EFFECTS OF LIMITING ACCESS TIME TO FEED AND OF PEN HOUSING ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

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This thesis is dedicated to my late, younger brother, Zachary Wade Prawl. Although the years have long since passed that we were able to enjoy the times of playing together, I know that he is still by my side and we are being the best friends that only brothers can be.

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CHAPTER I

INTRODUCTION

The beef industry has changed drastically since the early years of feeding and finishing cattle. Although technology has advanced cattle procurement and marketing, health care, and feed distribution, little change has occurred in the way that cattle are fed. Cattle have been given ad libitum access to feed ever since people began finishing cattle. The concept that cattle being finished should have continuous access to feed has been questioned and given much attention in recent years.

When feeding and finishing beef cattle for slaughter, the single factor with the greatest impact on profitability probably is feed efficiency. Simply stated, feed efficiency is the quantity of feed consumed by the animal per unit of weight gained. The less feed required for gain, the greater the economic incentive to feed cattle. Small increases or decreases in efficiency have a large economic impact.

Although defining feed efficiency is simple, improving it is difficult. Several factors including breed, environment, and type of feed consumed by the animal affect how efficient feed is converted to live weight or to an edible product that consumers purchase.

Products such as growth promoting hormones and ionophores that increase daily weight gains and/or improve efficiency in cattle have increased efficiency of beef production; however, other methods to improve efficiency of weight gain in beef cattle must be explored. The concept of limiting or controlling feed intake of growing and finishing cattle has become widely accepted as one method to improve feed efficiency and to provide other benefits to the producer. Such benefits include decreased feed waste, less labor and time required to read bunks, and more accurate prediction of finishing performance.

Most limit feeding trials have used two sets of cattle; one to determine ad libitum consumption with the second being fed a percentage (e.g. 90%) of the first group. Feeding trials conducted in this manner provide a consistent amount of feed available to the animal, but require that some cattle be fed an unlimited amount of feed. The intent and purpose of the research conducted for these current trials examined whether feed intake could be restricted by limiting the amount of time cattle have access to feed. By restricting the amount of time that cattle are allowed to eat, one can control intake without relying on a 'basis' of feed calling. Cattle would be allowed to eat what they could or desired in a specific amount of time. Therefore, the objective of our research was to determine if feed efficiency is improved by limiting the amount of time cattle could eat feed. In addition, some of these cattle were housed in small, partially covered, slatted concrete floor pens while others were housed without shelter in large pens on soil. Effects of housing (inside vs. outside) on cattle performance was monitored.

CHAPTER II

ALTERNATIVE METHODS OF SUPPLYING FEED TO FEEDLOT CATTLE: A REVIEW

Programmed Feeding

Several methods can be used to restrict energy intake. The classical "paired feeding" approach is to restrict intake of feed to a specified percentage of feed disappearance from pens of animals given ad libitum (AL) access to feed. Another system typically used for growing cattle but occasionally used for finishing cattle, is the 'programmed gain' method (Zinn, 1986; Hicks et al., 1988). This method employs Net Energy prediction equations to calculate the amount of feed needed to achieve a specified rate of gain. Zinn (1986) fed steers an 80% concentrate diet at a rate to gain 2.8 lbs/day using both AL and restricted feeding regimens. Although rates of gain were quite similar (2.73 vs. 2.76 lbs/day for restricted and AL fed, respectively), feed intake was 6.2% greater for cattle given AL access to feed. This resulted in a 4.6% advantage in feed efficiency for restricted fed steers. Hicks et al. (1988) fed cattle either AL, 80% of AL, or program fed them to achieve daily weight gains of 3.29 lbs/day (High) or 2.96 lbs/day (Low). Although carcass adjusted daily gains (hot carcass weight divided by a dressing percent of 62%) were reduced 6.2% by limit feeding, feed efficiency was improved by 4% by limit feeding.

Lusby et al. (1990), using early weaned calves as young as two months of age, fed a 90% concentrate diet at three different levels: 1) programmed to gain 1.0 lbs/day; 2) programmed to gain 1.5 lbs/day; or 3) free choice access to feed. For a fourth treatment, calves continued to nurse their dams but were fed 2 lbs/day of a salt-limiting creep ration (67% rolled corn, 33% soybean meal) until being weaned at six to seven months of age. During the subsequent finishing period when all calves had free choice access to feed, calves previously limit fed to gain 1.0 lbs/day calves had the highest rate of gain (3.23 lbs) while calves previously full fed had the lowest rate of gain (2.45 lbs) and the lowest feed intakes. As a result, feed efficiency was 7.1% superior (5.3 vs. 5.7 lbs feed/lb gain) for limit fed calves during the finishing phase. Whether or not the these calves would have exhibited similar improvements in feed efficiency if given limited access to feed while finishing is unknown. This idea warrants further study.

In comparison to program feeding during the finishing period, Rakestraw and Lusby (1991) fed steers one of three ways until they reached 750 lbs, thereafter they had AL access to feed until slaughter. Cattle received either a 61 Mcal NEg/cwt diet fed at a rate to gain 2.2 lbs/day, a 66 Mcal NEg/cwt diet fed at a rate to gain 2.2 lbs/day, or full fed a 61 Mcal NEg/cwt diet until steers reached 750 lbs. Steers then were given free choice access to the 61 Mcal NEg/cwt diet until they were slaughtered. During the growing period, steers fed the 66 Mcal diet were significantly more efficient than steers fed the other diets. During the finishing period, feed intake was similar for all treatments but feed efficiency tended to be superior for calves limit fed previously. Although 11 additional days were required for the limit fed calves to achieve similar slaughter weights, cost of gain was reduced by limit feeding because total feed consumption for the entire growing/finishing period was reduced.

Feeding a Percentage of Ad Libitum Intake

Most research on limit feeding conducted in recent years has dealt with feeding cattle a specified percentage of feed consumed by cattle given AL access to feed (Hicks et al., 1987; Loerch, 1990; Murphy et al., 1994a, 1994b; Murphy and Loerch, 1994; Rabearimisa and Hoffman, 1994, 1995). Steers were used in all of these trials with one exception (Hicks et al., 1987). In this trial, heifers were also studied in contrast to steers with similar limit feeding treatments. Hicks et al. (1987) observed that steers limited to 85% of intake consumed by control steers (AL) gained 7% slower but feed efficiency was improved by 8.9%. Heifers fed at 89% of AL intake had 3.1% smaller average daily gains compared to AL fed heifers, but had an 8.7% improvement in feed efficiency. Feed and yardage costs were lowered impressively (5.2%) for both steers and heifers by limit feeding.

Murphy and Loerch (1994) fed steers AL, 90% or 80% of AL of an all concentrate diet during both the growing and finishing phases before slaughter. These researchers showed that while reduced dry matter intake (14.5, 13.0, 11.5 lbs/day total intake, respectively) reduced daily gain (2.82, 2.49, and 2.27 lbs), feed efficiency was not affected by level of intake over the entire trial (.43, .42, .43 lbs gain/lb feed). In a second trial, corn-silage based diets were fed for 84 days followed by a 91% concentrate diet fed AL, or 90% and 80% of AL. Feed efficiency was not affected in the growing phase, but in the finishing phase, limit feeding improved FE by 8.1% and 1.25% by 80% and 90% restriction of AL fed steers, respectively. These results suggest that cattle fed high roughage diets during the growing phase benefit more from limit feeding during the finishing phase than do steers fed a high concentrate diet fed throughout the feeding period. However, this direct comparison was not tested in these experiments.

Additional studies conducted at Iowa State University (Rabearimisa and Hoffman, 1994, 1995) involved placing cattle on feed in four different months of the year (March, June, September, December). These steers were fed high concentrate diets at AL, 95% or 90% of AL rates. In the first trial, these researchers reported that average daily gain was depressed slightly when intake was limited, but FE was similar throughout the trial. Limit fed cattle started on feed in March and June tended to have improved FE whereas AL fed cattle were slightly more efficient in September and December. The improved efficiency from limit feeding during the summer perhaps was a result of heat stress on the AL fed cattle. Excess heat produced from feed fermentation during the summer may suppress the animal's ability to dissipate internal heat and depress production. Excess heat stress is more easily dissipated in fall and winter months.

Limiting Access Time to Feed

Although limiting the amount of time cattle are allowed to consume feed is not a common practice, the concept is not new. As early as 1978, Shaw (1978) used Calan Broadbent feeding gates to control the amount of time cattle had access to their feed. Cattle were trained to respond to certain stimuli such as music or a door buzzer that signaled the beginning of a meal. After a restricted period of time, a second stimulus (bell) would ring that signaled the end of the meal. After training, cattle responded solely to these sound stimuli to begin and end meals.

In Shaw's trial, eating behavior was studied. Cattle fed AL (control) ate for a total of approximately 2 hours/day. Time restricted cattle were limited to six meals/day with a duration of six minutes/meal; feeding commenced at 0700 each morning and cattle were allowed access to feed every two hours thereafter for a 12 hour period for a total allowed eating time of 36 minutes/day. Theoretically, this decrease in eating time of 70% should decrease feed intake by 70%. Intake actually was reduced by only 21%. These results indicate cattle adapted to the imposed time restriction by consuming feed more rapidly and perhaps taking larger mouthfuls while eating. In a similar study, Calan gates have been used to examine the effect of breed on eating behavior (Taylor and Murray, 1987). Six breeds including South Devon, Charlois X British Friesan, British Friesan, Hereford, Angus, and Jerseys were used. Taylor and Murray (1987) found no significant interaction with breed and meal length over two years when cattle were allowed 4, 5, or 6 minutes per meal to consume feed. This finding is important to the concept of limiting access time to feed because it excludes the possibility that an inferiority in eating speed or pattern between breeds would depress performance.

Garrett (1979) fed steers at 1600 and allowed them access to feed until 0800 the following morning in an attempt to limit the time that cattle had to consume feed. This allowed cattle a total of 16 hours to eat each day. This first attempt to limit access time to feed proved unsuccessful; time-restricted cattle ate less (16.3 vs 17.5 lbs/day for timed and AL fed cattle, respectively) and gained less (2.08 vs 2.25 lbs/day), so they were similar in feed efficiency (8.1 vs 8.0 lbs feed/lb gain).

Limiting access time to feed to 16 hours/day may seem sufficient for cattle to consume feed needed for desired gains. Taylor and Murray (1987) found that cattle fed a low energy pellet were able to consume enough feed to maintain their weight when given access to feed for a total eating time of only 24 minutes per day. In other words, the first 24 minutes spent eating per day should satisfy animal maintenance energy requirements. Additional eating time should result in weight gain although eating behavior must change for this method to be of any benefit.

In an attempt to further restrict access time to feed, Arp and Owens (1983) fed 12 individually penned lambs AL or restricted to 1 hour to eat each day. AL fed lambs ate 16% more feed but gained only 10% more weight during the trial. The 6% increase in feed efficiency observed from limit feeding these lambs was encouraging.

To test severe feed access time restriction on cattle, Hicks et al. (1989) fed 12 crossbred steers a high corn diet by one of three protocols: 1) AL, 2) 95% of AL, or 3) limited access time to feed for 2 hours/day. Initially, the 2 hours access time was allowed in the morning immediately after feed delivery. However, by 2 weeks into the trial, feed intake for these cattle was severely depressed. As a result, the access time to feed was changed to 1 hour immediately after the morning and evening feedings. Daily dry matter intake over the entire trial was 97.8% of AL for the limit fed group and 92.8% of AL for the time controlled group. Although feed efficiency over the entire trial was unaltered in the limit fed group, a 9.9% improvement in FE was achieved by limiting access time to feed (4.97, 4.92, and 4.48 lbs DM/lb gain for AL, limit fed, and time restricted treatments, respectively) despite these cattle never adjusting to the feeding regimen and having sizable day to day fluctuations in intake. Even though the possibility of subacute acidosis might be precipitated by large day to day fluctuations, the vast improvement in feed efficiency in this trial could not be overlooked. However, this method of limit feeding cattle did not catch on and has been ignored as a method for improving efficiency of feedlot cattle.

In 1992, Birkelo and Lounsberry restricted feed intake time by allowing access to feed for 6 to 7 hours/day through intensive bunk management and adjusting feed calls each day. Compared to AL feeding of cattle, limiting feed access time decreased feed intake by 7.9% for limited access time fed cattle. Degree of restriction was not consistent throughout the trial. Feed efficiency tended to be improved by restricted intake, but the difference was small (5.69 vs 5.63 lbs feed/lb gain for AL vs. timed, monensin fed cattle; 5.91 vs 5.67 lbs feed/lb gain for AL vs. timed, nonmonensin fed cattle). Factors affecting rate of intake, i.e., grain content of diet, heat stress, or ionophore type used, are important considerations when limiting intake through time restriction.

