THE UNIVERSITY OF ALBERTA

EFFECTS OF DATE OF WEANING AND SHELTER ON FEEDLOT PERFORMANCE OF THREE BREED-GROUPS OF BEEF CATTLE

by

HANS-MICHAEL KUBISCH

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Date August 11th, 1986

DEDICATION

To my parents

Renate and Hans-Karl Kubisch

ABSTRACT

A two-year study was undertaken to evaluate the effects of age at weaning and type of housing on post-weaning performance of beef calves of three different breed-groups, namely Hereford Crossbred (HX), Beef Synthetic (SY) and Dairy Synthetic (SD). A total of 376 bull calves were used. Records were also analysed to determine the effects of weaning treatment on subsequent cow performance.

Calves were weaned October 1 (early) or November 1 (late) averaging 156 and 189 days of age, respectively. Following an adjustment period of 4 weeks, the calves were fed a concentrate ration ad libitum for a period of 140 days. During the period between the two weaning dates, early weaned calves gained at a significantly higher rate (0.39 vs 0.13 kg/day) than their unweaned contemporaries. The performance of the two groups during the adjustment period did not differ.

Two different comparisons during the feedlot trial were performed. Average daily gain during the 140 days immediately following the adjustment period differed significantly between the two weaning groups (1.58 vs 1.76 kg/day for early and late weaned animals, respectively). Late weaned animals consumed significantly more feed (9.7 vs 8.7 kg/day), however, feed efficiency was not affected by weaning treatment. In the second comparison, in which the performance of the two weaning groups was compared during the period in which the late weaned calves were on

the feedlot trial, late weaned animals gained more ($P<.05$, 1.76 vs 1.61 kg) and had a better feed efficieny ($P<.05$, 5.4 vs 5.9 kg of feed/kg of gain). Daily feed consumption, however, was nearly the same between the two groups (9.6 vs 9.7 kg). Health status and mortality, as well as carcass characteristics, were not influenced by weaning treatment.

Following weaning, half of the calves were housed with access to an overhead shelter (sheltered), while the remaining animals were kept in an open feedlot and provided with only a windbreak (unsheltered). Overall, sheltered animals gained at a significantly higher rate than their unsheltered contemporaries (1.72 vs 1.65 kg/day) during the 140-day long feedlot trial. A stepwise regression model of average daily rates of gain on weather conditions, into which 13 climate parameters were entered, did not provide any consistent pattern with the exception of average daily temperature fluctuations, which proved to be a significant factor in both housing groups in the first year. Temperature variables explained a greater fraction of the total variation of gain in sheltered animals compared to unsheltered animals in both years. Feed consumption and efficiency did not differ between the housing groups (9.7 vs 9.6 kg and 5.6 vs 5.7 kg of feed/kg of gain for sheltered and unsheltered animals, respectively). Health status and mortality were not affected by housing type.

In all analyses of average daily rates of gain, breed-group proved to be a significant factor, with SY bulls growing at a faster rate than HX and SD. Significant differences between breed-groups also existed in carcass traits.

The analysis of cow performance revealed a significant difference in average daily rates of gain in the period between the two weaning dates. Overall, early weaned cows did not experience any weight change while late weaned dams lost 0.48 kg/day. Calving performance in the year following the weaning treatment did not differ between early and late weaned dams.

The analysis of calving records of heifers showed that the weaning treatment of heifer calves did not affect their subsequent reproductive performance.

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I. GENERAL INTRODUCTION

Few studies have been conducted to investigate the effects of early weaning of beef calves on their subsequent post-weaning performance. This is surprising considering that there are a number of potential benefits, which could be derived from weaning calves earlier than at the standard age of seven to nine months.

It is well known that milk production of cows is generally low in late summer and early fall, particularly during times of drought or feed shortage, and as a consequence, the genetic potential of calves for growth is often not fully realized. Calves born in late winter or early spring can, therefore, be adversely affected by the level of nutrition during late summer or early fall due to a decline in pasture productivity. This is especially evident in times of drought and hot climate conditions when the productivity of pasture plants adapted to a cold climate declines sharply.

It has also been suggested that feedstuffs are more efficiently utilized when consumed directly by the young animal rather than indirectly as milk, after going through digestive and metabolic processes in the lactating dam. There is also some evidence, which indicates that calves gain more efficiently and overall feeding cost for cow and calf per kg gained can be lowered when calves are weaned early and maintained at a high rate of gain, while their dams are kept at a maintenance level. An additional benefit of early weaning could be realized with cull cows, by selling them earlier or by giving them adequate time on pasture to regain some of their weight lost during lactation.

Another advantage of weaning calves early is that it could provide the producer with the opportunity to precondition his calves, that is to give them time to adjust to the change in feed and environment. It has been suggested that such a practice could result in a higher financial return, as a calf, which has already overcome the stress of weaning, been given all necessary vaccinations and might be heavier as a result of early weaning, might represent a more desirable product to the feedlot operator.

As a result of early weaning, stocking rates of cows could be increased and available pasture could be utilized by a greater number of cows, which could increase the financial return from the land.

It is apparent that the age of the calf at weaning will to some extend influence the performance of its dam. Early weaned cows would return earlier to estrus and might have shorter calving intervals. Furthermore, they would have the opportunity to increase their weight before the onset of winter, which might lower their maintenance cost during the winter and result in heavier and stronger calves in the following calving season.

The efficiency of beef production can be influenced by another factor, namely the usually cold weather experienced during much of the winter in Canada. This is particularly evident in most of western Canada, where temperatures can remain very low for extended periods of time. In traditional management systems, feedlot cattle are maintained in open pens during the winter, in most cases with little more than a windbreak for shelter.

The effects of exposure to long cold spells are well known. Lowered digestibility of feedstuffs has been reported, suggesting that temperature can influence rumen function, probably by increasing the rate of passage of feed. Also there is usually an adjustment in the energy exchanges of the animal in response to decreasing temperatures. As the animal is subjected to a colder environment, it tends to acclimatize itself to the increased heat loss it experiences by raising its heat production, which leads to an increase in its energy requirements.

Housing feedlot cattle in pens with access to a simple overhead shelter could provide them with a warmer and drier environment, which may result in a reduction in radiant heatloss and, thus, lower energy requirements.

The objectives of this study are, therefore, threefold: 1) to determine the influence of age at weaning on calf performance during a 140-day feedlot trial, as well as lifetime performance, as assessed by slaughter and carcass characteristics; 2) to investigate the effects of weaning age of the calf on the subsequent performance of its dam, particularly on her weight change and performance during the following calving season; 3) to assess the effects of providing a simple overhead shelter for growing feedlot cattle on rate of gain, feed efficiency and slaughter characteristics.

It was also hoped that this study would provide some insight into possible differences in response to the imposed treatments as a result of genetic differences between breed-groups.

II. EFFECTS OF AGE AT WEANING ON POST-WEANING PERFORMANCE OF BULL CALVES

II.1. INTRODUCTION

The fact that calves can be weaned at a very young age has been demonstrated in dairy calves for a long time. Dairy calves are generally separated from their dams after only a few days and raised artificially, without apparent adverse effects on their overall performance. Far less is known about the effects of weaning beef calves at a younger age than the usual age of seven to nine months.

It is well established that growth of the young calf is greatly dependent on its dam's milk production. Gifford (1949) found correlations between dam's daily milk production and calf weight to be .60, .71, .52 and .35 for the first, second, third and fourth months of lactation, respectively. Correlations between the same traits for the following four months were smaller and nonsignificant. Therefore, the growth potential of the calf may not be maximized by continuous nursing of the dam beyond four months of age. Neville (1962) and Rutledge et al. (1971) attributed about 60% of the variation in weaning weights of calves to the variation in milk production of their dams. Jeffery et al. (1971) determined the regression coefficients of pre-weaning performance on milk yield (kg) to be .05 and .06 kg for average daily gain to weaning and 8.4 and 10.9 kg for weaning weights. Butson et al. (1980) found that by far the greatest percentage of variance in average daily gain was explained by the variance in milk yields. These workers concluded that an increase of 1 kg in average daily milk yield was associated with 7.7 kg increase in weaning weight, which is considerably higher than the response reported by Marshall et al. (1976) for the traditional beef breeds. Correlation coefficients between milk yield and average daily gain have been reported by Furr and Nelson (1964), Gleddie and Berg (1968), Melton et al. (1967) and Wilson et al. (1968) and range from .58 to .85.

Thus, the influence of milk production of the dam on the rate of gain is apparent and must be kept in mind when investigating alternative weaning systems.

Most studies on post-weaning performance of early weaned beef calves indicate that beef calves can be weaned as early as two to three months of age without receiving any additional milk. Development of rumen function in calves occurs rapidly when the animal starts eating solid feed and depends largely on the presence of such feed in the rumen. Work by Preston (1960) with dairy calves showed that age and weight of the calf at weaning influence its ability to increase dry feed intake in response to the nutritional stress of weaning and to withstand that stress. The severity of the stress imposed is also largely determined by the level of dry feed consumption attained before weaning, and the abruptness of the weaning process. Hodgson (1965) found that early weaning of calves resulted in a considerable reduction in their growth during the 4 weeks following weaning, the severity of which was inversely related to the age of the calf at weaning, yet he did not find any differences in overall post-weaning performance between different weaning treatments.

In an early investigation, Green and Buric (1953) compared the performance of calves weaned at either 90 or 180 days of age from weaning to one year of age and found that there was no significant difference in the rate of gain between the two groups. Although early weaned calves had a lower average weight at the time of late weaning than those weaned at 180 days of age, this difference had virtually disappeared by the time the animals were one year old. The correlations of age at the start and gain during the following period were only -.007 and -.001 for the 90- and 180-day groups, respectively.

Williams et al. (1969) reported results of a study into the effects of weaning calves at 3.5 months of age versus the standard age of 7 months. A comparison of performance of weaned and unweaned calves between 106 and 203 days of age showed that early weaned animals were 29.5 kg heavier on day 203, however, the yearling weights differed only by 3.4 kg in favor of early weaned calves. It is noteworthy that the rate of gain for the standard weaned calves increased almost constantly following weaning while that of their early weaned contemporaries declined as the feedlot trial progressed. No significant difference was observed with regard to carcass quality. These workers concluded that the live value per hundredweight was greater for the early weaned animals. However, without considering any effects of weaning date on the feed costs of the dams, the net returns favored the late weaned group because of their initial lower feed cost.

Aitken et al. (1963) compared early and late weaning in two experiments using twin calves. Late weaned animals were given whole milk for 16 weeks in the first experiment and milk replacer for 12 weeks in the second experiment after which time they received a low roughage, high concentrate complete milled diet. Their early weaned contemporaries received the same diet but were weaned at three weeks of age. Live weights at slaughter were 368 and 367 kg for early and late weaned animals in experiment 1, and 360 and 362 kg in experiment 2. Carcass traits, such as grade, weight and fat thickness were also not affected by weaning treatment.

Glimp (1973) conducted a study in which calves were weaned at 56, 112 and 168 days of age. Half of the animals were fed a low, the other half a high energy diet. He concluded that neither type of diet nor weaning treatment had a significant influence on 224-day weight, and that the differences, which had existed at this age, had disappeared by one year of age.

A similar study by Bailey et al. (1975) into the effects of weaning calves at eight vs. ten months of age and the influence of quality of grazing on subsequent growth performance, indicated that early weaned calves can grow faster than their late weaned mates, provided their nutritional requirements are met. Calves, which were placed on poor grazing after early weaning had significantly lower liveweights at 12 months of age than either the well fed early weaned group or the late weaned group. The authors concluded that early weaning is an alternative to poor grazing conditions, but that it is essential to provide a high feeding standard if the calves are to grow at their full potential.

Harvey et al. (1975) reported the results of a 3-year investigation of the influence of salt level and varying stocking rates on the performance of early weaned calves fed concentrate on pasture. Following the grazing period the animals were kept in a feedlot to monitor their further development. These workers also concluded that neither the use of salt to limit concentrate intake nor variations in stocking rates resulted in any marked increase in the contribution of forage to gain. Average daily gains were, however, significantly increased in early weaned calves receiving diets with either 0 or 5% salt. Those fed the diet containing 10% salt gained similarly to the controls which remained with their dams during the period between the two weaning dates. During the feedlot trial, average daily rates of gain were inversely related to the pasture gains resulting in very similar slaughter weights. Control calves and those receiving the 10% salt diet prior to their feedlot period gained significantly faster. No significant differences in carcass characteristics as a result of summer treatment were observed.

Richardson et al. (1978) studied the effects of weaning calves at 120 and 210 days of age on pre- and post-weaning performance. These investigators concluded that weaning age influenced conformation score, which ranged from 3 to 17, when assessed at approximately 210 days of age. Overall, calves weaned at 120 days of age had a higher conformation score by .18 points and were heavier than late weaned animals (205.6 vs. 195.5 kg). There was, however, also a significant year x weaning treatment interaction indicating that the magnitude of the difference between the treatments depended on climatic and pasture conditions. Yearling weights of the two groups of calves were similar, which is in agreement with most of the other studies.

Neville and McCormick (1981) weaned calves at an average age of 67 days after which they were fed either a concentrate mix on pasture or a complete diet in feedlot until they were approximately 230 days of age. Their performance was then compared to that of calves which had remained with their dams during this time. Results of this study indicated that the early weaned calves in the feedlot gained 1.04 kg, those on pasture 0.96 kg and those which had remained with their dams 0.85 kg per day resulting in 230-day weights of 256 kg, 238 kg and 223 kg, respectively.

Somewhat different results were obtained by Butler-Hogg et al. (1981) who reported the results of a Scottish study in which steers were either weaned at 7 or 11 months. These workers concluded that the major effect of early weaning was to reduce the growth rates by 30 to 35% (0.3 kg/day) during the period in which late weaned calves were still suckling their dams. After the normal time of weaning, however, early weaned calves tended to grow faster, but this difference in growth rate was not significant. Observations made on grazing time of calves and milk production of cows suggested that the higher growth rate of the suckled calves was due to a higher total energy intake associated with their milk consumption. After a 138-day finishing period, early weaned steers had lighter hot carcass weights and a lower dressing percentage compared with those weaned at the normal age. These findings are in agreement with results reported by Powell (1975), who found a reduction of 21% in growth rate in his early weaned animals, although both reports are in disagreement with all the aforementioned studies. This is not a contradiction in itself, but an indication of the interaction of the management system with the weaning date.

Results of a number of less detailed studies into the effect of early weaning are available, many of these are investigations into the nutritional requirements of young calves. Swart and Swart (1965) conducted a study on calves, which had been separated from their dams immediately after birth. They compared the performance of calves, which were fed whole milk or milk replacer for three months with calves which had received milk replacer for only three weeks followed by a calf starter ration. These workers found average weight gains in the first three months of 66.0, 55.3 and 46.0 kg and for the following 5 months of 168.7, 153.3 and 159.2 kg resulting in 8-month liveweights of 272.6, 248.6 and 243.1 kg for the animals receiving whole milk, milk replacer and calf starter, respectively. These results would suggest that there is a limit to how early calves can be weaned and that weaning before this age may result in a setback to their overall performance.

These studies suggest that there is a considerable range of age at which calves can be weaned and be expected to perform as well as those weaned at the standard age. However, it is also apparent that the success of an early weaning system depends on the post-weaning management and factors such as the quality of available feed have to be considered.

The question of whether early weaning is an economical management practice depends on such factors as availability of grazing pasture for cows, the possibility of reducing supplementary feeding of cows and management cost to offset the increased calf cost. Neville (1970) suggested that in a

January-February calving program available feed energy is far more efficiently utilized if calves are weaned at 3 to 4 months of age and fed a high quality ration for maximum gain. Consequently, the pasture could support a greater number of cows. He also concluded that assuming the early weaned calf gained considerably more than its unweaned counterpart (1.5 vs 1.0 kg per day), the energy cost of cow and calf would actually be lower if the calf is weaned early, due to lowered energy requirements of the non-lactating dam and the higher and, thus, more efficient rate of gain of its offspring. Williams et al. (1969) concluded that due to increased rates of gain, early weaned calves represented the same cost of gain as their late weaned contemporaries.

The present study was initiated to obtain more information on the effects of early weaning under Alberta management and climate conditions. It was expected that this study would provide further information on the influence of age at weaning on feed efficiency and consumption, general herd health and carcass quality.

II.2. MATERIALS AND METHODS

This study was conducted during two consecutive years at the University of Alberta Ranch in Kinsella. A total of 376 bull calves, born between March and June of 1984 (193) and 1985 (183) were used for this experiment. The animals belonged to three breed-groups, Beef Synthetic (SY), developed through a synthesis from Angus, Charolais and Galloway breeds; Dairy Synthetic (SD) consisting of Holstein, Brown Swiss and a number of other breeds and Hereford Crossbreds (HX) (Berg and Peebles, 1983).

In each year, the calves were randomized into two groups; one weaned on October 1 (early weaned group), the other on November 1 (late weaned group). Following weaning, all animals were subjected to an adjustment period of four weeks (for time schedule refer to Appendix 1). During the first week they were offered only hay, to which increasing amounts of the finishing diet were added until the latter constituted 90% of the feed intake. From this point on the animals were offered their finishing diet ad libitum, which consisted of 63% barley, 22% oats, 10% alfalfa and 5% canola meal resulting in a diet with a protein content of 13% (Appendix 2).

During the 140-day feedlot trial following the adjustment period, all animals were weighed every 28 days and their weights were recorded. Records were also maintained on feed consumption, straw requirements for bedding and the occurrence of health problems as well as any other mishaps, which might have been caused by the age at weaning.

Early weaned animals remained in the feedlot an additional 28 days, to allow a comparison between early and late weaned animals of the same age. Thus, for the analysis of rate of gain, two comparisons were made, one between the two weaning groups in the 140 days of the feedlot test immediately following their respective adjustment period, (end of October to middle of March for early, end of November to the middle of April for late weaned animals) the other during the time which constituted the feedlot trial of late weaned animals (end of November to the middle of April).

Following the feedlot trial, all animals remained in the feedlot until reaching a desirable degree of finish, at which time they were weighed again and shipped for slaughter.

To assess the possibility of long-term effects of age at weaning, carcass data, as recorded by graders of Agriculture Canada, were analysed. Due to the time limitation, only slaughter records of the first year of the trial (1984/85) were evaluated for potential treatment effects.

Statistical Analyses

Least squares analyses of variance and covariance for unequal subclass numbers were computed as outlined by Mehlenbacher (1978).

For the analysis of weight changes during the time between early and late weaning as well as during the adjustment period, a model was used with effects of year, weaning treatment, breed-group the of calf and age the of dam as sources of variation and preweaning average daily gain as covariate.

Levels of the main effects were:

1. Year (R), classified as either 1984/85 or 1985/86;
2. Weaning treatment (W), classified as early or late;
3. Breed-group (B), classified as SY, HX and SD;
4. Age (A) of dam, classified as 2, 3, 4 years of age, or mature (over 4 years of age).

The model employed was:

$$Y_{ijklm} = u + R_i + W_j + B_k + A_l + RW_{ij} + RB_{ik} + RA_{il} + WB_{jk} + WA_{jl} + RWB_{ijk} + e_{ijklm}$$

where:

Y_{ijklm} = trait under consideration

u = overall mean

R_i = the effect of the ith year

W_j = the effect of the jth weaning treatment

B_k = the effect of the kth breed-group

A_l = the effect of the lth age of dam

RW_{ij} = the effect of the interaction between the ith year and the jth weaning treatment

RB_{ik} = the effect of the interaction between the ith year and the kth breed-group

RA_{il} = the effect of the interaction between the ith year and lth age of dam

WB_{jk} = the effect of the interaction between the jth weaning treatment and the kth breed-group

WA_{jl} = the effect of the interaction between the jth weaning treatment and the lth age of dam

RWB_{ijk} = the effect of the interaction between the ith year, the jth weaning treatment and the kth breed-group; and

e_{ijklm} = random error.

The same model was used for the analysis of daily gain during the feedlot trial, but the effect of age of dam, which was non-significant, was removed. Feedlot weights were analysed using this model as well after further removal of pre-weaning average daily gain. The adjusted final feedlot weight was computed by adding weight at the start of the test (October 1) as covariate.

The analysis of the effects of season of birth on performance was computed using the above model and introducing season of birth as a main effect with three levels.

A number of the cows in this study had been classified as culls before weaning. Culling was not based on weaning weights and as the distribution of cull cows during the first year was balanced between weaning treatments (13 early and 15 late weaned cows) no adjustment was necessary. However, in the second year all cull cows (24) were assigned to the early weaned group, which required a within-year analysis of the effect of culling the dam on the performance of its calf. For this analysis culling was added as a main effect, while the year effect was removed. Culling of the dam, however, did not result in any effect on calf performance (see paragraph 6) and no further adjustments were made in any of the analyses.

Feed consumption and efficiency were analysed on a pen basis and a simpler model had to be used, with year, weaning treatment and the interaction between the two as main effects. Carcass data were analysed with only weaning treatment, breed-group and their interaction as main effects.

Student-Newman-Keuls tests as outlined by Steel and Torrie (1980) were employed to test differences between subclass means whenever significant differences were established by the least squares analysis.

II.3. RESULTS AND DISCUSSION

1. AGE AND WEIGHT AT START OF TEST (DATE OF EARLY WEANING)

Early weaned calves in both years averaged 156 days of age at weaning (October 1), whereas those, which were weaned late, were 187 days old in the first and 192 days old in the second year. This greater difference in age between the two weaning groups in 1985 was probably due in part to the fact that the late weaning date in 1985 was 3 days later than in 1984 (November 4 vs 1).

An analysis of the weights on October 1 revealed a highly significant year effect ($P<.005$). While calves in 1984 weighed on average 202.5 kg, their average bodyweight was 212.9 kg in 1985 (Table II.1). As there was only an overall age difference of 2 days between the two years and neither the age nor the breed-group composition of the dam herd changed significantly in the two years, this difference was likely a result of better grazing conditions in the second year.

