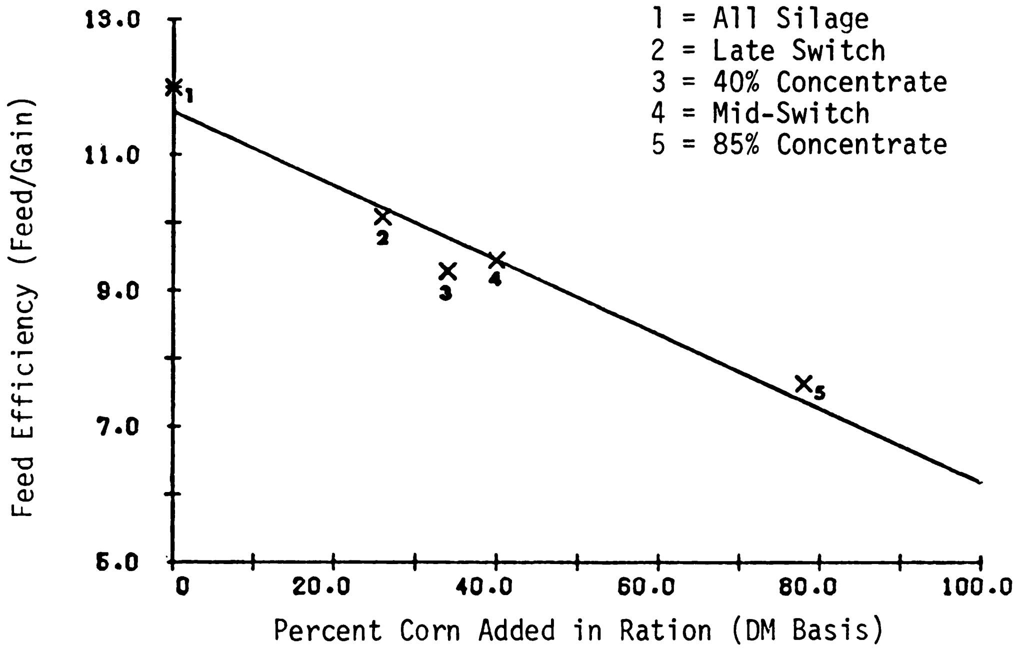


Figure 3. Average Daily Gain and Feed Efficiency with Regression Lines for Trial 1.

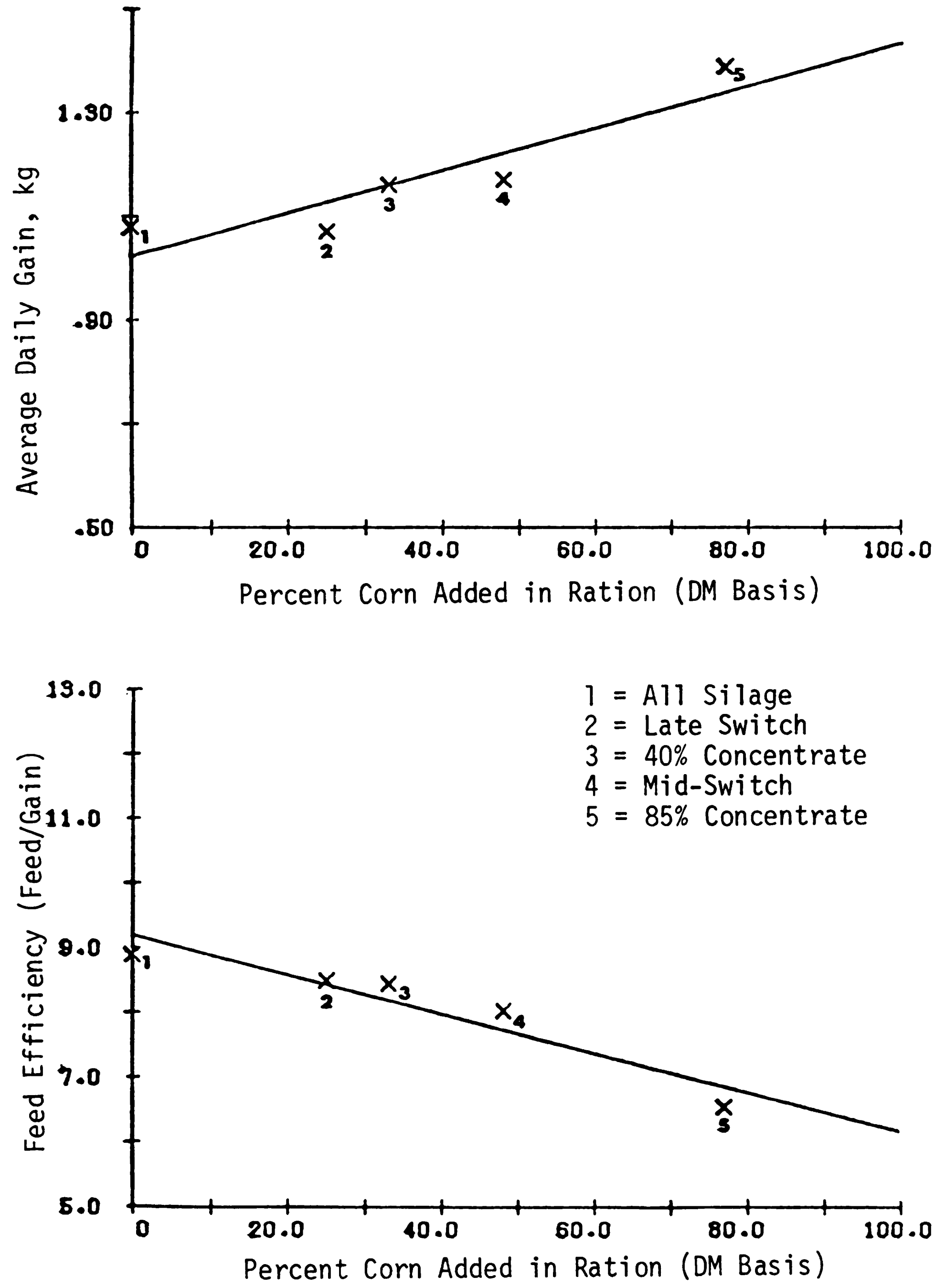


Figure 4. Average Daily Gain and Feed Efficiency with Regression Lines for Trial 2.

Table 7. Feedlot Performance[a] (Trial 3)

Ration: Energy level		100% Corn silage			68:32 (CS:Conc)			100% Concentrate		
Protein level		7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Initial wt, kg[b]		190	190	189	191	190	189	190	190	190
Final wt., kg[c]		336	372	397	382	379	384	397	388	389
Days on feed[d]		303	226	248	261	205	205	205	198	198
Average daily gain		0.48	0.80	0.84	0.73	0.93	0.95	1.01	1.00	1.01
Average daily dry matter consumption[e]	C.S.	5.3	5.8	5.5	4.2	4.3	4.1	0.1	0.1	0.1
	H.M.C.	0	0	0	1.6	1.5	1.3	5.8	5.4	5.1
	Supp.	0.05	0.45	0.86	0.05	0.36	0.77	0.09	0.27	0.54
	Total	5.35	6.25	6.36	5.85	6.16	6.17	5.99	5.77	5.74
DM/unit gain[e]		1108	771	761	797	668	650	595	583	578
Dressing, %		56.1	59.2	60.2	58.4	59.2	59.3	61.0	60.4	60.5
Carcass fat, %[f]		25.2	27.8	31.4	30.8	32.3	32.0	36.0	35.3	34.4
% Grading choice		40	50	63	63	40	50	65	75	60

[a]Twenty heifers/treatment except 68:32--low protein which had 19 due to one death loss.

[b]Initial wt. taken after 16 hr without feed and water.

[c]Final wt. = hot carcass wt ÷ .594 (avg. dressing % for all cattle) x 100.

[d]Slaughter date was determined when one pen was estimated to grade 80% choice with remaining pens slaughtered at approximately the same carcass weight.

[e]Dry matter of corn silage and high moisture corn was adjusted using the correction factors determined by Fox and Fenderson (1976) to account for errors in oven drying procedures. Correction factors: Corn silage = 1.068; HMC = 1.03.

[f]Based on specific gravity calculations using 10 heifers per pen.

grain occurred at the low protein level where cattle on the 68% CS ration gained 53% faster than those on 100% CS while those on 100% Conc outgained those at 68% CS by 38% (Figure 5). At the intermediate and high protein levels, ADG was improved 6 to 15% from the addition of grain.

The response to additional protein varied depending upon energy level (Figure 6). Cattle fed 100% CS or 68% CS rations had 67% and 26% higher ADG, respectively, from the addition of soybean meal up to the intermediate level. No significant improvement in gain occurred by increasing protein to the high level. Cattle fed 100% Conc rations did not respond to added protein. The responses observed at different protein levels may be partially explained by considering weather conditions. The winter of 1976-77 included some periods of very severe cold during which gains were reduced. Previous research by Ames (1976) has demonstrated that when gains are slowed due to severe weather, protein requirements are decreased. In addition, cattle in this trial were fed monensin which has recently been suggested to have a "protein sparing" effect (Byers and Moffitt, 1977; Gates et al., 1977; Gill et al., 1977; Hanson and Klopfenstein, 1977). Thus, in this experiment the protein requirements of the heifers on the 100% silage and 68% silage rations were met by the intermediate level of 10.9% crude protein in the ration. Protein requirements of the cattle fed the 100% concentrate ration were met by the high moisture corn and no additional soybean meal was needed.

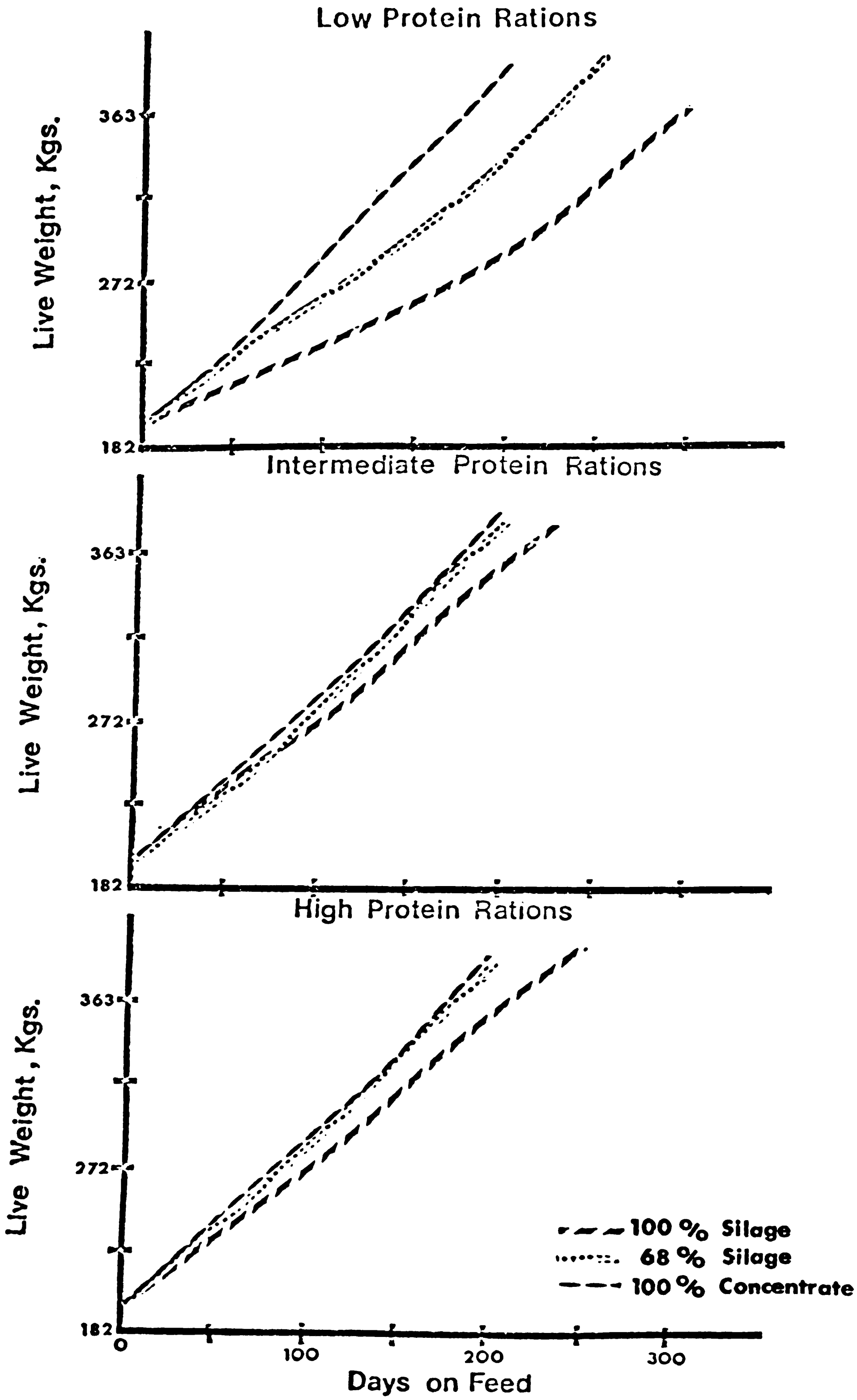


Figure 5. Effect of Energy Level on Low, Intermediate and High Protein Rations for Trial 3.