Why Does Limit Feeding Improve Efficiency?

Despite extensive research that documents the benefits from limit feeding on feed efficiency, the mechanisms by which limit feeding enhances performance remains unknown. But this lack of knowledge is not due to lack of interest. Many explanations have been offered to explain this phenomenon. Whether it is as simple as reduced feed wastage (Hicks et al., 1987, 1988), or a result of more complex processes such as a reduced incidence of subacute acidosis due to minimization of day to day fluctuations in intake (Hicks et al., 1988; Hill et al., 1996), or a decreased maintenance energy requirement (Hicks et al., 1987; Murphy and Loerch, 1994), the cause remains unclear. Nevertheless, economic and management benefits to the beef industry from limit feeding or a "slick bunk" policy are recognized widely.

Reduced Feed Wastage

Feeding systems and bunks are designed to reduce feed waste. Yet, animals sort out preferred feed, leave feed in the feedbunk to spoil, push feed out of the feedbunk onto the ground, and dribble feed out of their mouths. Feed loss can drastically affect calculated efficiency. Feed not ingested by the animal is a loss. If 100 head of cattle wasted .5 lbs of feed/head/daily (about 2%) over a 150 day feeding period and the feed cost is $160/ton, $6.00/head is lost. For a 50,000 head feedyard, this equals a yearly loss of $720,000 due to wasted feed.

With limit feeding, animals, although showing no signs of hunger, do not completely fill their gut to capacity. Therefore, they should be able to consume all the feed delivered to them before experiencing physical symptoms of being full. With a surplus of feed, cattle are more likely to sort feed and play with the feed. Hicks et al., (1988) measured residual feed that accumulated on the cement pad behind feedbunks for a 24 hour period. No feed wastage was detected by limit fed steers; they consumed all of their feed readily.

Reduced Day to Day Feed Intake Fluctuations

By limiting intake, eating pattern of feedlot cattle is more consistent from day to day throughout the feeding period (Rabearimisa and Hoffman, 1995). By reducing day to day fluctuations in feed intake, the rumen environment is more stable. This should decrease the prevalence of overeating and subacute acidosis. When specific amounts of feed were provided for consumption, Hicks et al. (1988, 1989) found that day to day intakes by restricted fed cattle were very consistent and daily variation in animal to animal weight gain was reduced substantially.

Decreased Maintenance Energy Requirement

Energy consumed by cattle is partitioned into two factions: one for maintenance of the animal, the remainder used for gain or production. Maintenance energy expenditures must be met with adequate feeding before any energy will be used from the feed source for gain or production.

Maintenance energy requirements depend on metabolic rate of the animal. One factor that affects metabolic rate is the size of the internal metabolically active organs, i. e., the liver, lungs, heart, and digestive tract. It has been documented that as feed intake is increased, oxygen intake by liver and intestinal epithelium is increased (Milligan and McBride, 1985). This suggests that energy expended by these organs is increased. Indicators and regulators of oxygen consumption in animals, e. g., thyroxine (T_4) and triiodothyronine (T_3), have been used to appraise metabolic rate. Pethes et al. (1985) found that when energy intake of cows was restricted by 20%, T_3 concentrations in the blood decreased, presumably indicating that maintenance energy expenditures by cattle were less at lower feed intakes.

Size of metabolically active organs has been measured to determine if limit feeding reduces maintenance requirements. The smaller the organ, the less energy needed to operate it. Some research suggests that level of feed intake alters organ size. It has been reported that animals with higher feed intakes have heavier weights for metabolically active organs (Koong et al., 1985; Rust et al., 1986). Similarly, Murphy and Loerch (1994) reported a trend for reduced liver weights in cattle that were limit fed. In a trial conducted by Hill et al. (1996b) steers were limit fed (15 lbs/day) a 78% corn diet for the first 62 days of a 130 day feeding trial. After the 62 day period, six head were slaughtered both from AL fed and limit fed treatments. Liver weights were reduced by 28% in limit fed steers compared to AL fed controls and heart weight was reduced by 7%. Total gastrointestinal tract weight was 13.6% less for restricted vs. AL fed cattle.

In contrast to these findings, Hicks et al. (1988) found no differences in organ weights at slaughter in steers either limit or AL fed. This suggests that while organ size reduction with limit feeding may reduce maintenance requirements and in turn allow more energy be partitioned for gain, this cannot fully explain the increased efficiency noted with limit feeding.

Pen Size

Decreasing physical activity of the animal reduces metabolic rate thereby decreasing maintenance requirements. By decreasing pen size, space allowed per animal is decreased, and physical movement by that animal is reduced. In an early study by Embry and Fredrikson (1969), steers were housed in open outside pens with 239 ft^2 of floor space per animal or a partially covered pen with 83 ft^2 of floor space per animal. Although rate of gain was virtually the same for both treatments, cattle given more limited pen space were 4% more efficient. This trial was conducted in South Dakota from mid-June to early November. Whether cattle fed in different seasons of the year or at different geographic locations would respond in the same manner remains undetermined. Leu et al. (1977) fed cattle in open lots with or without overhead shelter with 18 m^2 (194 ft^2) of floor space per animal and in confinement with only 2 m^2 (22 ft^2) of floor space per animal. Conducted in Iowa, the paper summarized eight trials, 4 in winter and 4 in summer. Results indicated confining cattle failed to improve feed efficiency.

Increased Feed Digestibility

One method to improve feed efficiency of feedlot cattle is to increase diet digestibility. With more nutrients digested and absorbed by an animal, it is obvious that efficiency will increase. If one reduces rate of passage, more time is available for digestion. If intake is decreased, digestibility should increase and greater absorption of feed nutrients should increase efficiency. Loerch (1990) reported that dry matter digestibility was increased by 36 and 11% by restricting intake by 30 and 20%, respectively. However, limit fed steers received a high concentrate diet while AL steers were fed a corn silage based diet! These improvements most likely were a result of corn being inherently more digestible than corn silage. However, restricting intake to a greater degree may reduce rate of passage , thus increasing the amount of time spent in rumen by feed particles for further breakdown.

Murphy et al. (1994a) studied the effect of feeding AL or 70% of AL intake and the effect of corn processing method (whole or rolled) on digestion using ruminally fistulated steers. Results from this trial indicated that when intake was high (2 X maintenance) DM digestibility was 4% lower for rolled vs. whole corn. However, when intake was low, the rolled corn diet was 8% more digestible than whole corn. Perhaps when unprocessed corn is fed at a low level, mechanical abrasion among kernels in the rumen is reduced. Murphy (1994a) found that apparent N digestion increased when intake was restricted (76.9% vs 65.3%).

This too probably was a function of reduced turnover of ruminal digesta at the low intake that allowed protein digestion to increase.

In a second trial conducted by Murphy et al. (1994b), wether lambs were used to determine the effects of restricting intake of diets increasing in percentage of energy concentration. Lambs were fed AL, or at 90%, 80%, or 70% of AL. Murphy et al.(1994b) found that limit feeding diets increasing in energy concentration linearly improved DM, OM, ADF, and NDF digestibility. Nitrogen retention also was greater for lambs that received higher energy concentrations at reduced levels of intakes. In a second trial reviewed in the same paper (Murphy et al., 1994b), they reported that restricting intake of a high concentrate diet improved digestibility of DM, ADF, CP, and starch by .142, .423, .497, and .046 percentage points for every 1% reduction in feed intake, respectively. N retention appeared to be greatest when intake was 89% of AL. In contrast, Hicks et al. (1988) detected no difference in diet digestibility when steers were fed 80% grain diets at 80% of AL or program fed to gain 2.96 vs 3.29 lbs/day.

Even though the results are still inconclusive, improved diet digestibility remains as one mechanism by which limit feeding improves feed efficiency.

Housing Effects on Cattle Performance

Most feedlots house cattle in open pens with no overhead shelter to protect cattle from the weather. However, the idea that cattle might perform better when protected from the environment has been studied to some degree. In Canada, McQuitty et al. (1972) fed steers during the winter in total confinement using three different types of pen floors. These consisted of 1) slatted floors for waste drainage, 2) solid floors with straw bedding, or 3) free standing stalls; McQuitty et al. (1972) concluded that cattle housed on slatted floors outgained all other steers.

In a second trial, McQuitty et al (1972) incorporated a fourth treatment that consisted of cattle being fed in an open lot. Cattle fed in the open lot consumed more feed than confined steers (21.9 vs 20.45 lbs/day) but required more pounds of feed per pound of gain (9.35 vs 8.35 lbs feed/lb gain).

Nichols et al. (1992) conducted two studies with sheep in which the sheep were housed in either open or covered lots. Lambs fed in covered pens had higher gains in the first trial (August – September) but housing did not affect daily gain in the second trial (October – December). Feed intake did not differ between lambs housed in open vs. covered pens in Trial 1, so lambs in covered pens were more efficient. These researchers postulated that this increase may be attributed to an increased energy expenditure to dissipate body heat by sheep in open lots during the hotter season.

In a series of trials that utilized three types of housing (Leu et al., 1977; Pusillo et al., 1991; Rabearimisa and Hoffman, 1994, 1995; Delehant and Hoffman, 1996), cattle were placed in 1) an open lot, 2) an open lot with access to overhead shelter, or 3) in a confinement facility that was open on one side (south). These researchers reported that cattle provided the access to overhead shelter consistently tended to be more efficient while consuming more feed than cattle housed in either total confinement or in the open lot. When confined cattle consumed 11% less dry matter, and had 18% less gain, Pusillo et al. (1991) postulated that greater indoor humidity inhibited the animal's ability to dissipate heat, thus making them less efficient. In contrast, Goodrich et al. (1973) documented that numerous pens of cattle fed over three years in a temperature controlled, slatted floor confinement facility gained faster than cattle housed in an open lot (2.56 vs 2.21 lbs/day). Feed efficiency also was 11% superior for inside vs outside fed cattle.

Although feeding cattle in a confinement facility requires a substantial initial investment and offers a minimal economic return, location is an important determinant of success at utilizing such a system. Environmental conditions may dictate when and if a confinement facility would be of benefit. However, confinement may improve operator comfort, decrease labor, and enhance bunk management.

Effects of Limit Feeding on Carcass Quality

When studying the effects of limit feeding practices on cattle performance, it is essential that the end product be considered. If superior performance during the feeding phase results in inferior carcasses, nothing has been gained. With the movement towards value based marketing systems in which producers are paid a premium for higher yielding and superior quality grading carcasses or discounted for fatter, undesirable carcasses, carcass quality and desirability is increasing in economic importance.

Limit feeding does not appear to affect carcass characteristics with the exception that marbling may be decreased if cattle are fed for an equal time period. Cattle fed a restricted diet may require additional days on feed to achieve a similar fat thickness endpoint. Limit fed cattle tend to be leaner and lean tissue accretion accounts for a greater percentage of their total gain (Murphy and Loerch, 1994). With steers fed 149 days, Hicks et al. (1987) noted that limit fed steers graded only 41.7% Choice compared to 61.1% for AL fed steers. Similar results were documented in a second trial conducted by Hicks et al. (1988); percentage of steers grading Choice decreased from 96% to 72% for AL vs. limit fed steers, respectively. Yield grade was decreased slightly with limit feeding due to slightly lighter carcass weights in limit fed steers; but this difference was nonsignificant for both traits. Other carcass parameters (REA, DP, %KPH fat, BF thickness) were similar for AL and limit fed steers.

Murphy and Loerch (1994a) observed that fat thickness and carcass quality grades were lower for limit fed than AL fed steers. However, in a subsequent trial conducted in which steers were fed a corn-silage based diet for 84 days and then finished using a 91% concentrate diet, no differences in carcass characteristics were noted. Since the first trial used an all concentrate diet throughout the entire feeding period, one might conclude that cattle should be grown on a high roughage diet if a FE advantage is to be obtained without decreasing carcass quality. In contrast, Lusby et al. (1990) found that quality grade did not differ between early weaned calves that had been limit fed vs those that had AL access to a high concentrate (90%) diet. Hill et al. (1996b) likewise reported that quality grade did not differ when yearling steers were restricted fed a 78% corn diet or a 36% corn diet for 62 days and then finished with AL access to a 78% corn diet.