As might have been expected, age of dam had a highly significant effect ($P<.005$) on October weights of calves. In total, dams which were 5 years and older had the heaviest calves in both years (228.6 and 227.3 kg in 1984 and 1985) followed by 4-year olds (206.6 and 226.1 kg), 3-year-olds (194.0 and 209.0 kg) and 2-year olds (180.7 and 194.1 kg). It is noteworthy that the difference between 4

TABLE II.1 Least squares means and standard errors of October 1 weights of calves (kg) by weaning treatment and breed group

	Breed-Group			
	SY	HX	SD	Total
1984				
Early weaned	$195.2^{a} \pm 4.6$	$187.8^{a} \pm 4.4$	$216.5^{b} \pm 5.3$	199.9 ± 3.0
Late weaned	$208.6^{a} \pm 4.3$	$197.1^{b} \pm 5.1$	$206.8^{a} \pm 6.0$	204.2 ± 3.4
Total	$202.1^{a} \pm 3.4$	$192.5^{b} \pm 3.7$	$212.7^{c} \pm 4.5$	202.0 ± 2.3
1985				
Early weaned	213.0 ± 5.0	201.1 ± 4.8	207.7 ± 5.9	207.3 ± 3.5
Late weaned	$217.4^{a} \pm 4.7$	$209.6^{b} \pm 4.9$	$235.2^{c} \pm 5.6$	220.8 ± 3.3
Total	$215.2^{a} \pm 3.8$	$205.3^{b} \pm 3.7$	$221.7^{a} \pm 4.6$	214.0 ± 2.5

a,b,c Means with different superscripts in the same row are significantly different ($P < .05$)

and 5 year old dams was significant only in 1984 and was very small in 1985, but as the latter group consisted of cows which ranged from 5 to 14 years of age, it is conceivable that this could be a seasonal influence, whereby old cows might be adversely affected by a climate which would only marginally influence younger cows.

Effect of breed-group was highly significant in both years (P<.005), although there was no interaction between breed-group and year. In both years, Dairy Synthetic dams weaned calves which were heavier than Beef Synthetic dams and Hereford Crossbreds (Table II.1). These results are in agreement with those reported by Arthur (1981), Butson (1981), Novak et al. (1984) and Ahunu and Makarechian (1984).

In the second year the early weaned Dairy Synthetic calves were much lighter than their late weaned contemporaries (Table II.1) and weighed 5.3 kg less than Beef Synthetic calves. This trend was the reverse of what was observed in 1984, where the late weaned SD group was lighter than the early weaned one, although the difference in that year was not as pronounced as it was in 1985. The reason for this difference between early and late weaned Dairy Synthetic calves during the two years is not clear, however, the somewhat younger age in the early weaned SD calves (158 vs 164 days on October 1) and their lower birthweight (39.7 vs 42.6 kg) in 1985, although not statistically significant, might have been contributing factors.

2. AVERAGE DAILY RATES OF GAIN DURING THE PERIOD BETWEEN EARLY AND LATE WEANING DATES

The comparison of daily rates of gain between early and late weaning dates is important as it allows an assessment of differences in performance of calves still nursing and calves being fed hay and concentrate. If early weaning is to be a successful alternative, then early weaned animals should not be substantially lighter than their late weaned mates at the time when the latter group is weaned.

The difference in October weights between weaning groups, particularly in the SD calves, made it necessary to perform an analysis of covariance with October weight as covariate within each breed-group to determine the effect of initial weight on daily rates of gain. This was particularly important for the comparison of daily rates of gain in weaned and unweaned calves during the period between the two weaning dates, as the effect of initial weight would have been confounded with the effect of weaning date. In all three analyses, the covariate proved not to be a significant factor, although as expected, year and weaning effects were significant ($P<.05$) within all three breed-groups. Correlation coefficients between October weight and gain between October and November ranged from -0.39 to 0.47 and were significant in only 4 of the twelve treatment groups. Neither the range of coefficients nor their significance levels showed any trends within breed-groups, years or weaning groups and based on these results, no adjustment for initial weight differences was made in any of the subsequent analyses of daily rates of gain. The lack of any firm correlation between weight and subsequent average daily gain is very much in agreement with results obtained by Green and Buric (1953), who reported correlation coefficients ranging from .46 to -.32 when analysing starting weight and average daily gains in ten weighing periods with no uniformity in pattern.

The analysis of rates of gain during the period between early and late weaning dates revealed a highly significant year and weaning treatment effect ($P<.005$), although there was no significant interaction between the two. Breed-group and age of dam and all the other two- and three-way interactions with the exception of the weaning treatment by age of dam interaction were not significant.

Generally, calves gained faster in 1985 than in 1984 (0.05 vs 0.48 kg/day). This is undoubtedly a result of the rather adverse weather conditions in October of 1984 during which temperatures were generally low and snow covered the ground for several days which resulted in a weight loss in the late weaned animals. Early weaned calves gained overall at a faster rate than those which remained with their dams (0.39 vs 0.13 kg/day for both years). As Table II.2 shows, the difference in performance between the two weaning groups remained nearly the same in both years (0.26 and

TABLE II.2 Least squares means and standard errors of average daily rates of gain (kg) of early and late weaned calves during the period between early and late weaning

	Early weaned	Late weaned	Total
1984	0.18[a] ± .03	-0.08[b] ± .03	0.05 ± .02
1985	0.61[a] ± .04	0.34[b] ± .03	0.48 ± .03
Total	0.39[a] ± .02	0.13[b] ± .02	

[a,b] means in the same row with different superscripts are significantly different ($P<.05$)

0.27 kg) which indicates that both groups were equally affected by the difference in weather conditions. This is somewhat surprising considering that feeding conditions for the late weaned calves in 1984 were relatively worse than in 1985 and the difference in rates of gain between early and late weaned calves should, therefore, have been greater in the first year.

The observed difference in growth rates between early and late weaned calves during the period between the two weaning dates is in agreement with most other reported results. Harvey et al. (1975) found daily rates of gain in early weaned calves ranging from 0.59 to 0.84 kg, depending on nutritional regime, compared to 0.58 kg for calves remaining with their dams. Neville and McCormick (1981) found between 0.11 and 0.19 kg difference in average daily gain in favor of early weaned animals and Richardson et al. (1978) reported 10.1 kg difference in 210-day adjusted bodyweights in favor of early weaned calves when compared with their late weaned contemporaries. However, these results are in contrast to those reported by Basarab et al. (1986). These workers, while studying the effects of pre-conditioning and using the same weaning regime as described in this study, found that early weaned calves grew 0.59 and 0.53 kg per day less in 1982 and 1983, respectively compared with late weaned animals in the period between early and late weaning. Wieringa et al. (1974) reached a similar conclusion and reported 2.7 kg higher liveweight gain in calves remaining with their dams during a twenty day preconditioning trial. This variablity is probably, at least in part, due to the fact that in this study the difference in the two weaning dates was only one month, whereas weaning dates in the aforementioned studies differed by as much as 170 days, which would reduce the effects of the stresses of weaning and nutritional adjustment on the rate of gain between weaning dates and thereby reduce the variability of the results.

Table II.3 shows the weights of the calves at the time of late weaning for both years, weaning treatments and breed-groups. When comparing this table with Table II.1, which showed the October weights, it becomes apparent that while weight gains in the first year were moderate, even in the early weaned group, they were considerably larger in the second year reaching up to 20 kg.

These results show that early weaned calves can in fact grow faster than calves remaining with their dams, particularly when grazing conditions are poor.

3. AVERAGE DAILY RATES OF GAIN DURING THE ADJUSTMENT PERIOD (FOUR WEEKS FOLLOWING WEANING)

To assess the possibility of an interaction between response to the stress of weaning and age at weaning, an analysis of daily rates of gain during the four weeks immediately following weaning was performed. As work by Novak et al. (1984) had indicated a considerably different

TABLE II.3 Least squares means and standard errors of November 1 weights of calves (kg) by weaning treatment and breed group

	Breed-group			
	SY	HX	SD	Total
1984				
Early weaned	$199.9^{a} \pm 4.7$	$194.1^{a} \pm 4.6$	$222.0^{b} \pm 5.0$	205.3 ± 3.1
Late weaned	$205.5^{a} \pm 4.5$	$193.6^{b} \pm 5.2$	$205.8^{a} \pm 6.3$	201.6 ± 3.5
Total	$202.7^{a} \pm 3.5$	$193.9^{b} \pm 3.8$	$213.9^{c} \pm 4.6$	203.5 ± 2.4
1985				
Early weaned	232.7 ± 5.1	223.4 ± 4.9	228.3 ± 6.2	228.1 ± 3.7
Late weaned	$227.7^{a} \pm 4.9$	$224.5^{a} \pm 5.1$	$245.0^{b} \pm 5.8$	232.4 ± 3.4
Total	$230.2^{ab} \pm 3.9$	$224.0^{a} \pm 3.9$	$236.6^{b} \pm 4.8$	230.3 ± 2.5

[a,b,c]Means within different superscripts in the same row are significantly different ($P < .05$)

growth pattern between the first two weeks and the second two weeks, statistical analyses for the total period of four weeks, as well as for each two-week period were performed.

During the first two weeks, the effects of year ($P<.05$) and weaning treatment ($P<.005$), as well as the interaction between the two ($P<.005$) were significant. Age of dam was not significant, neither was breed-group, however, the interaction between breed-group and weaning treatment approached significance ($P<.1$). Pre-weaning average daily gain, which was entered as covariate, proved to be a significant factor ($P<.05$) with a coefficient of -.54. In 1984 as well as 1985, early weaned calves lost weight in the two weeks following weaning, whereas the opposite took place in late weaned calves (Tables II.4 and II.5).

Change in weight after weaning depends on a number of factors such as the time required by the calf to adjust to the change in nutrition and environment, the type of diet offered and the quality of feed available prior to weaning. The opposite direction of change of weight between the two groups is certainly, at least in part, a result of the difference in pasture condition before the two weaning dates. Late weaned calves had lost weight during the four weeks before weaning in the first year and had shown a rather low daily rate of gain in the second year so that the increase in weight following weaning was likely a response to the poor nutritional status before weaning.

TABLE II.4 Least squares means and standard errors of average daily rates of gain (kg) during the first two weeks following weaning

	Early weaned	Late weaned
1984	$-0.57^{a} \pm .06$	$0.78^{b} \pm .08$
1985	$-0.22^{a} \pm .08$	$0.08^{b} \pm .07$
Both years	$-0.40^{a} \pm .05$	$0.43^{b} \pm .05$

a,b means in the same row with different superscripts are significantly different (P>.05)

TABLE II.5 Least squares means and standard errors of average daily rates of gain (kg) of the three breed-groups during the first two weeks following weaning

	Breed-group		
	SY	HX	SD
1984			
Early weaned	-0.59 ± .09	-0.60 ± .09	-0.53 ± .11
Late weaned	0.85 ± .09	0.80 ± .11	0.69 ± .14
Total	0.13 ± .07	0.10 ± .08	0.08 ± .10
1985			
Early weaned	-0.19 ± .11	-0.09 ± .10	-0.38 ± .13
Late weaned	0.03 ± .10	0.16 ± .10	0.06 ± .13
Total	-0.08 ± .08	0.03 ± .08	-0.16 ± .10
Both years	0.03 ± .05	0.07 ± .06	-0.04 ± .07

Unfortunately there is little detailed information available on the effects of weaning age or pre-weaning nutrition on immediate post-weaning gain. Herrick (1978) concluded that calves lose up to 3 to 5% of their bodyweight under normal conditions as a result of weaning and require at least 2 weeks to regain that loss. Novak et al. (1984) found a daily loss of 0.59 kg in early weaned calves from day one to day 14 and Hodgson (1965) reported a strong negative correlation between age at weaning and subsequent weight changes. Arguelles and Leiva (1978) concluded that weaning calves at 6, 7 or 8 months resulted in daily rates of gain of .29, .29 and .32 kg during the first month after weaning (P>.05).

It is noteworthy that with the exception of early weaned SD calves in the second year, the response to weaning was nearly the same in all breed-groups, which is surprising considering the differences in pre-weaning average daily gain.

During the second period of two weeks the effects of year (P<.005), weaning treatment (P<.005), as well as the interaction between the two proved to be highly significant (Tables II.6 and II.7). In 1984 and 1985, early weaned calves showed a positive weight change, gaining 0.94 and 1.16 kg per day, which indicates that they had overcome the stress of weaning. However, late weaned calves had no net gain during this period in the first year, although the rather large standard errors indicate a great variation

TABLE II.6 Least squares means and standard errors of average daily rates of gain (kg) during the second two weeks following weaning

	Early weaned	Late weaned
1984	0.94[a] ± .06	0.00[b] ± .08
1985	1.16[a] ± .07	0.66[b] ± .07
Both years	1.05[a] ± .04	0.33[b] ± .05

[a,b] means in the same row with different superscripts are significantly different (P<.05)

TABLE II.7 Least squares means and standard errors of average daily rates of gain (kg) of the three breed-groups during the second two weeks following weaning

	Breed-group		
	SY	HX	SD
1984			
Early weaned	1.04[a] ± .09	1.07[a] ± .09	0.72[b] ± .11
Late weaned	0.02 ± .09	0.08 ± .11	-0.11 ± .14
Total	0.53 ± .07	0.58 ± .08	0.31 ± .10
1985			
Early weaned	1.14 ± .10	1.26 ± .10	1.07 - .13
Late weaned	0.72[ab] ± .10	0.81[a] ± .10	0.46[b] ± .12
Total	0.93 ± .08	1.04 ± .08	0.76 ± .10
Both years	0.73[a] ± .05	0.81[a] ± .06	0.53[b] ± .08

[a,b] means with different superscripts in the same row are significantly different ($P<.05$)

among the calves. The reason for the low performance of the late weaned calves compared with their early weaned contemporaries is likely to be the result of an inadequate feeding regime during the adjustment period. As late weaned calves responded to weaning with an immediate weight gain during the first two post-weaning weeks, it is possible that their nutritional requirements were not met by the standard adjustment diet.

Breed-group of calf proved to be a significant factor influencing gain during the second two weeks (P<.05) and its interaction with weaning treatment approached significance (P<.01). In both years and weaning treatments, Hereford Crossbred calves overcame the effects of weaning in the shortest period and had, subsequently, the highest average daily rate of gain. Since this group also had the lowest pre-weaning average daily gains, the covariate proved again to be a significant factor (P<.05) with a positive coefficient of .57. This change of the coefficients from a negative to a positive value is not surprising as a high pre-weaning daily rate of gain is a reflection of a high milk yield by the dam (Butson et al., 1980; Butson and Berg, 1984) and it is, therefore, conceivable that calves, whose dams produce more milk depend to a greater extent on it for their nutrition. This greater dependence would be reflected by a lowered ability to switch to a total solid feed intake, and, thus, result in a lower rate of gain.

The analysis of weight change during the total adjustment period showed year, breed-group and year x weaning treatment interaction as significant factors (P<.005). Overall, early weaned calves gained 0.39 kg/d (0.19 kg in 1984 and 0.59 kg in 1985) while those weaned late gained 0.37 kg/d (0.39 and 0.36 kg in the two years, respectively), a small enough difference to remove weaning treatment as significant factor. Gains in 1985 were generally higher than in 1984 (0.48 vs 0.29 kg/d) and SY and HX calves gained more than SD (0.41, 0.46 and 0.28 kg/d respectively). The lower rate of gain in the SD calves is likely to be a reflection of the higher pre-weaning average daily rate of gain as a result of the superior milk production of their dams. Due to the fact that the covariate coefficients changed direction in the two periods, pre-weaning average daily gain was not significant when entered as a covariate for the whole period.

In conclusion it can be stated that based on these results, there is some difference in the immediate post-weaning performance between early and late weaned calves. However, this difference can be minimized provided that calves are adequately fed.. It would also appear that early weaning could cause greater variation in gains, and might, therefore be advisable only to good managers.

4. AVERAGE DAILY RATES OF GAIN DURING THE FEEDLOT TRIAL

4.I. Comparison of early and late weaned animals during the

140-day feedlot period following the end of their respective adjustment periods.

This comparison between early and late weaned animals was made during the 140-day periods, which immediately followed the adjustment period of each weaning group and which, consequently, was made between animals which were one month apart in age.

An analysis of covariance of daily rates of gain between the two weaning groups during the total length of the 140-day feedlot trial showed no significant year or year x weaning treatment interaction effects. Calves gained 1.65 kg/day in 1984/85 and 1.68 kg/day in 1985/86. Weaning treatment, however, was highly significant (P<.005). Whereas early weaned calves gained 1.58 and 1.57 kg per day, their late weaned mates averaged 1.72 and 1.79 kg in the two years, respectively.
Pre-weaning average daily gain, which was entered as covariate in this analysis, was also highly significant (P<.005) with a coefficient of .38. The genetic correlation between pre-weaning and post-weaning ADG has been well established. Nelson and Kress (1979) reported a correlation coefficient of .55 between the two traits in Hereford bull calves, while Brown et al. (1974) found higher values of .85 and .84 for Hereford and Angus bulls.

In order to ascertain whether the difference in daily rates of gain was not only a function of different weaning treatments but also of the difference in liveweights at the start of the test, an additional analysis of covariance with body weights at the start of the test as covariate was performed. As expected, body weight was a strong source of variation, with a significance le[illegible] of P<.005. Weaning treatment, however, was still a [illegible]ficant factor (P<.005) in this analysis. That both cov[illegible] proved to be highly significant is not surprising, as correlations between the two traits of .98 (Petty and Cartwright, 1966), .95 (Koch et al., 1973) and .94 (Nelsen and Kress, 1979) have been reported in the literature. Estimates of correlation coefficients between weaning weight and postweaning average daily gain in the literature are also fairly high. Dinkel and Busch (1973) gave an estimate of .77 in Hereford steers and Carter and Kincaid (1959) reported an estimate of .66 in Hereford, Angus and Shorthorn steers, whereas estimates for bulls were smaller (.18). The reason for the difference between bulls and steers was not clear.

The effect of breed-group was another significant source of variation (P<.005) and its interaction with year approached significance (P<.1). During the feedlot trials SY bulls grew faster in both years than HX and SD (1.78 vs 1.61 and 1.60 kg per day, respectively, Table II.8). In both treatments and years, SY exhibited a faster rate of gain than HX and SD, whereas SD performed better than HX only when they were weaned late. Thus, the set-back, which these calves received from early weaning appears to be greater than that of HX calves and it appears to last

TABLE II.8 Least squares means and standard errors of average daily rates of gain (kg) of the three breed-groups during the feedlot trial following the adjustment period of early and late weaned calves

	Breed-group		
	SY	HX	SD
1984/85			
Early weaned	$1.67^{a} \pm .04$	$1.57^{b} \pm .04$	$1.51^{b} \pm .04$
Late weaned	$1.86^{a} \pm .04$	$1.64^{b} \pm .04$	$1.66^{b} \pm .05$
Total	$1.82^{a} \pm .03$	$1.60^{b} \pm .03$	$1.54^{b} \pm .04$
1985/86			
Early weaned	$1.71^{a} \pm .04$	$1.53^{b} \pm .04$	$1.48^{b} \pm .05$
Late weaned	$1.88^{a} \pm .04$	$1.73^{b} \pm .04$	$1.76^{b} \pm .05$
Total	$1.75^{a} \pm .03$	$1.64^{b} \pm .03$	$1.66^{b} \pm .04$

a,b means in the same row with different superscripts are significantly different ($P<.05$)

throughout most of the feedlot period, although it must be kept in mind that neither breed-group x weaning treatment nor breed-group x weaning treatment x year were statistically significant factors.

The analyses of covariance of the five separate weighing periods, in which pre-weaning average daily rates of gain had been entered as covariate, showed a somewhat incoherent development of significance levels of the treatment effects. Year effect was significant during two periods (period 4 and 5), but as any single weighing period comparison in this analysis consists of a comparison of two different months in which climatic conditions could have been significantly different, the weaning treatment and season are confounded and any firm conclusion is difficult. Weaning treatment was significant in periods 1, 2 and 4, approached significance in period 3 and was non-significant in period 5. Average daily rates of gain for early vs late weaned animals were 1.38 vs 1.56, 1.62 vs 2.00, 1.67 vs 1.75, 1.53 vs 1.84 and 1.68 vs 1.71 kg for the five periods, respectively (Table II.9). It is likely that the rather small difference in period 3, which is in fact a comparison of performance of early weaned animals in January with that of late weaned animals in February is again the result of very different climatic conditions. A similar reason might be responsible for the small difference in period 5.

Breed-group had a significant effect on gain only

TABLE II.9 Least squares means and standard errors of daily rates of gain (kg) of early and late weaned calves during each weighing period

	Early weaned	Late weaned
Period 1*	1.38 ± .03	-
2	1.62 ± .03	1.56 ± .03
3	1.68 ± .03[a]	2.00 ± .03[b]
4	1.52 ± .03[a]	1.75 ± .03[b]
5	1.68 ± .03[a]	1.84 ± .03[b]
6	1.56 ± .03[a]	1.71 ± .04[b]
Total:		
Periods 1-5	1.58 ± .02	
Periods 2-6	1.61 ± .02[a]	1.76 ± .02[b]

* Period 1 marks start of feedlot trial for early weaned, 2 for late weaned calves

[a,b] Values with different superscripts in the same row are significantly different (P<.005)

during periods 2 to 5.

Pre-weaning average daily gain proved to be a significant source of variation in all periods with the exception of period 4. The reason for this is not clear.

From the preceding results it is apparent, that early weaned calves had a lower daily rate of gain than their late weaned mates when compared during the time immediately following the adjustment period, which holds true, even [illegible] removal of weight differences at the start of the [illegible] However, it must be kept in mind that this comparison [illegible]volved animals which were in fact one month apart in age and exposed to different climatic conditions in each period and, therefore, had different feed requirements for maintenance and growth rates. These factors were all confounded with the possible effect of early or late weaning and it was not possible to separate them. The lack of any significant difference between weaning groups in the last period might suggest that as calves become older they reach a state of maturity in which the effects of weaning and age difference disappear.

4.II. Comparison during the 140 days which followed the adjustment period of the late weaned calves

To determine if weaning treatment had an effect on calves of the same age, an analysis was performed, in which the performances of early and late weaned calves were compared during the same time period beginning with the start of the 140-day feedlot trial of the late weaned calves. At the beginning of this period, early weaned calves had already been on feedlot trial for one month, whereas late weaned calves were just entering their 140-day test period.

The analysis revealed again no significant year effect, although average daily rates of gain were higher in 1985/86 than in the previous year (1.66 vs 1.76 kg/d). Weaning treatment, however, was a highly significant source of variation (P<.005), although there was no significant interaction between the two factors. Late weaned animals gained 1.76 kg/d while early weaned animals averaged 1.61 kg/d (Table II.10).