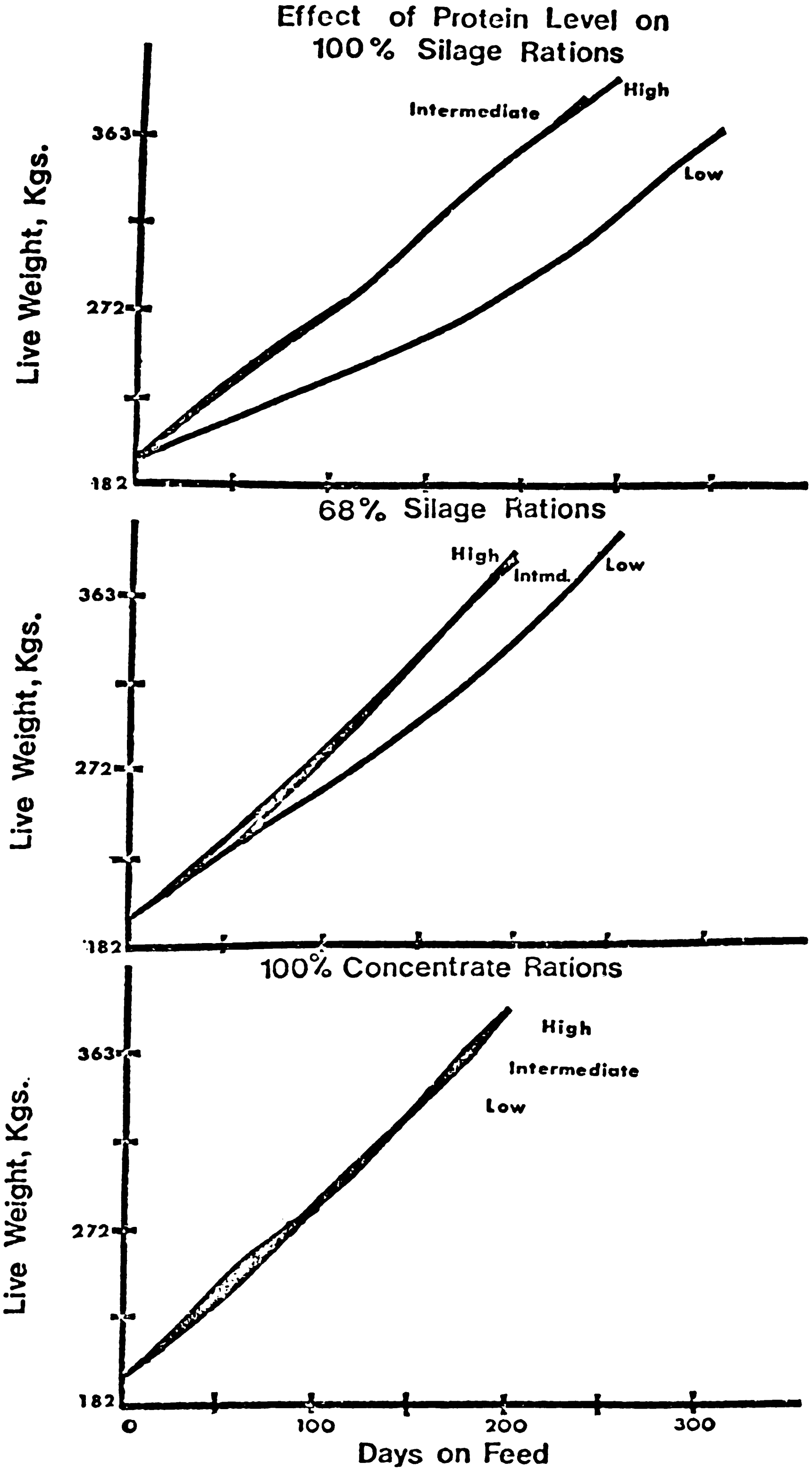


Figure 6. Effect of Protein Level on 100% Silage, 68% Silage and 100% Concentrate Rations for Trial 3.

No difficulty was encountered in maintaining constant intake levels with 100% concentrate rations. Further, no founder problems were encountered. This was in contrast to Trial 2 when several steers on the 85% concentrate ration foundered.

Feed efficiency, as measured by DM consumed per unit gained, followed the same response pattern as ADG. Cattle fed a low protein ration at 68% CS gained 28% more efficiently than those at 100% CS. A further 25% increase in efficiency was observed at the 100% Conc level compared to 68% CS. Efficiency improved 11 to 15% at the intermediate and high protein levels as more grain was added to the ration. The effect of protein on efficiency was demonstrated when comparing the intermediate protein level to the low level for 100% CS and 68% CS levels. Cattle on 100% CS and 68% CS intermediate protein levels gained 30% and 16%, respectively, more efficiently than low protein fed cattle. All other effects of protein level on efficiency were minor.

This series of experiments demonstrates the effect of ration on dressing percentage. Those cattle fed high silage averaged 1.6% lower in steers and 0.8% lower in heifers than cattle fed high grain. Final live weight was adjusted to the same dressing percentage for all treatments within each trial to remove this bias. Without this adjustment, performance of those fed high silage would be inflated due to a greater fill.

Carcass Characteristics

Carcass characteristics for Trials 1 and 2 are presented in Table 8. In order to correctly evaluate the effect of ration on carcass composition, all carcass traits were adjusted to the mean hot carcass weight for each trial. In yearling steers, energy level had little effect on marbling score or quality grade. Increasing energy level did, however, significantly increase fat thickness and yield grade while reducing rib eye area (REA) and % retail product (Figure 7).

Energy level also had an effect on carcass characteristics in Trial 2 although the pattern was somewhat different. Those cattle fed a 40% concentrate ration continuously had higher marbling scores and quality grades while those fed 100% silage had lower marbling scores and quality grades when compared at equal weights. Ration energy level was approaching significance for adjusted fat thickness while no effect of energy could be seen on REA, KPH fat %, yield grade or % retail product (Figure 8).

Carcass characteristics for Trial 3 are presented in Tables 9 and 10. Table 9 contains the means of all carcass traits for each treatment as well as the significance level of the main effects. Table 10 is a summation by protein and energy level for traits which had no interaction. All traits were adjusted to a constant hot carcass weight.

In all parameters measured, protein level had no significant effect on carcass traits. Much of the variation between treatments

Table 8. Carcass Characteristics by Treatment (Trials 1 and 2)

	85% Conc	40% Conc	Mid-switch	Late switch	100% silage	Significance of Energy Effect
			Trial 1[a]			
Marbling[c]	11.6	12.1	11.6	11.4	10.9	>.20
Quality grade[d]	9.9	10.1	10.0	9.9	9.7	>.20
Adjusted fat,[e] cm	1.19	1.02	0.97	1.02	0.86	<.005
Rib eye area, cm^2	74.2	79.4	80.0	80.0	80.0	.04
KPH fat, %	2.4	2.4	1.5	1.6	1.5	<.005
Yield grade	3.0	2.7	2.5	2.5	2.3	<.005
% Retail product	68.4	69.6	70.9	70.5	71.6	<.005
			Trial 2[b]			
Marbling[c]	10.5	12.6	11.3	10.8	8.4	.08
Quality grade[d]	9.4	10.4	9.8	9.5	8.1	.03
Adjusted fat,[e] cm	0.94	1.19	1.19	0.97	0.76	.10
Rib eye area, cm^2	87.7	92.3	85.2	85.2	84.5	>.20
KPH fat, %	1.6	2.2	2.1	2.0	1.5	>.20
Yield grade	2.2	2.4	2.7	2.5	2.2	>.20
% Retail product[f]	71.6	69.7	69.3	70.7	72.7	>.20

[a]All traits adjusted to a constant hot carcass weight of 312 kg.

[b]All traits adjusted to a constant hot carcass weight of 342 kg.

[c]Marbling score: 9 = slight+; 10 = small-; 11 = small°.

[d]Quality grade: 8 = Good°; 9 = Good+; 10 = Choice-.

[e]Fat thickness adjusted by USDA grader.

[f]Based on equation from Crouse and Dikeman (1976): 78.3 - 5.33 (adj. fat, cm) + .112 (REA, cm^2) - .95 (est. KPH fat, %) - .0227 (carc wt, kg) - .215 (marbl. score).

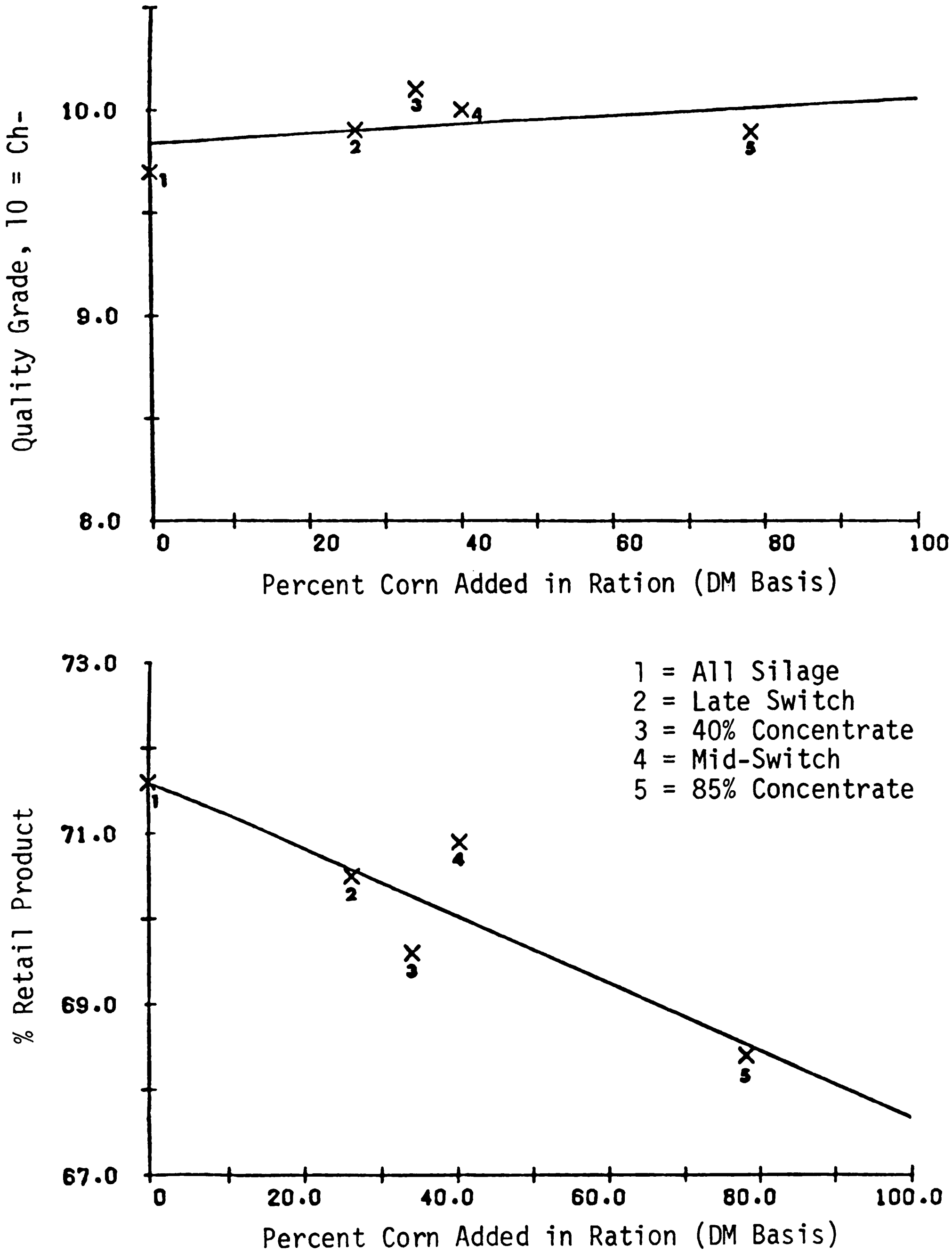
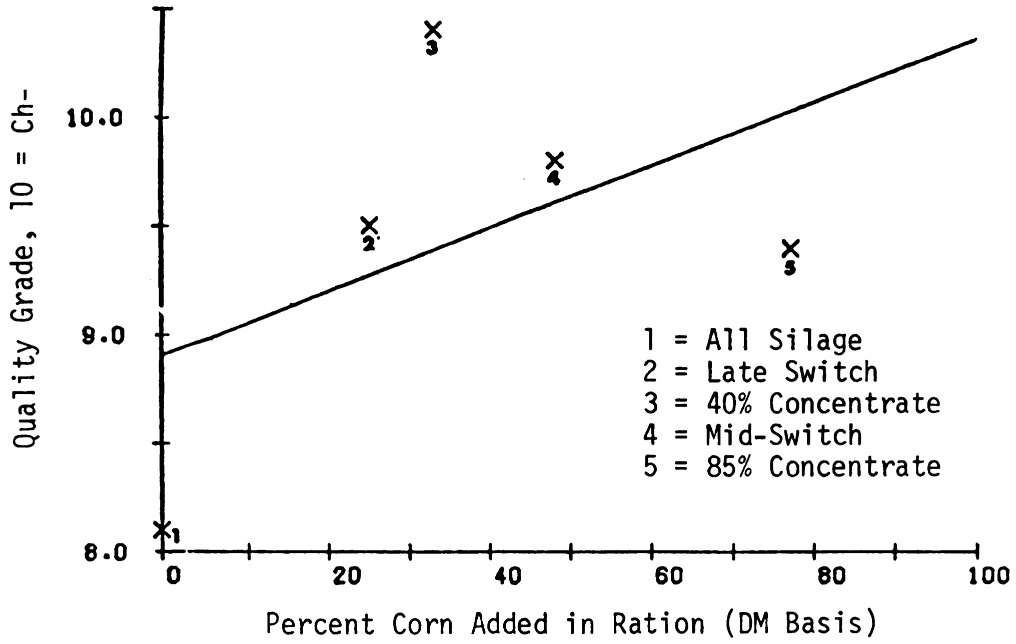


Figure 7. Effect of Energy Level on Quality Grade and % Retail Product with Regression Lines for Trial 1.