In conclusion, decreased marbling and lower quality grade, a potential detriment with limit feeding, has yet to be proven consistently. If AL and limit fed steers spend the same number of days on feed, one might expect a reduction in carcass weight for the limit fed steers (Hill et al., 1996a, 1996b; Hicks et al., 1987), although this may not always be the case (Rakestraw and Lusby, 1991). However, if limit and AL fed steers are harvested at an equal fat thickness endpoint, carcass quality characteristics may be maintained (Hill et al., 1996a).

Skeletal Maturity Effects on Carcass Quality

When feeding and marketing cattle on a live weight basis, concerns with carcass quality are non-existent; producers are paid for pounds of live weight produced, rather than quality of the edible product. However, value based marketing incorporates a grid system to discount for undesirable carcass weights, quality grades, and yield grades. As use of value based marketing increases, producers must develop feeding strategies with the end product in mind. Although actual quality and yield grades are the primary determinants of value in value based marketing, factors such as maturity also must be considered.

When quality grade is being determined, skeletal maturity is appraised by estimating the degree of calcification of the cartilage buttons at the end of the thoracic vertebrae along the animal's spine. This gives an estimate of the animal's age in months. Generally, carcasses from steers under 30 months of age are classified as 'A' maturity and eligible for normal quality grades. Carcasses grading 'B' maturity (30 months of age or older) are discounted, with older carcasses given substantially higher discounts in price.

Although age is the primary reason that calcification of these buttons occurs in the carcass, it is not the sole factor. What additional factors advance calcification of bone have been rarely studied so information is limited. Because maturity advances rapidly for heifers during pregnancy, hormones may be involved.

Estrogenic implants may increase skeletal maturity (Vanderwert et al., 1985; Field et al., 1990; Hardt et al., 1995; Foutz et al., 1997). In all of these trials, implanting with an estrogenic compound (estradiol or zeranol) or an androgen (trenbolone acetate) increased skeletal maturity scores in relation to nonimplanted cattle of similar age. Apple et al. (1991) noted that implanting with an androgen plus an estrogen implant increased skeletal and overall maturity. Although differences often were small, a slight advancement for cattle approaching 30 months of age may have a substantial economic impact.

If one is aware of the background and age of the cattle being fed, and cattle are relatively young, maturity problems usually are minor. However, if cattle are bought through unknown sources (sale barns), so age and background are unknown, maturity discounts can become a big factor. Often, tell-tale signs will warn a prospective buyer of advanced age. These signs include longer tail switches, and longer, broader heads. However, such signs can be misleading and chronologically older cattle can pass as yearlings. Determining age of cattle therefore, is often difficult.

Alkaline phosphatase (AP) in the blood has been used as an indicator of physiological age. Greater physiological bone maturity is associated with lower blood AP levels. Guenther (1977) reported that this enzyme is secreted by bone forming cells in the skeleton of the animal. It is used as a mechanism by which Ca is deposited in and resorbed from bone. As chronological age advances, bone calcifies. Accordingly, Ca mobilization from bone decreases and level of AP in the blood decreases (Guenther 1977; Evans et al., 1976). When cartilage is completely ossified, bone physiologically is mature (Guenther, 1977). At this point, level of AP in the blood is very low. Earlier maturing animals (i.e., British) reach bone maturity when chronologically younger than later maturing cattle (i.e., Continental) do. Consequently, though not precise as an estimator of age, alkaline phosphatase still may be useful as an estimator of skeletal maturity.

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CHAPTER III

EFFECTS OF LIMITING FEED ACCESS TIME AND OF PEN HOUSING ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

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Abstract

One hundred crossbred steers (768 lb initially) in 20 partially covered pens holding 5 steers each (60 ft^2/steer) were given access to a high concentrate diet for either 1.5, 3, 6, 9, or 24 h (20 steers/treatment) each day for 120 days to test how limiting access time to feed would affect performance and carcass characteristics. Additionally, twenty steers were housed in two open, outside pens (10 steers/pen) where they had 2250 ft^2/steer and were allowed 24 h/day (AL) access to feed. Gates to the time restricted feedbunks were opened at 0800 each morning and closed after the allotted feeding time. The diet consisted of 87% whole corn, 5% cottonseed hulls, and 8% supplement pellets. By 56 d on feed, steers limited to a 1.5 h/day feeding time had lower dry matter intakes and poorer feed to gain ratios compared to cattle in other treatments. Consequently, restriction time for these 20 steers was expanded to 9 h. After 120 days on feed, cattle restricted to 9 h/day access to feed for the total trial had

greater ($P<.05$) average daily gains, dressing percentage, and a superior feed to gain ratio compared to all other time allotments. Numerically, these cattle had slightly greater dry matter intake, carcass weight, and ribeye area than cattle given AL access to feed. This indicates if bunks in a feedlot are empty up to 15 h each day, performance will not be depressed. Whether this applies for cattle in large, uncovered pens, with limited bunk space, less stable feeds, or multiple feedings per day needs further study. Additionally, cattle fed AL and housed in inside, smaller pens had lower ($P<.05$) dry matter intake, but average daily gain was only slightly depressed as compared to steers in large, outside pens. The result was a 6% superior feed efficiency for cattle fed inside. Cattle fed inside also had a significantly higher ($P<.05$) dressing percentage, and a numerically higher ($P=.07$) ribeye area. By restricting movement and lowering metabolic rate, smaller pen size may lower maintenance energy requirements and improve feed efficiency.

(Key Words: Feedlot, Limit feeding, Limited access, Housing, Pen size, Steers.)

Introduction

Limiting the amount of feed provided to growing/finishing steers by 5 to 10% generally improves their feed to gain ratio (Hicks et al., 1990). Typically, feed supply is restricted by feeding either a fixed amount of diet each day in order to achieve a given rate of gain (program feeding) or an amount of feed that is a percentage of the expected or observed intake of cattle given free choice access to feed. Such limitation may prove overly restrictive for and reduce gain of steers with high gain potential. In this experiment, consumption time, not amount of feed, was limited. This forced a change in feeding behavior for limit fed cattle that is consistent with previous work (Shaw, 1978). Feedlot performance including feed intake, gain, and carcass responses were monitored in response to limiting access time to feed. Effects of open vs partially covered pen housing also was studied.

Materials and Methods

Animals and Housing. Crossbred steers (n=120) were received from a single ranch in east central Kansas on September 23, 1996 at the feedlot research facilities in Stillwater, OK. Before transport, each steer was vaccinated with a modified live IBR-BVD virus and 7-way clostridial vaccine, dewormed, implanted with 28 mg of Estradiol Benzoate and 200 mg of Progesterone, and individually weighed. Based on these weights, steers were stratified and assigned randomly within weight group to pen and treatment with 5 steers/pen and 4 pens/treatment. Upon arrival in Stillwater, cattle again were weighed individually off the truck and placed in their allotted pen. Because transport time from origination to destination was 5 hours, this weight was assumed to be a shrunk weight and was used as the initial weight for the trial. The inside housing consisted of 20 partially covered pens with 60 ft^2/steer of floor space with slatted floors and cement fenceline feedbunks. Automatic waterers placed between every other pen provided water for two pens each. Two outside, dirt floor pens with 2250 ft^2/steer of space were used to house 20 additional steers (10 steers/pen). These pens had separate cement fenceline feedbunks and a shared automatic waterer. Both pen settings provided bunk space at the rate of 24 in/steer.

Treatments and Diets. Treatments consisted of providing access to feed for different amounts of time (1.5, 3, 6, 9, and 24 h/day). Cattle in outside pens had 24 h/day (AL) access to feed. Access to feed was controlled by opening and closing gates between the feedbunk and the pen; the amount of feed in the bunk was not limited. While the gate was open, steers had continuous access to feed in the bunk. This system was implemented four days after arrival of the steers to the research facility. Gates were opened at 0800 each day. For the first four days after arrival of the steers, a whole corn based diet consisting of 15% cottonseed hulls, 25% alfalfa pellets, and 60% concentrate was fed (Table 1). Concentrate level was increased by 10% with the addition of corn and a reduction in the amount of cottonseed hulls and alfalfa pellets every third day thereafter for a total adaptation period to the final 87% concentrate diet (Table 2) of 13 days. Fresh feed was added at approximately 0800 throughout the feeding period.

Slaughter. Cattle were weighed at 28 day intervals during the feeding period with final weight being taken on day 120 (January 18, 1997). All animals were transported to a commercial meat packing facility in Dodge City, KS for harvest; carcass data were collected following a 36 h chill. Final shrunk weights were calculated by multiplying final live weight by .96; carcass-adjusted weight was calculated by dividing hot carcass weight by the mean dressing percentage (63.7%). Net energy content of the diet for each group of cattle was calculated from DMI, mean weight, and ADG.

Statistical Analysis. All data were analyzed as a randomized block design by the general linear models procedures of SAS (1988).

Results and Discussion

Limited Access Time Fed Cattle. After only one week of closing gates to restrict cattle from feed, eating behavior of severely restricted cattle (1.5 and 3 h/day) had changed. These cattle appeared very hungry and came to the bunk readily when the feed wagon approached the feedbunk. Upon feeding, these steers remained at the bunk for almost all of their allotted time. All cattle adjusted quite well to the feeding regimen and did not show signs of hunger when the gates were closed in front of their feedbunk. In contrast, Hicks et al. (1989) reported that with severe feed access time restriction, cattle never adjusted to their short feeding time. Although the steers in the 1.5 h/day treatment ate constantly while allowed in this trial, these steers failed to eat enough during their one 90 minute period/day to gain rapidly. After 56 days on feed, steers limited to 1.5 h/day feeding time had lower (P<.05) daily dry matter intakes (15.7 lbs/d), daily gains (3.17 lb), and a poorer feed/gain ratio (4.94) than pens of cattle on all other treatments (Table 5). At this time, 9 h/day restricted cattle displayed the optimum for these traits (DMI=19.3 lbs/d, ADG=4.65 lbs, F/G=4.15). Despite having 83% less time to eat (1.5 vs 9 h/day), time restriction had reduced DMI by 19%. Consequently, these cattle probably ate faster and perhaps took larger mouthfuls of feed. Shaw (1978) reported that limiting total eating time for steers to 36 min/day reduced feed intake by only 21% compared to AL fed steers; total eating time for their steers with free choice access to feed was slightly more than 2 h/day. Nonetheless, in order to obtain an adequate rate of gain for all steers in the trial, restriction time for the 1.5 h/day restricted steers was expanded to 9 h/day on day 57 of the trial.

From day 57-120, cattle previously fed for only 1.5 h/day now given feed access of 9 h/day rebounded by eating substantially more feed (Figure 1) (18.9 lbs/d) and gaining faster (2.19 lbs/day) than other cattle except the original 9 h/day restricted cattle which were still superior in all performance traits in the second half of the trial (DMI=18.9 lbs/d; ADG=2.28 lbs; F/G=8.31). Figure 2 illustrates the fact that 9 h/day restricted cattle had less week to week variation in feed intake, indicating less day to day fluctuation in intake as well. Hicks et al. (1989) reported that limit feeding reduced day to day fluctuation in feed intake and may have accounted for increases in efficiency in comparison to AL fed steers. During this time period, 6 h/day restricted cattle performed the worst (DMI=17.8 lbs/d; ADG=1.61 lbs; F/G=11.05) of all treatments in the trial. Visually, this group of cattle appeared to be fatter and may have been using additional feed energy for fat deposition, a process less efficient (gain/feed) than protein deposition.

At the end of the 120 day feeding period, cattle limited to a 9 h/day feeding time for the entire trial still had the highest ($P<.05$) live and carcass-adjusted average daily gain (3.35 and 3.39 lbs, respectively), the highest dressing percent (64.6%), were among the best in feed to gain ratios (5.71 and 5.64 based on live and carcass weights, respectively) and had the highest calculated diet NEg (62.4 Mcal/cwt). These steers numerically had higher dry matter intakes, carcass weights, and ribeye areas than cattle given AL access to feed. Interestingly, Birkelo and Lounsberry (1992) noted that steers given 6-7 h/day of feed access time by limiting feed calls reduced DMI in relation to steers with ad libitum access to feed. But with only 2 to 3 more hours to eat in this trial, time restricted fed steers actually ate more than AL fed steers. Knowing that a time limit on eating was being imposed, the 9 h/day cattle probably spent more time eating rather than lying down, and may have eaten more regular meals each day than steers given AL access to feed. Even though a 6 h/day restriction on feeding time proved detrimental to feed efficiency in our trial, the 3 h/day restriction actually improved feed efficiency by 7% compared to AL feeding while reducing DMI to 91.2% of AL intake. This is in agreement with Hicks et al. (1989) who reported that restricting feed access time to 2 h/day reduced DMI to 92.8% of AL but increased feed efficiency by 9.9%.