As expected, breed-group was also significant (P<.005) as was the year x breed-group interaction (P<.01). In total, SY calves had the highest rates of gain (1.78 kg/d) followed by HX (1.64 kg/d) and SD (1.62 kg/d). Separated by year, SY calves grew at the highest rate in both years (1.81 and 1.75 kg/d), however, HX grew faster than SD only in the first year, whereas they were growing at a far slower rate than SD in the second year (1.62 and 1.66 kg/d for HX, and 1.54 and 1.70 kg/d for SD in the two years, respectively). Table II.10 shows gains of breed-groups within weaning treatments in both years and it is apparent that all three breed-groups responded to the weaning treatment in a very similar pattern, with SY calves having

TABLE II.10 Least squares means and standard errors of average daily rates of gain during the feedlot trial corresponding to the feedlot period of the late weaned calves

	Breed-group		
	SY	HX	SD
1984/85			
Early weaned	$1.66^{a} \pm .04$	$1.61^{ab} \pm .04$	$1.52^{b} \pm .05$
Late weaned	$1.86^{a} \pm .04$	$1.63^{b} \pm .05$	$1.68^{b} \pm .05$
Total	$1.81^{a} \pm .03$	$1.62^{b} \pm .03$	$1.54^{b} \pm .04$
1985/86			
Early weaned	$1.73^{a} \pm .04$	$1.58^{b} \pm .04$	$1.55^{b} \pm .05$
Late weaned	$1.88^{a} \pm .04$	$1.75^{b} \pm .04$	$1.74^{b} \pm .05$
Total	$1.75^{a} \pm .03$	$1.66^{b} \pm .03$	$1.70^{ab} \pm .04$

[a,b] means with different superscripts in the same row are significantly different ($P<.05$)

a higher daily rate of gain in both weaning groups. Early weaned SD animals consistently had the lowest rate, whereas late weaned SD either outgrew their HX contemporaries or, as in the second year, had almost the same gains as the latter.

Pre-weaning average daily gain again proved to be a significant source of variation with a probability level of P<.005 and a covariate coefficient of .40.

To determine patterns of significance levels, separate analyses were again performed for each of the individual 28-day weighing periods of the 140-day feedlot trial.

Year had a significant effect only during period 3 (February) when gains differed by 0.15 kg per day. This, undoubtedly, was a reflection of the very cold weather conditions that prevailed during that month in 1985 which resulted in considerably lower average daily rates of gain. Weaning treatment was highly significant during all weighing periods (P<.005) with the exception of period 1, in which, however, a significant year × weaning treatment effect was noted. While early weaned calves gained 1.70 kg/d during that period in 1984, their late weaned contemporaries had an average daily rate of gain of 1.52 kg/d. This trend was reversed in 1985, when weight gains in both groups were similar (1.58 vs 1.55 kg/d). Generally both weaning groups showed the same fluctuations in daily gain, with a drop in February and a levelling off during the last weighing period. This is in contrast with results reported by Green and Buric (1953) who found a far greater variation in daily rates of gain per weighing period in late weaned animals than in early weaned calves.

The year x weaning treatment interaction was also significant in periods 2 and 5, but not in periods 3 and 4.

Breed-group had a significant effect in all 5 weighing periods with the exception of the last one, during which SY, HX and SD bulls had average daily rates of gain of 1.67, 1.62 and 1.63 kg respectively. Breed-group x year interaction was significant as well in periods 1 and 5.

Pre-weaning average daily gain had a significant effect on gain per weighing period in all periods except period 4, with significance levels ranging from <.05 to <.005.

The results of the analyses of post-weaning rates of gain during both test trial comparisons suggest strongly that late weaned animals gain at a significantly higher rate than early weaned animals. This was evident not only for the whole period, but for each individual weighing period as well.

There is little information available on feedlot performance of early vs late weaned calves, and the reported results vary greatly due to the differences in weaning treatments. Glimp (1973), weaning calves at 56, 112 and 168 days of age, found that calves, which were weaned later grew faster. While animals, which were weaned at 112 days peaked in the period between 168 and 224 days (1.5 kg vs 1.4 kd/d for 56- and 168-day animals) those weaned at 168 days grew fastest between 224 and 382 days (1.2 vs 1.1 and 1.0 kg/d). Harvey et al. (1975) in a comparison between calves weaned approximately 150 days apart, also found that late weaned animals had a significantly higher growth rate during the feedlot trial following weaning, than their early weaned contemporaries. However, this was not true for early weaned calves whose feed intake had been restricted by the addition of salt to their ration. Richardson et al. (1978) concluded that heifers weaned at 210 days of age gained 11 kg more in the period from 210 to 365 days than those weaned at 120 days. Butler-Hogg et al. (1981), however, who weaned calves at 7 vs 11 months and compared their growth rates from the date of late weaning to slaughter, found no significant difference in growth rate between the two weaning groups.

5. BODY WEIGHTS

In both years there was some variation in weights between weaning groups, which, however, had almost disappeared by November 1 (Table II.11). As these data indicate, late weaned calves did not end the test period heavier despite a significantly higher daily rate of gain and a higher weight in October. The reason for this somewhat surprising observation is the fact that by the beginning of November, early weaned animals weighed nearly as much as late weaned calves. This suggests clearly that

TABLE II.11 Least squares means and standard errors of body weights (kg) for each weighing date between October 1 and April 20

Weighing date	Early weaned	Late weaned
1*	203.0[a] ± 2.4	214.0[b] ± 2.5
2**	216.7 ± 2.5	217.0 ± 2.5
3	257.3[a] ± 2.8	226.2[b] ± 2.9
4	303.2[a] ± 3.0	269.3[b] ± 3.1
5	350.2[a] ± 3.3	324.2[b] ± 3.5
6	393.2[a] ± 3.6	372.8[b] ± 3.8
7	440.5[a] ± 3.9	424.6[b] ± 4.1
8	485.0[a] ± 4.1	473.8[b] ± 4.3
***	486.1[a] ± 4.1	461.8[b] ± 4.2
****	282.0	259.1

* October 1, weaning date of early weaned calves

** November 1, weaning date of late weaned calves

*** Final weights with initial weight as covariate

**** Weight changes during test period

a,b Weights with different superscripts in the same row within the same year are significantly different (P<.05) calves, which had remained with their dams during October remained very much below their growth potential, undoubtedly a result of inadequate nutrition. During the month of November, early weaned animals had overcome the stress of weaning and were growing at a relatively fast rate, while late weaned animals were undergoing their adjustment period, which resulted in a further advantage for early weaned animals. This is demonstrated in Figure II.1, which shows the actual body weight gains of early and late weaned animals in each of the weighing periods beginning with October 1.

During the total period from October to April, early weaned animals gained 282.0 kg, while late weaned animals gained 259.1 kg, the difference being significant (P<.05). Entering weight in October as covariate still resulted in a significant difference between weights at the end of the feedlot test in April.

The analysis of body weights also indicated that April weights in 1985 were significantly lower than in 1986 (459.5 vs 498.6 kg, P<.005), and the differences between the three breed-groups were all significant (P<.005), with SY calves weighing 499.2, HX 455.4 and SD 482.5 kg. During the total length of the trial from October 1 to the end of the test in April, SY had gained 287.0 kg which was significantly different from HX (261.7 kg) and SD (264.4 kg). Figure II.2 shows the liveweight development of the early and late weaned calves within each breed-group

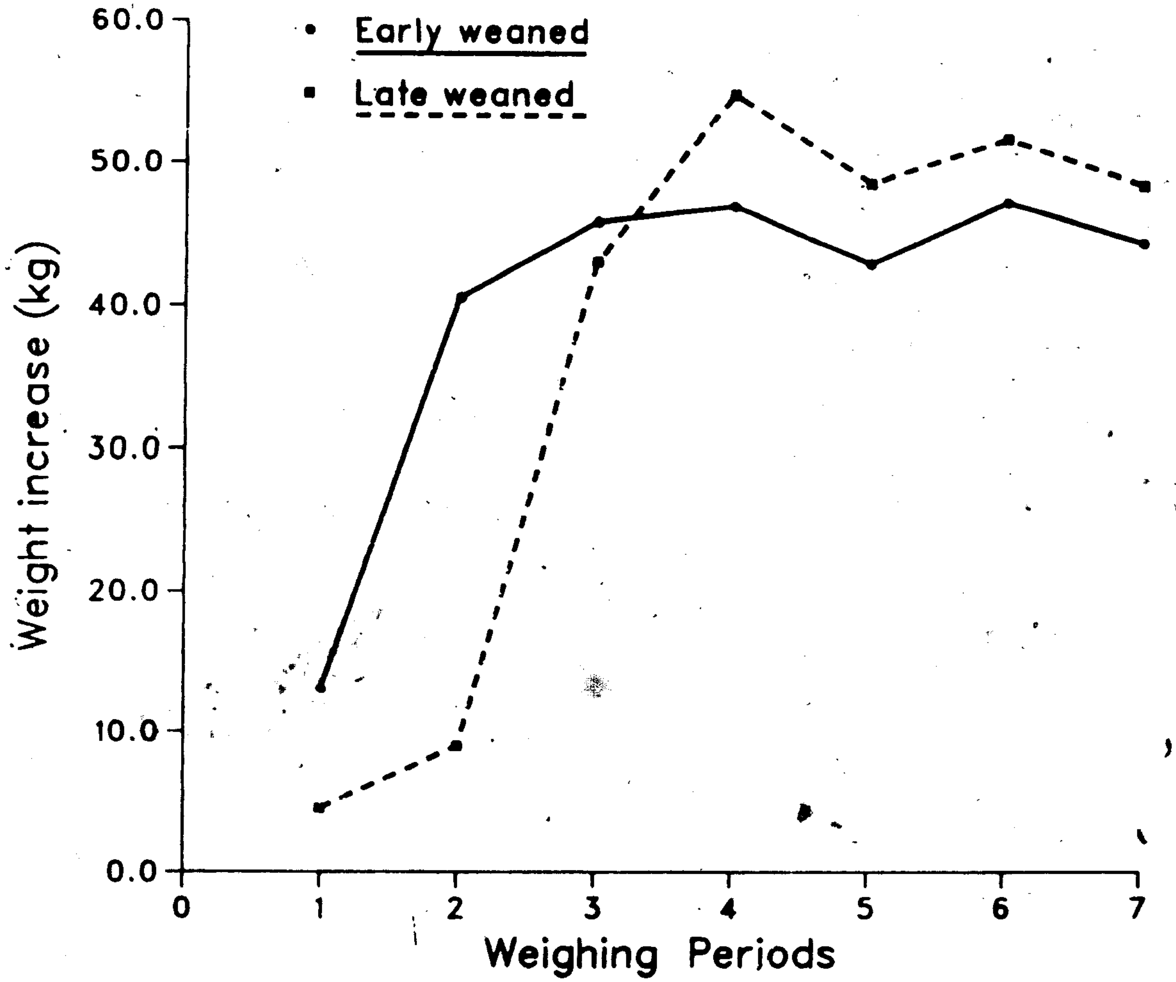

FIGURE II.1. Increase in body weight in the early and late weaned calves in each 28-day weighing period starting from the date of early weaning (October 1)

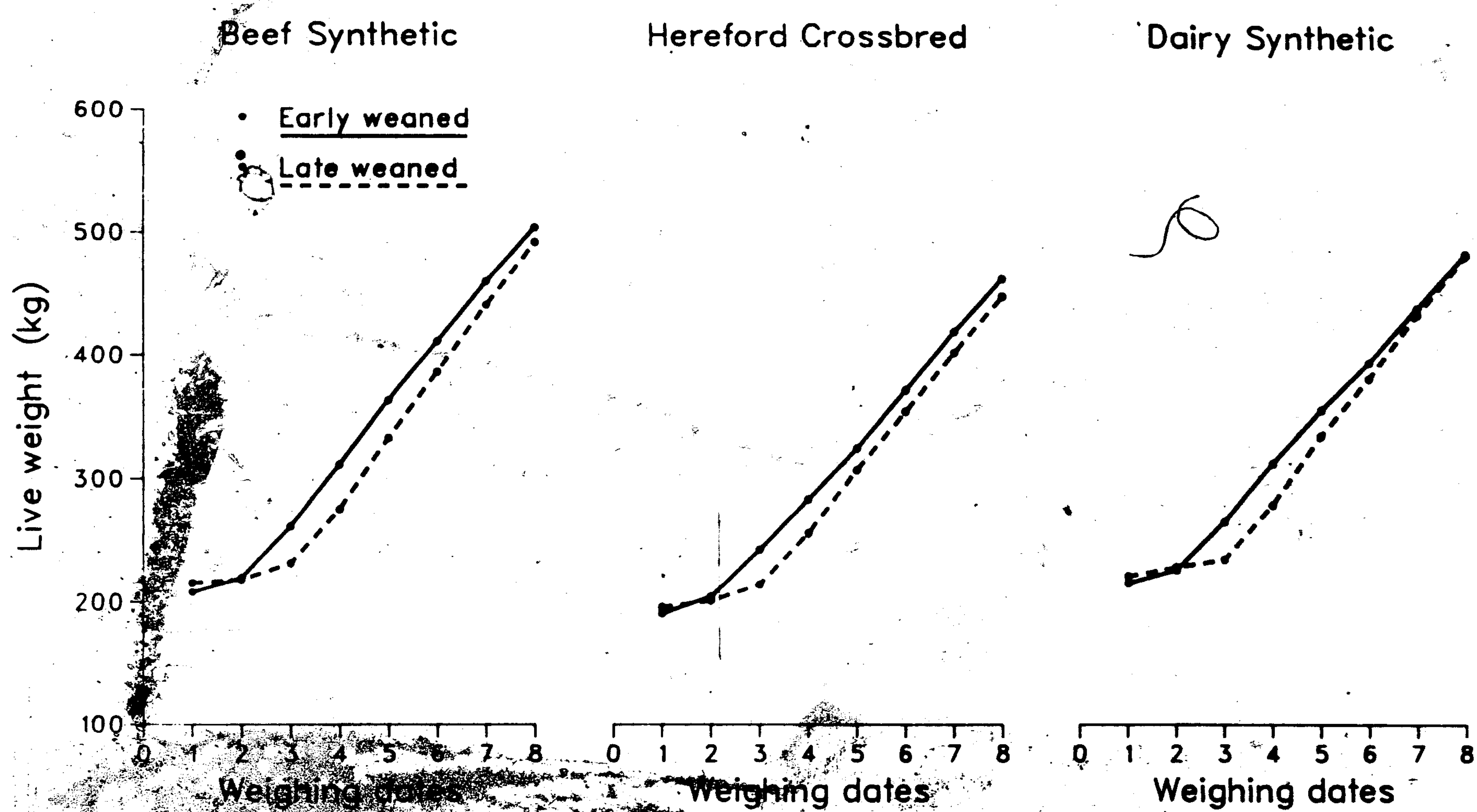

FIGURE II.2 Body weights of the three breed-groups from the date of early weaning to the end of the feedlot trial beginning with October 1. It demonstrates that each breed-group responded quite similarly to the weaning treatment, with early weaned calves being at a clear advantage from the third weighing date on. But it is also apparent that difference between the two weaning groups in each breed-group became consistently smaller as the trial progressed.

6. EFFECT OF CULLING THE DAM ON CALF PERFORMANCE

As all cull cows in 1985 were allocated to the early weaning group (24 of the 87 cows), factors associated with culling would have been confounded with weaning treatment. A within weaning treatment analysis was performed for the second trial year with culling of dam as main effect and pre-weaning average daily gain, October weights and ADG during the feedlot trial as traits under consideration. Pre-weaning average daily gain did not differ significantly between the two dam groups; calves of cull cows gained 1.06, those of dams maintained 1.10 kg. As calves of cull cows were on the average 5 days younger, their October 1 weights were 202.8 kg, while the rest of the calves weighed 211.3 kg, the difference between the two weights, however, was not statistically significant. ADG during the feedlot trial was 1.59 and 1.60 for the two groups, respectively. The lack of any significant difference between the two groups of calves, particularly in the preweaning ADG, is probably due to the fact that these cows were not culled on the basis of weaning weights, but for a number of different reasons, such as bad udders, lameness, poor condition and age, conditions which might not necessarly result in lowered weaning weights.

7. INFLUENCE OF SEASON OF BIRTH

To determine if the season of birth was interacting with age at weaning, all calves were classified into three birth groups, ranging in birth dates (day 1 = January 1) from 89 to 109 (early born group), 110 to 128 (medium group), and 129 to 158 (late born group) days. The fact that the three age groups did not cover an equal range of days was caused by the uneven distribution of birth dates during the calving season. The average ages of the three groups at each weaning are given in Table II.12. Weight changes during the four week long adjustment period were very similar in all six birth groups and did not differ significantly, ranging from .35 to .41 kg per day. Separate analyses for each two-week period showed that with increasing age, calves in each weaning group had lower gains - or greater losses - during the first two weeks, and higher gains in the second two weeks. Table II.12 also gives the average daily rates of gain during the feedlot trial, comparing the initial 140 days following each adjustment period. Although the gains during this period followed the same pattern, i.e. the older the calf, the higher its average daily gain, they also suggest that

TABLE II.12 Range of birthdates (days), average age (days) and least squares means and standard errors of average daily gains (kg) of calves in the three age groups

Range of birth dates*	Average age at weaning		Average daily gain	
	Early	Late	Early	Late
89 - 109	171	203	1.60 ± .03	1.82 ± .03
110 - 128	158	189	1.59 ± .03	1.71 ± .03
129 - 158	135	165	1.51 ± .04	1.74 ± .04

* Day 1 = January 1

calves of approximately the same age at weaning, namely group 1 and 2 of the early and group 3 of the late weaned calves, had significantly different daily rates of gain (1.60 and 1.59 kg/d vs 1.74 kg/d). This might indicate that animals born in different seasons had in fact different optimal weaning ages.

8. FEED CONSUMPTION AND EFFICIENCY

To determine the effects of age at weaning on subsequent feed intake and efficiency of gain, which was determined as kg of feed consumed per kg of weight gained, two analyses were performed. One to compare the two weaning groups in the 140 days immediately following their respective adjustment periods, the other for the 140 days, which corresponded to the feedlot trial of the late weaned calves. To determine possible changes in feed consumption and efficiency during the course of the trial, the two traits were also analysed within each weighing period, however, as records during the first year were not available for this analysis, only data of the second trial year were used. Feed intake and efficiency were calculated on a pen basis, thus, breed-group effects could not be considered in these analyses.

Table II.13 shows the results of the comparison of feed intake between early and late weaned calves during the 140 days following their respective adjustment period, which revealed highly significant year and weaning treatment

TABLE II.13 Least squares means and standard errors of feed consumption and efficiency during the feedlot trial following the adjustment period of each weaning group

	1984/85	1985/86	Total
A) Feed consumption			
Early weaned	$8.5^{a} \pm .1$	$9.2^{a} \pm .1$	$8.8^{a} \pm .07$
Late weaned	$8.9^{b} \pm .09$	$10.3^{b} \pm .09$	$9.6^{b} \pm .06$
Total	$8.7 \pm .07$	$9.7 \pm .06$	
B) Feed efficiency			
Early weaned	$5.2 \pm .05$	$5.7 \pm .04$	$5.5 \pm .04$
Late weaned	$5.1 \pm .04$	$5.7 \pm .04$	$5.4 \pm .03$
Total	$5.2 \pm .04$	$5.7 \pm .03$	

^{a,b} means with different superscripts in the same column are significantly different ($P<.05$)

effects (P<.005). Animals in the second year consumed on the average over 1 kg of feed more daily than in the first year (9.7 vs 8.7 kg, respectively) and, as a result of a non-significant difference in daily rates of gain, feed efficiency was also significantly different in the two years (5.7 vs 5.2 kg of feed per kg of gain). The reason for this difference is partly due to the difference in body weights at the start of the test, however, entering initial weight as covariate still resulted in significant differences between years and weaning groups. Another contributing factor might have been a difference in the quality of feed between the two years. Although the protein content was nearly the same, it is possible that differences existed which were not revealed through the standard feed analyses.

Differences in feed intake between the weaning groups was also highly significant (P<.005) (8.8 vs 9.6 kg for early and late weaned animals, respectively), which is not surprising considering that the animals differed in age by 30 days during this particular comparison. As these groups also differed in growth rates, feed efficiency was nearly the same between weaning groups (5.5 vs 5.4 kg). None of the interactions between treatment factors proved to be significant. Adjusting for weight differences in the analyses did alter the means, however, levels of significance remained the same.

The analysis of feed intake and efficiency for the period when the late weaned group was in the feedlot trial (Table II.14) showed also a highly significant year effect (P<.005). 9.1 kg of feed per day were consumed per animal in the first year, 10.2 kg in the second year during this period, with feed efficiencies of 5.4 and 5.9 kg for the two years, respectively. Weaning treatment did not affect feed intake significantly (9.7 vs 9.6 kg for early and late weaned calves, respectively), however, feed efficiency was significantly different (P<.005) between the two groups (5.9 vs 5.4 kg). Adjusting for differences in November weights did not change any of the levels of significance.

In summarizing it can be concluded that year had a significant effect on feed intake and efficiency, not only through differences in weights, but likely also through differences in climate and possibly health and management conditions. Weaning treatment did not affect feed intake when animals of the same age were compared. Feed efficiency, however, was significantly different between the two groups of animals during the same period due to a faster rate of gain of late weaned animals.

The analysis of data of individual weighing periods in the second year during the period immediately follo[illegible]e adjustment periods showed a significant difference [illegible]ed intake only during the month following the adjustment period in which early weaned calves consumed 6.6 kg compared with 8.1 kg eaten by their late weaned mates. Late weaned calves consumed .6 to 1.4 kg more feed per day in

TABLE II.14 Least squares means and standard errors of feed consumption and efficiency during the period corresponding to the feedlot trial of the late weaned calves

	1984/85	1985/86	Total
A) Feed consumption			
Early weaned	9.3 ± .1	10.1 ± .1	9.7 ± .08
Late weaned	8.9 ± .1	10.3 ± .1	9.6 ± .07
Total	9.1 ± .08	10.2 ± .07	
B) Feed efficiency			
Early weaned	5.7^{a} ± .04	6.2 ± .03	5.9^{a} ± .03
Late weaned	5.1^{b} ± .03	5.7 ± .03	5.4^{b} ± .02
Total	5.4 ± .03	5.9 ± .02	

^{a,b} means with different superscripts in the same column are significantly different ($P<.05$)

each of the five periods, however, with the exception of the first period and the total 140 days, (10.3 vs 9.1 kg), none of these differences were significant.