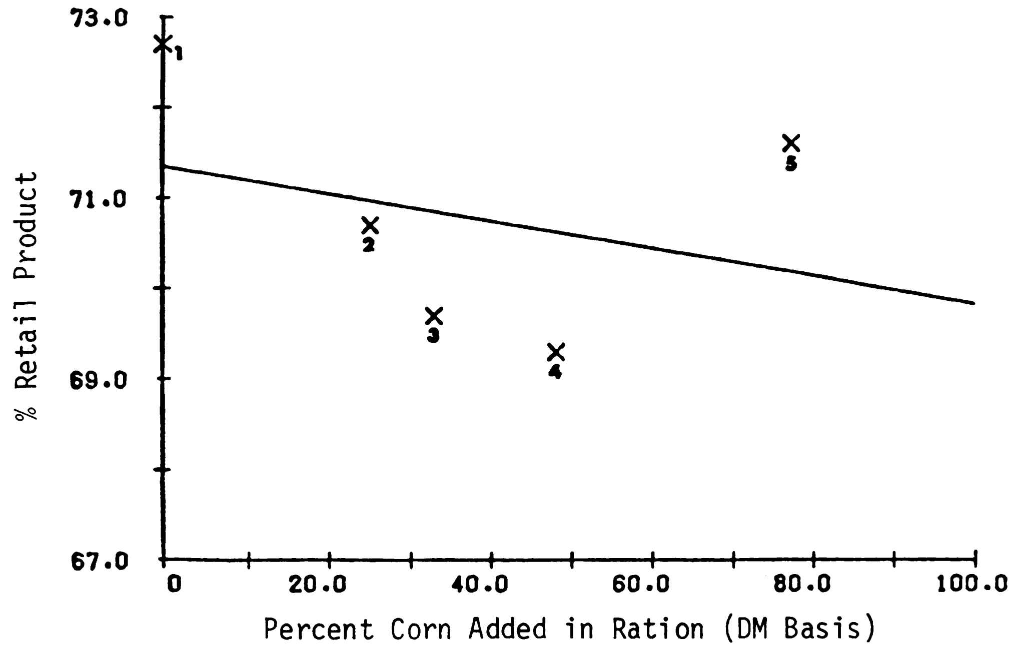


Figure 8. Effect of Energy Level on Quality Grade and % Retail Product with Regression Lines for Trial 2.

Table 9. Carcass Characteristics by Treatment (Trial 3)[a]

Ration: Energy level	100% Corn silage			68:32 (CS:Conc)			100% Concentrate			Significance of Main Effects	
Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%	Protein	Energy
Marbling[b]	9.2	9.9	9.1	10.2	10.0	9.1	10.6	10.3	9.7	.20	>.20
Quality grade[c]	8.7	9.0	8.6	9.3	9.1	8.8	9.5	9.6	9.2	>.20	.13
Adjusted fat,[d] cm	0.84	0.91	0.97	0.91	1.12	1.04	1.32	1.47	1.42	.12	<.005
Rib eye area, cm^2	68.4	66.5	68.4	69.7	68.4	67.1	62.6	63.2	64.5	>.20	<.005
KPH fat, %[e]	2.5	3.1	3.1	3.0	3.1	3.2	3.3	3.1	3.0	--	--
Yield grade	2.3	2.6	2.3	2.4	2.7	2.7	3.2	3.2	3.1	>.20	<.005
% Retail product[f]	72.0	70.7	70.8	71.1	69.8	70.2	67.7	67.3	67.9	.13	<.005
% Carcass fat[g]	26.9	28.3	30.9	30.4	32.4	31.9	35.4	35.0	34.1	>.20	<.005
% Carcass protein[g]	16.1	15.8	15.2	15.3	14.8	14.9	14.1	14.2	14.4	>.20	<.005

[a]Adjusted to constant hot carcass weight of 226 kg.

[b]Marbling: 9 = slight+; 10 = small-; 11 = small°.

[c]Quality grade: 8 = Good°; 9 = Good+; 10 = Choice-.

[d]Fat thickness adjusted by USDA grader.

[e]No main effects were tested since there was a highly significant interaction ($P < .005$).

[f]Based on equation from Crouse and Dikeman (1976): 78.3 - 5.33 (adj. fat, cm) + .112 (REA, cm^2) - .95 (est. KPH Fat, %) - .0227 (carc. wt, kg) - .215 (marbl. score).

[g]Determined using specific gravity techniques.

Table 10. Carcass Characteristics Summarized by Protein and Energy Level (Trial 3)[a]

	Protein level			Energy level		
	Low	Interm	High	100% CS	68% CS	100% Conc
Marbling[b]	10.0	10.1	9.3	9.4	9.8	10.2
Quality grade[c]	9.2	9.2	8.9	8.8	9.1	9.4
Adj. fat,[d] cm	1.02	1.17	1.14	0.91	1.02	1.40
REA, cm^2	67.1	65.8	66.5	67.7	68.4	63.2
YG	2.6	2.8	2.7	2.4	2.6	3.2
% Ret. prod.[f]	70.3	69.3	69.6	71.1	70.4	67.6
% Carcass fat[g]	30.9	31.9	32.3	28.7	31.6	34.8
% Carcass protein[g]	15.2	14.9	14.8	15.7	15.0	14.2

[a]Adjusted to constant hot carcass weight of 226 kg.

[b]Marbling score: 9 = slight+; 10 = small-; 11 = small°.

[c]Quality grade: 8 = Good°; 9 = Good+; 10 = Choice-.

[d]Fat thickness adjusted by USDA grader.

[e]No main effects were tested since there was a highly significant interaction ($P < .005$).

[f]Based on equation from Crouse and Dikeman (1976): 78.3 - 5.33 (adj. fat, cm) + .112 (REA, cm^2) - .95 (est. KPH Fat, %) - .0227 (carc. wt, kg) - .215 (marbl. score).

[g]Determined using specific gravity techniques.

was due to energy level (Figure 9). Those cattle on 100% Conc rations had significantly more backfat, smaller rib eyes and poorer yield grades with a lower percentage of retail product than those on 100% CS or 68% CS rations. In addition, they had a higher carcass fat percentage and a lower carcass protein percentage. Differences between the 100% CS and 68% CS rations were small for all carcass traits except for the body composition data which revealed that those on 100% CS rations had a lower carcass fat percentage and a higher carcass protein percentage. Across all three energy levels, marbling and quality grade differences were only slight and could be explained by normal animal variation. Thus, in Trial 3 there was a distinct effect of ration on carcass composition which revealed that those on 100% concentrate rations deposited more external fat with no corresponding increase in marbling. Furthermore, those cattle fed 100% CS had carcasses with a lower percentage fat and a higher percentage protein. This is supported by other researchers at this station who determined that at constant weights, high grain fed cattle will have more carcass fat and fat thickness with no effect of energy on carcass quality (Crickenberger, 1977; Woody, 1978; Harpster, 1978).

Similar conclusions were also reached by other workers (Young and Kauffman, 1978; Preston, 1975; Gill et al., 1976; Buchanan-Smith and Alhassan, 1975; Prior et al., 1977; Smith et al., 1977; Ferrell et al., 1978; Utley et al., 1975). Together these experiments lend strong support for the theory that the maximum potential for protein and muscle growth is genetically set; thus energy intake above needs for protein deposition is stored as fat.

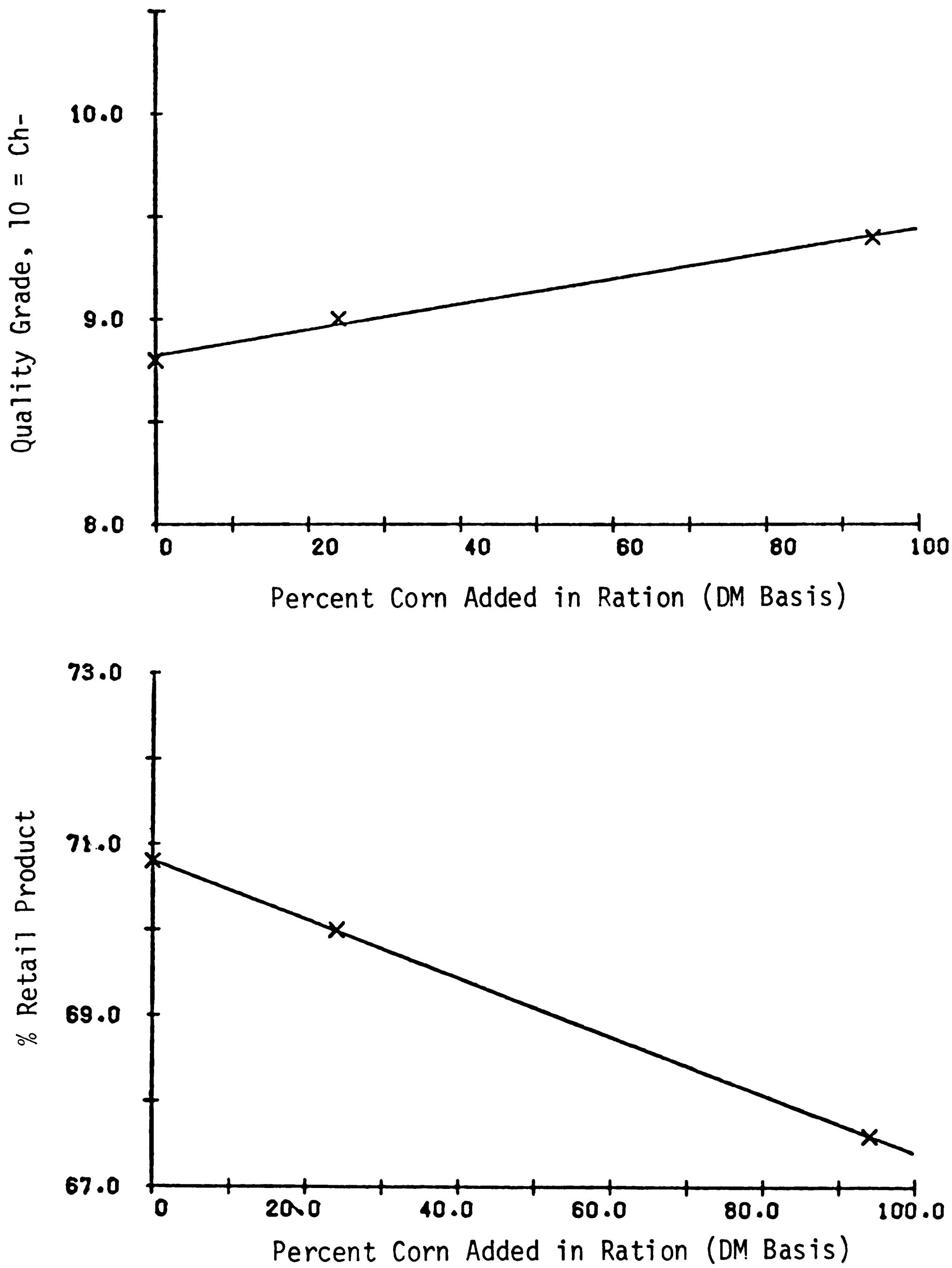


Figure 9. Effect of Energy Level on Quality Grade and % Retail Product with Regression Lines for Trial 3 (Values Are Pooled for all Protein Levels).

Energetic Efficiency

Energetic efficiency was calculated as metabolizable energy (ME) consumed per kg of retail product gained (Table 11). This measure was chosen because it reflects not only differences in the energy density of the dry matter intake but also differences in the composition of the gain. ME intake was determined using NRC (1976) ME values and unadjusted dry matter intake. Percentage retail product (RP) was determined using the equation of Crouse and Dikeman (1976).

In Trial 1, differences in energetic efficiency were small, except those on the mid-switch program tended to be more efficient than the others. Steer calves were more efficient at converting ME to retail product than yearling steers. This undoubtedly reflects the higher maintenance costs of yearling steers since they were much heavier at the start of the feeding trial.

Comparisons of energetic efficiency between steer calves tends to favor those fed high grain or high silage. However the low fat content of the carcasses of the high silage cattle would have influenced this measurement. There were no clear trends in differences in energetic efficiency among the other three systems.

The heifer calves of Trial 3 were less efficient in their utilization of energy from high concentrate rations than steer calves but were equal to or superior in their utilization of high silage rations.

Since underfeeding protein is not a typical feedlot practice, the unsupplemented rations will be excluded from comparisons among

Table 11. Energetic Efficiency

	Trial 1					Trial 2				
	85% Conc	40% Conc	Mid-switch	Late switch	100% Silage	85% Conc	40% Conc	Mid-switch	Late switch	100% Silage
Total ME intake, Mcal[a]	3,175	3,125	3,308	3,554	3,307	5,566	6,077	6,265	6,498	5,655
Kg retail product[b]	51.2	50.1	55.6	56.3	53.4	134.8	123.6	126.5	137.1	132.4
ME/kg retail product, Mcal	62.0	62.4	59.5	63.1	61.9	41.3	49.2	49.5	47.4	42.7

Ration	Trial 3								
Energy level	100% CS			68:32 (CS:Conc)			100% Conc		
Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Total ME intake, Mcal[a]	3,799	3,353	3,837	3,941	3,269	3,280	3,841	3,583	3,574
Kg retail product[b]	66.2	76.2	85.3	80.7	76.7	80.3	78.0	72.6	76.7
ME/kg retail product, Mcal	57.4	44.0	45.0	48.8	42.6	40.9	49.2	49.4	46.6

[a]Metabolizable energy (ME) values used were (Mcal/kg DM): Corn silage = 2.54; high moisture corn = 3.28; supplement = 2.93 x % soybean meal in each supplement (NRC, 1976). ME intake was not adjusted for errors in dry matter determination.