Except for a greater ($P<.05$) dressing percentage (64.6%), and a slightly greater hot carcass weight (746 lb) for 9 h/day restricted cattle, carcass characteristics did not differ statistically from cattle on other treatments (Table 6). Ribeye area was substantially greater for cattle with 9 h/day rather than 24 h/day feed access (14.2 vs 13.7 in^2). Steers on both these treatments had larger ($P<.05$) REA than steers on the three shorter time allotments (12.5, 13.3, 12.4 in^2 for 1.5, 3 and 6 h/day restrictions, respectively). Marbling score was lowered slightly but not significantly by limiting access time to feed to 9 h/day. Of the 6 h/day restricted cattle, 60% graded U.S. Choice; these cattle had marbling scores similar to AL cattle (55% U.S. Choice), but were the fattest (Adjusted BF=.6 in).

Inside vs Outside fed Cattle. Cattle that were housed in partially covered pens and fed AL were compared to steers fed in outside, open pens, which were also fed AL and allotted from the same weight groups. During the first 56 days of the trial, no significant differences were detected in DMI, ADG, or F/G ratios between the two sets of cattle (Table 11). However, cattle fed outside had numerically higher DMI than cattle fed inside (21.1 vs 19.0 lbs/d) while gaining only slightly more weight (4.39 vs 4.05 lbs/d). For the total feeding period, cattle fed outside consumed more feed ($P<.05$) (21.2 vs 18.5 lbs DM/d) while only gaining slightly more weight on a live weight basis (3.0 vs 2.8 lbs/d) but slightly less on a carcass weight basis (2.82 vs 2.86 lbs/d). Consequently, cattle fed inside were 6% more efficient than cattle fed outside on a live weight basis (6.61 vs 7.04 lbs feed/lb gain) and 14% more efficient on a carcass weight basis (6.47 vs 7.52 lbs feed/lb gain). Embry and Fredrikson (1969) also reported that as compared to steers fed in open, outside pens given 239 ft^2 of floor space/steer, steers fed in partially covered pens given only 83 ft^2 of floor space/steer were 4% more efficient. In our trial, cattle fed inside had a higher ($P<.05$) dressing percentage (64.8 vs 63.0%) (Table 11). REA also tended to be larger for cattle fed inside (13.4 vs 12.8 in^2). No other carcass traits were affected by pen housing.

Implications

Limiting the time that cattle had access to feed consistently improved feed efficiency on a live weight basis. However, anything less than a 9 h/day restriction also reduced daily gain. Whether results would be similar for cattle fed twice daily is not known. Nevertheless, reducing access to feed from 24 to 9 h/day improved both gain and efficiency while also increasing DMI. This suggests that having the bunk empty for up to 15 hours each day may have beneficial effects on steer performance. Additionally, steers fed in smaller, partially covered pens ate less feed while gaining at a similar rate to cattle fed in large, outside pens. Optimum time for and duration of feed access and feeding frequency may differ with season and heat stress. Grain processing method as well as ration stability in the feedbunk may also play a role in determining if limiting feed access time would be of benefit.

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CHAPTER IV

EFFECTS OF DAY VS NIGHT FEEDING, LIMITED FEED ACCESS TIME AND PEN HOUSING ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

Z. I. Prawl, F. N. Owens, and D. R. Gill

Abstract

Crossbred steers were used to determine the effects of limiting access time to feed on performance and carcass characteristics of feedlot steers. Additionally, morning vs evening feeding regimens were used to determine if time of day that cattle are fed affects cattle performance. Of the 120 steers, 20 were housed in uncovered, dirt floor pens. The remaining steers were housed in partially covered pens with cement slatted floors. Morning fed cattle, provided fresh feed at 0800 daily, were fed one of three ways: 1) Ad Libitum access to feed (AL), 2) 9 h access to feed controlled by closing a gate in front of the bunk (DG), or 3) 9 h access to feed controlled by feed calls (DC). Evening fed cattle, provided fresh feed at 1700 each day, were fed in one of two ways: 1) 9 h access to feed controlled by closing a gate in front of the bunk (NG), or 2) 15 h access to feed controlled by feed calls (NC). For the total 118 d feeding period, dry matter intake (DMI) did not differ significantly among limited feed access treatments or time of feeding. However, there was a tendency (P=.07) for cattle fed in the morning to gain faster than those fed in the evening. Consequently, cattle fed in the morning were more efficient, the difference being significant (P<.05) between DC vs NG and NC fed cattle on both a live and carcass basis. While consuming .4% less feed than AL cattle, DC fed cattle had slightly better feed efficiency. Restricting feed access from 24 to 9 h daily did not depress DMI as DG cattle ate 99% and NG cattle ate 102% of AL steers. Except for lighter (P<.05) hot carcass weight (HCW) for NG cattle, no differences in carcass characteristics were noted among limited access time fed cattle. However, DC steers had higher (P=.06) marbling scores, grading 80% Choice, while having slightly leaner carcasses. DMI was greater (P<.05) for cattle outside but ADG was similar yielding a feed efficiency improvement (P<.05) for cattle housed inside on both a live and carcass adjusted weight basis. No differences in carcass characteristics were detected except for dressing percentage (DP) being higher (P<.05) for cattle housed inside. Limiting access time to feed to 9 h/day can be accomplished by intense bunk management and feed calling. This sustained DMI and slightly improved feed efficiency with no detrimental effects on carcass characteristics. Providing access to overhead shelter, especially in times of warmer weather, improved feed efficiency while reducing DMI.

(Key words: Limited Access, Feeding Time, Housing, Steers, Feedlot)

Introduction

Limit feeding of growing/finishing beef cattle generally improves feed efficiency. However, ADG often is depressed when DMI is restricted (Murphy and Loerch, 1994; Hicks et al. 1987, 1988). Conversely, limiting access time to feed rather than total feed supply in a previous study increased feed efficiency as well as DMI and ADG (Prawl et al., 1997). Limiting feed access time to 9 h/day may stimulate cattle to eat more frequently and regularly than cattle given free choice access to feed. However, time limitation is impractical and labor intensive if done by closing a gate in a larger pen setting. The intent of this study was to determine if feed calls could be made in a manner so that feed would be present in the bunk for a total of 9 h/day. Subsequent effects on performance and carcass characteristics were monitored. Additionally, the effects of pen housing (small, partially covered vs larger, open lots) were monitored to determine how housing would affect performance of steers given free choice access to feed.

Materials and Methods

Animals and Housing. Crossbred steers (797 lbs initially), primarily of Hereford, Angus, and Limousin breeding were received from a single ranch in east central Kansas on July 14, 1997 at the feedlot research facilities in Stillwater, OK. Before transit, cattle were vaccinated with a modified live IBR-BVD virus and 7-way clostridial vaccine, dewormed, and implanted with 28 mg of

Estradiol Benzoate and 200 mg of Progesterone. Upon arrival, cattle were divided equally into three pens and housed overnight without feed. Steers were weighed individually the following morning. Based on these weights, steers were stratified by weight, assigned randomly to pen and treatment (5 steers/pen; 4 pens/treatment), and placed in their allotted pen. Inside housing consisted of 20 partially covered pens with slatted floors and cement fenceline feedbunks with 60 ft^2 of floor space per steer. Automatic waterers were shared by adjacent pens. Additionally, two outside, dirt floor pens were used to house 20 steers (10 steers/pen); these provided 2250 ft^2 of floor space per steer. Separate fenceline feedbunks and a shared automatic waterer were provided for feeding and watering of these two pens of cattle. Bunk space was provided at the rate of 24 in/steer in both pen settings.

Treatments and Diets. The five treatments consisted of 1) steers fed at 0800 daily and provided ad libitum access to feed (AL), 2) steers fed at 0800 and allowed 9 h access to feed with a gate being closed in front of the bunk at 1700 daily (DG), 3) steers fed at 0800 and allowed 9 h access to feed controlled by feed calling (DC), 4) steers fed at 1700 and allowed 9 h access to feed with a gate being closed in front of the bunk at 0200 daily (NG), or 5) steers fed at 1700 and allowed 15 h access to feed controlled by feed calling (NC). Cattle in outside pens had continuous access to feed. Feed was provided so that DG and NG steers had feed in the bunk the entire time the gates were open. The amount of feed delivered to DC and NC steers each day was slightly increased or decreased so that feed would be totally consumed within 9 or 15 h after feeding.

After that time, the bunk was "slick" for the remainder of the day. This system was implemented six days after the steers arrived at the research facility. A whole corn based diet consisting of 15% cottonseed hulls, 25% alfalfa pellets, and 60% concentrate was fed the first four days (Table 3). Thereafter, the concentrate level was increased by 10% every fourth day so that after 16 days, steers received the final 87% concentrate diet. This whole corn based finishing diet was fed throughout the remainder of the feeding period (Table 4).

Animal Behavior. Behavior was observed every 30 minutes during two separate 24 hour periods. The first observation was on September 16 and 17, 1997 (days 64 and 65 of the trial) and the second was on October 30 and 31, 1997 (days 108 and 109 of the trial). From 0630 the first day to 0600 of the second day, the activity of each steer in the partially covered pens was recorded each 30 minutes. Activity classifications included eating, drinking, standing, lying, standing while ruminating, or lying while ruminating. Results from the two different observation periods were averaged together. These data were then regressed against the performance of the cattle to determine if activity was related to performance of individual cattle.

Slaughter. Cattle were weighed at 28 day intervals throughout the feeding period with final weight being taken on day 118 (November 7,1997). All animals were transported to a commercial meat packing facility in Dodge City, KS for harvest; carcass data were collected following a 36 h chill. Final shrunk weights were calculated by applying a 4% pencil shrink to final live weight; carcass adjusted live weight was calculated by dividing hot carcass weight by the mean dressing percentage (64%). Net energy content of the diet for each group of cattle was calculated from DMI, mean weight, and ADG.

Statistical Analysis. All performance and carcass data were analyzed as a randomized block design by the general linear models procedures of SAS (1988).

Results and Discussion

Limited Feed Access Time. In a previous study, limiting the time that cattle had access to their feed to 9 h/day increased DMI, ADG and feed efficiency (FE) as compared to steers given free choice access to feed (Prawl et al., 1997). Reducing feed access time by 62% (9 vs 24 h), theoretically would result in a 62% restriction of AL intake, but as shown previously by Shaw (1978), limiting the amount of time cattle had to eat provided a stimulus for the cattle to eat faster and presumably take larger mouthfuls. For the entire 118 d trial here, limiting feed access time did not significantly reduce DMI (Table 7), although DMI for DG and DC cattle was slightly lower than for cattle given AL access to feed (18.63 and 17.97 vs 18.76 lbs/d). However, Figures 3 and 4 show that as AL fed steers were decreasing intake towards the end of the trial, DC and DG fed steers were increasing intake, the DC steers moving upward at a more steady pace. This may have allowed for these two sets of steers to gain steadily more weight if the trial would have increased in length. As DMI for the DC steers was very consistent from week to week in the last half of the trial, it shows that calling feed to restrict intake to 9 h/day was consistently done without having negative effects on DMI. In contrast, NG cattle consumed slightly more feed than AL steers overall (19.21 vs 18.76 lbs/d). No significant differences in ADG among limited feed access time treatments were detected, although the day fed cattle gained slightly (P=.07) faster than night fed cattle (DC=2.49, DG=2.47 vs NG=2.27, NC=2.31 lbs/d). Steers given AL access to feed had numerically higher ADG (2.56 lbs/d). This agrees with results of previous limit feeding trials that depressed ADG of limit fed steers in relation to steers given AL access to feed (Hicks et al. 1987; Murphy and Loerch, 1994). As a result of slightly greater ADG for day fed cattle with no differences in DMI, FE on a live basis was improved (P<.05) for DC cattle vs NG and NC cattle (7.23 vs 8.53 and 7.86 lbs feed/lb gain). Numerically, DG cattle also were more efficient (7.52 lbs feed/lb gain) than the two night fed treatments. DC cattle held a slight FE advantage over AL fed steers as well (7.23 vs 7.33 lbs feed/lb gain). The FE advantage with the 9 h feed access time restriction we found agrees with a previous advantage in FE from a 9 h feed access restriction time (Prawl et al., 1997). The cause for this improvement in FE remains unclear. Perhaps placing a time limit on eating causes animals to spend a longer amount of time at the bunk.