The second comparison during the time the late weaned calves were in the trial, showed a significant difference in feed consumption between early and late weaned animals only during the first weighing period in which early weaned animals consumed considerably more feed than their late weaned mates (9.1 vs 8.1 kg), very likely a result of the one month the early weaned animals had already spent in the feedlot. The difference for the total period of 140 days, however, was not significant (10.1 vs 10.3 kg for early and late weaned animals, respectively). Feed efficiency, however, favored late weaned animals throughout the trial, with varying levels of significance.

Little information is available on the effects of weaning treatment on feed intake and efficiency, and it is, therefore, difficult to determine the validity of these findings. Butler-Hogg (1981) reported feed intakes (DM) of 7.16 and 7.08 kg in normally weaned Angus and Charolais calves compared to 6.70 and 6.85 kg for early weaned animals with corresponding feed efficiencies of 8.21 and 8.53 vs 7.87 and 8.53 kg for the four groups, respectively, none of these differences were significant. Glimp (1973) determined feed efficienoies in animals weaned at three different ages and concluded that the amount of feed required per kg of gain decreased with increasing age at weaning, however, in his study, differences failed to be significant as well.

It is difficult to suggest any reasons for the more efficient feed conversion of late weaned animals in this study, particularly as the weaning age between the two groups differed only by one month. It might be conceivable that the more efficient growth of late weaned animals was a reflection of catch-up growth.

9. HEALTH STATUS AND MORTALITY

In order to assess any possible effects of weaning age on the occurrence of sickness and death losses, an analysis of health records was undertaken. Occurrences of sickness were only classified as such, if animals had received treatment either by the ranch staff or by a veterinarian and were subsequently entered into the records. Due to the nature of the data, a statistical analysis is difficult and conclusions must be drawn with caution. This is particularly true because of the greater exposure which a pen of animals has to any infection once one of its members has contracted it.

Whenever possible, Fisher's Exact Method, as described by Keeping (1962), was used to determine the significance levels of any differences in animals becoming sick or dying between the two weaning treatments. The parameters of interest in this study were the number of animals becoming sick, the average length of sickness and the number of animals, which were either sent to slaughter prematurely as the result of health problems or which died during the feedlot trial. The period of interest was from day of weaning to the end of the respective feedlot trials of early and late weaned animals.

The main cause of health problems in both years were infections of the respiratory tract, usually diagnosed as laryngitis or pneumonia. In both years, early weaned animals tended to be more affected, eight animals in the first and thirteen in the second year requiring treatment with an average length of treatment of 3.5 days. Among the late weaned animals, only three were affected in the first and two in the second year with an average length of 1.2 days. The difference in the occurrence of respiratory infections was highly significant ($P<.005$) between weaning groups.

The occurrence of respiratory infections seemed to be concentrated in the months from October to December with 93% of all cases being noted during this time. This was particularly evident in the second year in which thirteen early weaned animals contracted the infection at the end of October.

Bloat was the second most common health problem requiring treatment and the most common cause of death. During the first year, one animal from each weaning group was treated for bloat, while two of the early and one of the late weaned animals were found dead and suspected of having died of bloat. In the second year, 5 animals of the early group were treated, while one had died of the condition, five late weaned calves were treated and two were found dead. (An additional seven early weaned animals were treated for bloat, one of which died, as a result of grain overload after their feeder had been empty for some time. However, as this was not a treatment effect, these animals were not considered in the analysis.) There was no significant difference between weaning groups in their susceptibility to bloat, nor was there any pattern in the time of its occurrence.

Three more animals of the early weaned group were treated for abscesses and scours.

In total, of the 198 early weaned animals entering the test in both years, 30 received treatment, compared to 19 of the 183 late weaned calves, however, this difference was statistically not significant.

During the two years, 8 early weaned calves died, 4 as a result of bloat, two of pneumonia and the remaining two for reasons which could not be identified with certainty. Among late weaned animals, 3 losses were recorded, all suspected to have died as a result of bloat. Although the difference between the two weaning groups appears large, it was statistically not significant.

Two of the early and 1 of the late weaned calves were sent to slaughter before finishing the trial period with stiff joints, likely to be the result of acidosis. Two more late weaned animals had to be shipped prematurely, one because of recurring bloat, the other with an injured back.

As already mentioned, it would be inappropriate to generalize these results because of the great number of factors, which can influence herd health. However, these data could lead to the suggestion that early weaned animals have a greater susceptibility to repiratory problems, although there might be a confounding of season with age at weaning which could not be removed. However, Woods et al. (1973) reporting the results of a three-year study on a pre-conditioning program, found no consistent pattern in the occurrence of respiratory diseases. While pre-conditioned calves, which had been weaned four weeks before their un-preconditioned contemporaries, required a greater number of treatments during the preconditioning period in the first year, the trend was reversed in the two following years, when later weaned animals showed more symptoms of respiratory infections.

10. SLAUGHTER CHARACTERISTICS

In order to determine any effects of weaning treatment on carcass characteristics, slaughter data were collected from graders of Agriculture Canada and analysed. Animals were usually sent to slaughter when they had reached a desirable degree of finish and were expected to obtain an optimal carcass grade. This decision was made by visual appraisal. Only results of the first year are considered in this analysis, with a total of 157 animals being slaughtered. The traits investigated were age at slaughter in days, the live weight at the packing plant, fat thickness measured between the 12th and 13th rib over the rib eye (measured perpendicular to the site three quarters of the rib eye area), dressing percentage and the grade, which the carcass received from the graders. As some of the grades occurred in very low numbers, they had to be divided into three groups; group 1 consisting of grade A1, group 2 of grades A2 and A3 and group 3 of all B and C grades.

None of the carcass traits considered differed significantly between early and late weaned calves, although the difference in weight at slaughter was approaching significance (P<.1, Table II.15). Late weaned animals were 7 days older while they were also 14.3 kg lighter. Differences in fat thickness (.5mm) and dressing percentage (.5%) were negligible.

There was also no significant difference in the distribution of grades between early and late weaned animals (Table II.16). Of the carcasses receiving grade 3 (grades B and C), only two were graded as "C" (one of each weaning group), both due to an insufficient fat cover and a light discoloration of the meat. All remaining 21 carcasses of this group received the grade B (17 graded as B1, 3 graded as B2 and 1 graded as B3) because they were classified as "dark cutters", although all ~~of the carcasses~~ had a grade A fat cover. Dark cutting is usually associated

TABLE II.15 Least squares means and standard errors of age (days) and weight at slaughter (kg), fat thickness (mm) and dressing percentage by weaning treatment and breed-group

	Age at slaughter	Weight at slaughter	Fat thickness	Dressing percentage
Early weaned	430 ± 3.9	543.2 ± 5.5	11.0 ± .4	59.7 ± .2
Late weaned	437 ± 4.7	528.9 ± 6.5	10.5 ± .4	59.2 ± .3
Beef Synthetic	422^{a} ± 4.6	544.6^{a} ± 6.5	9.9^{a} ± .4	60.1^{a} ± .3
Hereford Xbred	426^{a} ± 4.8	502.7^{b} ± 6.6	12.2^{b} ± .4	58.5^{b} ± .3
Dairy Synthetic	452^{b} ± 6.3	560.9^{a} ± 8.7	10.1^{a} ± .6	59.8^{a} ± .4

[a,b] Means in the same column with different superscripts are significantly different (P<.05)

TABLE II.16 Number of each grade received by each weaning and breed-group (percentage in parentheses)

	Grade 1*	Grade 2	Grade 3	Total
Early weaned	46 (52.9)	28 (32.2)	13 (14.9)	87
Late weaned	44 (62.9)	16 (22.9)	10 (14.3)	70
Beef Synthetic	37^{a}(60.7)	10^{a}(16.4)	14^{a}(23.0)	61
Hereford Crossbred	35^{a}(59.3)	21^{b}(35.6)	3^{b}(5.1)	59
Dairy Synthetic	18^{b}(48.6)	13^{b}(35.1)	6^{ab}(16.2)	37

* Grades were grouped, Grade 1= A1; Grade 2= A2,A3; Grade 3= B,C

a,b Numbers in the same column with different superscripts are significantly different (P<.05) with pre-slaughter stress (Lewis et al. 1962) and is, thus, not likely to be a result of weaning treatment.

These results are in general agreement with most of the reported studies. Aitken et al. (1963) concluded that although late weaned animals usually had less fat cover, the difference was not significant. All other carcass traits, namely carcass weight, dressing percentage and carcass grade favored early weaned animals, but none of the observed differences approached significance. Swart and Swart (1965), when investigating dressing percentage, weight at slaughter and carcass grading, also reported no difference between weaning treatments with regard to carcass characteristics. Harvey et al. (1975) came to a similar conclusion reporting no significant differences in carcass traits between early and late weaned animals with the exception of kidney and heart fat percentage. However, El-Naggar et al. (1970) studied the effects of weaning at 45 vs 120 days of age of buffalo calves and concluded that dressing percentage was significantly lower for early weaned buffalo bulls and the muscle to bone ratio was in favor of late weaned animals, although on a carcass weight basis there were no significant differences between the two weaning groups. Based on the results reported above and those of other workers, it appears reasonable to conclude that early weaning, at least when the difference between weaning dates does not exceed two or three months, does not result in carcasses of lower quality, any major difference in slaughter age or in lower slaughter weights.

The significant differences in carcass characteristics in this study were all of genetic origin. Hereford Crossbreds and Beef Synthetics were significantly younger in age than Dairy Synthetics (P<.05). Beef and Dairy Synthetics were heavier than Hereford (P<.05) and had a better dressing percentage and a lower fat cover.

60.7% of Beef Synthetic and 59.3% of Dairy Synthetic carcasses received the grade A1, compared to only 48.6% of Hereford Crossbreds, the difference being significant (P<.05). Dairy Synthetics and Hereford Crossbreds received more A2 and A3 grades, however, significantly less B grades than Beef Synthetics, which could indicate a greater susceptibility to stress in this breed-group. Both carcasses receiving the grade C came from bulls of the Dairy Synthetic breed-group.

11. ECONOMIC ANALYSIS

A brief economic comparison between early and late weaned animals which took into account the additional 30 days early weaned animals remained in the feedlot was attempted. Table II.17 shows the cost which occurred during the 170 and 140 days which the early and late weaned animals spent in the feedlot trial. Due to their more efficient feed conversion and the lower straw and labour requirements, late weaned animals gained more economically

TABLE II.17 Cost of gain in the feedlot

Item	Early weaned		Late weaned
Days in feedlot	170		140
Initial weight (kg)	216.70		226.20
Final weight (kg)	485.00		473.10
Total gain (kg)	268.30		246.90
Feed conversion	5.77		5.40
Total feed consumed during feedlot period	1548.09		1333.26
Cost per kg of feed		$0.099	
Cost of feed consumed	152.94		131.70
Straw/day/animal	2.18		2.14
Straw/animal	370.60		299.60
Cost per kg of straw		$0.044	
Cost of straw/animal	16.31		13.18
Labour/animal (bedding, feeding) (hrs)	1.08		0.90
Cost of labour ($15.00 /hr)	16.20		13.50
Total cost of gain	185.45		158.38
Cost per kg of gain	0.69		0.64

than their early weaned contemporaries. Costs of gain for early and late weaned animals were respectively $ 0.69 and $ 0.64.

A partial budget (Table II.18) was constructed to evaluate the performance of early weaned against late weaned calves. The added costs are computed from those presented in Table II.17. As weaning occurred rather late in the season and the two weaning dates were only one month apart, it was unlikely that the saved grazing could be used to delay the start of winter feeding of the dams. It was also assumed that the growth of the pasture in the following year was not influenced to a great extent by the removal of the early weaned calves. For this reason, the pasture which was saved was thought to have no alternative use and hence a value of zero. Based on these assumptions, the partial budget revealed a negative net benefit due to early weaning of $ 9.81 per animal at the end of the feedlot trial.

Costs arising from sick animals have not been included as sickness may not only require treatment, but also lower rate of gain and feed efficiency. It is obvious that an economic analysis of early weaning would require a more detailed investigation of the period from the end of the feedlot trial to the time of slaughter as well as the financial consequences of differences in grading between the two weaning groups. The fact that early weaned bulls were younger at slaughter and heavier might well offset the

TABLE II.18 Partial budget evaluating net benefit of feedlot performance of early weaned calves

Added cost:	
Feed (152.94 - 131.70) =	[illegible]
Bedding (16.31 - 13.18) =	$ 3.13
Labour (16.20 - 13.50) =	$ 2.70
Total added cost	$ 27.07
Added revenue:	
Liveweight (485.0 - 473.1) = 11.9 kg @ $ 1.45 =	$ 17.26
Value of pasture saved	0
Total added revenue	$ 17.26
Added benefit	$ -9.81

higher cost per kg of gain. However, such an analysis would well exceed the limits of this study.

When comparing the cost of gain per kg in this study, it is important to remember that the weaning age differed only by one month. It is conceivable that in situations, in which a feed shortage might persist for a long period of time and unweaned calves could face considerable loss of weight, the cost of gain might well be in favour of early weaned animals. It should also be pointed out that early weaning could lower winter maintenance cost of the dam, which might outweigh the somewhat higher cost of gain of early weaned animals.

II.4. SUMMARY AND CONCLUSIONS

The results reported here support most of those cited in the literature, which indicate that calves can be weaned at different ages without being greatly affected by their weaning treatment. The greatest difference between the two groups in this study occurred during the time between the two weaning dates and the ensuing adjustment periods, when early weaned calves were at a clear advantage and out-gained their late weaned contemporaries. This is crucial, considering that there was merely one month difference between the two weaning dates, whereas in situations of drought or feed shortage, this period could be considerably longer and the advantage; thus, greater.

However, these data also indicate that late weaned animals might respond to the lower growth rate in the early stages with catch-up growth, and subsequently gain faster and more efficiently. Weaning treatment in this study, as well as in others, did not appear to affect overall lifetime performance as assessed by slaughter data. There also does not appear to be a breed influence on performance after different weaning dates, suggesting that animals of different genetic background respond similarly to the effects of age at weaning, although there might be some interaction between season of birth and age at weaning. The herein presented data also suggest that early weaned animals might be more susceptible to respiratory problems, although a firm conclusion is difficult because of the factors involved and the reported findings might be more a result of climatic differences than of weaning treatment. Overall, it appears that early weaning is a viable alternative to customary weaning dates at least from a biological point of view. However, any decision on weaning age will certainly have to meet economic criteria as well, and the feasibility of an early weaning system will depend on a greater number of factors than could be investigated in this study.

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III. EFFECTS OF SHELTER ON FEEDLOT PERFORMANCE OF BULL CALVES

III.1. INTRODUCTION

An increase in efficiency of beef production might be achieved by the provision of an overhead shelter for feedlot cattle, which could reduce the radiant heat loss and keep animals protected and dry during rain or snow storms. The effects of a cold environment on cattle have been well documented.

According to Webster et al. (1970), acclimatization of a large animal to the prolonged cold stress of a western Canadian winter involves adjustment in the energy exchanges of the animal designed to increase comfort and enhance survival. Changes also occur in the processes of energy metabolism which give rise to an elevation in the resting metabolic rate (RMR). It may also lead to an increase in the extent and duration to which an animal can elevate its heat production in the face of severe cold stress, that is, its summit metabolism. Changes can also occur in the superficial tissues of the body and in the hair coat which reduce heat loss by increasing tissue insulation and external insulation, respectively.

Young (1975) noted that prolonged exposure to naturally occurring cold environments causes an elevation in resting metabolism as well as an increased capacity to produce heat, enabling the animal to shift its thermoneutral zone downward.

Warren et al. (1974) reported a difference of 0.30 units of digestibility of chopped forage diets per degree C for steers exposed to temperatures of either 18 or 32 C. These workers also reported longer retention times of feed in the digestive tract and higher fiber digestibility at 32 C as compared to 18 C, which suggests that temperature has an influence on rumen function since the rumen is the major site of fiber digestion. Studies by Christopherson and Milligan (1973), Christopherson and Thompson (1973) and Christopherson (1975) further suggest that feed digestibility might be decreased due to long exposure to cold. In the latter study calves and steers were kept out- or indoors and measurements on digestibility and resting metabolic rates were taken. The results showed that digestibility was directly related to the exposure temperature. As temperatures declined, digestibility also decreased. This decrease in digestibility was estimated at 0.11 units per degree C.

Christopherson (1976) reported results of a study, in which digestion experiments were performed on sheep, steers and calves exposed for prolonged periods to various temperatures in controlled environmental chambers and in field studies on cattle kept outdoors during the winter. Exposure to cold temperatures resulted in reduction of digestibility in sheep, calves and the steers of 0.31, 0.21 and 0.08 units per degree C, respectively. These findings also suggest that, following the principle of similitude, animals of a larger body size are relatively less affected by low temperatures than smaller ones.

Greater losses of nitrogen in the feces and urine for outdoor compared to indoor calves were reported by Christopherson (1973), resulting in a reduction in nitrogen retention.

A lower feed digestibility due to cold weather might result in either a higher feed intake, a lower growth rate or both. Webster et al. (1970) reported in the aforementioned study a 20% overall increase in hay consumption by heifer calves exposed to cold stress, compared with control animals, which were continuously housed at an air temperature of about 20 C.

Milligan and Christison (1974) reported an analysis of records of 7 years involving 1970 steers to determine the effects of climate on steer performance. They concluded that during the months of December, January and February, during which the mean monthly temperature was recorded at -17 C, average daily gain fell to about 70% of its level recorded during the rest of the year. Feed required per unit gain and the metabolizable energy intake per unit of gain were 149 and 140% of the requirements of the remainder of the year. Regression equations indicated that a decrease of 10 C in the mean monthly temperature resulted in a decrease of 0.14 kg gain/day, an increase of 0.7 kg feed/gain and an increase of 1.1 Mcal ME/kg gain.

A number of studies have been conducted to determine the benefits of shelter for feedlot cattle, ranging from a simple windbreak to elaborate heated housing.

Christopherson (1982) estimated feed savings through provision of a windbreak. Basing his estimates on measurement of changes in heat production in bulls gaining 1.3 kg per day and exposed to a 15 km/hour windspeed in a wind tunnel, he concluded that a windbreak could result in a saving of up to 3.3 Mcal ME per day at a temperature of -15 C. Results by Williams (1969) suggest that this savings would be greater in animals gaining at a lower rate.

In an Irish study, McCarrick and Drennan (1972) reported no response in liveweight gain resulting from the provision of lateral shelter during winters with temperatures ranging from 10 to -10 C.

Bond and Laster (1974) in a study in Nebraska also concluded that there was no significant difference in growth rates of cattle maintained with or without windbreak and suggested that provision of a windbreak might actually result in lower feed consumption due to the fact that the animals spend most of their time close to the fence, rather than at the feed bunk.

The benefits of provision of an overhead shelter would result from mainly two factors, the reduction of radiant heatloss and the possibility for the animal to stay dry during rain or snow storms. The actual amount of saving of energy expenditure is difficult to predict as a radiant heat loss during the night might be partially offset by an influx of radiant heat during a sunny day. However, Webster (1970) indicated that heat loss could be 30% higher on cloudless than on cloudy nights, suggesting that if an animal were to remain under the overhead shelter at night and stand outside in the sun during the day, the energy and, thereby, feed savings could be considerable.

Berg and Young (1973) estimated that cows with access to an overhead shelter required nearly 0.74 Mcal per day less during approximate mean temperatures of -10 C than those without shelter, which is the equivalent of the ME content of nearly 0.5 kg of hay. Young, Dietz and Berg (1972) reported savings of 2.8 Mcal ME or 1.59 kg/day of hay when average temperatures were at a low of - 21 C.

Jordan et al. (1969) reported results of a study in Northern Ontario of the effects of provision of a simple unheated shed for growing calves. These calves were born in the fall and remained with their dams either outside or inside. Average daily temperatures of -11 and -15 were recorded in two consecutive years. Calf gains differed significantly only in the second year when the inside group averaged 0.76, the outside group 0.67 kg/day; calf mortality, as might be expected, differed significantly in both years and groups, approaching nearly 50% in the outdoor group whereas it was 20% for the indoor group.

However, the gain of their dams was not affected by the shelter, although the sheltered group consumed 0.68 kg of hay per day less than their unsheltered mates.

Lister et al. (1972) compared benefits of an insulated barn, an open shed and a windbreak for pregnant beef cows on either ad libitum hay intake, restricted hay intake or grass silage fed in the same manner. Average outside temperatures of -12 C were recorded. Cows in these three environments exhibited weight changes during the winter in the order of +273, +257 and -31 g/day respectively after all cows were adjusted to the mean digestible energy intake for hay-fed cows. The saving in metabolizable energy in this study was approximately 4.66 Mcal/100 kg initial weight for the insulated barn and 4.32 for the open shed when compared to the cows wintered outside. This would be equivalent to a saving of 2.64 and 2.45 kg of hay per day. These findings represent one of the largest feed saving observations associated with shelter reported in the literature. This might have been caused, at least in part, by the restriction in feed intake imposed on some of the cows, as well as by the rather wet winter conditions which could have resulted in poor outdoor bedding conditions.

Results from investigations into the benefits of providing overhead shelter for growing feedlot cattle have been somewhat variable. Hoffman and Self (1970) conducted trials in Iowa to evaluate the effect of shelter on feedlot steers during winter and summer trials. During their winter trials, lasting from November to April, the average daily mean temperature was -2 C, and during the summer trial it was +14.5 C. Their findings suggest that cattle with access to shelter gained 0.17 kg per day more than cattle without, but this difference was significant on a within-trial basis only in one winter, although pooling the data by season resulted in a significant effect of shelter in the winter as well as in the summer trials. Daily feed consumption was not affected by shelter in any of the trials and the pooled data indicated essentially no difference between the sheltered and unsheltered group. Shelter, however, lowered the feed requirements per kg of gain in all trials and significantly so in three of the winter trials. Pooling the data by season indicated that feed efficiency over all winter trials was 4.15 kg of feed per kg of gain for the sheltered and 4.77 kg for the unsheltered group.