[b]Kg retail product = hot carcass weight x unadjusted % retail product. For determination of % retail product see Table 8.

treatments in Trial 3. Removing the low protein rations allows for combining the remaining rations by protein and energy level since it removes the source of interaction.

At all three energy levels, there is no appreciable difference between the intermediate and high protein treatments ($P > .2$). When the two protein levels are combined, those cattle fed 68% CS rations were the most efficient followed by those fed 100% CS rations, while those fed the high concentrate 100% Conc rations were the least efficient ($P < .075$).

These conclusions do not agree with those of Harpster (1978) who observed efficiency of ME use for production of edible beef was not influenced by ration energy level. Likewise Smith et al. (1977) concluded that Mcal of metabolizable energy per kg gain did not differ among rations varying in energy density. However, Prior et al. (1977) reported that in small type cattle, a more efficient utilization of energy for production of carcass retail product was obtained with a low energy ration while large type cattle showed only very small differences in efficiency.

The results of Trial 3 do agree with the conclusions of Klosterman and Parker (1976) who noted that lower energy rations were best utilized by early maturing types which consume more feed per unit of weight.

Associative Effects

The energy value of a ration is generally assumed to be the sum of the energy values of the dietary ingredients. However, several investigators have suggested that the energy value of an ingredient is not constant but is dependent upon the associative effects (interaction with other ingredients in the ration). If this is true, then the energy value of feedstuffs ought to be higher when fed by themselves than when fed in a mixed ration.

One explanation for this interaction, as proposed by Kromann (1971), is that the micro-organisms in the rumen use the most readily available carbohydrate as an energy source. Thus when a ration consisting of both high fiber and high carbohydrate sources is fed, the high fiber portion is utilized less efficiently.

If, in fact, corn grain and corn silage are used more efficiently when fed alone, then feeding a mixture of them, such as the 68% corn silage, 32% concentrate ration in this experiment, should give lower than predicted feed efficiency. By weighting the efficiencies (DM/cwt gain) of the 100% CS and 100% Conc rations, the efficiency of the 68% CS ration can be predicted as follows (excluding low protein rations): (0.68) (DM/cwt gain for 100% CS) + (.32) (DM/cwt gain for 100% Conc) = DM/cwt gain for 68% CS.

	Predicted	Observed
Intermediate protein	711	668
High protein	702	650

Comparing the predicted efficiency to the observed efficiency reveals that there was no depression but actually there was an improvement in feed efficiency. Those cattle fed the mixture of corn and corn silage were 6 to 8% more efficient at converting feed to gain than was predicted based on the efficiencies of each ingredient fed alone. One problem in validating this comparison lies in the use of 100% concentrate rations to determine the efficiency of corn grain. In order to maintain normal rumen function, it is generally recommended and widely practiced to include a minimum of 5 to 10% fiber in the diet. By feeding 100% concentrate rations with no additional fiber, this could have caused a decrease in rumen effectiveness and thereby depressed feed efficiency. The extent to which this may have occurred is not known but this is merely pointed out to avoid erroneous conclusions.

Ration Net Energy Values

In Trial 3 net energy values for each ration were calculated and are presented in Table 12 along with net energy values published by NRC (1976). Since lack of protein was obviously limiting energy utilization on the 100% CS, low protein and 68% CS, low protein rations, these will be ignored in this discussion. Calculated net energy for maintenance values for 100% CS and 68% CS rations compare very closely to those of NRC. However, the 100% concentrate rations calculated values were 5% lower than those of NRC.

Net energy for gain values of 100% CS rations agree very closely with those of the NRC (Figure 10). NEg values of 100% concentrate rations averaged 12% below those of NRC. If energy

Table 12. Net Energy Values for Rations (Trial 3)[a]

Ration	Energy level	100% CS			68:32 (CS:Conc)			100% Conc		
	Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
NE_m	Predicted[b]	1.54	1.59	1.61	1.74	1.74	1.74	2.20	2.20	2.18
	Actual[c]	1.41	1.54	1.61	1.68	1.74	1.74	2.09	2.09	2.07
NE_g	Predicted[b]	0.99	1.01	1.01	1.12	1.12	1.12	1.46	1.46	1.43
	Actual[c]	0.84	0.95	1.06	1.08	1.17	1.17	1.26	1.30	1.28

[a]All values are expressed in Mcals/kg of dry matter.

[b]Values are predicted from NRC (1976).

[c]Values were calculated using the Comparative Slaughter Technique in conjunction with NRC (1976) ME values. ME intake was not adjusted for errors in dry matter determination.

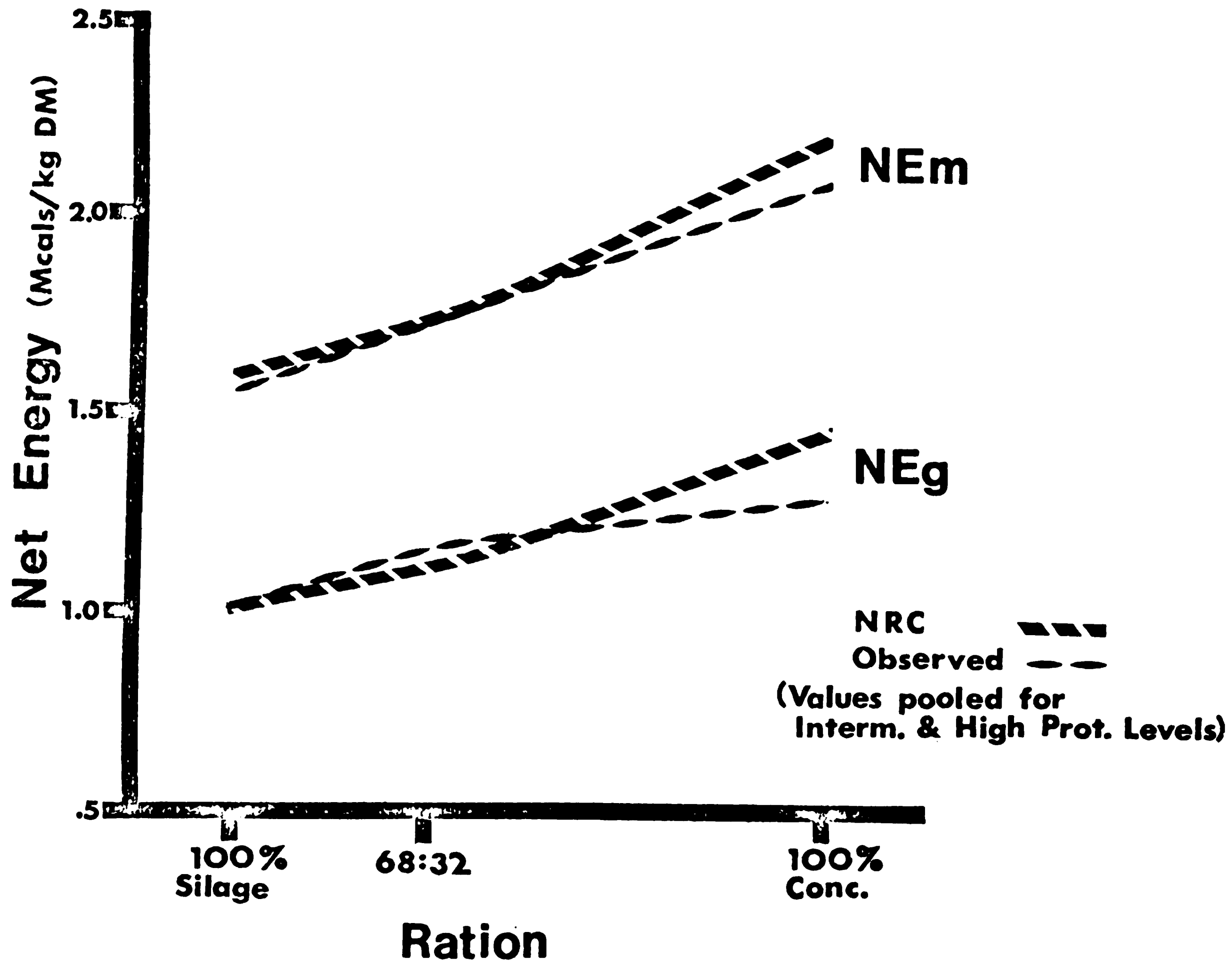


Figure 10. Comparison of NRC to Observed Net Energy Values.

utilization increased linearly as more grain was added to the ration then one would expect NEg values of 68% CS rations to be somewhat lower than those of NRC due to the low NEg value of the corn. However, this clearly was not the case. In fact when 32% corn grain was added to the silage the NEg values of the rations actually improved 4% over NRC and 6% over what would have been expected based on NEg values of the silage and corn grain when each was fed separately. Clearly, the cattle fed the mixture of the two feeds were more efficient at utilization of the energy than the cattle fed each feed separately. These conclusions support those previously discussed regarding associative effects of feeds. They are in direct conflict with those of Byers et al. (1975a; 1975b) who observed NEm and NEg values were depressed 4 to 15% below the predicted values when corn and corn silage were fed in combination indicating marked feed interaction.

Cost Summary

In yearling steers (Trial 1) the 85% concentrate ration provided the most economical gains at all corn prices studied. The 40% concentrate ration provided slightly more economical gains than the mid-switch which was slightly lower cost than the late switch. At all corn prices studied, the 100% silage ration was the most expensive by a wide margin. The additional expense of feeding an all silage ration was a combination of both feed and non-feed costs.

In the Charolais crossbred steer calves (Trial 2) the pattern was somewhat different. At low corn prices the 85% concentrate provided the least-cost ration. However at $3.67/bu the 100% silage

ration became more economical. At slaughter only 25% of the all-silage cattle graded choice, however. Had these cattle been finished out to similar carcass compositions as the other pens, their feed efficiencies would have declined and feed costs have risen. The same situation exists with the late switch cattle since only 50% of them graded choice. The 40% concentrate and mid-switch cattle were nearly identical in their costs of gain which averaged approximately $4/cwt gain more than the 85% concentrate cattle.

The results of both steer trials would agree with the work of Harpster (1978) who determined that corn grain would have to increase to $5.50/bu before an all corn silage ration would become least cost. This conclusion was based on steer calves of beef breeds of cattle. However for Angus x Hereford x Holstein steer calves the price of corn would need only be $2.50/bu for an all silage ration to be less expensive.

Similar results were also obtained by Larson et al. (1976) when they determined that Hereford yearling steers produced the lowest cost gains when the ration contained 29.4% corn silage. However, Utley et al. (1975) concluded that both calves and yearlings fed an all-forage diet returned more profit than those fed a high energy diet. Neither Larson et al. (1976) or Utley et al. (1975) adjusted DM intakes for errors in oven drying procedures which may or may not have changed their conclusions.

Costs for Trial 3 Hereford heifers are summarized in Table 14. At all corn prices studied, the intermediate protein,

Table 13. Cost Summary (Trials 1 and 2)[a]

		Trial 1					Trial 2				
		85% Conc	40% Conc	Mid-switch	Late switch	100% Silage	85% Conc	40% Conc	Mid-switch	Late switch	100% Silage
Non-feed cost[b]		5.65	6.79	7.67	8.16	10.08	5.71	7.40	7.18	8.16	8.45
Feed cost:[c]											
Corn price	$2.00/bu	30.32	31.18	31.67	32.23	34.35	27.03	29.21	29.24	28.33	26.74
	$3.00/bu	45.08	45.74	46.48	47.00	49.38	40.24	42.88	43.03	41.30	38.48
	$4.00/bu	59.84	60.31	61.29	61.76	64.41	53.44	56.54	56.82	54.27	50.21
Total cost:											
Corn price	$2.00/bu	35.97	37.97	39.33	40.39	44.43	32.74	36.61	36.41	36.49	35.19
	$3.00/bu	50.73	53.53	54.14	55.16	59.46	45.95	50.28	50.21	49.46	46.93
	$4.00/bu	65.49	67.10	68.95	69.92	74.49	59.15	63.94	64.00	62.44	58.66

[a]All costs are expressed in $ per cwt gain.

[b]Non-feed cost = $\frac{\text{interest charge} + \text{manure handling cost} + \text{facility cost} + \text{feeding cost}}{\text{ADG}}$.

[c]Prices of corn, corn silage and soybean meal, respectively ($/cwt, as fed): at $2.00/bu = 3.57, 0.78, 8.03; at $3.00/bu = 5.36, 1.11, 12.16; and at $4.00/bu = 7.14, 1.45, 16.28. Other prices constant ($/cwt): deflourinated phosphate, 13.00; limestone, 2.00; trace mineral salt, 4.20; vitamin A_{30}, 48.00; vitamin D_3, 20.00.

Table 14. Cost Summary (Trial 3)[a]

Ration	Energy level	100% Corn silage			68:32 (CS:Conc)			100% Concentrate		
	Protein level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Non-feed cost[b]		13.81	8.35	8.07	8.64	6.95	6.86	5.58	5.72	5.77
Feed cost:[c]										
Corn price	$2.00/bu	28.85	23.74	26.29	24.43	22.55	24.32	25.25	25.83	26.96
	$3.00/bu	40.34	33.52	37.60	35.06	32.36	35.17	37.36	38.09	39.83
	$4.00/bu	51.83	43.31	48.91	45.69	42.17	46.02	49.46	50.35	52.70
Total cost:										
Corn price	$2.00/bu	42.66	32.09	34.36	33.07	29.50	31.18	30.83	31.55	32.72
	$3.00/bu	54.15	41.87	45.67	43.70	39.31	42.03	42.94	43.81	45.60
	$4.00/bu	65.64	51.66	56.98	54.33	49.12	52.88	55.04	56.07	58.47

[a]All costs are expressed in $ per cwt gain.