In studying animal behavior, we found that DC cattle spent the greatest amount of time eating, 110 minutes or 7.6% of total time/day (Table 9). This was 1% longer than AL fed steers that ate for 97 minutes/day. Even though DC cattle spent more time at the feedbunk, they ate slower (Table 10) and their DMI was slightly lower than AL steers. However, the more time steers took in eating feed, the more efficient they were. This decrease in eating rate and presumably a more thorough mastication of feed might account for increased feed digestibility. Whether this would hold true for cattle consuming a more processed grain diet remains unclear. Maximum eating times for day and night fed steers were related closely to when feed was delivered (Figure 5). However, AL fed steers did not follow the same pattern and ate smaller, more frequent meals throughout the day. As expected, percentage of steers lying at feed delivery time was small (Figure 6). However, when morning fed steers were fed, night fed steers also stood up, even though they did not receive feed. This also was true for afternoon feeding as well with day fed steers standing up in reaction to night fed steers being fed. Perhaps steers tended to react to other steers in close proximity to them. Day fed steers, although fed in the morning, tended to do the majority of their ruminating in the evening or night (Figure 7). In contrast, night fed steers consumed their feed and quickly started to ruminate within 3 to 6 hours of being fed and continued to ruminate throughout the next day.

DC cattle spent less time standing while ruminating, which was found to have a slightly (R^2=.14) negative effect on ADG. DC cattle spent more time lying down than AL fed steers (745 vs 692 minutes; 52 vs 48% of total time/day); less movement may reflect a lower metabolic rate for these animals. These factors when taken together may explain the slightly improved FE for 9 h DC cattle over AL fed cattle. However, when expressed on a carcass basis, AL fed steers still held an advantage over DC and DG steers in FE (7.35 vs 7.47 and 7.56 lbs feed/lb gain). Day fed treatments were more efficient than night fed steers on a carcass adjusted weight basis; this difference was significant when comparing NG cattle to AL, DC and DG steers (8.6 vs 7.35, 7.47 and 7.56 lbs feed/lb gain).

With the exception of a lighter ($P<.05$) HCW for NC steers (664 lbs), carcass characteristics were not changed by method of limiting feed access time or time of feeding (Table 8). The DC cattle had higher marbling scores ($P=.067$) (Modest[13]) than all other treatments including AL access (Small[43]). This might be a function of physiological maturity being greater for DC than AL fed steers although DC cattle had leaner carcasses compared to AL fed cattle. Even though DC cattle were slightly restricted in intake (96% of AL) and fed for the same number of days compared to AL fed steers, marbling score was not reduced by limit feeding. This is in agreement with the work of Lusby et al. (1990) who detected no quality grade depression in early weaned calves that had been limit fed a 90% concentrate diet until slaughter. Likewise, Hill et al. (1996) found no differences in quality grade in steers that had been restricted fed a 78% or 36% corn diet for 62 days followed by AL feeding of a 78% corn diet until slaughter.

Inside vs Outside Housed Steers. Throughout the entire trial, DMI was less ($P<.05$) for steers fed in partially covered pens (17.85 vs 21.11 lbs/d). This is in agreement with the work of McQuitty et al. (1972) who reported that steers fed in confinement consumed less feed than steers fed in an open lot. Even though inside housed cattle ate 15% less feed vs outside housed cattle in this trial, ADG was 9% higher for the inside housed cattle (2.41 vs 2.19 lbs/d). This resulted in an improved FE for inside housed cattle of 16% (7.27 vs 8.68 lbs feed/lb gain) on a live basis and a 23% improvement in FE (7.39 vs 9.66 lbs feed/lb gain) on a carcass basis (Table 12). Goodrich et al. (1973) also reported that numerous pens of cattle fed in confinement over a span of two years gained faster compared to steers fed in open lots. In their trials, confined cattle were 11% more efficient than open lot housed cattle. Carcass characteristics were not different for inside vs outside housed steers in our trial, except for DP which was greater (P<.05) for steers housed inside (Table 12). This agrees with previous work done by Rabearimisa and Hoffman (1994) who reported that DP increased in limit fed steers fed in confinement. In another trial conducted by Delehant and Hoffman (1996), they reported that steers fed once in the morning had higher DP than steers fed either once in the afternoon or twice per day. Hill (1997) found that steers that had been limit fed a high concentrate diet for 62 days had higher DP than steers that had free choice access to the same diet. This may be attributed to lower empty rumen, small intestine and mesenteric fat weights as compared to AL fed steers. The reduced levels of DMI may allow for the total size of the G. I. tract to be smaller and hence account for an increase of DP for limit fed steers.

Reasons for the markedly superior FE for cattle in smaller pens and allowed access to overhead shelter remains unclear. Nichols et al. (1992) fed sheep in open or covered lots and found that in warmer weather, sheep with access to shelter were more efficient. They postulated that sheep in open lots wasted more energy dissipating excess internal body heat. In contrast, Pusillo et al. (1991) observed that confined cattle consumed 11% less feed and had 18%

less gain than steers in open lots. These researchers postulated that a higher humidity level indoors inhibited the animal's ability to dissipate internal heat and made them less efficient.

Implications

Limiting the time that cattle have access to feed may increase feed efficiency of feedlot cattle without depressing dry matter intake or average daily gain.. Results from this study indicate that cattle can be consistently limited to 9 h/day of eating time by adjusting feed calls and having minimal detrimental effects on feed intake and gain while improving feed efficiency on a live weight basis. Compared to feeding in the morning, feeding in the evening was of no benefit during this summer trial (July to November) and had a deleterious effect on feed efficiency. Providing overhead shelter and limiting pen space to finishing steers improved rate and efficiency of gain. However, geography and season may alter effects of housing on performance. Shade may be of greater value in summer in areas of consistently warm ambient temperatures and solar radiation whereas confinement may prove necessary to reduce mud and cold stress in other regions.

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Table 1. Composition of Trial 1 start-up diets and days fed (x).

	Diet #1 (4)	Diet #2 (3)	Diet #3 (3)	Diet #4 (3)
Ingredient	% of diet DM	% of diet DM	% of diet DM	% of diet DM
Corn, whole shelled	52.0	62.0	72.0	82.0
Cottonseed hulls	15.0	10.0	5.0	5.0
Alfalfa pellets	25.0	20.0	15.0	5.0
Cottonseed meal	5.0	5.0	5.0	5.0
Wheat middlings	.8	.8	.8	.8
Urea	.6	.6	.6	.6
Salt	.3	.3	.3	.3
Limestone	1.1	1.1	1.1	1.1
Potassium chloride	.152	.152	.152	.152
Zinc sulfate	.0048	.0048	.0048	.0048
Manganese oxide	.004	.004	.004	.004
Vitamin A-30	.011	.011	.011	.011
Rumensin-80	.0184	.0184	.0184	.0184
Tylan-40	.0095	.0095	.0095	.0095

Table 2. Trial 1 diet ingredients and calculated nutrient composition of finishing diet.

Ingredient	% of diet DM
Corn, whole shelled	87.0
Cottonseed hulls	5.0
Cottonseed meal	5.0
Wheat middlings	.8
Urea	.6
Salt	.3
Limestone	1.1
Potassium chloride	.152
Zinc sulfate	.0048
Manganese oxide	.004
Vitamin A-30	.011
Rumensin-80	.0184
Tylan-40	.0095
Nutrient composition, calculated	
NEm, Mcal/cwt	96.42
NEg, Mcal/cwt	61.65
Crude protein, %	12.28
Potassium, %	.57
Calcium, %	.47
Phosphorus, %	.33
Magnesium, %	.159
Cobalt, ppm	.104
Copper, ppm	5.2
Manganese, ppm	40.8
Zinc, ppm	36.6

Table 3. Composition of Trial 2 start-up diets and days fed (x).

	Diet #1 (4)	Diet #2 (4)	Diet #3 (4)	Diet #4 (4)
Ingredient	% of diet DM	% of diet DM	% of diet DM	% of diet DM
Corn, whole shelled	52.0	62.0	72.0	82.0
Cottonseed hulls	15.0	10.0	5.0	5.0
Alfalfa pellets	25.0	20.0	15.0	5.0
Cottonseed meal	5.0	5.0	5.0	5.0
Soybean hulls	.8	.8	.8	.8
Urea	.6	.6	.6	.6
Salt	.3	.3	.3	.3
Limestone	1.1	1.1	1.1	1.1
Potassium chloride	.152	.152	.152	.152
Zinc sulfate	.0048	.0048	.0048	.0048
Manganese oxide	.004	.004	.004	.004
Vitamin A-30	.011	.011	.011	.011
Rumensin-80	.0184	.0184	.0184	.0184
Tylan-40	.0095	.0095	.0095	.0095

Table 4. Trial 2 diet ingredients and calculated nutrient composition of finishing diet.

Ingredient	**% of diet DM**
Corn, whole shelled	87.0
Cottonseed hulls	5.0
Cottonseed meal	5.0
Soybean hulls	.8
Urea	.6
Salt	.3
Limestone	1.1
Potassium chloride	.152
Zinc sulfate	.0048
Manganese oxide	.004
Vitamin A-30	.011
Rumensin-80	.0184
Tylan-40	.0095
Nutrient composition, calculated	
NEm, Mcal/cwt	87.21
NEg, Mcal/cwt	59.3
Crude protein, %	11.48
Potassium, %	.55
Calcium, %	.59
Phosphorus, %	.26
Magnesium, %	.12
Cobalt, ppm	.1
Copper, ppm	5.3
Manganese, ppm	43.0
Zinc, ppm	38.1

Table 5. Effect of limiting the time of feed access on performance of feedlot steers.

	Time exposed to feed (h)				
	1.5 (to 9)	3.0	6.0	9.0	24.0
Number of head	20	20	20	20	20
Weight, lb					
Initial wt	762	765	779	766	776
Final wt	1140[a]	1157[a]	1153[a]	1203[b]	1175[ab]
Shrunk wt	1094[a]	1111[a]	1107[a]	1155[b]	1128[ab]
Carcass wt (live)	1079[a]	1110[ab]	1103[a]	1172[c]	1141[bc]
ADG, lb					
Period 1 (0-56d)	3.17[a]	4.22[bc]	3.95[b]	4.65[c]	4.45[bc]
Period 2 (57-120d)	2.19[c]	1.70[ab]	1.61[a]	2.28[c]	1.80[b]
Liveadg	2.86[a]	2.98[a]	2.83[a]	3.35[b]	3.04[a]
Carcadg	2.65[a]	2.88[ab]	2.70[a]	3.39[c]	3.05[ab]
Dry matter intake, lb/d					
Period 1 (0-56d)	15.7[a]	17.5[b]	18.7[bc]	19.3[c]	19.3[c]
Period 2 (57-120d)	18.9[b]	16.8[a]	17.8[ab]	18.9[b]	18.3[b]
DMI total (0-120d)	17.3[a]	17.1[a]	18.2[ab]	19.1[b]	18.8[b]
Feed/gain (DM basis)					
Period 1 (0-56d)	4.94[c]	4.16[a]	4.72[b]	4.15[a]	4.33[ab]
Period 2 (57-120d)	8.63[a]	9.86[b]	11.05[b]	8.31[a]	10.04[b]
F/G, live	6.06[abc]	5.74[ab]	6.43[c]	5.71[a]	6.17[bc]
F/G, carcass	6.53[c]	5.94[ab]	6.74[d]	5.64[a]	6.15[bc]
NEg calc., Mcal/cwt	61.0[ab]	61.1[ab]	57.1[a]	62.4[b]	58.6[a]

[a,b,c,d] Means with different superscripts within a row differ ($P<.05$).

Table 6. Effect of limiting the time of feed access on carcass characteristics of feedlot steers.

	Time exposed to feed (h)				
	1.5 (to 9)	**3.0**	**6.0**	**9.0**	**24.0**
Number of head	20	20	20	20	20
Dressing %	62.83^{a}	63.61^{ab}	63.39^{ab}	64.61^{c}	64.34^{b}
Hot carcass wt., lb	687^{a}	707^{ab}	702^{a}	746^{c}	727^{bc}
Ribeye area, in^2	12.5^{a}	13.3^{ab}	12.4^{a}	14.2^{c}	13.7^{bc}
Fat thickness, in.	.42	.45	.54	.49	.49
Adj. fat thickness, in	.51	.51	.60	.52	.55
KPH, %	2.24	2.22	2.53	2.35	2.45
Skeletal maturity[e]	186	179	188	200	206
Lean maturity[f]	171	155	149	156	157
Total maturity[g]	178	167	168	178	181
Marbling score[h]	393	386	430	388	430
Quality grade					
Choice, %	35	41	60	50	55
Select, %	55	53	40	45	40
Standard, %	10	5	0	5	5
Yield grade, mean	2.64	2.48	3.04	2.50	2.57
YG 1, %	20	32	10	20	25
YG 2, %	45	52	25	55	40
YG 3, %	35^{b}	10^{a}	65^{c}	25^{ab}	35^{b}
YG 4, %	0	5	0	0	0

[a,b,c] Means with different superscripts within a row differ ($P<.05$).