Leu et al. (1977) compared different housing systems in another Iowa study and found small differences in average daily gain (1.09 kg vs 1.00 kg per day), dry matter consumption (5.98 kg vs 6.00 kg per day) and feed efficiency (5.49 units vs 6.04 units of grain dry matter per unit liveweight gain) between animals with and without access to the shelter, respectively, with none of these differences being statistically significant. These workers concluded that although sheltered animals tended to perform better, the small increase in productivity did not justify the investment associated with provision of shelter.

Christopherson (1981) and Christopherson and Thompson (1981) in a study conducted at the University of Alberta concluded that provision of a shelter [illegible]ncrease the rate of gain or the feed efficiency significantly, in fact un-sheltered animals tended to perform better than those without access to an overhead shelter, the difference being due to wetter conditions in the sheltered pen. Several studies have been conducted to determine the feasability of housing growing beef cattle in confined buildings. Hidiroglou and Lessard (1971) maintained yearling steers in unheated pole barns and concluded that there was a significant advantage in housing only during the months of January and February when temperatures fell to their lowest, whereas there was either no difference between inside and outside groups of animals, or those maintained inside were at a disadavantage due to high humidity. However, for the total length of the winter, these workers reported that outdoor steers required 16% more total digestible nutrients and gained about 15% less than the animals kept in the barn.

Ingalls and Seale (1967), at the University of Manitoba, compared the performance of Holstein steers and bulls in heated housing (10 - 15 C) with a similar group assigned to open shed housing for a period starting in October and ending in May. Daily feed intake (kg), weight gain (kg) and feed efficiency (kg of feed consumed per kg of gain) for heated vs open housing were reported to be

6.83, 7.55; 1.31, 1.38 and 5.14, 5.51 respectively, none of these differences being statistically significant.

A study at the University of Alberta by McQuitty et al. (1972) in which different confinement systems were compared to housing feedlot steers in an open lot, led to the same conclusion. Average daily gains, feed efficiency and carcass quality of animals raised in straw-bedded pens, slatted floor pens or feedlot pens did not differ significantly and the authors suggested that considerations other than animal performance would be required to justify provision of warm barn facilities for beef cattle over an open feedlot.

Although studies on the benefits of providing growing feedlot animals with shelter appear variable, there are apparent trends. One is that the provision of a windbreak, at least under Canadian climatic conditions, results in a higher growth rate and better feed efficiency and, given the relatively low investment required for its installation, is a viable tool for increasing productivity. It is also clear from the presented research reports that there is no advantage in raising growing cattle, at least from a biological point of view, in a total confinement system. Little feed savings or increase in rate of gain seem to be associated with this type of management and health problems arising from high humidity could be considerable.

The possible benefits of providing a simple overhead shelter, however, are not quite as easy to estimate as there could be a number of factors involved which would determine the profitability of such a system. Christopherson (1982) suggested that animals growing at a rate higher than 1.5 kg per day would not benefit from an overhead shelter because such animals have a high rate of heat production making them more tolerant to cold weather. For animals growing at a rate lower than this and young animals, however, an advantage could be realized provided that economic considerations such as cost of shelter, additional labor, possible health problems and other factors associated with it, are taken into account. Further studies in western Canada and under actual feedlot conditions appear justified given the possibility that provision of an overhead shelter might result in greater productivity.

III.2. MATERIALS AND METHODS

This study was conducted at the University of Alberta ranch at Kinsella during 1984/85 and 1985/86. A total of 376 bull calves were used, which were the same animals involved in the previous study on the effects of age at weaning (see Section II).

Four weeks after weaning, the animals were randomized into four subgroups, two of which were housed with access to an open-front shed ("sheltered" pen location), whereas the other two groups were kept in open pens and provided with windbreaks on three sides ("unsheltered" pen location). This resulted in a total of eight pens with 23 to 24 animals per pen. The open pens were approximately 40 m by 40 m (1600 m^2) and were equipped with self-feeders and automatic waterers. The windbreaks were 2.5 m high and consisted of 2.5 m long vertical boards 15 cm wide and 2 cm thick, spaced about 3 cm apart with a 17% porosity.

The pens with access to the shelter were 20 m long and 12 m wide (240 m^2) 6 m by 20 m of which was covered by a three-sided shed and contained the feeding trough. Sheltered animals were fed daily, whereas those in the outside pens had access to self-feeders, which had to be filled once a week. Straw was provided in all pens as necessary to maintain dry bedding.

During the 140-day long feedlot trial, all animals were weighed at 28-day intervals and records of feed consumption, on a pen basis, were obtained. Occurrence of sickness or death losses were recorded, and daily minimum and maximum temperatures were monitored.

To assess any possible long-term effects of provision of shelter, carcass data were obtained from graders of Agriculture Canada and analysed.

Statistical analyses

Least squares analyses of variance and covariance for unequal subclass numbers were computed as outlined by Mehlenbacher (1978).

For the analysis of weights and daily rates of gain, a model was used with effects of year, pen location and breed-group of calf as sources of variation and preweaning average daily gain as covariate.

Levels of the main effects were:

1. Year (R), classified as either 1984/85 or 1985/86;
2. Pen location (L), classified as inside or outside;
3. Breed-group (B), classified as SY, HX and SD.

The model employed was:

$$Y_{ijkl} = u + R_i + L_j + B_k + RL_{ij} + RB_{ik} + LB_{jk} + RLB_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = trait under consideration

u = overall mean

R_i = the effect of the ith year

L_j = the effect of the jth pen location

B_k = the effect of the kth breed-group

RL_{ij} = the effect of the interaction between the ith year and the jth pen location

RB_{ik} = the effect of the interaction between the ith year and the kth breed-group

LB_{jk} = the effect of the interaction between the jth pen location and the kth breed-group

RLB_{ijk} = the effect of the interaction between the ith year, the jth pen location and the kth breed-group; and

e_{ijkl} = random error.

As the animals in this experiment were the same as in the previous chapter, preliminary analyses were performed using a model which contained weaning and housing treatments and their interactions as main effects. However, as none of the interactions proved to be significant, separate models were used for the analyses of the effects of age at weaning and type of housing.

Correlation and regression coefficients were computed using the SPSSX computer package (SPSS Inc. 1983).

Feed consumption and efficiency were analysed on a pen basis and a simpler model had to be used, with year, pen location and the interaction between the two as main effects. Carcass data were analysed with only pen location, breed-group and their interaction as main effects.

Student-Newman-Keuls tests as outlined by Steel and Torrie (1980) were employed to test differences between individual means whenever significant differences were established by least square analysis.

Differences between the categorical data in the health analysis were tested by Fisher's Exact Method, as described by Keeping (1962).

III.3. RESULTS AND DISCUSSION

1. CONFOUNDED EFFECTS

Due to the difference in design between sheltered and unsheltered pens, confounding of the effects of shelter with those arising from the differences in pen size and feeding management was unavoidable. While bulls with shelter had only a space allotment of 10.2 m^2 per animal, the average space for bulls without shelter was approximately 68 m^2 per animal. However, both housing types exceeded the minimum space recommendations for similar housing arrangements. Values of recommended space in the literature range from 6.9 and 2.8 m^2 (Ensminger, 1976) to 13.8 - 37.7 and 4.6 m^2 (Minish, 1979; Lasley, 1981) per animal in an open lot or a surfaced pen with access to shelter, respectively. It is, of course, possible that the behaviour of the sheltered bulls was influenced by their higher stocking rate. It is known that bulls establish a dominance hierarchy and that the frequency of aggressive acts depends on the group size and the stocking density (Tennessen, 1983). Fraser (1982) pointed out that avoidance serves to reduce agonistic contests between animals, and it is possible that the higher density of animals in the sheltered groups resulted in a higher incidence of agressive behaviour. This, of course, might have had a negative effect on the rate of gain and feed conversion of the sheltered bulls. However, it could be argued that shelter generally influences behaviour to some extent as it motivates animals to remain in more crowded conditions whenever they make use of the sheltered area. But as the number of bulls per pen in all of the groups was relatively small (23 to 24), it is probable that a rather stable dominance order evolved within a short period of time, which would not be greatly affected by a somewhat higher density.

As already described, animals in both groups were fed ad libitum and, thus, had access to feed at all times. In the sheltered pens, feed was added daily to leftover feed in the troughs, whereas bulls in the unsheltered pens had access to a self-feeder which was filled approximately once a week. Animals in the sheltered pens usually ate throughout the day and were seldom observed to crowd around the trough during feeding time, although indications in the literature are that the feeder space of 0.50 m/head would have been adequate, had this occurred. Recommendations for trough space per head, when animals are eating simultaneously, range from 0.45 m (Blake, 1985) and 0.45 - 0.55 m (Minish, 1979; Lasley 1981) to 0.50 - 0.60 m (Neumann, 1977).

Despite the fact that the effects of these confounded factors might be negligible, it is important to be aware of them when considering the following results.

2. AGE AND WEIGHT AT START OF TEST

The 140-day feedlot trial in 1984/85 began on November 29 and lasted until April 18; in 1985/86 it started on December 3 and ended on April 22. Calves entering the trial were 217 and 216 days of age in the first year and 223 and 224 days of age in the second year, in the unsheltered and sheltered groups, respectively. As a result of the difference in age, as well as due to the 4 days, which the test started later in the second year, the weights of the calves entering the test were significantly different between the two years. For the first year, the average weight was 229.6 kg, whereas in the second year it reached 255.8 kg (P<.005). This was not only a reflection of the older age of the calves at the start of the test, but could also be the result of better pasture conditions during the summer of 1985.

There was no significant difference in weights between pen locations, with unsheltered animals weighing 239.9 kg and those with access to shelter 245.5 kg. Breed-group proved to be a strong effect, with Beef Synthetic (246.6 kg) and Dairy Synthetic calves (251.5 kg) being significantly heavier than Hereford Crossbreds (230.0 kg, P<.005). The differences between the three breed-groups is in agreement with those between the weaning weights as reported by Berg and Peebles (1983).

3. AVERAGE DAILY RATES OF GAIN DURING THE FEEDLOT TRIAL

For the total feedlot period, ADG's between the two years did not differ significantly (1.66 vs 1.71 kg/day for 1984/85 and 1985/86, respectively), however, pen location had a significant effect on average daily rates of gain (P<.05), with sheltered animals gaining 1.72 kg/day and those without shelter 1.65 kg/day. The trend was the same for both years with 1.71 vs 1.61 kg/day and 1.72 vs 1.69 Kg/day, for the two pen locations and years, respectively, however, the difference in the second year was not significant. The smaller difference was undoubtedly a reflection of the warmer average temperatures, which were recorded during that year.

As Table III.1 shows, the effect of breed-group was also highly significant (P<.005). SY calves gained at a significantly faster rate than SD or HX (1.78 vs 1.64 and 1.62 kg/day, respectively). The trend between pen location was noticeable within each breed-group, however, the difference between sheltered and unsheltered animals was significant only in the slower gaining Hereford Crossbreds and Dairy Synthetics. This would support suggestions in the literature that animals gaining at a higher rate are less affected by low temperature. To a great extent, this is probably due to the fact that these animals have a higher feed intake and subsequently a higher heat production and are, thus, better able to compensate for declining temperatures.

Average daily rates of gain were computed for each of the five weighing periods to determine if the differences

TABLE III.1 Least squares means and standard errors of average daily rates of gain of the three breed-groups

	Sheltered	Unsheltered
Beef Synthetic	$1.80^{a} \pm .03$	$1.76^{a} \pm .03$
Hereford Crossbred	$1.67^{b} \pm .03$	$1.61^{b} \pm .03$
Dairy Synthetic	$1.66^{b} \pm .04$	$1.58^{b} \pm .04$
Total	$1.72 \pm .02$	$1.65 \pm .02$

a,b means in the same column with different superscripts are significantly different ($P<.05$). For significance levels within the same breed-group, refer to text.

in average temperatures between weighing periods had different effects on average daily rates of gain in the two housing groups, and the results are shown in Figure III.1. Average daily rates of gain dropped in the third weighing period, which corresponded to the coldest period of the feedlot trial. Table III.2 shows the gains and temperatures for each of the two years and there was a very obvious trend in the average daily rates of gain during the first year. With declining temperatures, animals with access to shelter were at an increasing advantage, although the lowest temperature did not correspond to the greatest difference. With increasing temperature, however, it was apparent that sheltered animals tended to lose this advantage until they actually had lower rates of gain.

In the second year, this trend was not as obvious as it had been in the first year. While temperatures were actually considerably higher, there appeared to be no strong connection between ADG and temperature of any given weighing period, and, in fact, during the period with the lowest temperature, unsheltered animals gained at a higher rate. The reason for this discrepancy and for the low performance of the unsheltered animals in the successive weighing period is not clear. However, it could be suggested, that the performance of sheltered and unsheltered animals only favors the former in the case of extended periods of cold weather, as was observed during the first year.

FIGURE III.1 Average daily gain (ADG) of sheltered and unsheltered calves and average maximum and minimum temperatures during each of the five weighing periods

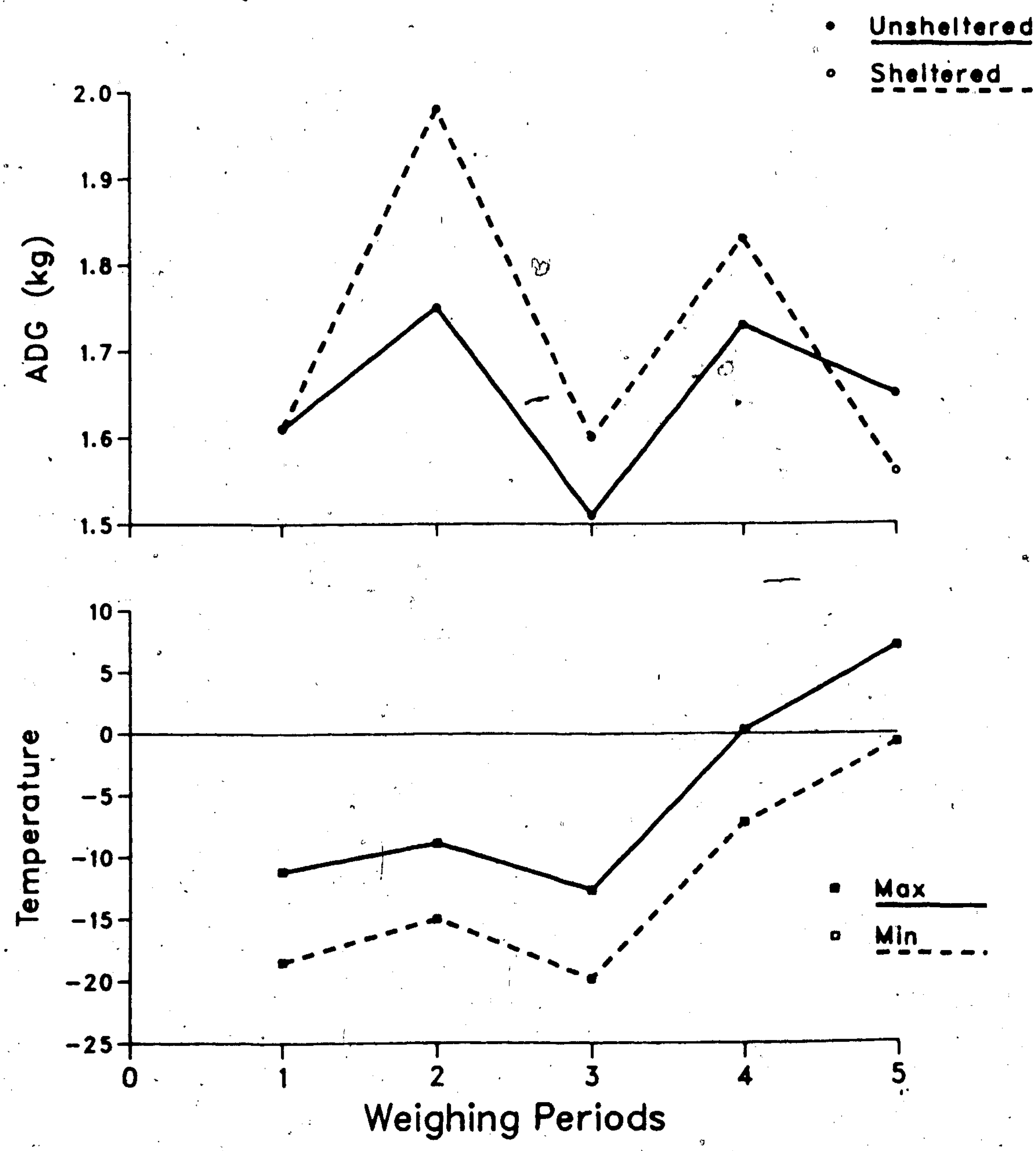

TABLE III.2 Least squares means and standard errors of average daily rates of gain (kg), and average daily maximum and minimum temperatures (C) in each of the five periods

Weighing	Average daily rate of gain			Temperatures	
period	Unsheltered	Sheltered	Difference	max.	min.
1984/85:					
1	1.61 ± .05	1.61 ± .05	0	-11.2	-18.9
2	1.75 ± .05	1.98 ± .05	-.23	- 8.9	-15.0
3	1.51 ± .04	1.60 ± .04	-.09	-12.7	-19.8
4	1.73 ± .04	1.83 ± .05	-.10	+ 0.3	- 7.2
5	1.65 ± .05	1.56 ± .05	.09	+ 7.1	- 0.7
Total	1.61 ± .03	1.71 ± .03			
1985/86:					
1	1.66 ± .05	1.47 ± .06	.19	- 3.6	-10.1
2	1.73 ± .05	1.93 ± .05	-.20	- 2.7	- 8.5
3	1.75 ± .04	1.66 ± .05	.09	-12.3	-19.3
4	1.57 ± .04	1.94 ± .05	-.37	+ 3.0	- 3.3
5	1.74 ± .05	1.59 ± .05	.15	+ 8.5	+ 0.3
Total	1.69 ± .03	1.72 ± .03			

In order to correlate ADG and climate conditions, a number of additional weather factors were determined for each weighing period and included in the analyses. These factors were: average maximum and minimum temperatures; average daily temperatures (determined by averaging the two measurements taken each day); number of days below -15, -20, -25 and -30 degrees C; average fluctuations between the lowest, highest and mean daily temperatures between days; average fluctuations within days (between night and day) and the highest and lowest recorded temperatures within each weighing period (referred to as variables T1 to T13).

The analysis of the average of the daily rates of gain in each of the five weighing periods for both years combined, revealed that there was no significant correlation between any of the climate parameters and rate of gain in the sheltered or unsheltered groups. Correlations between observed temperatures were usually positive with the exception of a coefficient of - 0.01 between maximum temperature and ADG of the sheltered group, which indicated, as already mentioned, that animals with access to a shelter were actually at a disadvantage with increasing temperature, compared to animals housed without shelter. Coefficients were negative for ADG and number of days below a certain temperature, with the lowest values reached between - 20 and -25 degrees C. As the influence of climate on growth in each weighing period would be confounded with the change in the development of the animals, the difference between the ADG's of the two groups was included as a third dependent variable and its correlation with the climate parameters was determined. The analysis showed that it was significantly correlated only with observed maximum temperature ($P<.05$).

As there had been a considerable climatic difference, between the two years, particularly in average temperature, it was necessary to consider each year separately and, therefore, additional correlation analyses were performed. None of the correlations between ADG and any of the climate variables in any of the two housing groups proved to be significant in any year, with the exception of daily average temperature fluctuation, whose correlation with ADG of the unsheltered group approached significance ($P=.06$) in the first year.

The difference in ADG between the two housing groups was correlated with the climate parameters to a varying degree with correlation coefficients ranging from .77 to .76 and probability levels from .06 to .07 in the first year. Number of days below -15 degrees had a correlation coefficient of -.70 ($P=.09$), average daily fluctuation between days showed a coefficient of -.73 ($P=.08$) and average daily fluctuation within days had a coefficient of -.80 ($P=0.5$), Highest and lowest recorded temperatures were significantly correlated with the difference in ADG, with probability levels of .05 and .003.

Correlations in the second year followed a different pattern. Neither average temperatures, nor number of days below the set temperatures or highest and lowest recorded temperature in any of the weighing periods were significantly correlated with the difference in ADG between the two groups. Average daily fluctuation, however, was (P<.05), but in the second year with a positive correlation coefficient of .82.

To determine which of the climate variables contributed to the variation in ADG, and to assess how much of the variation in average daily rates of gain was caused by these parameters, a stepwise regression analysis was peformed for each of the years and each pen location. All of the thirteen climate parameters were included in the model and the results are shown in Table III.3. Overall, each year x pen analysis resulted in different variables with probabilities below the 5% level, with the exception of the fluctuation in minimum temperatures between days (T9), which contributed to the variation in both groups during the first year. Both regression coefficients were positive and were significantly different (P<.005). As Table III.2 showed, average minimum and maximum temperatures differed greatly between the two years, which probably explains the fact that it did not contribute to the variation in the second year.

It is interesting to note that in both years, weather variables contributed far more to the variation in gain in

TABLE III.3 Stepwise regressions of average daily rates of gain on climate variables*

Year	housing type	variables in equation**	b_1	SEb	% Variance explained (R^2x100)***
1	unsheltered	T5	-.023	.005	
		T9	.049	.020	4.4
	sheltered	T2	.062	.008	
		T9	.138	.029	
		T13	-.045	.008	37.0
2	unsheltered	T10	.096	.030	2.2
	sheltered	T1	-.040	.007	
		T7	.057	.021	
		T12	.057	.007	13.3

* Variables are: T1 and T2: average maximum and minimum temperatures, T5 and T7: number of days below -15 and -30 C, T9 and T10: fluctuations in minimum and mean temperatures between days, T12 and T13: minimum and maximum recorded temperatures. All values based on weighing period means.

** $P<.05$

*** by all variables in the equation

sheltered animals than in those in open lots (37.0 and 13.3 vs 4.4 and 2.2% for the two groups and years, respectively). This is likely a reflection of the fact that rates of gain in sheltered animals tended to decrease not only as a result of very cold, but also of warm weather and this greater dependency on climatic factors would certainly account for a greater influence of climate on variation in gain.