[b]Non-feed cost = $\frac{\text{interest charge} + \text{manure handling cost} + \text{facility cost} + \text{feeding cost}}{\text{ADG}}$.

[c]Prices of corn, corn silage and soybean meal, respectively ($/cwt, as fed): at $2.00/bu = 3.57, 0.78, 8.03; at $3.00/bu = 5.36, 1.11, 12.16; and at $4.00/bu = 7.14, 1.45, 16.28. Other prices constant ($/cwt): Deflourinated phosphate, 13.00; limestone, 2.00; potassium chloride, 3.00; trace mineral salt, 4.20; vitamin A_{30}, 48.00; vitamin D_3, 20.00; and rumensin, 268.00.

68% silage, 32% concentrate ration was least cost. At approximately $2.25/bu corn, the intermediate protein, 100% silage ration became more economical than the unsupplemented 100% concentrate ration. At all prices, the unsupplemented 100% silage ration was the most expensive.

These results agree well with those from the Ohio Station by Klosterman and Parker (1976) and Newland (1976) who concluded that heifers made greater economic returns when fed an all silage ration versus an all concentrate ration.

CONCLUSIONS

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

1. All cattle performed as expected from the energy level fed except in Trial 2 where 100% silage cattle gained faster than expected.
2. In Trial 3 the protein requirements of the heifers fed the 100% silage and the 68% silage rations were met by the intermediate level of 10.9% while protein requirements of the cattle fed the 100% concentrate ration were met by the high moisture corn with no additional soybean meal needed.
3. Cattle fed high silage averaged 1.6% lower dressing percentage in steers and 0.8% lower in heifers than cattle fed high grain.
4. In Trials 1 and 3 energy level had little effect on marbling score or quality grade while increasing energy level did significantly increase fat thickness and yield grade while reducing rib eye area and % retail product at an equal carcass weight.
5. In Trial 2 energy level had no effect on external fat thickness or muscling but 100% silage rations produced carcasses with lower marbling scores and quality grades.

6. Protein level had no effect on carcass characteristics in Trial 3.
7. In Trial 1, differences in ME/kg retail beef were small, except those fed on the mid-switch program tended to be most efficient.
8. In Trial 2, those fed the 85% concentrate ration continuously required the least ME/kg retail beef produced.
9. In Trial 3, considering only adequately supplemented rations, those heifers fed 68% CS rations were the most energetically efficient followed by those fed 100% CS rations, while those fed 100% Conc rations were the least efficient.
10. Dry matter efficiencies and ration net energy values indicate that the heifers performed better when fed a mixture of corn and corn silage than when each ingredient was fed alone.
11. In Trials 1 and 2, steers made the most economical gains when high concentrate rations were fed.
12. In Trial 3, heifers produced the lowest cost gains on adequately supplemented high silage rations while 100% Conc rations were competitive at low corn prices.

APPENDIX

Table A.1. Total Feed Consumption (as fed/cwt. gain).[a]

	85% Conc.	40% Conc.	Mid Switch	Late Switch	100% Silage
			TRIAL 1		
Corn silage, tons	.19	.81	.75	.99	1.60
Shelled corn, bu.	12.5	6.6	8.0	5.6	---
Supplement, lbs.	35.0	55.5	44.5	55.4	89.6
			TRIAL 2		
Corn silage, tons	.16	.72	.54	.83	1.15
Shelled corn, bu.	10.9	6.0	8.2	4.6	---
Supplement, lbs.	49.0	67.8	50.9	65.6	88.6

TRIAL 3

RATION Energy level	100% CS			68:32(CS:Conc)			100% Conc.		
Protein level	7.7	10.9	13.7	8.6	10.9	14.0	10.4	11.7	13.8
Corn silage, tons	1.6	1.0	1.0	.8	.7	.6	0	0	0
Shelled corn, bu.	0	0	0	4.7	3.6	2.9	12.1	11.4	10.8
Supplement, lbs.	13	62	113	9	44	89	12	30	59

[a]Adjusted to 35%, 84.5% and 90% DM for corn silage, shelled corn and soybean meal, respectively.

Table A. 2. Weight and Composition of Initial Slaughter Cattle (Trial 3).

No. of animals	Shrunk weight, kg	Carcass weight, kg	Dressing %	Carcass protein, %	Carcass fat, %
6	196.5	110.8	56.4	17.17	21.94

Table A.3 Calculation of Net Energy Values of Rations Fed to Hereford Heifers (Trial 3)

RATION Energy Level	100% Corn Silage			68:32 (CS:Conc)			100% Concentrate		
Protein Level	7.7%	10.9%	13.7%	8.6%	10.9%	14.0%	10.4%	11.7%	13.8%
Average initial wt. (lb)	418.000	412.000	416.000	428.500	419.500	416.000	409.500	427.000	419.500
% empty body protein, initial	17.800	17.800	17.800	17.800	17.800	17.800	17.800	17.800	17.803
% empty body protein, final	17.320	16.831	16.138	16.257	15.978	16.031	15.280	15.408	15.581
% empty body fat, initial	19.630	19.630	19.630	19.630	19.630	19.630	19.630	19.630	19.630
% empty body fat, final	22.571	25.010	28.465	27.879	29.273	29.000	32.750	32.115	31.247
Empty body wt., final (lb)	660.700	718.900	771.700	763.700	740.800	749.130	771.800	760.300	760.600
Days on feed	303.000	226.000	248.000	261.000	205.000	205.000	205.000	198.000	193.000
Average daily DM intake	11.030	12.870	13.280	12.230	12.900	12.970	12.880	12.460	12.460
Empty body wt., initial	386.441	380.894	386.441	396.148	387.828	384.592	378.583	394.762	387.828
Average protein gain/steer(lb)	45.536	52.859	55.707	53.392	49.208	51.620	50.711	46.665	49.207
Ave. energy gain protein(Mcal)	117.424	136.307	143.650	137.682	126.892	133.113	130.767	120.333	126.883
Average fat gain/steer(lb)	73.817	106.726	144.028	136.394	141.338	141.796	177.612	167.754	162.876
Ave. energy gain fat(Mcal)	313.579	453.381	611.840	579.414	600.414	602.359	754.509	712.632	691.909
Ave. daily ME-maintenance(Mcal)	4.654	4.829	5.020	5.025	4.925	4.941	4.995	5.009	4.986
Ave. daily ME-main. + gain(Mcal)	6.076	7.439	8.067	7.773	8.473	8.528	9.313	9.215	9.121
Ration ME value (Mcal/lb)	.551	.578	.607	.636	.657	.658	.723	.740	.732
Daily ME intake (Mcal)	12.541	14.826	15.458	15.129	15.944	16.005	18.869	18.204	18.154
Daily ME intake/unit met wt(kg)	208.496	237.203	237.862	232.742	249.978	250.269	291.931	281.252	232.253
Heat prod. (ME/kg of metab wt)	185.066	196.076	191.074	190.836	194.659	194.264	224.972	216.835	218.705
ME-protein equilibrium (Kcal)	136.974	126.799	123.198	125.475	120.086	119.860	119.465	119.012	119.354
NE for maintenance (Mcal/lb)	.642	.703	.728	.761	.794	.793	.945	.946	.941
NE for gain (Mcal/lb)	.376	.434	.478	.488	.530	.533	.569	.589	.580

TABLE A. 4. INDIVIDUAL SHRUNK WEIGHTS, ADG AND CARCASS DATA FOR ANGUS x HEREFORD YEARLING STEERS (TRIAL 1).

PEN NO.	ANIM. NO.	DAYS ON FEED	INITIAL WT, KG	FINAL WT, KG	ADG, KG	HOT CARC. WT, KG	MARB[A]	QUAL GRADE[B]	ADJ. FAT,[C] CM	EST. FAT,[D] CM	ACTUAL FAT,[E] CM	KPH FAT, %	REA, CM^2	YIELD GRADE
101	2	107	347.0	497.6	1.31	295.3	8	8	.64	1.02		1.5	76.8	2.0
	5	93	394.6	510.3	1.24	293.9	12	10	1.40	1.52	1.02	3.5	64.5	3.8
	10	93	379.8	494.4	1.24	293.0	11	10	1.40	1.02	1.14	2.5	73.5	3.1
	17	107	385.6	510.3	1.27	313.9	12	10	1.27	.76		1.0	65.8	3.3
	18	107	344.7	494.4	1.40	291.7	9	9	.76	.76		.5	71.0	2.2
	20	107	365.1	465.4	1.12	295.7	12	10	.76	.76		3.5	74.8	2.7
	22	107	378.8	487.6	1.02	308.9	12	10	1.14	.51		.5	74.9	2.6
	27	93	417.3	546.6	1.39	340.2	12	10	1.65	1.27	1.40	3.0	83.2	3.4
	29	93	410.5	555.7	1.56	324.3	12	10	.76	.76	.89	3.5	74.8	2.9
	30	93	401.4	530.7	1.39	319.8	12	10	1.02	1.02	.89	3.5	69.7	3.4
	32	107	417.3	555.7	1.29	350.6	12	10	1.27	.76		1.5	76.1	3.2
	40	107	353.8	467.2	1.06	291.7	12	10	1.40	.76		2.5	76.8	3.0
	43	93	446.8	594.2	1.59	367.0	12	10	1.65	1.27	1.40	3.5	79.4	3.9
	48	93	390.1	542.1	1.63	321.1	11	10	1.40	1.27	1.40	3.0	64.5	3.8
	56	93	428.7	591.9	1.76	357.4	12	10	1.40	1.27	1.02	3.0	84.5	3.2
	59	93	381.0	523.9	1.54	313.9	13	11	1.40	1.02	1.40	3.5	65.8	3.9
	69	107	406.0	555.7	1.40	340.7	11	10	1.02	.76		1.0	88.4	2.1
	75	93	437.7	595.8	1.73	372.9	11	10	1.02	1.02	.89	3.0	100.0	2.2
	80	107	369.7	478.5	1.02	291.7	14	11	1.78	1.02		2.0	66.4	3.5
	95	107	360.6	474.0	1.06	286.2	12	10	1.14	1.02		3.0	69.4	3.2
102	1	107	333.4	444.5	1.04	264.4	8	8	.64	.25		1.0	72.9	1.9
	3	93	387.8	510.3	1.32	306.2	13	11	.76	.51	.76	3.0	74.8	2.7
	4	93	408.2	545.6	1.49	327.5	11	10	1.27	.76	1.02	3.5	70.3	3.7
	6	107	356.1	505.8	1.40	290.8	8	8	.64	.76		2.0	61.3	1.9
	9	107	401.4	535.2	1.25	336.1	9	9	2.03	1.27		3.5	80.0	4.0
	16	93	387.8	514.8	1.37	304.8	12	10	1.40	1.02	1.02	2.5	78.1	3.0
	23	93	415.0	553.4	1.49	326.1	11	10	1.02	.76	.76	3.0	76.1	3.0
	25	107	365.1	455.9	.85	276.7	12	10	.76	.76		1.0	78.1	1.8
	39	107	394.6	523.9	1.21	340.2	12	10	1.14	1.02		2.0	77.4	3.0
	42	107	351.5	478.5	1.19	298.9	11	10	.64	1.02		.5	83.2	1.5
	61	93	378.8	508.0	1.39	298.5	12	10	.76	.76	.89	2.5	75.1	2.5
	63	107	360.6	464.9	.98	288.9	12	10	1.02	1.27		1.5	87.1	1.9
	64	107	372.0	494.4	1.14	301.6	23	14	1.27	.76		2.0	74.3	2.9
	66	93	444.5	587.4	1.54	349.3	14	11	1.02	.76	.76	2.5	83.2	2.7
	67	107	383.3	457.2	.78	299.9	8	8	1.27	.76		2.0	65.8	3.3
	71	93	440.0	571.5	1.41	340.7	12	10	.25	1.02	.51	3.5	74.8	2.5
	83	93	430.9	562.5	1.41	331.6	14	11	1.02	1.02	1.02	2.5	79.4	2.8
	93	93	419.6	553.4	1.44	335.2	14	11	1.27	.76	1.14	3.0	78.7	3.2
	94	107	375.5	474.0	.91	291.7	14	11	1.27	.76		3.0	72.3	3.2
	97	93	406.0	530.7	1.34	311.2	12	10	1.02	.76	.76	2.5	78.7	2.7

[A] MARBLING SCORES: SL = 8; SL+ = 9; SM- = 10.
[B] QUALITY GRADES: G = 8; G+ = 9; CH- = 10.
[C] ADJUSTED BY USDA GRADER.
[D] ESTIMATED BY ITHACO ULTRASONIC SCANOPROBE, ITHACO, N.Y.
[E] ACTUAL FAT THICKNESS MEASURED.