[e,f] 100-199 = 'A' (approximately 9-30 months of age); 200-299 = 'B' (approximately 31-42 months of age).

[g] Skeletal + Lean maturity/2.

[h] Select = 300-399; Choice = 400-499.

Table 7. Effect of limiting access time to feed and time of feeding on performance of feedlot steers.

	Time and exposure to feed				
	AL	**9 h DC**	**9 h DG**	**9 h NG**	**15 h NC**
Number of head	20	20	20	20	20
Weight, lb					
Inital wt	802^{bc}	796^{b}	800^{bc}	816^{c}	773^{a}
Final wt	1142^{b}	1127^{b}	1130^{b}	1122^{b}	1082^{a}
Shrunk wt	1096^{b}	1082^{b}	1085^{b}	1077^{b}	1038^{a}
Carcass wt (live)	1104^{b}	1080^{b}	1091^{b}	1082^{b}	1041^{a}
ADG, lb					
Period 1 (0-56d)	3.28	2.81	2.84	3.16	2.93
Period 2 (57-118d)	2.65^{bc}	2.95^{c}	2.89^{c}	2.19^{a}	2.46^{ab}
Liveadg	2.56	2.49	2.47	2.27	2.31
Carcadg	2.56	2.41	2.46	2.26	2.27
Dry matter intake, lb					
Period 1 (0-56d)	17.1	16.3	16.9	17.7	16.9
Period 2 (57-118d)	20.3	19.6	20.3	20.7	19.3
DMI total (0-120d)	18.8	18.0	18.6	19.2	18.1
Feed/gain (DM basis)					
Period 1 (0-56d)	5.22	5.80	5.98	5.71	5.85
Period 2 (57-118d)	7.72^{ab}	6.66^{a}	7.08^{ab}	9.45^{c}	7.93^{b}
F/G, live	7.33^{ab}	7.23^{a}	7.52^{ab}	8.53^{c}	7.86^{b}
F/G, carcass	7.35^{a}	7.47^{a}	7.56^{a}	8.60^{b}	8.00^{ab}
NEg calc., Mcal/cwt	48.6	49.57	48.08	45.48	45.39

^{a,b,c} Means with different superscripts within a row differ ($P<.05$).

Table 8. Effect of limiting access time to feed and time of feeding on carcass characteristics of feedlot steers.

	Time and exposure to feed				
	AL	9 h DC	9 h DG	9 h NG	15 h NC
Number of head	20	20	20	20	20
Dressing percentage	64.18	63.7	64.15	64.08	63.96
Hot carcass wt., lb	704^b	689^b	696^b	690^b	664^a
Ribeye area, in^2	11.70	11.73	12.00	11.43	11.90
Fat thickness, in.	.58	.57	.61	.54	.55
Adj. fat thickness, in.	.72	.65	.70	.64	.66
KPH, %	2.23	2.19	2.43	2.24	2.28
Skeletal maturity[c]	219	252	204	200	230
Lean maturity[c]	170	181	183	163	177
Total maturity[d]	194	217	194	182	203
Marbling score[e]	443	513	419	437	419
Quality Grade					
Choice, %	65	80	55	50	60
Select, %	35	20	40	45	35
Standard, %	0	0	5	5	5
Yield grade, mean	3.33	3.23	3.32	3.27	3.06
YG 1, %	10	5	5	10	10
YG 2, %	20	50	30	35	35
YG 3, %	55	20	50	35	45
YG 4, %	15	25	15	25	10

[a,b] Means with different superscripts within a row differ ($P<.05$).

[c] 100-199 = 'A' (approximately 9-30 months of age); 200-299 = 'B' (approximately 31-42 months of age).

[d] Skeletal + Lean maturity/2.

[e] 400 = $Small^{00}$, the minimum required for U.S. Low Choice; 500 = $Modest^{00}$, the minimum required for U.S. Avg. Choice.

Table 9. Daily activity of feedlot steers housed in partially covered pens.[a]

	Time and exposure to feed				
	AL	9 h DG	9 h DC	9 h NG	15 h NC
Number of head	20	20	20	20	20
			Fraction of day (%)		
Eating	6.7	6.9	7.6	4.5	7
Lying	48	46	52	50	51
Standing	30	32	29	33	30
Drinking	2.8	3.7	2.8	2.5	2.1
Lying while ruminating	9.5	8.3	6.8	8.3	7.6
Standing while ruminating	2.7	1.8	1.8	1.7	2

[a] Times represent an average of the two observation periods from days 64 and 65 and days 108 and 109 of the trial.

Table 10. Intake, eating time, and eating rate of steers housed in partially covered pens.

Time fed	Access time	DMI, lb[a]	Eating time, min	Eating rate, min/lb feed	Rumination time, min/lb feed	F/G[a]
0800	24 h	20.3	97	4.8	8.7	7.72
0800	9 h (gate)	20.3	99	4.9	7.0	7.08
0800	9 h (called)	19.6	110	5.6	7.1	6.66
1700	9 h (gate)	20.7	65	3.1	7.0	9.45
1700	9 h (called)	19.3	101	5.2	6.8	7.93

[a] Mean from day 57-118 of the trial.

Table 11. Effect of small, partially covered vs large, open pen housing on performance and carcass characteristics of feedlot steers.

	Covered	Open
Number of head	10	20
Weight, lb		
Initial wt	771	765
Final wt	1142	1161
Shrunk wt	1096	1114
Carcass wt (live)	1114	1103
ADG, lb		
Period 1 (0-56d)	4.05	4.39
Period 2 (57-120d)	1.82	1.44
Liveadg	2.8	3.01
Carcadg	2.86	2.82
Dry matter intake, lb		
Period 1 (0-56d)	19.0	21.1
Period 2 (57-120d)	18.0[a]	21.2[b]
DMI total (0-120d)	18.5[a]	21.2[b]
Feed/gain (DM basis)		
Period 1 (0-56d)	4.7	4.81
Period 2 (57-120d)	9.89	14.72
F/G, live	6.61	7.04
F/G, carcass	6.47	7.52
Carcass characteristics		
Dressing percentage	64.77[a]	63.03[b]
Hot carcass wt, lb	710	702
Ribeye area, in^2	13.36	12.77
Fat thickness, in	.47	.46
Adj, fat thickness, in	.54	.52
KPH, %	2.5	2.6
Skeletal maturity[c]	211	182
Lean maturity[c]	160	165
Total maturity[d]	186	174
Marbling Score[e]	473	440
Quality grade		
Choice, %	70	65
Select, %	30	35
Yield grade, mean	2.6	2.78
YG 1, %	20	20
YG 2, %	50	50
YG 3, %	30	25
YG 4, %	0	5

[a,b] Means with different superscripts within a row differ ($P<.05$).

[c] 100-199 = 'A' (approximately 9-30 months of age); 200-299 = 'B' (approximately 31-42 months of age).

[d] Skeletal + Lean maturity/2.

[e] 400 = Small^{00}, the minimum required for U. S. Low Choice; 500 = Modest^{00}, the minimum required for U. S. Avg. Choice.

Table 12. Effect of small, partially covered vs large, open pen housing on performance and carcass characteristics of feedlot steers.

	Covered	Open
Number of head	10	20
Weight, lb		
Initial wt	789	799
Final wt	1116	1124
Shrunk wt	1071	1079
Carcass wt (live)	1073	1057
ADG, lb		
Period 1 (0-56d)	2.54	2.39
Period 2 (57-118d)	2.57	2.66
Liveadg	2.55	2.53
Carcadg	2.41[a]	2.19[b]
Dry matter intake, lb		
Period 1 (0-56d)	16.4[a]	19.0[b]
Period 2 (57-118d)	19.2[a]	23.2[b]
DMI total (0-118d)	17.9[a]	21.1[b]
Feed/gain (DM basis)		
Period 1 (0-56d)	6.71	8.31
Period 2 (57-118d)	7.8	9.05
F/G, live	7.27[a]	8.68[b]
F/G, carcass	7.39[a]	9.66[b]
Carcass characteristics		
Dressing percentage	63.9[a]	62.5[b]
Hot carcass wt, lb	684	674
Ribeye area, in^2	12.0	11.9
Fat thickness, in	.6	.48
Adj, fat thickness, in	.68	.6
KPH, %	2.3	2.4
Skeletal maturity[c]	247	228
Lean maturity[c]	174	174
Total maturity[d]	211	201
Marbling Score[e]	451	435
Quality grade		
Choice, %	60	50
Select, %	40	50
Yield grade, mean	3.22	2.93
YG 1, %	10	10
YG 2, %	30	55
YG 3, %	50	20
YG 4, %	10	15

[a,b] Means with different superscripts within a row differ (P<.05).

[c] 100-199 = 'A' (approximately 9-30 months of age); 200-299 = 'B' (approximately 31-42 months of age).

[d] Skeletal + Lean maturity/2.

[e] 400 = Small^{00}, the minimum required for U. S. Low Choice; 500 = Modest^{00}, the minimum required for U. S. Avg. Choice.

Figure 1. 1.5 (to 9) vs 24 h steer weekly feed intake pattern.

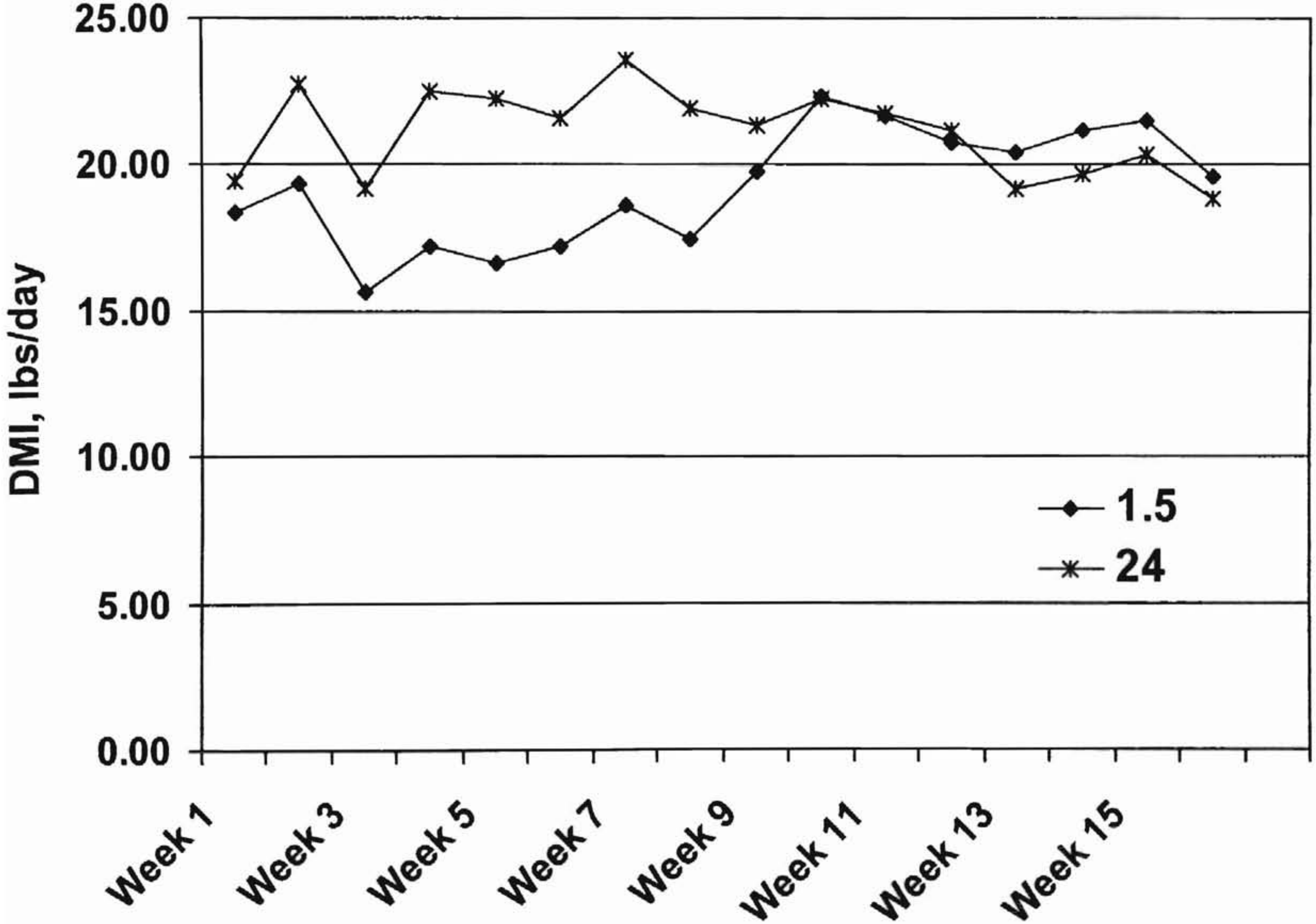


Figure 2. 9 vs 24 h steer weekly feed intake pattern.