As the correlation coefficients had revealed a correlation between the difference in average daily rates of gain between the two housing groups and average temperatures (T3) and fluctuations in average daily temperatures (T10), regression analyses were performed with ADG as dependent and these two climate factors as independent variables in the model. Table III.4 shows the regression coefficients and their levels of significance. Average temperatures explained only very little of the variation in daily rates of gain and the regression coefficients of ADG on average temperatures between housing groups differed significantly only in the first year. Average temperature seemed to have little effect on gain, particularly in the second year. Fluctuation between average daily temperatures also had little effect, although differences within years were all significant.

It should be emphasized that it is difficult to draw conclusions from these regression coefficients, because, as already mentioned, the change in climate towards spring is

TABLE III.4 Regressions of average daily rate of gain on average daily temperature and average temperature fluctuations between days.

Year	Independent variable	housing type	b_1	SEb	$R^2 \times 100$
1	Ave. Temp.	unsheltered	.008*a	.002	2.10
		sheltered	-.001b	.003	.48
2		unsheltered	-.005	.003	.64
		sheltered	-.001	.004	.02
1	Fluctuation	unsheltered	-.030*a	.013	.96
		sheltered	.038*b	.080	1.40
2		unsheltered	.096*a	.030	2.02
		sheltered	-.175*b	.039	4.45

* $P<.05$

a,b coefficients with different superscripts within the same year and independent variable are significantly different confounded with the physiological changes associated with advancement in age. At the end of the trial, bulls were about one year of age and rates of gain tended to slow down during the last month. It was probably partly due to this fact that the regression coefficients were not consistent and changed between negative and positive values. It should also be noted that these data represent only two years of observations in which weather conditions were quite different and that other climatic factors, such as wind velocity, precipitation, extend of cloud cover as well as degree of acclimatization and hair coat depth of the animal can influence performance (Webster 1970, 1971); none of these parameters were measured in this study. It is, however, apparent that animals within each year and housing group were affected by different climatic factors and that sheltered animals tended to be at an advantage, which increased with overall decreasing temperatures.

The correlation and regression coefficients reported here are lower than those found by Milligan and Christison (1974). Their study showed highly significant correlation coefficients of .74 and -.74 between average daily rate of gain and average temperature and days below -23 C. and in a regression coefficient of .014 of gain on temperature. However, this might be a result of the fact that these authors analysed data collected during all months of the year.

The observation in this study that animals with access to a shelter gained at a faster rate than those exposed to the cold, agrees with most of the reported studies, although because of the diversity in housing systems under investigation and in winter climate between locations, comparisons have to be made cautiously. Bennett and O'Mary (1985), Kearl et al. (1965) and Crawford and Butcher (1966) noted beneficial effects when cattle were protected from cold weather. Hidiroglou and Lessard (1971) found a 15% higher growth rate in housed animals compared to those maintained outside, and Hoffman and Self (1970) described a significant difference of 0.17 kg in average daily gain in favor of sheltered animals. Webster et al. (1970) found calves which had access to shelter gained 18 kg more during the winter than those exposed. Holmes et al. (1978) reported increased winter live weight gains of 3.6 and 7.2 kg for sheltered animals in 44 and 54 day-long trials, respectively. Yet, Leu et al. (1977) reported insignificantly higher average daily rates of gain in both winter and summer months (1.09 vs. 1.00 and 1.22 vs. 1.14 kg/d for sheltered vs. unsheltered during winter and summer months, respectively). It could be argued that shelter might result in additional benefits by increasing daily gain during the summer months. However, this appears to contradict suggestions arising from this study that benefits of shelter are not significant during warmer temperatures. Christopherson and Thompson (1981) found no improvement in rates of gain as a result of shelter during a mild winter. However, Garrett et al. (1962) concluded that in California, shade can reduce the radiant heat load by as much as 30 percent and lead to an increase in average daily rate of gain of 0.29 kg. Hoffman and Self (1970), in a study in Iowa, also concluded that shade resulted in a significant advantage in average daily rate of gain during the summer, however, studies by McCormick et al. (1963) in Georgia, Bond and Laster (1975) and Leu et al. (1977) in Iowa and Nebraska failed to find any significant advantage for animals with access to shade.

4. BODY WEIGHTS

Table III.5 shows the development of body weights of bulls in each of the pen locations. As there was no significant interaction between breed-group and housing type, all breed-groups followed a very similar pattern, with sheltered animals being heavier throughout the feedlot trial. This indicates that there is no difference in genetic response to type of housing among these three breed-groups. After adjusting for initial differences in weight at the start of the test between the two housing groups in each breed-group, the actual differences were 4.0, 6.3 and 8.5 kg for Beef Synthetic, Hereford Crossbreds and Dairy Synthetics, respectively.

During the trial, Beef Synthetic bulls gained a total of 252.3 kg which was significantly higher than gains exhibited by Hereford Crossbreds (226.5 kg) and Dairy

TABLE III.5 Least squares means and standard errors of weights at each weighing date and total weight gain (kg) during the feedlot trial

Weighing date	Unsheltered	Sheltered
1	239.9 ± 3.1	245.5 ± 3.1
2	285.7 ± 3.3	288.9 ± 3.4
3	333.4 ± 3.5	343.2 ± 3.6
4	378.8 ± 3.7	389.1 ± 3.8
5	425.2[a] ± 4.0	442.1[b] ± 4.0
6	473.5[a] ± 4.2	486.4[b] ± 4.2
*	474.8 ± 2.3	481.3 ± 2.4
**	233.6[a] ± 2.4	240.9[b] ± 2.4

* Means of final weights adjusted for weight at test start

** Total weight gain during feedlot trial

a,b Means with different superscripts in the same row are significantly different ($P<.05$)

Synthetics (219.3 kg). Overall, animals with access to shelter gained 240.9 kg compared to 233.6 kg of animals without (P.<05).

5. INFLUENCE OF AGE ON PERFORMANCE

To investigate if age has any effect on performance of calves under different environments, the animals were divided into three age groups ranging in birth dates from day 89 to 106 (group 1), day 107 to 128 (group 2) and day 129 to 158 (group 3, day 1 = January 1) with average ages of 236, 222 and 198 days at the start of the test. There was no significant difference in the performance between the three age groups in any of the weighing periods, although the differences between groups 2 and 3 in period 2 (1.86 vs. 1.75 kg/day) and between group 1 and group 3 in period 4 (1.85 vs 1.70 kg/day) approached significance (P<.1). The analysis of gain during the total feedlot trial, however, resulted in a significant age group effect (P<.05), with average daily rates of gain of 1.71, 1.72 and 1.64 kg for groups 1, 2 and 3, respectively (Table III.6).

As there was no significant interaction between type of housing and age of calves, the differences between the pen locations followed a very similar pattern throughout the test period. Pen location within age group had a significant effect only during period 2 and 5, but not in period 3, which corresponded to the coldest period. This is somewhat surprising, as any effect of age and pen location

TABLE III.6 Least squares means and standard errors of average daily rates of gain (kg) of the three age groups within each pen location for each of the weighing periods

Age groups (average ages at the start of the test)					
1 (236 days)		2 (222 days)		3 (198 days)	
Unsheltered	Sheltered	Unsheltered	Sheltered	Unsheltered	Sheltered
1.65 ± .06	1.56 ± .06	1.69 ± .04	1.59 ± .04	1.53 ± .07	1.52 ± .07
1.71^{a} ± .06	1.89^{b} ± .05	1.77^{a} ± .04	1.96^{b} ± .04	1.66^{a} ± .06	1.84^{b} ± .06
1.68 ± .05	1.67 ± .05	1.63 ± .04	1.68 ± .04	1.57 ± .06	1.60 ± .06
1.71^{a} ± .06	1.98^{b} ± .06	1.64^{a} ± .04	1.89^{b} ± .04	1.65^{a} ± .07	1.76^{b} ± .07
1.62 ± .06	1.59-.06	1.75 ± .04	1.61 ± .05	1.78 ± .07	1.51 ± .07
For total feedlot period:					
1.68^{a} ± .03	1.74^{b} ± .03	1.69^{a} ± .02	1.74^{b} ± .02	1.64 ± .04	1.64 ± .04

a,b Means with different superscripts within the same row and age group are significantly different ($P < .05$)

should be particularly noticeable during the period of more adverse weather conditions. Surprising also was the fact that the analysis of the total feedlot gain showed an advantage of shelter only in the two older age groups, whereas the younger animals appeared not to be greatly affected by the type of housing. This can partly be explained by the fact that unsheltered animals in group 3 outgained their sheltered contemporaries in the last period by a far larger margin than sheltered animals in the two other groups, which partly offset any overall advantage sheltered animals might have had up to that point. Another reason was the fact that there were considerable differences in the number of bulls within each age group and the number of animals in group 3 was particularly small. Although this study did not result in any great advantage of shelter between ages, it might be that this would be different if the age difference between groups had been greater, although there is no indication in the literature that this might be the case.

6. FEED CONSUMPTION AND EFFICIENCY

Feed consumption and efficiency were calculated on a pen basis and analysed for possible effects of type of housing. As each trial year consisted of eight pens, and one pen in 1984/85 had to be eliminated from this analysis because of incomplete records, a total of only 15 records were available, which greatly restricted the degrees of freedom in the error term. Furthermore, records per weighing period were availbale only for the second year and an attempt to compare the treatment groups within each of these periods or to correlate climate and feed efficiency and consumption was limited to a very small number of observations within a rather mild winter. Breed-group effects on these parameters could also not be determined as pens consisted of animals of all three breed-groups, whose individual feed intakes could not be determined.

The analysis of the feedlot trials of both years combined (Table III.7) revealed a significant year effect ($P<.005$), with animals consuming 9.1 kg in the first, and 10.2 kg in the second year. This is surprising in light of the milder winter in the second year, and would indicate that the difference in the temperatures between the two years was not sufficient to cause any difference in consumption, or that feed intake was influenced to a greater degree by factors other than average temperatures. Overall, type of housing did not prove to be a significant effect, with sheltered animals consuming 9.7 kg/day, those without shelter 9.6 kg/day. There was no significant year x shelter interaction.

The analysis of feed efficiency (Table III.8) showed that the difference between the two groups approached significance ($P<.1$) with sheltered animals being more efficient in their feed conversion (5.6 vs 5.7 kg of feed/kg of gain). However, this analysis also showed a

TABLE III.7 Least squares means and standard errors of daily feed consumption (kg) of unsheltered and sheltered calves

	Unsheltered	Sheltered	Total
1984/85	9.2 ± .13	9.0 ± .11	9.1[a] ± .08
1985/86	10.1 ± .11	10.4 ± .11	10.2[b] ± .07
Total	9.6 ± .08	9.7 ± .07	9.7 ± .06

[a,b] Means with different superscripts within the same column are significantly different ($P<.05$)

TABLE III.8 Least squares means and standard errors of feed efficiency (kg of feed/kg of gain) of unsheltered and sheltered calves

	Unsheltered	Sheltered	Total
1984/85	5.5 ± .04	5.3 ± .03	5.4[a] ± .03
1985/86	5.9 ± .03	5.9 ± .03	5.9[b] ± .02
Total	5.7 ± .03	5.6 ± .02	5.7 ± .02

[a,b] Means with different superscripts within the same column are significantly different (P<.05)

significant year x housing type effect ($P<.05$). While animals with access to the shelter were at an advantage in the first year with a feed conversion of 5.3 vs 5.5 kg, this trend was not consistent and in the second year both groups had the same feed conversion of 5.9

The absence of any significant difference in feed consumption is in agreement with most of the reported results. Webster et al. (1970) found only a small difference in feed intake between sheltered and exposed animals during severe climatic conditions in Alberta. Hoffman and Self (1970) and Leu et al. (1977) also concluded that feed consumption was not lowered as a result of provision of shelter, however, these workers found significantly better feed conversions in sheltered animals during three of the six winters under investigation. However, Christopherson (1981) in an experiment similar to this one, found no significant differences in feed efficieny, but observed that sheltered animals had slightly less efficient feed conversions due to adverse environmental conditions in the sheltered pens.

The analysis of the second year, in which records of feed consumption and conversion in each weighing period were included, did not show any significant difference between housing groups in any of the 5 weighing periods (Table III.9). With the exception of the first period, sheltered animals had a greater feed intake throughout the feedlot trial, whereas there was no consistent trend in

TABLE III.9 Least squares means of average daily feed consumption, feed conversion and average maximum and minimum temperatures for each of the five weighing periods during the second trial year

	Feed consumed		Feed conversion		temperatures	
					min	max
Housing:	U*	S	U	S		
Period:						
Dec 3/ Dec 31:	8.86	8.32	5.37	5.73	-10.1	- 3.6
Jan 1/ Jan 28:	9.65	9.72	5.55	4.95	- 8.5	- 2.7
Jan 29/ Feb 28:	10.34	10.49	5.79	6.11	-19.3	-12.3
Feb 29/ Mar 25:	10.21	11.48	6.54	5.90	- 3.3	+ 3.0
Mar 26/ Apr 22:	11.45	11.83	6.54	7.31	- 0.8	+ 8.5
Total	10.05	10.36	5.90	5.93		

* U = Unsheltered, S = sheltered

feed efficiency. It is noteworthy that during the coldest period, in which average mimimum and maximum temperatures were -19.3 C and -12.3 C respectively, unsheltered animals had a slightly lower feed intake (10.34 vs 10.49 kg) and a better feed conversion (5.79 vs 6.11 kg) compared with the sheltered ones. A lowered feed intake by animals exposed to colder temperatures would in itself not be a contradiction, as feed intake is affected by water intake (Milligan and Christison, 1974) and water consumption has been found to be reduced during the winter (Hoffman and Self, 1972: Hegg et al., 1974). However, a better feed conversion by unsheltered animals would rather indicate that a temperature of -19 C is not low enough to give sheltered animals an advantage.

The correlation estimates, in which feed consumption and feed efficiency of the two groups, as well as the difference in these traits between them were correlated with average minimum and maximum temperatures, number of days below - 15, -20, -25 and -30 C, average fluctuations between minimum and maximum temperatures between and within days were included, showed no significant correlation between feed consumption and any of these parameters. The difference between groups in feed consumption, however, was significantly correlated with average temperature fluctuations between days ($P<.05$), with a coefficient of .92.

Average temperature fluctuations within days, that is between daily maximum and daily minimum temperatures, was significantly correlated only with the feed efficiency of the sheltered group with a coefficient of .87. The difference in efficiency between the two treatment groups was also significantly correlated with fluctuations in temperatures, however, its correlation coefficient was negative at -.87. These correlation coefficients suggest that fluctuations in temperature are more likely to affect feed efficiency and consumption than actual temperatures, although it must be kept in mind that these data represent only a relatively mild winter without prolonged severe cold weather and, therefore, definite conclusions can not be drawn.

Milligan and Christison (1974), in their study in Saskatchewan, concluded that mean temperature, windchill factor and number of days below -23 were significantly correlated with efficiency, although none of the climate variables included in their model, showed any significant effect on feed intake.

The results reported here are generally in agreement with most of the studies reported in the literature leading to the conclusion that winter climate does not affect feed consumption to a great extent. However, the results are somewhat in disagreement with most other studies, which report differences in feed efficiency between animals with and without access to shelter. This could either be due to the rather mild winter in the second year, or could in fact be a reflection of the high growth rate of the animals under study receiving a high concentrate ration. This could result in such a high heat production that these animals did not benefit from the provision of shelter, as suggested by Christopherson (1982).

7. HEALTH STATUS AND MORTALITY

To determine whether the type of housing had any influence on the health status of the herd, an analysis of the health records was carried out. Only animals which were treated either by the ranch staff or a veterinarian and whose treatment was subsequently entered into the records were considered in this analysis. Levels of significance in this analysis were determined with Fisher's Exact Method, as outlined by Keeping (1962).

Of the 193 animals entering the feedlot trial during the first year, a total of 18 required treatment, and of the 183 animals during the second year, 14 animals were treated. There was no appreciable difference in the average length for which treatment was required either between years (2 vs 3 days, for the first and second year, respectively) or between the housing treatments (3.4 vs 1.7 days for unsheltered and sheltered calves, respectively).

Infections of the respiratory tract were by far the greatest cause of sickness in both years, however, its occurrence varied greatly between the two years. This is not an unusual phenomenon, as Church and Radostits (1981), in an Alberta-wide survey of feedlots found that respiratory diseases accounted for 59% of total morbidity and 61% of total mortality. During the first year, 9 animals showed symptoms of pneumonia, 7 of which were housed in pens with access to shelter, whereas only 2 animals in the unsheltered pens developed this problem. The difference between the two groups was not significant. In the second year, only 3 animals had to be treated for the condition, with 2 being housed with, and 1 without access to shelter. In both years, the occurrence of pneumonia was concentrated in the months of December and January. It is noteworthy that of the animals requiring treatment for respiratory infections, none belonged to the Dairy Synthetic breed-group. There is, in fact, some evidence that dairy cattle are less affected by some of the respiratory problems than beef cattle (McKercher, 1959), although the number of animals of this breed-group in this study is far too small to confirm those findings.

The occurrence of bloat, the second most prevalent health problem, did not show any pattern, which could be attributed to the type of housing. During the first trial year, 4 unsheltered animals developed the condition, whereas none of the sheltered animals was affected. This trend was reversed in the second year, when 7 sheltered animals required treatment, while the condition did not occur among the unsheltered calves. The difference in the second year between the two groups was significant (P<.05).

Another common problem in both years was lameness, mostly caused by inflammation of the joints, however, there was no difference between the two housing treatments.

During the first year of the trial, a total of 3 animals died, 2 in the unsheltered group as a result of bloat, 1 in the sheltered group following a respiratory infection. In the second year, 2 sheltered calves died, 1 of bloat and 1 of a malignant edema, whereas only 1 animal in the unsheltered group died as a result of pneumonia. A total of 3 calves in the unsheltered and 2 in the sheltered group had to be shipped to slaughter before the end of the feedlot trial, primarily because of lameness or recurring bloat.

These results might suggest that the health status of cattle would not be improved by providing overhead shelter, and, in fact, sheltered calves could be at a disadvantage and be more susceptible to infections of the respiratory tract. There are a great number of respiratory infections in cattle, which are often referred to as the bovine respiratory disease complex and among which infectious bovine rhinotracheitis (IBR) and pneumonic pasteurellosis are the chief causes of losses in feedlot cattle. Yates (1982) pointed out that these infections could be associated with a variety of stressors, such as temperature extremes, inadequate or irregular feeding, changes in diet, increased humidity and crowding. It is well established that transmission of these infections under natural conditions is by infected aerosol droplets, although exposure to excretions and secretions may play a role as well. In case of the virus causing IBR, Elazhary and Derbyshire (1979) showed that it can survive long enough in the atmosphere for airborne transmission to occur, especially so among intensively reared or housed animals, with optimal survival occurring at low temperatures and high humidity.

It is, therefore, conceivable that animals with access to shelter, under which they presumably spend considerable time in somewhat crowded conditions, are at a higher risk of contracting respiratory infections than unsheltered animals.

8. SLAUGHTER CHARACTERISTICS

Animals remained in their respective pens until they were considered to have reached a desirable degree of finish at which point they were weighed and shipped to the processing plant. To determine if type of housing had an effect on carcass and slaughter traits, carcass evaluation data from graders of Agriculture Canada were obtained and in addition age and weight at slaughter and carcass composition were analysed. Only animals in the first year were available for this analysis with a total of 157 records. As Table III.10 shows, there was almost no difference in any of the carcass traits between the two

TABLE III.10 Least squares means and standard errors of age (days) and weight (kg) at slaughter, fat thickness (mm) and dressing percentage and grades received by each housing group

	Unsheltered	Sheltered
Age at slaughter	437	432
Weight at slaughter	541.6	530.7
Fat thickness	10.7	10.7
Dressing percentage	59.5	59.4
Number of grades:		
A1	44	46
A2 and A3	24	20
B and C	11	12

groups. Unsheltered animals were 5 days older (437 vs 432) and 10.9 kg heavier (541.6 vs 530.6 kg) than their unsheltered contemporaries. It is noteworthy that unsheltered and sheltered animals had entered the trial in the first year weighing 231.1 and 228.2 kg and had finished the test with weights of 458.3 and 463.2 kg, respectively. Even after adjusting for the age difference at slaughter, unsheltered bulls weighed 535.4 kg compared to sheltered animals whose average weight was 530.6 kg. This would indicate that during the warmer months, sheltered animals gained less to such a degree that the weight advantage, which these animals had after the winter, disappeared completely.

Fat thickness, as determined between the 12th and 13th rib, and dressing percentage between the two groups did not differ at all. There was a significant breed-group effect (which was already reported in the previous chapter), however, there was no interaction between breed-group and type of housing in any of the measured traits. The carcass grades, which had to be grouped into three groups due to the small numbers of animals involved, showed an almost equal distribution of grades among bulls of the two treatment groups. Of the carcasses 44 and 46 were graded A1, 24 and 20 graded A2 and A3 and 11 and 12 graded in the B and C range in the unsheltered and sheltered groups. As already mentioned in the previous chapter, of the 23 carcasses graded in the lowest carcass grade group, only 2 received the grade C, while all other obtained B grades as a result of discoloration of the meat. The absence of any difference in carcass traits between the two groups was not surprising given the rather small advantage in average daily rates of gain and feed efficiency sheltered animals had over their unsheltered mates during the first year.

There is not much evidence linking type of housing with slaughter traits although Young et al. (1976) reported differences in carcass composition between animals in confinement and those kept outdoors. Animals, which had been maintained indoors had heavier carcasses, a greater fat cover and higher dressing percentage. However, McQuitty et al. (1972), who also compared performance of housed animals with that of calves maintained outside, based on results of a very detailed carcass analysis, concluded that type of housing did not cause any significant differences in carcass quality. This study, although only comprised of data from one year, would support the latter conclusion.

III.4. SUMMARY AND CONCLUSIONS

The results of a two-year investigation into the effects of providing an overhead shelter on the performance of bull calves during a 140-day feedlot trial between December and April are reported. Shelter had a significantly beneficial effect on average daily rates of gain during the feedlot trial, however, feed consumption and efficiency were not significantly different between the two housing groups. Neither breed-group nor age of calf showed a signifciant interaction with type of housing. Although there were no significant effects of type of housing on health status, animals in sheltered pens appeared more susceptible to respiratory infections than their unsheltered contemporaries

It could be argued that an additional benefit from the provision of shelter could be derived during the summer, by offering the animals shade, however the lower rate of gain in sheltered animals during the warmer months suggests that sheltered animals are, in fact, at a disadvantage during the summer and weigh less at slaughter despite their heavier weights at the end of the feedlot trial in April. Presumably, this disadvantage arose from a greater concentration of animals in the sheltered pens, which led to a considerable manure build-up and probably had a pronounced negative effect on the environmental quality in these pens.