Table A.4--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade
103	7	128	369.7	526.2	1.22	299.8	13	11	.76	.64	.76	1.5	77.4	2.2
	15	107	433.2	573.8	1.31	351.5	12	10	.51	.51		1.0	89.7	1.6
	25	107	442.3	555.7	1.06	341.6	13	11	.89	.89		1.0	91.0	1.9
	35	128	349.3	486.3	1.07	280.3	11	10	.64	.76	.64	1.0	74.8	2.0
	39	107	403.7	546.6	1.34	320.2	13	11	.76	.76	.64	.5	76.1	2.2
	49	107	379.8	510.3	1.23	306.2	11	10	1.14	1.02		2.0	69.7	3.1
	50	107	403.7	519.4	1.08	316.2	15	11	.89	.51		2.5	67.1	3.2
	57	128	379.8	551.1	1.35	336.6	9	9	1.40	1.27	1.02	1.5	75.5	3.2
	58	128	367.4	523.9	1.22	316.6	12	10	.76	.76	.76	2.0	73.5	2.5
	60	128	387.8	539.8	1.19	312.1	8	8	1.27	1.02	1.52	1.5	78.1	2.7
	68	128	391.0	521.6	1.10	313.0	12	10	.89	.76	.76	1.5	85.2	2.9
	70	107	390.1	487.6	.91	293.5	14	11	1.14	.89		1.5	71.6	2.8
	77	107	424.1	562.5	1.29	340.2	12	10	.76	.76		1.0	72.3	2.7
	78	128	358.3	481.7	.96	291.2	12	10	.89	.76	1.27	1.0	80.6	2.0
	87	107	394.6	514.8	1.12	307.1	12	10	.89	1.02		1.5	69.0	2.8
	89	128	360.6	463.1	.96	292.6	8	8	.64	1.02	.76	1.0	87.1	1.4
	92	107	430.9	533.0	.95	317.5	12	10	1.78	1.02		3.5	75.1	3.8
	96	128	342.5	471.7	1.01	284.0	11	10	1.14	.89	1.02	2.0	79.4	2.4
	98	128	415.0	562.5	1.15	332.5	12	10	1.14	1.02		1.5	80.5	2.4
	100	107	410.5	510.3	.93	291.7	9	9	1.14	1.02		.5	76.1	2.3
104	11	128	387.8	519.4	1.03	311.6	11	10	.76	.51	.76	1.0	76.8	2.2
	14	128	399.2	526.2	.99	326.1	13	11	.89	.89	.89	2.5	83.9	2.4
	19	128	381.0	510.3	1.01	304.4	12	10	1.27	.76	1.02	2.0	76.8	2.8
	31	128	342.5	483.1	1.10	281.2	12	10	.64		.64	1.0	72.9	2.0
	33	128	412.8	530.7	.92	332.5	12	10	1.52	.76	1.65	2.5	73.1	3.4
	37	128	379.8	551.1	1.35	327.5	11	10	1.40	1.02		1.0	76.1	3.0
	46	128	376.5	512.6	1.06	285.8	12	10	.89	.76	1.02	1.5	74.3	2.4
	47	128	359.3	476.3	.92	280.8	11	10	1.40	.76	1.14	1.5	75.3	2.7
	51	128	351.5	474.0	.96	282.6	12	10	1.27	1.02	1.14	2.0	72.9	2.9
	53	128	396.9	531.6	1.05	325.2	13	11	1.02	.89	1.02	2.5	73.5	3.0
	62	128	440.0	587.4	1.15	361.5	9	9	.76	1.27	.64	1.0	83.4	2.0
	65	128	369.7	480.8	.87	293.9	12	10	.76	.76	.76	1.5	78.7	2.1
	72	128	417.3	567.0	1.17	331.6	9	9	1.52	.76	1.27	2.0	75.5	3.4
	74	128	426.4	598.8	1.35	348.8	11	10	.89	1.02	1.02	1.5	80.6	2.5
	81	128	369.7	495.7	.99	292.6	7	7	.89	.89	.89	1.0	87.1	1.7
	82	128	408.2	535.2	.99	331.1	12	10	.76	.76	.76	1.0	81.3	2.1
	85	128	406.0	555.7	1.17	336.8	13	11	1.27	.76	1.14	2.0	75.5	3.2
	86	128	360.6	496.7	1.06	287.6	12	10	.76	.76	1.02	2.0	73.5	2.4
	88	128	385.6	469.5	.66	291.7	12	10	.64	.51	.51	1.0	85.8	1.5
	99	128	453.6	616.9	1.28	330.1	12	10	1.27	1.02	1.02	2.5	81.3	3.4

[A]Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B]Quality grades: G = 8; G+ = 9; CH- = 10.
[C]Adjusted by USDA grader.
[D]Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E]Actual fat thickness measured.

Table A.4--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade
105														
	8	128	379.9	428.7	.78	257.2	12	10	.64	.76	.64	1.0	75.5	1.7
	12	128	365.1	499.0	1.05	289.4	15	11	.51	.76	.51	.5	81.9	1.4
	13	128	383.3	510.3	.99	301.6	11	10	.89	1.27	1.02	1.5	71.0	2.6
	21	128	406.0	537.5	1.03	314.3	12	10	.76	1.02	.89	1.5	79.4	2.2
	24	128	354.3	471.7	.89	265.4	11	10	.76	.64	.64	.5	70.3	2.0
	26	128	399.2	492.2	.73	265.8	12	10	.76	.76	.89	1.0	71.6	2.2
	34	128	390.1	548.9	1.24	326.6	11	10	.89	.89	.76	1.0	79.7	2.4
	36	128	369.7	503.5	1.05	291.2	8	8	.51	.76	.38	1.0	85.2	1.4
	41	128	430.9	523.9	.73	320.7	9	9	1.02	.76	1.02	1.5	76.1	2.7
	44	128	374.2	483.1	.85	276.7	11	10	.76	.76	.64	1.5	71.0	2.3
	45	128	455.9	562.5	.83	346.1	12	10	1.27	1.02		1.5	74.8	3.2
	52	128	410.5	546.6	1.06	329.3	11	10	.76	.76	.64	2.0	87.1	2.0
	54	128	392.4	532.1	1.09					.76				
	55	128	379.8	478.5	.78	283.5	11	10	.76	1.02	1.02	2.0	77.4	2.1
	73	128	437.7	626.0	1.47	370.6	9	9	1.14	.75	1.02	1.5	89.0	2.6
	76	128	367.4	485.4	.92	288.9	12	10	1.27	1.02	1.02	3.5	69.0	3.4
	79	128	381.0	533.9	1.19	313.0	8	8	.64	1.02	.51	1.0	76.1	2.1
	84	128	426.4	557.9	1.03	325.2	11	10	.76	.76	.76	1.5	85.3	2.0
	90	128	349.3	444.5	.74	268.1	12	10	.89	.76	.76	2.0	65.8	2.6
	91	128	410.5	523.9	.89	313.4	8	8	.76	.51	.51	1.0	75.5	2.3

[A]Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B]Quality grades: G = 8; G+ = 9; CH- = 10.
[C]Adjusted by USDA grader.
[D]Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E]Actual fat thickness measured.

TABLE A. 5. INDIVIDUAL SHRUNK WEIGHTS, ADG AND CARCASS DATA FOR CHAROLAIS CROSS STEER CALVES (TRIAL 2).

PEN NO.	ANIM. NO.	DAYS ON FEED	INITIAL WT, KG	FINAL WT, KG	ADG, KG	HOT CARC. WT, KG	MARB[A]	QUAL GRADE[B]	ADJ. FAT,[C] CM	EST. FAT,[D] CM	ACTUAL FAT,[E] CM	KPH FAT, %	REA, CM^2	YIELD GRADE
106														
	910	212	260.8	569.3	1.45	370.1	9	9	.64	.51		2.0	96.1	1.8
	911	212	256.3	551.1	1.39	359.7	12	10	1.02	.76		2.0	90.3	2.4
	912	212	240.4	517.1	1.31	341.6	9	9	1.02	.64		1.5	92.3	2.0
	916	191	244.9	483.1	1.25	300.3	7	7	1.27	.51		1.0	72.9	2.8
	923	191	274.4	553.4	1.46	349.3	8	8	.64	.76		1.5	90.3	1.8
	930	212	272.2	601.0	1.55	380.6	12	10	1.14	.76		1.5	87.1	2.7
	936	212	269.9	548.9	1.32	352.0	12	10	.89	.64		1.5	92.3	2.0
	939	212	247.2	451.3	.96	290.6	12	10	.76	1.02		1.5	78.1	2.1
	943	212	267.6	501.2	1.10	321.1	11	10	.76	.51		1.0	88.4	1.7
	949	212	260.8	521.6	1.23	336.1	12	10	.89	.76		1.5	81.9	2.4
	955	191	294.8	576.1	1.47	376.5	8	8	.76	.51		1.0	111.0	1.1
	969	191	285.8	564.7	1.46	362.9	12	10	1.02	.76		2.0	80.0	2.9
	973	191	254.0	546.6	1.53	350.2	11	10	1.14	.64		1.5	82.6	2.7
	983	191	279.0	519.4	1.26	331.1	11	10	1.02	.64		1.5	88.4	2.1
	987	191	249.5	555.7	1.60	344.7	11	10	1.14	.76		2.5	89.0	2.5
107														
	896	233	269.9	605.6	1.44	386.5	11	10	1.65	1.14	1.40	1.5	93.5	3.0
	899	233	292.6	542.1	1.07	347.9	10	10	.76	1.02	.38	2.0	83.4	2.1
	904	233	267.6	505.8	1.02	324.3	12	10	.89	1.02	.89	2.5	94.9	1.9
	919	233	272.2	596.5	1.39	345.2	17	12	1.52	1.02	1.52	3.5	96.1	2.8
	925	233	254.0	499.0	1.05	318.0	16	12	1.52	.76	1.27	3.5	80.6	3.3
	931	233	281.2	521.6	1.03	324.3	11	10	.89	.76	1.02	1.5	81.9	2.3
	934	233	249.5	535.2	1.23	342.5	17	12	1.40	1.02	1.14	2.0	81.3	3.1
	937	233	283.5	569.3	1.23	372.0	10	10	.76	.76	.51	2.0	103.9	1.6
	941	233	240.4	451.3	.91	296.2	15	11	1.65	1.27	1.27	3.0	78.1	3.3
	948	233	269.9	528.4	1.11	346.1	14	11	1.78	1.02	1.52	2.0	92.9	2.9
	954	233	258.6	551.1	1.26	336.1	8	8	.51	.76	.51	1.5	112.9	.7
	970	233	244.9	510.3	1.14	324.8	7	7	1.40	.76	.76	1.0	95.5	1.9
	971	233	235.9	548.9	1.34	344.3	10	10	.89	.76	.89	1.5	88.4	2.1
	980	233	256.3	483.1	.97	291.2	17	12	.89	1.02	.89	3.5	87.7	2.1
	986	233	276.7	555.7	1.20	362.9	15	11	1.40	1.02	1.27	2.5	97.4	2.6

[A] MARBLING SCORES: SL = 8; SL+ = 9; SM- = 10.
[B] QUALITY GRADES: G = 8; G+ = 9; CH- = 10.
[C] ADJUSTED BY USDA GRADER.
[D] ESTIMATED BY ITHACO ULTRASONIC SCANOPROBE, ITHACO, N.Y.
[E] ACTUAL FAT THICKNESS MEASURED.

Table A.5--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade
108	904	240	295.8	555.7	1.12	355.2	9	9	1.40	1.02	1.14	2.0	80.0	3.3
	909	240	233.1	522.5	1.19	340.7	11	10	1.40	1.02	1.27	3.0	81.9	3.2
	913	240	240.4	548.9	1.29	349.7	14	11	1.40	1.27	1.14	2.5	87.1	3.0
	915	240	244.9	524.4	1.16	336.6	8	8	.76	1.02	.76	2.0	87.1	2.1
	920	240	249.5	478.1	.95	307.1	18	12	1.65	1.52	1.52	2.5	83.2	3.0
	929	240	294.8	544.8	1.04	348.4	8	8	.51	.76	.38	1.5	85.8	1.9
	938	240	269.9	591.0	1.34	340.7	13	11	.64	.76	.51	2.0	94.8	1.6
	945	240	263.1	571.1	1.28	356.5	12	10	1.52	1.14	1.65	2.5	91.6	2.9
	946	240	256.3	524.4	1.12	337.5	12	10	1.65	1.02	1.78	2.0	76.8	3.5
	947	240	272.2	553.4	1.17	352.0	9	9	1.02	.76	.51	1.5	85.2	2.5
	957	240	251.7	526.6	1.15	347.0	14	11	1.40	1.27	1.02	2.0	81.3	3.1
	961	240	279.0	526.6	1.03	339.3	8	8	1.27	1.02	1.02	2.0	85.8	2.7
	968	240	269.9	528.9	1.08	350.2	12	10	1.27	1.02	1.02	3.0	87.1	2.9
	985	240	260.8	580.2	1.33	337.0	12	10	.76	1.02	.38	1.5	86.5	2.1
	988	240	254.0	533.4	1.16	349.7	9	9	.89	.76	.76	1.5	89.7	2.1
	990	240	276.7	524.4	1.03	340.7	12	10	1.52	.51	1.40	2.5	80.0	3.3
109	891	275	242.7	557.9	1.15	351.5	9	9	.76	.76	.64	1.5	92.3	1.9
	892	275	247.2	503.5	.93	324.3	17	12	1.27	.25	1.02	2.5	79.4	3.0
	895	275	274.4	533.0	.94	335.7	9	9	1.02	.64	.89	1.0	84.5	2.3
	897	275	272.2	626.0	1.29	396.9	12	10	.76	.51	.64	1.5	103.9	1.7
	901	275	238.1	512.6	1.00	315.3	15	11	1.27	.51	1.02	3.5	67.7	3.7
	906	275	260.8	560.2	1.09	344.7	9	9	.76	.76	.89	1.5	89.7	2.0
	927	275	269.9	555.7	1.04	348.4	7	7	.89	.51	.76	1.5	91.0	2.0
	932	275	256.3	632.8	1.37	304.6	14	11	1.40	1.02	1.27	3.0	92.9	3.1
	940	275	247.2	530.7	1.03	331.1	10	10	1.02	.76	.89	1.5	86.5	2.3
	944	275	279.0	530.7	.92	326.6	8	8	1.40	.64	1.40	1.5	79.4	2.9
	951	275	283.5	548.9	.96	335.7	12	10	.38	.51	.51	2.0	73.5	2.4
	960	275	290.3	571.5	1.02	362.9	8	8	.51	.25	.25	1.5	98.1	1.5
	962	275	267.6	628.2	1.31	394.6	11	10	1.52	.76	1.52	3.0	90.3	3.4
	966	275	254.0	596.5	1.25	362.9	12	10	.89	.76	.76	3.0	79.4	3.0
	973	275	251.7	551.1	1.09	340.2	8	8	.64	.38	.51	1.5	89.0	1.8
	991	275	256.3	551.1	1.07	351.5	9	9	.89	.64	.76	2.5	89.0	2.4

[A] Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B] Quality grades: G = 8; G+ = 9; CH- = 10.
[C] Adjusted by USDA grader.
[D] Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E] Actual fat thickness measured.