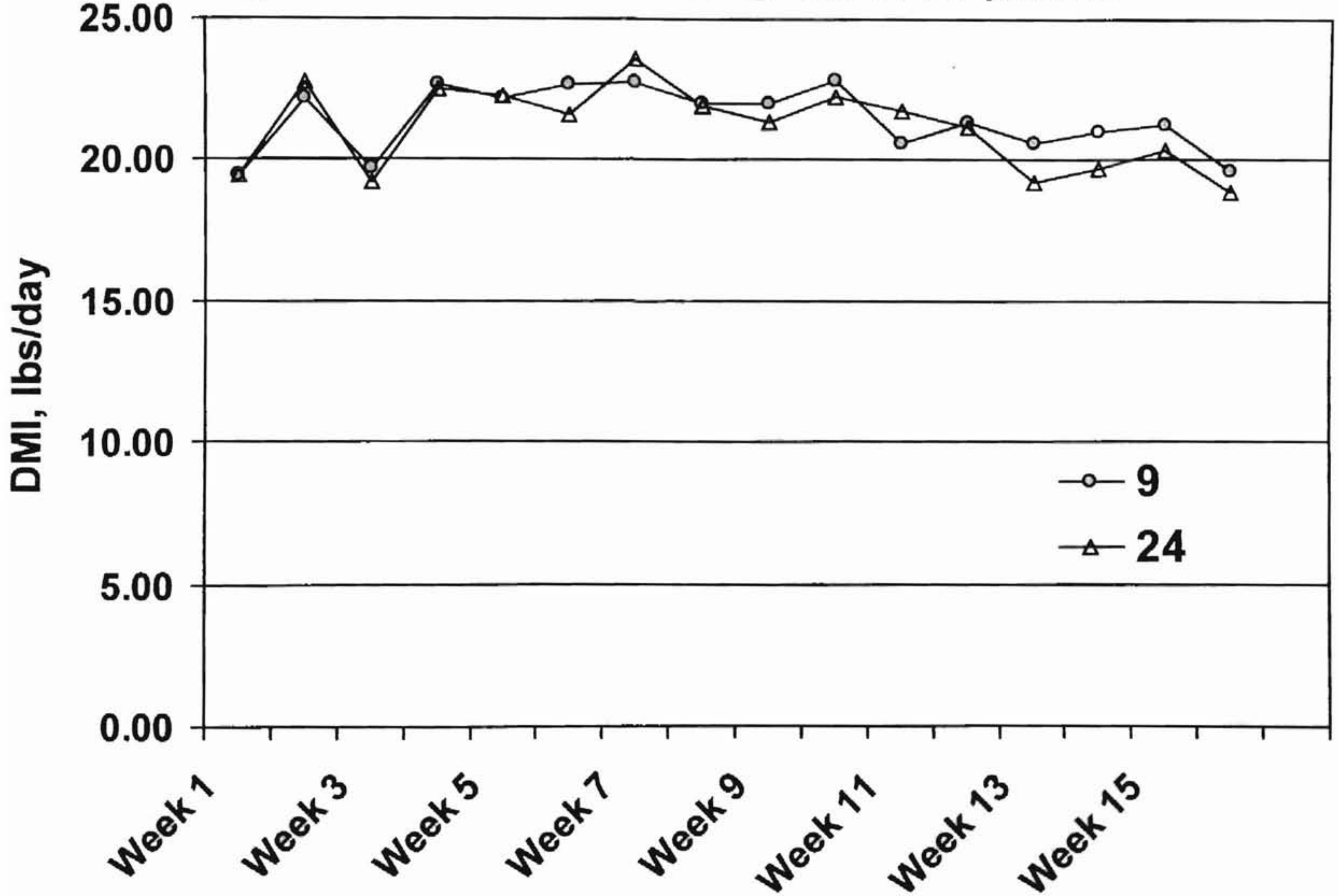


Figure 3. Weekly eating pattern of AL vs DC fed steers.

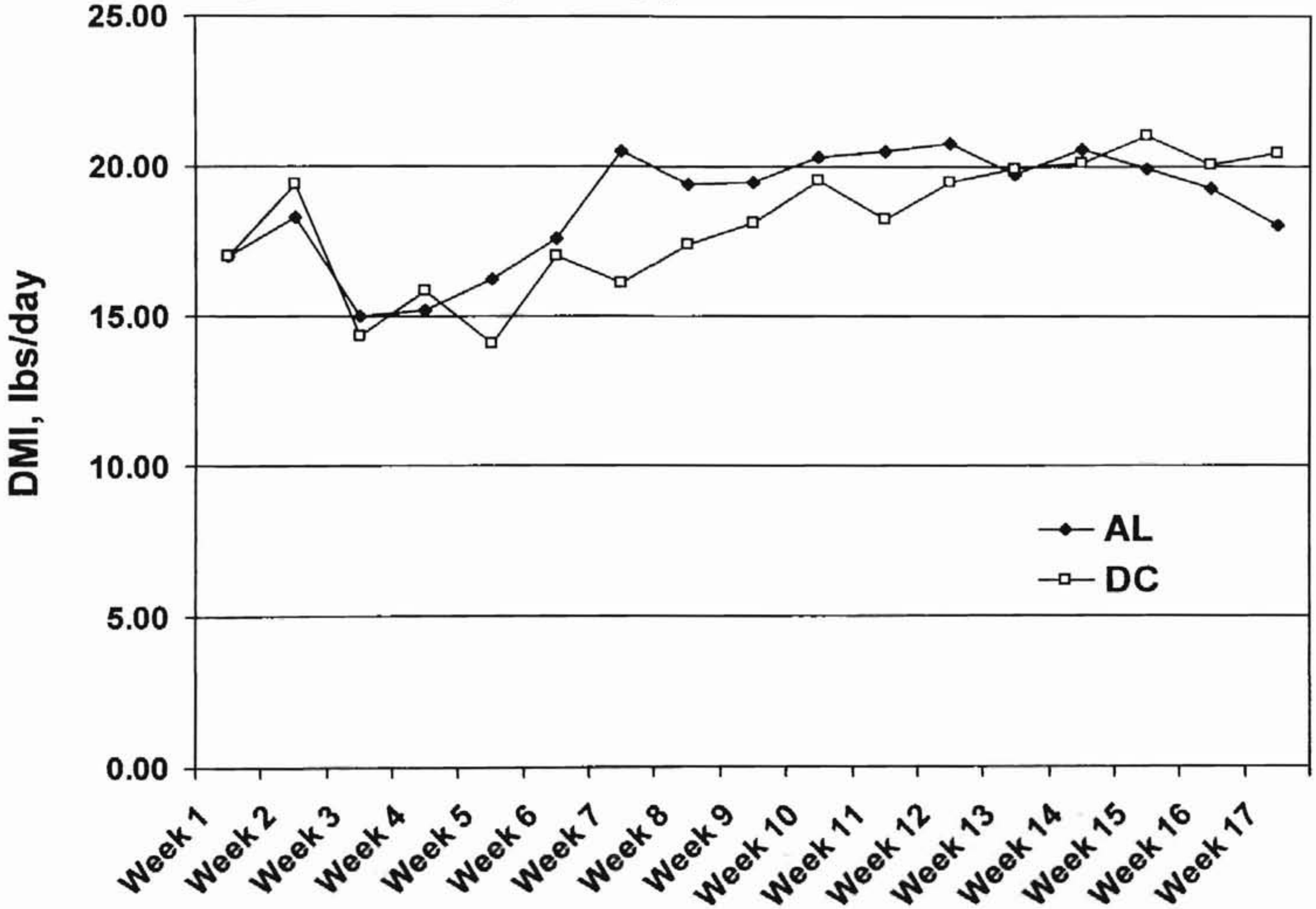


Figure 4. Weekly eating pattern of AL vs DG fed steers.

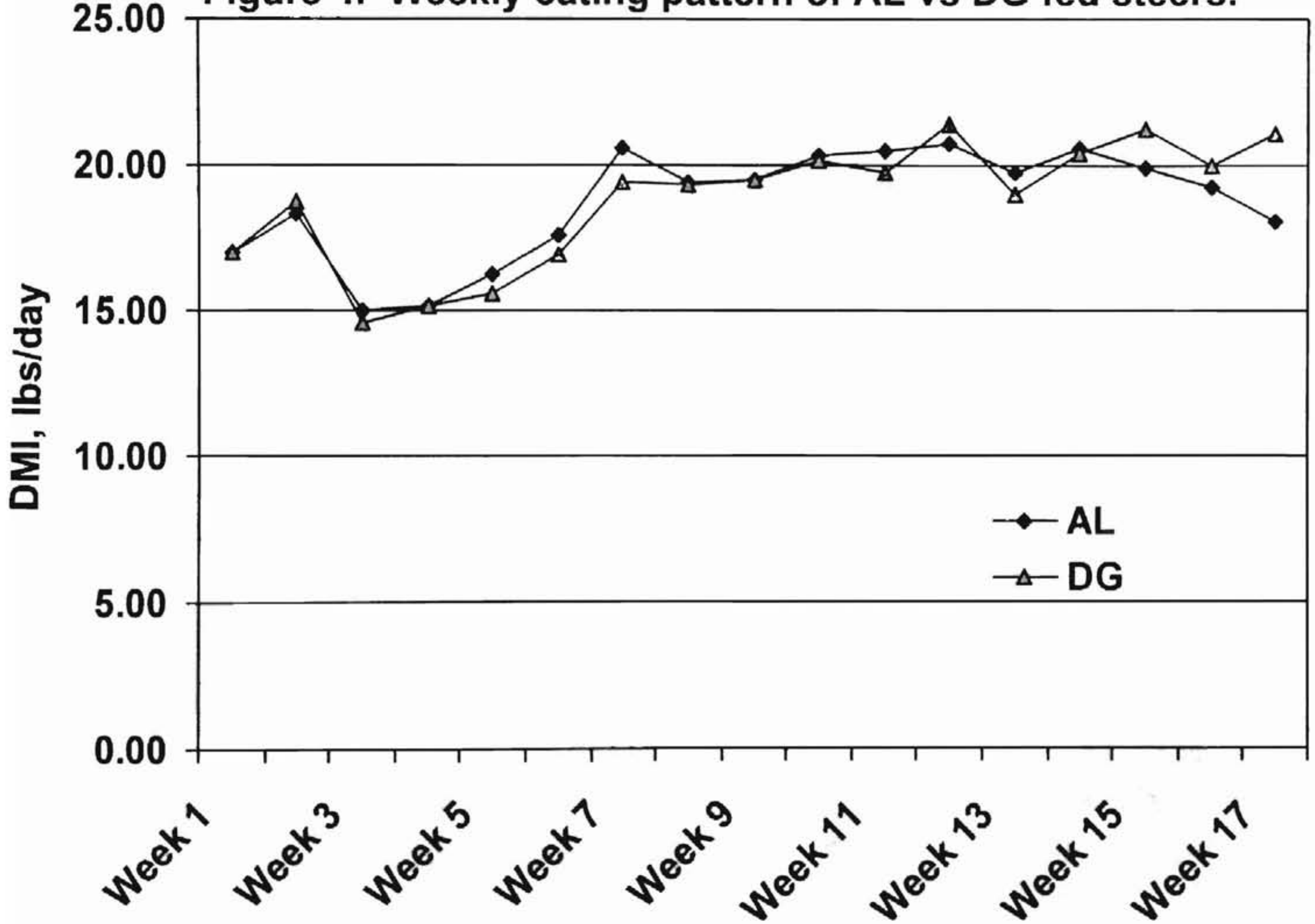


Figure 5. Eating patterns of steers housed in partially covered pens.