These results suggest that calves with the growth rate and the genetic composition of the animals in this study, do not benefit from an overhead shelter and that its provision with the aim to increase the efficiency of beef production, appears not to be advisable.

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IV. EFFECTS OF DATE OF WEANING ON COW PERFORMANCE

IV.I. INTRODUCTION

An investigation into the effects of early weaning would not be complete without consideration of the influence it would have on the performance of the dams. Many studies indicate that weaning the calf before or during the breeding season can affect the subsequent reproductive performance of the cow considerably. It had been shown early that lactation or suckling delays initiation of postpartum estrus in the cow (Wiltbank and Cook, 1958; Oxenreider, 1968; Wagner and Hansel, 1969; Oxenreider and Wagner, 1971), although these early studies did not investigate whether removal of a calf would actually result in higher conception rates. Laster et al. (1973), however, reported that weaning calves at 55 days of age resulted in a 17% increase in conception rate in their dams compared with cows which had kept their calves during the breeding season. Similar findings were reported by Bellows et al. (1974) who concluded that weaning calves several days after birth shortened the average postpartum anestrus interval to 19.6 days compared to 39.1 days in a group of cows which had nursed their calves for a length of 35 days. Posey (1976) carried out a number of trials in which calves were weaned at two to four weeks or at the standard age of seven months. He concluded that late weaning increased the service period of the cows from an average of 57 days for early weaned to 70 days for dams weaned at seven months.

Pimentel and Deschamps (1979), when comparing cows which had their calves weaned at the age of 90 days with animals remaining with their offspring throughout the breeding season, determined that pregnancy rate after 60 days was 43% higher in dams of early weaned calves and that postpartum anestrus was considerably shorter in the early weaned group. Lusby et al. (1981) observed that weaning calves at 6 to 8 weeks of age increased conception rates significantly. After 64 days of the breeding season, 97% of the early weaned cows were pregnant, compared to 59% of the late weaned animals. The average interval from parturition to conception was also reduced considerably from 91 to 73 days.

Similar findings were reported by Suzuki (1980) and Maree et al. (1974), who investigated the influence of temporary weaning on cow fertility; Arthur and Mayer (1975), Schlotter and Williams (1975) and Wilson (1981) who noted that early weaning at 60 days of age increased conception rates of cows subjected to estrus synchronization.

Whereas the evidence for immediate benefits of early weaning, that is higher fertility in the ensuing breeding season, is well documented, the changes in performance due to early weaning taking place after the breeding season, are still rather elusive.

Richardson et al. (1978), weaning calves at either 120 or 210 days, concluded that the primary and only effect of early weaning on the dam was a statistically significant increase in weight gain of 12 kg between 120 and 210 days post-partum. An increase in dam's weight between 120 and 210 days post-partum in the previous year showed a correlation coefficient of .17 ($P<.1$) with pregnancy rate. The positive weight change showed higher associations with increased live calf percentage and early calving date. However, added weight between 120 and 210 days post-partum was associated with increased calving difficulties in the following year. Lastly, these workers concluded that weight changes of the dam in the previous year had no significant association with weight of her subsequent calf.

Neville and McCormick (1981) weaning calves at 67 or 230 days found that early weaned dams gained 0.63 compared to 0.29 kg per day compared to the control group from time of early weaning to normal weaning. These workers also concluded that age had a significant effect on the animal's response to early weaning, the 2-year-old dams with normal weaned calves had an ADG of 0.15, compared with 0.54 kg for those with early weaned calves. This difference of 0.39 kg was significantly higher from the respective 0.27 kg difference observed for mature dams. Thus, the burden of nursing their calves was greater for 2-year-old dams than for mature dams, probably because the 2-year-olds were still growing. The year following the weaning treatment, dams that had early weaned calves calved six to seven days later ($P<.05$) than did dams that had normally weaned calves.

Novak et al. (1984), reporting a study at the University of Alberta, concluded that weaning calves at 5 rather than 6 months of age did not result in any difference in cow performance. Early weaned cows gained more weight during the period from early to normal weaning (7.3% vs 4.6% of bodyweight, respectively), however, the difference was not sufficiently large to change winter feeding requirements. Weight loss during the following winter was nearly identical in both groups.

The study reported here was initiated to assess the influence of date of weaning on subsequent performance of the dams, with particular interest in weight changes following the weaning treatment and performance during the subsequent calving season.

In order to enable a more accurate assessment of these factors, data of an experiment which had been conducted with the same weaning treatments in the two years preceding this study (Novak et al., 1984), were included in the analyses. This was done with the hope that pooling the data for four years would provide more conclusive results compared with utilizing the limited data collected during the two years.

IV.2. MATERIALS AND METHODS

This study was conducted at the University of Alberta Ranch at Kinsella in four consecutive years (1982 to 1985). A total of 1233 cow-calf pairs of three breed-groups, namely Beef Synthetic, Dairy Synthetic and Hereford Crossbred were used in this experiment. Their genetic composition was described in previous chapters. In each year, cows were randomized within breed-groups into either an early or a late weaning group. Table IV.1 shows the distribution of cows within breed-groups and weaning treatments during the four years of this experiment.

Calves, which were born during April and May were removed from their dams according to their weaning allotment either at the end of September (early weaning) or at the end of October (late weaning). (The actual weaning dates over the four years ranged from September 26/28 to October 2/4 for the early and October 25/27 to November 2/4 for the late weaned animals). At the time of early weaning, all dams were weighed and while early weaned calves were separated from their dams, late weaned calves remained with their dams on pasture until the time of late weaning. At late weaning, all cows were again weighed and late weaned calves were separated from their dams.

During the winter, cows received hay, straw and grain supplement when necessary, as described by Berg (1975). After calving in the following year, cow weights were again

TABLE IV.1 Number of cows of the three breed-groups in the early and late weaning treatments from 1982 to 1985

Breed-group	Weaning treatment	1982	1983	1984	1985
SY*					
	Early	80	79	34	28
	Late	83	86	39	38
HX*					
	Early	90	105	43	20
	Late	102	107	33	38
SD*					
	Early	38	44	21	13
	Late	39	40	15	18
Total		432	461	185	155

* SY = Beef Synthetic, HX = Hereford Crossbred,
SD = Dairy Synthetic

recorded. Records of birth dates, weights of calves, calving difficulties, death losses and subsequent weaning weights were kept, to allow an assessment of possible effects of the previous year's weaning treatment on cow and calf performance. These records were available for the calving seasons of 1983 to 1986, with the exception of the weaning weights for the latter.

In the weeks following calving of each year the number of cows to be culled was determined. The decision on which cows to cull was made based on such factors as failure to deliver and raise a calf to weaning, age, poor condition, bad teeth or udder, lameness or bad temperament. Weaning weights of calves was not a consideration for culling the dams whose data were used in this study. Cows to be culled were not exposed to bulls in the subsequent breeding season.

A second group of cows was culled in January of each year after a pregnancy test (by rectal palpation) had shown them not to be pregnant. It was the number of these cull cows which was used to determine the calving rates. Culling for other factors was assumed to be independent of weaning treatment and was not considered. (For the number of cows culled at both occasions in the four years, see Appendix 3).

Statistical Analyses

Least squares analyses of variance for unequal subclass numbers were computed using the General Linear Model procedure of the Statistical Analysis System (Freund and Littell, 1981). For the within-year analyses of weights and weight changes during the period between early and late weaning as well as for calving performance, weaning treatment, breed-group and age of dam and all two- and three-way interactions were used as sources of variation.

Levels of the main effects were:

1. Weaning treatment (W), classified as early or late;
2. Breed-group (B), classified as SY, HX and SD;
3. Age (A) of dam, classified as 2, 3, or mature (over three years of age).

The model employed was:

$$Y_{ijkl} = u + W_i + B_j + A_k + WB_{ij} + WA_{ik} + BA_{jk} + WBA_{ijk} + e_{ijkl}$$

where:

Y_{ijkl} = trait under consideration

u = overall mean

W_i = the effect of the ith weaning treatment;

B_j = the effect of the jth breed-group;

A_k = the effect of the kth age of dam;

WB_{ij} = the effect of the interaction between the ith weaning treatment and the jth breed-group;

WA_{ik} = the effect of the interaction between the ith weaning treatment and the kth age of dam;

WA_{jk} = the effect of the interaction between the jth breed-group and the kth age of dam; and

e_{ijkl} = random error.

The same model was used in the analyses of calving performance in the year following the weaning treatment, with the weaning treatment of the preceeding year as main effect. Sex of calf and all of its two-way interactions were, however, entered into the model in these analyses.

Effect of weaning treatment as a calf on subsequent performance as a heifer was determined using the same model.

Whenever sources of variation proved to be significant, Student-Newman-Keuls multiple comparisons of means were employed as described by Steel and Torrie (1980). Categorical data, such as calving rates and number of animals requiring assitance at birth, were analyzed using Fisher's Exact Method as outlined be Keeping (1962).

IV.3. RESULTS AND DISCUSSION

1. WEIGHTS AND WEIGHT CHANGES OF COWS

A total of 1233 records were analyzed to determine the influence of an early or late weaning treatment on weight changes of the dams during the period between the two weaning dates, as well as between weaning and subsequent calving season. It must be noted that these 1233 records do not correspond to 1233 cows as some of the cows remained in the study throughout the four years, whereas other cows were culled during the experiment and first-calving heifers entered the trial every year.

Only during the last two years of the study was there a significant difference between the two weaning groups in cow weights at the time of late weaning (Table IV.2). In both years (1984 and 1985) cows, which had been weaned late experienced significantly greater weight losses between the two weaning dates than those, which had been weaned early. Even after adjusting for the differences in weight at the time of early weaning in 1984, late weaned cows were still lighter at the time of late weaning. Table IV.3 shows the corresponding average daily weight changes in the two groups. Average daily rates of gain differed significantly between weaning groups, although the weight changes were not consistent throughout the four years. While all cows were gaining weight during the first year (0.96 vs 0.65 kg/day for early and late weaned animals, respectively),

TABLE IV.2 Least squares means and standard errors of bodyweights (kg) of cows in the two weaning groups at the time of early (EW) and late (LW) weaning and after calving

	Early weaned cows	Late weaned cows
1982		
at EW	484.2 ± 4.9	482.7 ± 4.7
at LW	511.2 ± 4.4	500.9 ± 4.2
1983		
after calving	476.3 ± 5.9	478.7 ± 6.0
at EW	505.5 ± 4.0	506.4 ± 3.9
at LW	508.6 ± 4.0	501.3 ± 3.9
1984		
after calving	469.0 ± 5.6	454.8 ± 5.9
at EW	510.7^{a} ± 6.5	472.7^{b} ± 6.1
at LW	492.4^{a} ± 6.5	438.1^{b} ± 6.1
1985		
after calving	471.3 ± 7.8	453.5 ± 7.2
at EW	497.8 ± 7.6	507.9 ± 7.3
at LW	502.9^{a} ± 6.2	485.8^{b} ± 5.9
1986		
after calving	500.0 ± 8.1	493.1 ± 7.5

a,b means with different superscripts in the same row are significantly different ($P<.05$)

TABLE IV.3 Least squares means and standard errors of average daily rates of gain (kg) between early and late weaning dates of the two weaning groups, and the three breed and age groups

	Early weaned	Late weaned
1982	$0.96^{a} \pm .07$	$0.65^{b} \pm .07$
1983	$0.03^{a} \pm .05$	$-0.25^{b} \pm .05$
1984	$-1.27^{a} \pm .08$	$-1.81^{b} \pm .08$
1985	$0.30^{a} \pm .06$	$-0.50^{b} \pm .05$
Total	$0.00^{a} \pm .04$	$-0.48^{b} \pm .04$

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1982	$0.80 \pm .08$	$0.70 \pm .07$	$0.93 \pm .11$
1983	$0.01^{a} \pm .05$	$-0.21^{b} \pm .04$	$-0.13^{ab} \pm .07$
1984	$-1.31^{a} \pm .09$	$-1.61^{b} \pm .08$	$-1.70^{b} \pm .10$
1985	$-0.16 \pm .06$	$0.03 \pm .07$	$-0.17 \pm .08$
Total	$-0.16 \pm .04$	$-0.29 \pm .04$	$-0.27 \pm .06$

	2 year olds	3 year olds	[illegible] years and older
1982	$0.04^{a} \pm .09$	$1.23^{b} \pm .10$	$1.15^{b} \pm .07$
1983	$-0.02^{a} \pm .06$	$-0.09^{a} \pm .07$	$-0.23^{b} \pm .04$
1984	$-1.37 \pm .10$	$-1.58 \pm .10$	$-1.66 \pm .08$
1985	$-0.05 \pm .07$	$-0.09 \pm .09$	$-0.17 \pm .05$
Total	$-0.36^{a} \pm .04$	$-0.13^{b} \pm .06$	$0.23^{b} \pm .03$

[a,b] means in the same row with different superscripts are significantly different ($P<.05$)

early and late weaned animals lost weight during this period in 1984 (1.27 vs 1.81 kg/day) while in the two remaining years early weaned cows gained and late weaned cows lost weight. The rather large weight loss in 1984 could be attributed to the harsh weather conditions in October of that year during which snow covered the ground for several days and the cows did not receive any supplementary feed.

To obtain an estimate of the year effect on weight changes, the data of the four years were analyzed concurrently by treating them as independent observations. This was necessary because of the number of observations and the nested design of the experiment, which imposed limitations on the use of the computer. It was thought that this was justified because environmental factors as well as weaning treatment are likely to have had a greater influence on weight changes between weaning dates than that of the individual's genotype.

This analysis revealed that early weaned animals generally experienced very small weight changes between early and late weaning (-0.003 kg/day), whereas late weaned cows lost 0.48 kg/day during this period, with the difference being statistically significant. Not surprisingly, this analysis also showed a highly significant year effect, with ADG in 1982 (0.82 kg) being significantly greater than gains in 1983 and 1985 (-0.13 kg in both years), and all three being different from gains in

1984 (-1.52 kg). This variability between years is probably a reflection of the differences in climate and pasture conditions which existed in the four years of this study.Year x weaning treatment interaction proved to be a highly significant effect as well (P<.005), which shows the importance of environmental factors for the response of the animal to the weaning date.

Weights of cows at calving in the subsequent year did not differ between the weaning groups, although early weaned cows tended to be somewhat heavier in the last three calving seasons (1984 to 1985). This corresponded to the weight change during the period between the two weaning dates. However, the greatest difference in weight changes between weaning dates did not correspond to the greatest difference in weight after calving in the following year. It would be reasonable to assume that whatever weight differences had been caused by the weaning treatment until the time of late weaning gradually disappeared and, therefore, the weights were not significantly different at calving.

Tables IV.3 and IV.4 show weights and average daily gains (losses) of early and late weaned cows belonging to the three breed-groups. Body weights of Dairy Synthetic and Beef Synthetic cows were significantly different from Hereford Crossbred cows in the first two years, with the exception of weights at the time of early weaning in 1982. Weights did, however, not differ significantly between the

TABLE IV.4 Least squares means and standard errors of bodyweights (kg) of cows of the three breed-groups at the time of early (EW) and late (LW) weaning and after calving

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1982			
at EW	485.6 ± 5.2	474.3 ± 4.9	490.4 ± 7.5
at LW	507.8[a] ± 4.6	493.9[b] ± 4.3	516.4[a] ± 6.6
1983			
after calving	488.0[a] ± 6.0	456.8[b] ± 6.3	487.8[a] ± 9.1
at EW	511.3[a] ± 4.6	493.5[b] ± 3.8	516.3[a] ± 6.2
at LW	511.7[a] ± 4.4	487.2[b] ± 3.7	512.5[a] ± 6.0
1984			
after calving	459.2 ± 6.4	453.8 ± 5.9	472.7 ± 8.7
at EW	497.1 ± 7.0	492.1 ± 6.3	515.5 ± 9.9
at LW	457.9 ± 6.6	443.8 ± 5.9	464.5 ± 9.3
1985			
after calving	457.7 ± 8.1	462.7 ± 7.0	466.7 ± 12.5
at EW	514.4 ± 7.3	488.4 ± 8.1	498.2 ± 10.0
at LW	508.9 ± 7.0	489.4 ± 7.8	492.4 ± 9.5
1986			
after calving	501.7 ± 8.3	493.0 ± 9.5	494.9 ± 11.0

[a,b] means with different superscripts in the same row are significantly different ($P < .05$)

breed-groups in the last two years of the experiment, which was probably in part due to the much smaller number of animals under investigation during these years. Generally, Dairy Synthetic cows were heavier than Beef Synthetic and Hereford Crossbred dams and as there was no significant breed-group x weaning treatment interaction, the SD cows remained heavier until the time of late weaning regardless of weaning treatment. Averages of daily weight gain and loss between weaning dates were significantly different between the Beef Synthetic and Hereford Crossbred breed-groups only during the second and third year of the study.

The within-year analysis of variance showed a significant breed-group x weaning treatment interaction only in the second year in which early weaned Beef Synthetic cows gained 0.26 kg per day, while their late weaned breed-group mates experienced a loss of 0.23 kg per day. Dairy Synthetic and Hereford Crossbred dams in both weaning groups lost weight (0.08 and 0.35 for HX and .09 and .17 for SD in the early and late weaned groups, respectively).

Weight after calving was significantly different between breed-groups only in 1983, when Beef and Dairy Synthetic cows weighed significantly more than Hereford Crossbreds and the difference between the breed-groups did in fact become noticeably smaller over the four years until there was only a difference of 8.3 kg between cows of the heaviest (SY) and lightest (HX) breed-group.

Tables IV.3 and IV.5 show weights and averages of daily gain (loss) of dams within the three age groups. As there were no animals within one breed- x age group, the system of four age groups was replaced with another model containing only three age groups, namely two-, three- and four year old and older cows. With the exception of the weights at the time of early weaning in 1982 and after calving in 1986, body weights between the three age groups differed significantly at all weighing dates, with two-year-olds being lightest and four year and older cows being the heaviest.

Weight changes between the weaning dates followed a somewhat different pattern. While heifers had significantly lower weight gains compared to older cows in the first year, their weight loss in the succeeding year was not significantly different from that of three year old dams. In the last two years, there was no significant difference in weight losses between age groups. The fact that older animals tended to lose a greater amount of weight is undoubtedly a reflection of their greater milk production and concurring mobilization of body tissues to maintain it. There was no significant interaction between weaning treatment and age of dam in any of the four years, with later weaned animals always being at a disadvantage throughout the trial.

Throughout the four years of this study the difference

TABLE IV.5 Least squares means and standard errors of bodyweights (kg) of cows of the three age groups at the time of early (EW) and late (LW) weaning and after calving

	2-year olds	3 year olds	4 years and older
1982			
at EW	465.7[a] ± 6.0	462.1[a] ± 7.0	522.4[b] ± 4.5
at LW	467.0[a] ± 5.3	496.4[b] ± 6.2	554.7[c] ± 4.0
1983			
after calving	446.4[a] ± 7.5	470.0[b] ± 8.1	516.1[c] ± 6.2
at EW	451.6[a] ± 5.1	507.6[b] ± 5.9	561.9[c] ± 3.6
at LW	451.1[a] ± 5.0	505.1[b] ± 5.7	555.3[c] ± 3.5
1984			
after calving	424.6[a] ± 7.7	461.4[b] ± 8.2	499.8[c] ± 5.1
at EW	441.8[a] ± 7.6	500.1[b] ± 9.7	562.8[c] ± 6.3
at LW	400.6[a] ± 7.1	452.7[b] ± 9.0	512.9[c] ± 5.9
1985			
after calving	423.3[a] ± 9.4	456.4[b] ± 11.5	507.4[c] ± 7.2
at EW	453.4[b] ± 7.7	485.1[b] ± 11.0	562.4[c] ± 6.3
at LW	451.8[a] ± 7.4	482.0[b] ± 10.5	556.8[c] ± 6.0
1986			
after calving	468.6[a] ± 8.6	482.9[a] ± 12.4	538.1[b] ± 7.3

a,b,c means with different superscripts in the same row are significantly different (P<.01) in average daily weight changes between early and late weaned cows in the three age groups did not follow a recognizable pattern. Differences were 0.07, 0.52 and 0.36 kg in the first, 0.32, 0.25 and 0.28 kg in the second, 0.26, 0.69 and 0.69 kg in the third and 0.67, 0.92 and 0.81 kg in the fourth year between early and late weaned dams in the three age groups, respectively. However, the results suggest that in the years with extremely favorable or unfavorable weather conditions (e.g. the first, in which all cows gained and the third, in which all cows lost weight), the difference between the two-year old heifers in the two weaning treatments would be relatively small.

Reports on the effects of early or late weaning on dam weight are scarce and it is difficult to evaluate these findings in light of other studies.

Richardson et al. (1978), weaning calves at 120 and 210 days of age, noted significantly higher body weights of 12 kg in early weaned cows at the time of late weaning. Neville and McCormick (1981), who investigated the effects of weaning calves at 67 and 230 days of age, concluded that early weaned dams gained 0.63 and 0.60 kg per day in the two years of the experiment, compared to 0.29 and 0.35 kg by dams still nursing their offspring. Keeping in mind climatic differences and the fact that weaning in this study occurred rather late in the season, it would appear that the findings reported here are in good agreement with those in the literature. The latter workers also reported that the difference in average daily gain between early and late weaned two-year old dams was greater than that of mature dams and concluded that the burden of nursing their calves was greater for younger dams, probably due to the fact that these animals still used some of their feed for growth. The findings reported here would suggest that in times of mild weather or of very adverse climate, this advantage of early weaned two-year old dams appears to become smaller and that both weaning groups perform similarly.

2. CALVING PERFORMANCE

To assess the possible influence of date of weaning on subsequent calving performance, data obtained in the calving seasons from 1983 to 1986 were studied. A total of 889 records were available for the analysis of the calving performance of dams and the pre-weaning growth of their calves. As not all cows raising a calf were bred and calved in the following breeding season, only 589 records could be analysed for calving intervals and calving rates.