Table A.5--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm²	Yield Grade
110														
	893	247	274.4	562.5	1.17	356.5	9	9	.76	.51	.64	2.0	83.2	2.5
	902	247	290.3	560.2	1.09	357.4	12	10	.76	.64	.76	2.0	89.0	2.2
	914	247	249.5	533.0	1.15	325.2	5	6	.76	.76	.51	2.0	92.9	1.7
	918	247	240.4	495.7	1.04	306.6	13	11	.64	.51	.51	2.0	74.8	2.3
	933	247	247.2	521.6	1.11	318.0	7	7	.76	.51	.51	1.0	85.8	1.8
	935	247	281.2	560.2	1.13	341.6	8	8	.76	.76	.76	1.5	87.7	2.0
	942	247	269.9	499.0	.93	318.9	9	9	.76	.76	.89	1.5	75.5	2.4
	952	247	254.0	533.0	1.13	336.1	6	6	.51	.51	.51	1.0	82.6	1.9
	956	247	251.7	519.4	1.08	329.8	8	8	.51	.25	.51	1.0	86.5	1.6
	958	247	256.3	494.4	.96	305.3	8	8	.64	.76	.64	1.5	81.9	1.9
	965	247	256.3	553.4	1.20	346.1	6	6	.38	.25	.38	1.0	87.1	1.6
	972	247	267.6	523.9	1.04	337.0	9	9	.64	.51	.38	1.5	91.6	1.7
	976	247	267.6	528.4	1.06	336.6	6	6	.76	.25	.64	1.5	76.8	2.3
	981	247	233.6	492.2	1.05	303.9	12	10	1.52	.76	1.27	2.0	74.8	3.2
	982	247	283.5	551.1	1.08	335.7	7	7	.38	.51		1.0	81.3	1.8
	989	247	269.9	598.8	1.33	361.0	12	10	1.52	.76	1.14	1.5	74.8	3.7

[A] Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B] Quality grades: G = 8; G+ = 9; CH- = 10.
[C] Adjusted by USDA grader.
[D] Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E] Actual fat thickness measured.

Table A. 6. Individual Shrunk Weights, ADG and Carcass Data for Hereford Heifer Calves (Trial 3).

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade	Carcass Protein, %	Carcass Fat, %
102	4	303	147.4	283.5	.45	145.6	5	6	.38	.25	.38	2.5	55.5	1.8		
	30	303	192.8	369.7	.58	215.0	10	10	1.02	.64	.76	2.5	62.6	2.6	16.35	25.97
	31	303	188.2	328.9	.46	185.5	7	7	.51	.64	.51	2.5	71.0	1.5	16.14	26.86
	55	303	176.9	290.3	.37	160.6	5	6	.25	.25	.25	2.0	58.7	1.5	17.90	19.38
	64	303	217.7	403.7	.61	230.4	12	10	1.52	1.02	1.27	3.0	72.9	2.9		
	73	303	222.3	415.0	.64	232.7	11	10	.64	.38	.38	2.0	69.0	2.0	17.11	22.74
	79	303	181.4	335.7	.51	185.5	10	10	.64	.64	.64	2.5	59.7	2.2		
	85	303	201.9	358.3	.52	199.6	8	8	.76	.64	.38	2.0	66.5	2.0		
	96	303	231.3	442.3	.70	256.3	11	10	1.02	.64	.89	2.5	66.5	2.8		
	97	303	200.4	383.3	.58	212.3	5	6	.51	.51	.38	2.5	72.9	1.6		
	107	303	163.3	306.2	.47	166.9	5	6	.51	.51	.51	2.5	54.2	2.2	15.72	28.62
	110	303	175.9	374.2	.65	212.3	7	7	.51	.51	.38	3.0	64.5	2.1		
	114	303	206.4	358.3	.50	198.7	7	7	.38	.51	.25	3.0	63.2	2.0	17.69	20.28
	152	303	190.5	347.0	.52	200.5	10	10	.51	.51	.76	2.0	58.7	2.1	16.85	23.92
	153	303	195.0	369.7	.58	211.8	13	11	.64	.38	.38	2.5	70.3	1.9	15.08	31.36
	161	303	153.8	335.7	.58	190.5	4	5	.25	.51	.25	2.0	61.3	1.7	17.07	22.92
	164	303	201.9	385.6	.61	215.9	7	7	.51	.51	.38	2.0	67.7	1.8	15.48	29.63
	165	303	213.2	369.7	.52	210.5	10	10	1.27	.76	1.14	3.0	73.5	2.4		
	167	303	156.5	333.4	.58	189.6	7	7	.38	.38	.38	3.0	61.3	2.0		
	191	303	167.8	322.1	.51	180.5	5	6	.38	.51	.25	2.5	52.9	2.2		
103	15	226	158.8	342.5	.81	204.6	8	8	.89	.76	.64	3.0	64.5	2.4		
	23	226	195.0	417.3	.98	251.3	14	11	1.52	1.02	1.52	4.0	70.3	3.4	16.35	25.97
	28	226	176.9	329.9	.67	190.1	6	6	.51	.76	.51	3.0	58.7	2.2	16.14	26.86
	38	226	201.9	394.6	.85	237.2	7	7	.64	.89	1.02	3.0	61.9	2.6	17.90	19.38
	49	226	215.5	399.2	.81	234.5	11	10	1.27	1.02	1.02	3.5	72.3	2.8		
	54	226	199.6	393.1	.84	225.4	9	9	.25	.51	.51	3.0	60.6	2.2	17.11	22.74
	79	226	225.8	424.1	.87	256.3	10	10	1.40	.64	1.02	3.0	79.4	2.6		
	81	226	179.2	335.7	.69	196.0	15	11	1.02	1.02	1.14	3.0	66.5	2.4		
	101	226	165.6	362.9	.87	210.9	4	5	.25	.64	.51	2.5	63.2	1.8		
	120	226	179.2	328.9	.66	199.6	11	10	.38	.89	.38	2.5	67.1	1.7		
	126	226	192.8	376.5	.81	224.1	10	10	.76	.64	.76	2.5	60.6	2.6	15.72	28.62
	151	226	190.5	390.1	.88	235.4	10	10	.89	1.27	1.27	3.0	69.7	2.4		
	155	226	170.1	333.4	.72	200.0	9	9	1.27	.64	.76	3.0	64.5	2.8	17.69	20.28
	172	226	206.4	390.1	.81	232.7	11	10	.76	1.02	.64	3.0	69.4	2.4	16.85	23.92
	175	226	188.2	394.6	.91	227.3	9	9	1.40	.89	.76	3.5	56.1	3.6	15.08	31.36
	178	226	224.5	410.5	.82	241.3	16	12	1.52	.89	.64	3.0	71.0	3.1	17.07	22.92
	184	226	152.0	303.9	.67	174.2	4	5	.38	.51	.38	3.0	59.7	2.0	15.48	29.63
	198	226	208.7	406.0	.87	239.0	15	11	.76	.51	.76	3.5	69.7	2.4		
	195	226	152.0	340.2	.83	201.4	7	7	.38	.51	.38	3.0	64.5	1.9		
	196	226	217.7	395.9	.79	235.4	8	8	1.27	.76	.64	3.0	63.2	3.1		

[A] Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B] Quality grades: G = 8; G+ = 9; CH- = 10.
[C] Adjusted by USDA grader.
[D] Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E] Actual fat thickness measured.

Table A.6--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade	Carcass Protein, %	Carcass Fat, %
104	18	248	192.8	399.2	.83	238.6	10	10	1.65	1.27	1.40	2.5	75.5	2.8	15.06	31.44
	24	248	176.9	369.7	.78	228.6	16	12	1.27	.89	.76	3.5	68.4	2.9	13.55	37.85
	70	248	220.0	396.9	.71	244.5				1.27	1.65				13.50	38.05
	72	248	172.4	381.0	.84	226.8	8	8	1.14	.76		3.5	78.1	2.3		
	75	248	213.2	408.2	.79	240.9	11	10	1.27	.89		3.5	72.3	2.8		
	83	248	195.0	403.7	.84	251.7	11	10	1.52	1.02		4.0	85.8	2.6		
	95	248	199.6	376.5	.71	227.3	7	7	.89	.64		3.0	80.5	1.8		
	99	248	179.2	367.4	.76	222.3	9	9	.76	.76		3.5	75.5	2.0		
	100	248	190.5	401.4	.85	243.1	8	8	1.02	.64		3.0	80.0	2.1		
	102	248	206.4	415.0	.84	242.7	12	10	1.02	.64	.76	3.0	71.0	2.6	15.56	29.31
	117	248	163.3	347.0	.74	204.6	9	9	.76	.64		3.0	69.7	2.1		
	124	248	231.3	426.4	.79	260.4	10	10	1.27	1.02	1.14	3.5	67.7	3.2	15.60	29.16
	127	248	183.7	394.6	.85	230.0	10	10	1.40	1.14	1.27	3.0	65.9	3.1	15.12	31.17
	132	248	155.5	392.4	.95	239.0	10	10	.64	.64		3.0	81.9	1.6		
	169	248	161.0	360.6	.80	215.0	7	7	.76	.64	.76	3.5	63.2	2.6	16.09	27.05
	179	248	147.4	374.2	.91	222.3	7	7	.51	.51	.64	3.0	76.3	1.6	16.46	25.50
	186	248	215.5	442.3	.91	274.9	14	11	1.65	.89		3.5	74.2	3.4		
	187	248	201.9	373.8	.71	237.7	12	10	1.27	1.65		4.0	71.0	3.0		
	189	248	172.4	355.6	.86	221.8	10	10	1.27	1.02	1.27	3.5	68.4	2.9	14.50	33.80
	192	248	204.1	410.5	.83	244.5	10	10	.51	.64	.64	2.5	72.3	1.9	15.16	30.99
105	6	261	165.6	362.9	.76	224.1	11	10	1.65	.76	1.52	3.5	60.6	3.7	14.26	34.83
	12	261	217.7	421.8	.78	252.2	14	11	1.40	1.14	1.02	3.5	71.0	3.1	14.22	35.01
	43	261	204.1	401.4	.76	230.9	10	10	.76	.51	.51	3.0	75.5	2.0		
	47	261	210.9	399.2	.72	229.5	8	8	1.14	1.02	1.02	2.5	72.9	2.4	15.24	30.67
	51	261	154.2	362.9	.80	212.7	13	10	.76	.89	.64	2.5	71.6	1.9		
	59	261	222.3	442.3	.64	259.5	11	10	.76	.76	.76	3.0	83.2	1.9		
	86	261	170.1	372.0	.77	214.1	9	9	1.40	.51	.89	3.0	63.9	3.1	14.86	32.26
	93	261	190.5	356.1	.63	200.0	11	10	.76	.64	.64	3.0	65.9	2.2	15.95	27.63
	94	261	195.0	372.0	.68	215.9	8	8	.76	.51	.76	3.0	63.2	2.5		
	106	261	201.9	401.4	.76	236.8	15	11	.76	.64	.89	2.5	76.1	1.9		
	112	261	176.9	399.2	.85	228.2	8	8	1.27	.76	.89	2.5	75.5	2.4		
	115	261	229.1	426.4	.76	256.7	11	10	1.40	.76	1.02	2.5	69.0	3.1	14.93	31.98
	133	261	158.8	311.7	.58	162.8	4	5	.25	.25	.25	3.5	59.4	1.8		
	135	261	181.4	383.3	.77	230.0	10	10	.76	.51	.76	2.5	70.3	2.2		
	136	261	213.2	453.6	.92	273.1	9	9	.76	.76	.76	3.5	76.1	2.4	14.58	33.46
	143	261	172.4	367.4	.75	212.7	8	8	.38	.51	.51	3.0	65.8	1.9	17.22	22.26
	150	261	192.8	381.0	.72	225.0	10	10	1.02	.51	1.14	3.0	69.0	2.5	15.48	29.63
	166	261	181.4	400.0	.86	233.6	15	11	.76	.76	.76	3.0	64.5	2.6	15.32	30.33
	182	261	183.7	374.2	.73	218.2	10	10	.76	.76	.64	3.5	71.0	2.2		

[A]Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B]Quality grades: G = 8; G+ = 9; CH- = 10.
[C]Adjusted by USDA grader.
[D]Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E]Actual fat thickness measured.