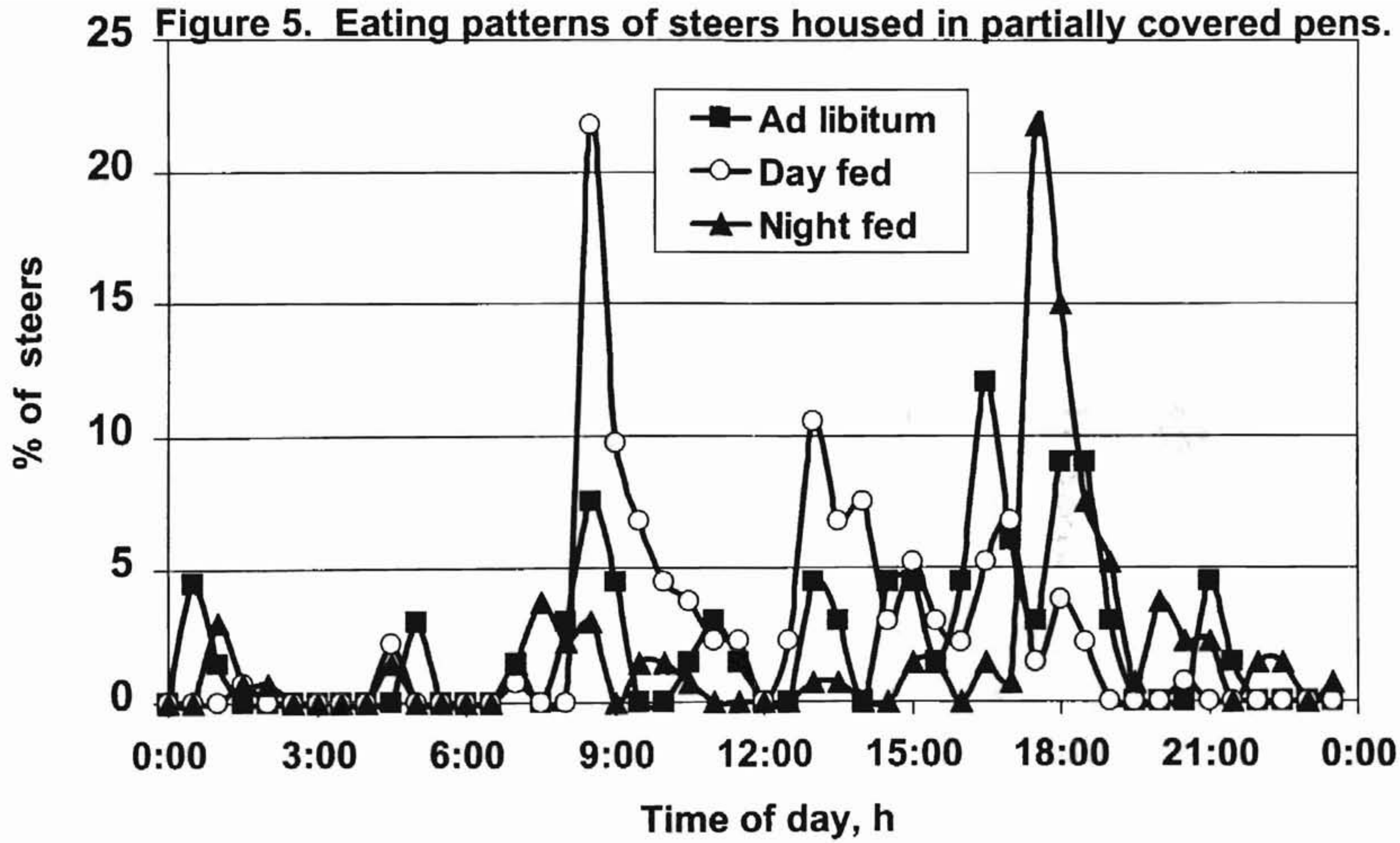


Figure 6. Lying patterns of steers housed in partially covered pens

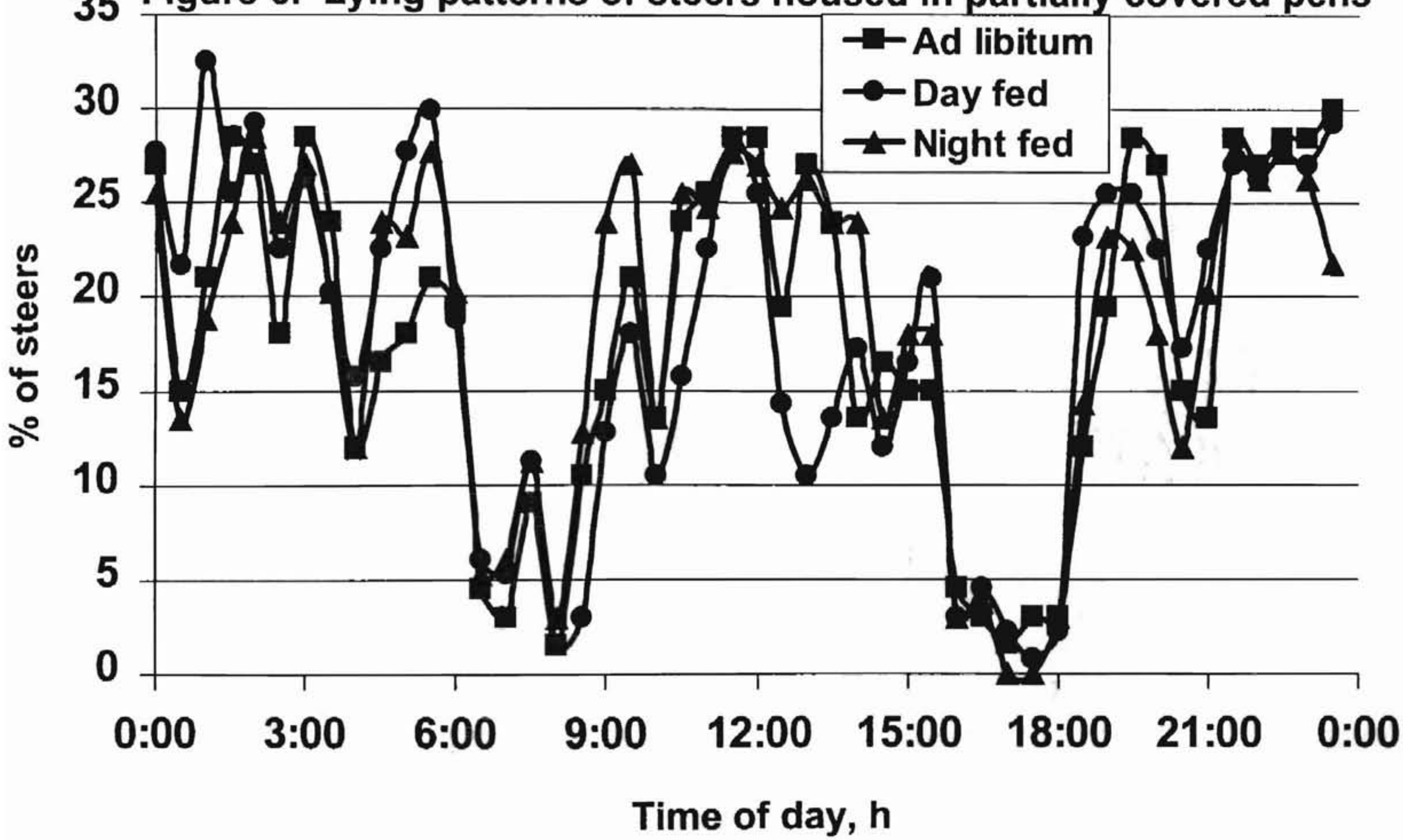
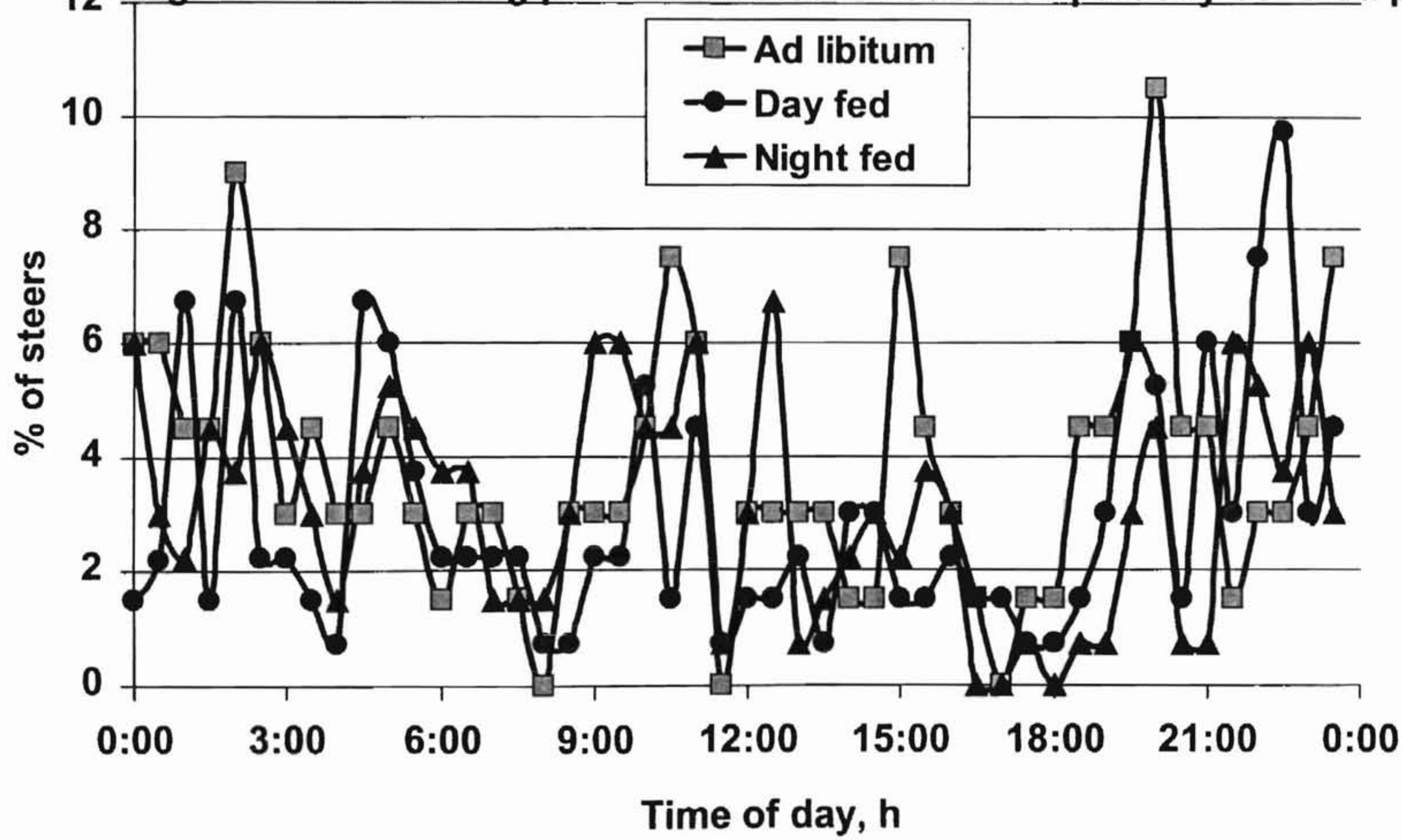


Figure 7. Ruminating patterns of steers housed in partially covered pens.



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VITA

Zeb I. Prawl

Candidate for the Degree of

MASTER OF SCIENCE

Thesis: EFFECTS OF LIMITING ACCESS TIME TO FEED AND OF PEN HOUSING ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDLOT STEERS

Major Field: Animal Science

Biographical:

Personal Data: Born in Mt. Ayr, Iowa, on January 7, 1974, the son of Jake and Jerry Prawl.

Education: Graduated from Ulysses High School, Ulysses, Kansas in May 1992; received Bachelor of Science degree in Agricultural Business from Northwestern Oklahoma State University, Alva, Oklahoma in May 1996. Completed requirements for the Master of Science degree with a major in Animal Science at Oklahoma State University in May 1998.

Experience: Lived in rural settings in Missouri, Kansas, and Texas. Employed by Bouziden and Foote Cattle Co., Alva, Oklahoma, school year 1992-93; employed by Schwein Farms, Ulysses, Kansas, summer 1993; employed by Koppitz Farms, Alva, Oklahoma, school year 1993-94; employed by Lewis Farms, Pretty Prairie, Kansas, summer 1994; employed by Sol Bouziden and Sons Farm and Cattle Company, Alva, Oklahoma, school year 1994-95; employed by Burnet Farms, Manchester, Oklahoma, summer 1995; employed by Sol Bouziden and Sons Farm and Cattle Company, Alva, Oklahoma, school year 1995-96; graduate research and teaching assistant at Oklahoma State University, Department of Animal Science, Stillwater, Oklahoma, fall 1996 to present.

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