Cows were again grouped into the three age groups with the age representing that of the cows at weaning during the fall of the preceding year. Thus, a cow in the two-year old group would, in fact, be three years old during the calving season under investigation. Records of first-calving heifers were not included in the analyses as they would, of course, not have been part of the weaning treatment in the preceding fall and their performance could not be analysed for weaning treatment effects. The traits studied in this analysis were birth weights and dates, weaning weights and preweaning average daily rates of gain of calves and calving intervals and calving rates of dams in the next calving season. It was assumed that if weaning date did have any effect on the condition of cows it could manifest itself in their performance during the ensuing calving and breeding season.

Birth dates of calves are listed in Table IV.6 and it is apparent that weaning date had no influence on the birthdate in the following year. In fact, birth date was the trait which was least affected by any of the factors entered into the model. Sex of calf had no influence on birth date and only in the first two calving seasons was there even a significant difference between dates of cows in different age groups with two-year olds calving significantly later than their older herd mates. It is not surprising that birth date was not affected by weaning treatment. Any difference in weaning dates would have had to arise from differences in the rate of conception and as weaning in this study occurred well after the breeding season it could not exert any influence on it. As well, the only marginal difference in condition of early and late weaned cows at weaning was not expected to influence the prenatal development of their calves.

This is also evidenced by the lack of any effect of

TABLE IV.6 Least squares means and standard errors of birthdates of calves (days) following the weaning treatment of their dams in the preceding year.*

Calving season:	Early weaned	Late weaned
1983	114.9 ± 1.0	115.1 ± 1.0
1984	120.4 ± 1.3	117.7 ± 1.4
1985	113.3 ± 2.0	114.1 ± 1.8
1986	112.5 ± 2.0	114.1 ± 1.8

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1983	114.8 ± 1.1	113.7 ± 1.0	116.6 ± 1.6
1984	119.2 ± 1.5	118.0 ± 1.4	120.0 ± 2.1
1985	112.5 ± 2.3	112.8 ± 2.1	111.9 ± 2.8
1986	115.2 ± 2.0	114.8 ± 2.4	109.8 ± 2.7

	2-year olds	3-year olds	4 years and older
1983	118.9^{a} ± 1.3	111.6^{b} ± 1.4	114.6^{b} ± 1.0
1984	122.3^{a} ± 1.8	118.8^{b} ± 2.0	116.0^{b} ± 1.2
1985	111.9 ± 2.7	110.8 ± 2.6	114.5 ± 1.9
1986	115.1 ± 2.0	112.4 ± 3.1	112.4 ± 1.8

* Day 1 = January 1

a,b means with different superscripts in the same row are significantly different ($P<.05$)

weaning treatment on birth weights, as shown in Table IV.7. Significant differences, however, did exist between age and breed-groups in the first three years of this study. Dairy Synthetic dams had consistently heavier calves than Beef Synthetic and Hereford Crossbred dams, with the latter delivering the lightest calves during all four calving seasons. These differences were likely a reflection of the differences in body weights between these three breed-groups. Likely for the same reason, age of dam proved to be a significant effect as well, with older cows giving birth to heavier calves, although this effect was not noticeable during the last calving season in 1986. Sex of calf had a significant effect on birth weight in the first three years and approached significance in 1986 (P=.08) with 44.4, 40.3, 41.4 and 40.5 kg for male and 41.3, 37.2, 38.6 and 38.0 kg for female calves in the four years, respectively. None of the interactions between any of these factors was significant.

Tables IV.8 and IV.9 list the weaning weights and average daily gain of calves of dams by weaning treatment, breed- and age of dam groups. Data of 1986 were not yet available for this analysis so the results of data from only 1982 to 1985 are presented. The trend in weaning weights generally followed that of birth weights. Weaning treatment of the dam had no effect on weaning weight of her calf, which was determined at the time of early weaning in the following year. Dairy Synthetic dams weaned the

TABLE IV.7 Least squares means and standard errors of birthweights of calves (kg) following the weaning treatment of their dams in the preceding year.

Calving season:	Early weaned	Late weaned
1983	43.4 ± .5	42.6 ± .5
1984	39.0 ± .5	38.3 ± .5
1985	39.7 ± .7	40.9 ± .7
1986	39.4 ± .9	39.1 ± .8

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1983	42.1^{a} ± .5	40.2^{b} ± .5	46.7^{c} ± .7
1984	37.8^{a} ± .6	37.7^{a} ± .5	40.4^{b} ± 2.1
1985	40.1^{ab} ± .9	38.9^{a} ± .8	41.9^{b} ± 1.0
1986	39.9 ± .9	37.8 ± 1.1	40.0 ± 1.2

	2-year olds	3-year olds	4 years and older
1983	41.6^{a} ± .6	43.6^{b} ± .7	43.8^{b} ± .5
1984	38.5^{ab} ± .7	37.8^{a} ± .7	39.8^{b} ± .4
1985	38.6^{a} ± 1.0	40.3^{ab} ± 1.0	41.9^{b} ± .7
1986	39.3 ± .9	39.1 ± 1.4	39.3 ± .8

[a,b] means with different superscripts in the same row are significantly different (P<.05)

TABLE IV.8 Least squares means and standard errors of weaning weights of calves (kg) following the weaning treatment of their dams in the preceding year.

Calving season:	Early weaned	Late weaned
1983	219.0 ± 2.3	220.1 ± 2.2
1984	207.2 ± 2.7	203.1 ± 2.9
1985	217.2 ± 2.7	222.8 ± 4.0

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1983	219.7[a] ± 2.4	209.8[b] ± 2.2	229.2[c] ± 3.5
1984	206.5 ± 3.1	199.5 ± 2.9	210.4 ± 4.4
1985	224.7[a] ± 4.9	210.1[b] ± 4.3	225.8[a] ± 5.7

	2-year olds	3-year olds	4 years and older
1983	204.1[a] ± 2.9	224.5[b] ± 3.1	230.1[b] ± 2.2
1984	194.4[a] ± 3.8	205.5[b] ± 4.0	216.6[c] ± 2.5
1985	214.5 ± 5.6	217.3 ± 5.4	228.8 ± 3.9

[a,b] means with different superscripts in the same row are significantly different (P<.05)

TABLE IV.9 Least squares means and standard errors of preweaning ADG (kg) of calves following the weaning treatment of their dams in the preceding year.

Calving season:	Early weaned	Late weaned
1983	1.09 ± .01	1.09 ± .01
1984	1.08 ± .01	1.05 ± .01
1985	1.11 ± .02	1.13 ± .02

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
1983	1.09[a] ± .01	1.04[b] ± .01	1.34[c] ± .02
1984	1.07[a] ± .02	1.02[b] ± .01	1.10[c] ± .02
1985	1.15[a] ± .02	1.07[b] ± .02	1.14[a] ± .03

	2-year olds	3-year olds	4 years and older
1983	1.03[a] ± .01	1.09[b] ± .01	1.15[c] ± .01
1984	1.02[a] ± .02	1.07[b] ± .02	1.11[c] ± .01
1985	1.09[a] ± .03	1.09[b] ± .02	1.18[b] ± .02

a,b means with different superscripts in the same row are significantly different (P<.05) heaviest calves in all three years, however their weights were significantly different from both other breed-groups only in the first year. Significant differences were also found between age groups in the first two years, with those in the last year approaching significance (P=.06). In all three years, the weaning weight of the calf increased with the age of its dam. Weaning weight was also influenced by the sex of the calf and differences were significant in the first two years of the study, with 225.6, 210.8 and 223.5 kg for male and 213.2, 199.9 and 214.6 kg for heifer calves.

Average daily rates of gain followed a very similar pattern. While weaning treatment of the dam had no effect, her genetic composition proved to be a significant factor in all three years. Whereas differences between all three breed-groups were significant in the first two years, with calves of Dairy Synthetic dams gaining at a faster rate than those of Beef Synthetic and Hereford Crossbred dams, the difference between the former two was not significant in the last year. All differences between the three age groups were significant in the first two years as well, whereas calves of two and three year old cows were gaining at the same rate in the last year. Sex of calf was a highly significant factor, with bull calves consistently gaining at a faster rate than heifer calves (1.12, 1.10 and 1.15 kg/day vs 1.07, 1.03 and 1.08 kg/day for male and female calves in the three years, respectively). There was no significant interaction between any of the factors in the model.

Table IV.10 shows the calving intervals following the weaning treatment in the early and late weaned groups. As the analysis of body weights after calving had already indicated, there was no difference in the condition of dams between the two weaning groups and, as might have been, expected, there appeared to be no difference in the rate at which dams of the two weaning groups became pregnant, resulting in virtually equal calving intervals. Neither breed- nor age group differences were significant although Dairy Synthetic dams had the shortest calving interval in each of the three years.

To determine if weaning treatment had an influence on the calving rate, the number of cows exposed to bulls in the year following the weaning treatment and of those which subsequently calved was determined (Table IV.11). Pregnancy was usually established by rectal palpation during January and cows which had failed to conceive were shipped to slaughter. Data, which were available for three breeding/calving seasons, showed no difference in the calving rate between the two weaning groups in any of the years.

These results indicate that weaning treatment, which follows the breeding season as in this study, and in which weaning dates differ by only one month, is not likely to influence the reproductive performance of cows. Any such

TABLE IV.10 Least squares means and standard errors of calving intervals (days) following the weaning treatment.

Calving seasons:	Early weaned	Late weaned
83/84	368.5 ± 1.8	367.5 ± 1.8
84/85	359.1 ± 2.0	360.3 ± 2.2
85/86	365.6 ± 6.4	362.1 ± 6.5

	Beef Synthetic	Hereford Crossbred	Dairy Synthetic
83/84	368.7 ± 1.9	368.7 ± 2.0	366.6 ± 2.6
84/85	359.2 ± 2.2	362.7 ± 2.1	357.2 ± 3.3
85/86	366.5 ± 7.7	367.2 ± 9.6	357.8 ± 6.6

	2-year olds	3-year olds	4 years and older
83/84	366.3 ± 2.3	370.9 ± 2.5	366.8 ± 1.7
84/85	355.7 ± 2.8	361.7 ± 3.0	362.3 ± 1.9
85/86	364.3 ± 9.7	366.7 ± 7.3	360.4 ± 5.2

TABLE IV.11 Calving rates of early and late weaned cows during the calving season following the weaning treatment.

	Number of cows exposed	Number of cows calving	Calving rate
82 Weaning/			
83 Breeding/			
84 Calving:			
Early weaned	130	107	82.3
Late weaned	138	113	81.9
83 Weaning/			
84 Breeding/			
85 Calvi[illegible]			
Early weaned	112	92	82.1
Late weaned	101	90	89.1
84 Weaning/			
85 Breeding/			
86 Calving:			
Early weaned	59	47	79.7
Late weaned	51	45	88.2

influence would have to arise from a marked improvement of the condition of early weaned dams to such an extent that it would persist well into the next breeding season. This effect, clearly, was not seen in this study.

Richardson et al. (1978) concluded that the significant weight increase of dams, which had resulted from weaning calves early, did not influence the weights of calves born in the following calving season. These workers did, however, note a significant association between increased weight gain and calving difficulty during the following calving season. This was not the case in this study although the average weight gains between weaning dates found here were far smaller than those in Richardson's study.

3. EFFECTS OF WEANING TREATMENT DURING CALFHOOD ON CALVING PERFORMANCE OF HEIFERS

To determine if weaning treatment as a calf would influence the calving performance of first-calving heifers, calving data of heifers in 1984 and 1985, which had been part of the weaning experiment as calves in 1982 and 1983, were analyzed. Data for 1986 were not available, as all calves in the 1984 weaning experiment had been males. A total of 311 heifers were kept for breeding in the two years (122 and 189 in 1982 and 1983, respectively). The results of this analysis are shown in Table IV.12. Calving rates between the two groups did not differ; there was,

TABLE IV.12 Calving performance of heifers in 1984 and 1985 as a result of their weaning treatment as calves in 1982 and 1983.

	Early weaned	Late weaned
Number of heifers exposed	161	150
Number of heifers calving	110	104
Calving rate	68.3	69.3
Number of heifers requiring assistance at calving	33	31
Birth dates of calves*	110.0 ± 1.4	110.8 ± 1.3
Birth weights (kg)	33.4 ± .5	34.3 ± .5
Weaning weights	181.9 ± 2.8	188.5 ± 2.6

* Day 1 = January 1.

however, a significant year effect (P<.05). While of the 122 heifers exposed in the first year, 92 subsequently calved (75.4%), of the 189 animals exposed in the second year only, 121 gave birth (64.4%). This difference was caused by an apparently infertile bull, which was assigned to a group of about 20 heifers.

There was no difference between the two groups in the number of animals requiring assistance at birth with 32 and 31% of heifers in the early and late weaned groups, respectively, needing some help at calving. Birth dates, weights and weaning weights were also not affected by weaning treatment during calfhood. Surprisingly, none of the other factors which had been entered into the model, namely year, breed-group of heifer and sex of calf and any of their interactions, proved to have any significant influence on calving performance.

Richardson et al. (1978) reported similar findings. These workers concluded that the difference in pregnancy rate between early and late weaned heifers was only 0.5% in favor of animals, which had been weaned early. As had been observed by Reynolds et al. (1971), Richardson et al. (1978) also reported a higher live calf percentage in early weaned heifers as a result of higher body weights. This was not supported in this study where 6.4% (7) of calves of early and 3.9% (4) of calves of late weaned heifers were either born dead or died at birth.

The results reported here suggest that a difference of one month in the weaning dates of calves has no influence on their subsequent maternal performance. This is in agreement with results reported in Chapter II., which indicated that this difference in weaning dates is not large enough to have any long term effect on calf performance.

IV. SUMMARY AND CONCLUSIONS

Results of a four-year study on the effects of weaning date on cow performance are presented. Early weaned cows tended to be heavier at the time of late weaning, however, the effect was significant only for two years of this study. There was no difference in weights after calving in the subsequent year. None of the calving traits was influenced by weaning treatment. Weaning date of a female calf did not influence her subsequent performance as a heifer.

These results suggest that there would be no economic advantage in weaning cows early under a system similar to that described in this study, as the small body weight advantage of early weaned dams at the time of late weaning is unlikely to result in lowered maintenance cost during the winter. One month difference in weaning date does not appear to have a significant influence on the subsequent reproduction of the cows.

However, early weaning of cows should not be rejected entirely as an alternative to traditional weaning systems. It could be suggested that a study into the effects of different weaning dates might have produced different results if weaning in the two groups would either have been further apart or if weaning had taken place during the summer in which feeding conditions would have been better and early weaned cows could have realized a greater benefit. It is also quite conceivable that, in times of feed shortage, for example, during extended periods of drought, a cow's condition could deteriorate to an extent that it might result in higher maintenance cost during the winter or even influence her reproductive performance in the following year.

The same argument, of course, is applicable to heifers, whose reproductive performance might be adversly affected by periods of feed shortage and which might benefit if they were weaned early and maintained with adequate nutrition.

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IV. GENERAL SUMMARY AND CONCLUSIONS

The overall objectives of this study were to assess the effects of weaning age on the post-weaning performance of calves and their dams. Assuming that under certain conditions, weaning calves early could be beneficial and that it would be necessary to evaluate the effect of such an alternative weaning system on the productive potential of the animals. A further aspect of this study was to investigate the effects of the provision of a simple overhead shelter during the winter for growing feedlot cattle, assuming that such a shelter would reduce heat loss and, thus, decrease feed requirements and increase the efficiency of gain. It was also hoped that this study would reveal possible differences in the response to these experimental parameters as a result of differences in the genetic composition of the animals.

Results showed that weaning treatment had little effect on the overall post-weaning productivity of the calves. The greatest effect was noted in the period between the two weaning dates when early weaned animals gained a significantly greater amount of weight than their contemporaries, which had remained with their dams. During the subsequent feedlot period, however, late weaned animals had a higher rate of gain and had, in fact, almost reached the same body weights as their early weaned contemporaries at the end of the 140-day trial. As slaughter records indicated, by the time these animals had reached a desirable degree of finish, there was no difference in either age at slaughter or carcass composition, indicating that lifetime productivity was not affected by weaning treatment. Although there were differences between the three breed-groups in average daily rates of gain, with the Beef Synthetic calves gaining significantly faster, all three breed-groups responded similarly to the weaning treatment. Feed consumption did not differ between the weaning groups when compared during the period in which both were of the same age, however, late weaned animals did exhibit a better feed efficiency. There was no appreciable difference between the two groups with regard to health status or mortality.

The investigation of the effects of weaning treatment on subsequent cow productivity revealed some advantage in weight gain in early weaned dams between the two weaning dates, however, in the subsequent calving season this difference had disappeared. It is safe to conclude that the small weight advantage experienced by early weaned cows did not result in any substantial feed savings during the winter, nor did it result in a better condition to such an extent that it would have affected their calving performance, reproductive efficiency or the pre-weaning growth of their calves.

The analysis of calving records of heifers, which had themselves been subjected to the weaning treatment as calves, revealed no effect between early and late weaned animals in either calving rate, birth dates or weight of their calves.

Although the observed weight differences between early and late weaned dams and their calves were small in this study, it must again be emphasized that there could be a considerable advantage realized by early weaning under a different management system. Calves could be weaned at a younger age than the animals in this study, thereby providing enough advantage for their dams to result in actual feed savings during the winter or it could influence their subsequent calving performance. Grazing intensity of cows could be increased if their calves were removed earlier or calves could be maintained at a maximum growth rate during times of feed shortage. An additional advantage could be realized if an early weaned and preconditioned calf were to bring a higher price, due to the fact that it would be less affected by the stress of being moved to a feedlot than a calf which has just been separated from its mother.

Any decision when to wean calves will ultimately involve a variety of factors, most of which are specific to each individual operation and, therefore, no particular recommendations can arise from this study. However, the results presented here might serve as an indication that the productivity of calves can be maintained under an alternative weaning system.

The investigation into the effects of providing an overhead shelter for growing beef cattle showed that sheltered animals had a significantly higher rate of gain, although feed consumption and efficiency were not influenced by the type of housing. There appeared to be a somewhat greater susceptibility in sheltered animals to respiratory infections, which was likely the result of the greater density of animals in the sheltered pens and the lower environmental quality associated with it. The analysis of slaughter records did not reveal any long term advantage of sheltered animals, nor was there any difference between breed-groups in their response to the type of housing. The results also showed that there was no difference between housing types in the performance of calves belonging to different age groups.

There are somewhat stronger conclusions, which can be drawn from these results namely that the small advantage of sheltering animals during this feedlot trial and the lack of any effects on lifetime productivity would suggest that even animals with a lower rate of gain would not profit enough from the provision of an overhead shelter to make it a profitable alternative to the traditional feedlot equipped only with windbreaks.

Although weaning and housing treatments were superimposed on the calves in this study, none of the traits considered revealed any significant interaction between the two. The implications arising from this are that early and late weaned calves can be expected to perform equally well in both housing types and that there is no advantage in providing either weaning group with a shelter.

APPENDICES

APPENDIX 1

Time schedule of experiment

1) 1984/85

DAY	DATE	EXPERIMENTAL PROCEDURE	
1	Jan 1		
90	Mar 30	Beginning of calving season.	
118	Apr 27	50% of calving completed.	
158	Jun 6	100% of calving completed.	
275	Oct 1	EARLY WEANING Adjustment period of early weaned calves.	
306	Nov 1	Feedlot period #1 of early weaned calves begins.	LATE WEANING Adjustment period of late weaned calves.
334	Nov 28	Feedlot period #2 of early weaned calves begins.	Feedlot trial of late weaned calves begins.
		Calves separated into sheltered and unsheltered groups. Feedlot trial to determine effects of housing begins.	
445	Mar 20	Feedlot period #1 of early weaned calves ends.	
474	Apr 18	Feedlot period #2 of early weaned calves ends.	Feedlot trial of late weaned calves ends.
		Feedlot trial to determine effects of housing ends.	

501	May 15	First bulls sent to slaughter.	
536	Jun 19	50% of bulls sent to slaughter.	
637	Sep. 18	100% of bulls sent to slaughter.	

2) 1985/86

89	Mar 30	Begin of calving season.	
114	Apr. 24	50% of calving completed.	
157	Jun 6	100% of calving completed.	
274	Oct 1	EARLY WEANING Adjustment period of early weaned calves.	
308	Nov 4	Feedlot period #1 of early weaned calves begins.	LATE WEANING Adjustment period of late weaned calves.
336	Dec 2	Feedlot period #2 of early weaned begins.	Feedlot trial of late weaned calves begins.
		Calves separated into sheltered and unsheltered groups. Feedlot trial to determine effects of housing begins.	
449	Mar 25	Feedlot period #1 of early weaned calves ends.	
477	Apr 22	Feedlot period #2 of early weaned calves ends.	Feedlot trial of late weaned calves ends.
		Feedlot trial to determine effects of housing ends. End of experiment.	

APPENDIX 2

Composition of feedlot diet

Item	per kg DM	per kg as fed
DM (kg)	1.00	0.90
DE (Mcal)	3.40	3.05
ME (Mcal)	2.82	2.53
NEm (Mcal)	1.85	1.66
NEg (Mcal)	1.23	1.10
Protein (g)	133.90	120.18
ADF (g)	122.00	109.50
Calcium (g)	5.70	5.11
Phosphorus (g)	4.70	4.22
Salt (g)	1.78	1.60

APPENDIX 3 Number of cows culled in the year following the weaning treatment

Weaning treatment	Number of cows calving in the following year	Cows culled in the following year: after calving number	after calving %	after breeding number	after breeding %	total number	total %
1982:							
Early	156	26	16.7	27	17.3	53	34.0
Late	183	45	24.6	25	13.7	70	38.8
Total	339	71	20.9	52	15.3	123	36.3
1983:							
Early	158	46	29.1	8	5.1	54	34.2
Late	146	45	30.8	11	7.5	56	38.4
Total	304	91	29.9	19	6.25	110	36.2
1984:							
Early	64	5	7.8	12	18.8	17	26.6
Late	60	9	15.0	6	10.0	15	25.0
Total	124	14	11.3	18	14.5	32	25.8
1985:							
Early	55	7	12.7				
Late	67	11	16.4				
Total	122	18	14.8				