Table A.6--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade	Carcass Protein, %	Carcass Fat, %
106																
	11	205	192.8	353.8	.79	209.6	12	10	.76	1.40	.76	3.0	65.2	2.3	14.99	31.71
	34	205	201.9	372.0	.83	221.8	16	12	1.27	1.27	.89	3.5	65.2	3.0		
	40	205	224.5	419.6	.95	245.9	9	9	1.27	1.02	.89	2.5	67.1	2.9		
	42	205	190.5	399.2	1.02	235.0	10	10	.76	1.40	.64	2.5	69.7	2.2		
	44	205	174.6	344.7	.83	205.5	10	10	1.27	1.02	1.14	3.0	65.5	2.7	15.54	29.37
	71	205	154.2	344.7	.93	201.4	7	7	.51	1.52	.76	3.0	68.4	1.8	15.41	29.93
	74	205	179.2	365.1	.91	221.8	9	9	1.40	1.27	1.27	3.0	67.7	2.9	14.16	35.25
	84	205	195.0	374.2	.87	220.4	7	7	.64	.76	.89	3.0	71.0	2.0	15.41	29.95
	87	205	167.8	347.0	.87	200.0	7	7	.76	.76	.64	3.5	71.0	2.1		
	92	205	181.4	408.2	1.11	240.9	12	10	.76	.76	.76	3.0	79.4	1.9	15.30	30.40
	103	205	217.7	390.1	.84	234.1	7	7	1.40	1.52	1.52	3.5	69.7	3.0	13.93	36.21
	125	205	186.0	401.4	1.05	239.0	7	7	.51	1.02	.51	3.5	67.7	2.3	15.01	31.66
	129	205	199.6	385.6	.91	229.1	9	9	1.27	1.40	1.27	3.0	69.0	2.8		
	140	205	165.6	361.6	.95	210.0	9	9	1.27	1.40	.76	2.5	63.9	2.8		
	141	205	217.7	444.5	1.11	259.5	11	10	1.40	1.27	1.02	2.5	63.9	3.3		
	146	205	213.2	412.8	.97	256.7	23	14	1.78	1.52	1.40	3.5	91.6	2.5	14.09	35.56
	148	205	206.4	387.8	.89	230.9	8	8	1.52	1.27	1.65	3.5	62.6	3.5		
	158	205	208.7	365.1	.76	215.5	8	8	1.27	.89	1.14	3.5	61.9	3.1	14.72	32.87
	171	205	149.7	367.4	1.06	215.0	10	10	1.27	1.40	.64	3.5	61.9	3.1		
	173	205	151.0	349.3	.92	205.9	8	8	1.02	1.02	.89	3.0	61.3	2.7		
107																
	29	205	195.0	410.5	1.05	250.8	13	11	1.52	.89	1.02	3.5	64.5	3.6		
	33	205	204.1	385.6	.89	230.0	9	9	.89	.76	.76	3.5	75.5	2.2		
	45	205	170.1	394.6	1.10	231.8	10	10	.76	1.65	.76	3.0	67.1	2.4		
	58	205	217.7	426.4	1.02	251.7	10	10	1.40	1.52	1.14	3.0	73.5	2.9	14.55	33.58
	62	205	210.9	406.0	.95	240.9	7	7	.76	1.40	.76	3.5	72.9	2.3	15.26	30.59
	63	205	172.4	369.7	.96	220.9	10	10	1.40	1.40	1.27	3.0	61.9	3.2		
	69	205	179.2	387.8	1.02	228.6	7	7	.76	1.40	.89	3.0	72.9	2.1		
	76	205	226.8	435.5	1.02	271.3	11	10	2.03	1.78	1.65	3.5	67.1	4.1		
	82	205	192.8	378.8	.91	226.8	10	10	1.52	.89	1.02	2.5	65.5	3.1	15.49	29.58
	104	205	208.7	369.7	.79	217.7	10	10	1.27	.76	.64	3.0	56.8	3.2		
	105	205	161.0	374.2	1.04	225.9	7	7	.64	.64	.51	3.5	70.3	2.2	15.94	27.70
	111	205	183.7	390.1	1.01	225.9	10	10	1.40	1.52	1.02	3.5	72.9	2.8	0.00	
	131	205	217.7	410.5	.94	239.5	7	7	.25	.76	.25	2.5	81.9	1.1	15.76	28.47
	137	205	147.4	315.3	.82	179.6	7	7	.38	1.02	.51	3.0	58.1	2.0		
	138	205	179.2	365.1	.91	217.7	8	8	1.40	1.14	1.02	3.5	67.7	3.0	13.96	36.10
	144	205	156.5	353.8	.96	205.0	8	8	.38	.64	.76	3.0	62.6	2.0	15.25	30.62
	149	205	161.0	353.8	.94	204.1	8	8	1.02	1.14	.89	3.5	61.9	2.8	15.01	31.63
	168	205	201.9	396.9	.95	233.2	12	10	.89	.76	.89	3.5	65.2	2.7		
	170	205	190.5	381.0	.93	228.6	8	8	.76	1.78	.89	2.5	72.9	2.0	14.74	32.79
	143	205	199.6	390.1	.93	232.2	11	10	1.78	1.78	1.27	3.5	60.6	3.8	13.29	38.93

[A] Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B] Quality grades: G = 8; G+ = 9; CH- = 10.
[C] Adjusted by USDA grader.
[D] Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E] Actual fat thickness measured.

Table A.6--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm²	Yield Grade	Carcass Protein, %	Carcass Fat, %
108	7	205	201.9	395.9	.95	245.4	7	7	1.27	1.52	1.02	3.0	74.2	2.7		
	10	205	188.2	385.6	.96	226.3	11	10	1.27	1.45	.89	4.0	55.5	3.6		
	13	205	192.8	369.7	.86	229.1	8	8	1.40	.69	1.40	4.0	60.6	3.5	13.03	40.02
	17	205	204.1	372.0	.82	236.3	12	10	1.14	1.14	1.02	4.0	65.2	3.1		
	19	205	163.3	367.4	1.00	223.6	16	12	1.65	1.14	1.65	3.0	58.1	3.7		
	20	205	201.9	390.1	.92	249.5	15	11	2.16	1.91	1.65	3.0	64.5	4.1		
	36	205	229.1	421.8	.94	257.2	10	10	.76	.64	.89	3.5	88.4	1.7	15.20	30.84
	37	205	195.0	335.7	.69	202.3	10	10	.76	1.14	1.02	3.0	56.1	2.8		
	50	205	158.8	387.8	1.12	235.0	9	9	.76	.76	1.14	4.0	54.8	3.2		
	53	205	156.5	347.0	.93	207.3	13	11	1.65	1.14	1.78	2.5	59.4	3.4	12.95	40.40
	113	205	170.1	372.0	.98	220.9	10	10	1.40	1.02	1.27	3.0	58.1	3.4	14.59	33.44
	122	205	222.3	435.5	1.04	271.3	8	8	1.65	1.91	1.52	4.0	71.0	3.6		
	123	205	213.2	396.9	.90	233.2	11	10	1.40	1.02	1.27	3.5	69.7	3.0	14.71	32.59
	124	205	205.4	401.4	.95	250.8	14	11	1.52	1.52	1.65	4.0	63.2	3.7	13.58	37.72
	139	205	147.4	362.9	1.05	214.6	14	11	2.29	1.40	1.52	3.5	50.3	4.7	12.81	40.96
	156	205	181.4	355.3	.86	218.2	8	8	1.27	1.02	.89	2.5	63.9	2.9		
	162	205	215.5	421.8	1.01	256.7	17	12	1.40	1.02	1.27	3.5	56.8	3.9		
	174	205	190.5	406.0	1.05	246.1	8	8	.76	.89	1.14	3.0	81.3	1.8	13.72	37.10
	180	205	172.4	412.8	1.17	251.7	10	10	1.78	1.27	1.78	3.0	71.0	3.4	14.25	34.85
	193	205	179.2	387.8	1.02	235.0	9	9	1.78	1.02	1.52	2.5	62.6	3.6	15.00	31.68
109	1	198	192.8	387.8	.99	240.4	10	10	1.78	1.40		3.5	71.0	3.4		
	9	198	204.1	392.4	.95	248.1	15	11	1.52	.89	1.40	4.0	66.5	3.5	13.97	36.04
	26	198	197.3	376.5	.90	229.1	11	10	1.78	1.52	1.27	3.0	54.2	4.0	13.94	36.17
	39	198	217.7	403.7	.94	250.4	10	10	1.78	1.02		3.0	75.8	3.1		
	41	198	210.9	376.5	.84	230.9	8	8	.89	1.02		2.5	76.1	2.0		
	48	198	229.1	426.4	1.00	260.8	13	11	1.78	1.02	1.65	4.0	65.8	3.9	13.72	37.11
	56	198	190.5	424.1	1.18	253.6	10	10	2.29	1.14	1.40	3.5	64.5	4.3	13.98	36.00
	57	198	176.9	356.1	.90	216.4	10	10	1.78	1.02		2.5	64.5	3.3		
	65	198	181.4	355.1	.88	214.1	10	10	1.40	.76	1.14	4.0	63.9	3.3	13.49	38.10
	67	198	201.9	373.8	.89	221.4	14	11	1.78	1.27	1.52	3.5	59.4	3.8	14.39	34.27
	68	198	190.5	358.3	.85	222.3	16	12	1.27	.89	1.02	3.5	59.4	3.3	14.43	34.08
	80	198	201.9	435.5	1.18	262.6	10	10	1.27	.89		2.5	65.8	3.1		
	88	198	154.2	322.1	.85	191.9	8	8	1.27	.76	.89	3.0	55.5	3.2	15.38	30.05
	90	198	167.8	374.2	1.04	225.0	9	9	1.52	.89		3.0	62.6	3.3		
	109	198	224.5	417.3	.97	257.2	9	9	1.65	1.14	1.02	3.5	68.4	3.5	13.46	38.23
	118	198	158.8	353.8	.99	215.9	10	10	1.91	.76		1.5	54.8	3.7		
	154	198	149.7	356.1	1.04	213.6	4	5	1.52	.89		2.5	66.5	2.9		
	177	198	174.6	328.9	.78	186.0	12	10	1.02	1.02		2.5	52.3	2.9		
	190	198	215.5	435.5	1.11	260.4	11	10	.89	.76		3.0	83.2	2.0		
	197	198	163.3	367.4	1.03	211.4	11	10	1.02	.89	.76	3.0	56.1	3.0	14.76	33.07

[A]Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B]Quality grades: G = 8; G+ = 9; CH- = 10.
[C]Adjusted by USDA grader.
[D]Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E]Actual fat thickness measured.

Table A.6--Continued

Pen No.	Anim. No.	Days on Feed	Initial Wt, kg	Final Wt, kg	ADG, kg	Hot Carc. Wt, kg	Marb[A]	Qual Grade[B]	Adj. Fat,[C] cm	Est. Fat,[D] cm	Actual Fat,[E] cm	KPH Fat, %	REA, cm^2	Yield Grade	Carcass Protein, %	Carcass Fat, %
110	2	198	192.8	381.0	.95	229.5	13	11	1.78	1.02	1.27	3.5	58.7	3.9	13.76	36.96
	3	198	201.9	426.4	1.13	261.7	10	10	2.29	1.14	1.52	3.5	71.6	4.0	13.31	38.36
	5	198	204.1	390.1	.94	236.3	9	9	1.65	1.14		2.0	63.2	3.3		
	14	198	217.7	469.5	1.27	288.0	12	10	1.65	1.27		2.5	74.2	3.3		
	32	198	176.9	360.6	.93	221.4	9	9	1.27	.89		3.5	70.3	2.8		
	60	198	213.2	415.0	1.02	252.2	12	10	1.78	.89	1.78	3.0	74.9	3.2	13.96	36.09
	77	198	226.8	396.9	.86	237.7	8	8	1.27	.89	.76	3.5	58.1	3.5	14.76	32.72
	89	198	170.1	367.4	1.00	218.2	14	11	1.02	.76		3.0	56.8	3.1		
	96	198	154.2	328.9	.88	197.3	7	7	1.78	1.14	1.52	3.5	66.5	3.3	13.94	36.20
	108	198	158.8	322.1	.82	191.0	11	10	.25	.25	.38	2.0	58.1	1.8	16.06	27.18
	116	198	222.3	445.8	1.13	277.6	10	10	1.52	.64	1.52	3.5	76.8	3.2	13.94	36.18
	119	198	199.6	401.4	1.02	243.1	8	8	1.52	1.14		3.0	67.7	3.2		
	121	198	145.2	385.6	1.21	225.0	10	10	.89	1.02	.89	3.0	78.1	1.9	15.74	28.54
	130	198	195.0	358.3	.82	217.3	9	9	2.29	1.02	2.03	3.0	60.5	4.1	13.90	36.36
	134	198	208.7	430.9	1.12	263.1	10	10	1.14	.89		2.0	72.3	2.6		
	142	198	181.4	369.7	.95	228.2	12	10	2.41	1.14		3.5	56.8	4.6		
	145	198	165.6	288.0	.62	168.7	7	7	.25	.64		3.0	54.8	2.0		
	163	198	179.2	383.3	1.03	230.0	8	8	1.27	.76		3.5	64.5	3.1		
	185	198	181.4	356.1	.88	209.6	10	10	1.78	1.27		2.5	58.1	3.6		
	194	198	192.8	362.9	.86	221.8	10	10	1.52	1.14	1.14	3.0	67.1	3.1	14.27	34.88

[A]Marbling scores: SL = 8; SL+ = 9; SM- = 10.
[B]Quality grades: G = 8; G+ = 9; CH- = 10.
[C]Adjusted by USDA grader.
[D]Estimated by Ithaco Ultrasonic Scanoprobe, Ithaco, N.Y.
[E]Actual fat thickness measured.

Table A 7. Trial Numbers, Pen Numbers and Corresponding Rations

Pen No.	Ration
	Trial 1
101	85% Concentrate
102	40% Concentrate
103	Mid-Switch
104	Late Switch
105	All Silage
	Trial 2
106	85% Concentrate
107	40% Concentrate
108	Mid-Switch
109	Late Switch
110	All Silage
	Trial 3
102	100% Silage, Low Protein
103	100% Silage, Intermediate Protein
104	100% Silage, High Protein
105	68:32 (CS:Conc.), Low Protein
106	68:32 (CS:Conc), Intermediate Prot.
107	68:32 (CS:Conc.), High Protein
108	100% Concentrate, Low Protein
109	100% Concentrate, Intermediate Prot.
110	100% Concentrate, High Protein

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