RESTRICTING DRY MATTER INTAKE OF STOCKER CALVES AND ITS SUBSEQUENT
EFFECTS ON GRAZING, FEEDLOT PERFORMANCE, AND CARCASS
CHARACTERISTICS

by

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Abstract

An experiment was conducted to evaluate the effects of dry matter intake (DMI) restriction on early receiving performance by steers in a drylot and subsequent grazing performance, feedlot performance, and carcass characteristics. During the backgrounding period, crossbred, weanling steers (n = 329; initial BW = 191± 5.52 kg) were randomly assigned to 1 of 4 DMI levels corresponding to ad libitum, 2.50% of BW (2.50%), 2.25% of BW (2.25%), and 2.00% of BW (2.00%) for 62 d. During the subsequent grazing period, the same steers were randomly assigned to 13 paddocks to graze for 90 d. Paddocks were stocked at 281 kg live weight per hectare. Initial steer BW were similar on each pasture and each backgrounding treatment was equally represented within a paddock. During the feedlot period, steers were finished at a commercial feedlot and were assigned to 1 of 4 pens according to their rank in BW. Entire pens were harvested when average steer BW reached 545 kg. During the backgrounding period, ad libitum-fed steers had greater ($P < 0.001$) ADG and final BW than other treatments; steers fed at 2.50 and 2.25% of BW had similar ADG and final BW and were greater ($P < 0.001$) than steers fed 2.00% of BW. During the grazing period, compensatory gain was observed in restricted DMI treatments. Steers fed at 2.00% of BW had greater ($P = 0.006$) ADG than ad libitum-fed steers but an ADG similar to that of the other restricted DMI treatments. Steers fed ad libitum, 2.50% of BW, and 2.25% of BW had similar final BW and steers fed 2.00% of BW had lesser ($P < 0.001$) final BW than other treatments. During the feedlot phase, steers fed 2.00% of BW were on feed longer ($P < 0.05$) than other treatments. Growth compensation

during grazing illustrated that restricted feeding immediately prior to pasture grazing can reduce

backgrounding costs.

Key Words: backgrounding, compensatory gain, grazing, limit-feeding, steers

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CHAPTER 1 - Review of the Literature

Introduction

Beef stocker operators attempt to achieve efficient, cost-effective gains prior to entry into the finishing segment of the beef industry (Nickell et al., 2008). These are typically at high risk for respiratory disease because of improper weaning management, a long and stressful transport, and comingling with other non-immunized cohorts. A primary objective of a stocker operator is to quickly introduce nutritious feedstuffs so that the calf can overcome the stressors its body has encountered (Blasi et al., 2000). Cattle feeders usually strive for maximum voluntary feed intake; once it is achieved, animals can increase caloric intake well above maintenance thereby maximizing ADG (Zinn, 1986 and Murphy and Loerch, 1994). Unfortunately, feed intake by a stressed calf is generally low until it is fully adapted to its new management system. This is a challenge to stocker operators who try to maximize growth. Recently, rising energy costs have driven feed prices sharply higher, forcing stocker operators to consider alternative feeding strategies. Programmed restriction of DMI (i.e., limit-feeding) can reduce feed costs, improve diet digestibility, increase growth efficiency, and reduce the amount of manure produced.

Galyean (1999) classified limit-feeding strategies into two categories: restricted feeding and programmed feeding. Restricted feeding encompasses any method of feed management where intake is restricted relative to an anticipated ad libitum intake. This can include limiting maximum intake, limiting intake to a percentage of the expected maximum, and restricting the amount of time cattle have access to feed. Programmed feeding consists of using net energy equations to quantify the amount of feed necessary for a desired rate of gain. According to Galyean (1999), limit-feeding is particularly useful when feeding roughages because they are

typically more costly when considering the price per unit for the nutrients, processing, and handling. Limit-feeding can also be used to avoid metabolic diseases associated with overconsumption of feed and to manage rates of gain for small- and medium-framed cattle.

Previous research has demonstrated that limit-feeding growing cattle can improve feed efficiency (Plegge, 1987; Loerch, 1990; Sainz, 1995; Reinhardt et al., 1998; Schmidt et al., 2005),improve digestion (Brown, 1966; Loerch, 1990; Reinhardt et al., 1998; Löest et al., 2001; Clark et al., 2007), and not affect feedlot performance or carcass traits (Loerch, 1990; Murphy and Loerch, 1994; Reinhardt et al., 1998; Wertz et al., 2001). In some situations, limit-feeding improved growth performance and certain carcass characteristics when NE and metabolizable protein intake were maintained similar to cattle fed at ad libitum intakes (Schmidt et al., 2005).

According to Drouillard and Kuhl (1999), cattle experience compensatory growth immediately following a period of growth restriction. In our study, we hypothesized that stocker cattle managed on a limit-feeding regime during late winter would experience compensatory growth while grazing burned, native tallgrass pastures in the Flint Hills of eastern Kansas during the spring and summer.

Restricted Feeding

Loerch (1990) conducted a trial that evaluated the effects of feeding growing cattle a high concentrate diet at three intake levels and its effects on subsequent feedlot performance. Steers were fed corn-silage at ad libitum intake or high moisture corn and corn silage fed at either 80 or 70% of ad libitum intake during an 85-d growing study. Restricted diets were formulated to have greater nutrient densities so that NE_g and protein intakes were similar to the ad libitum fed steers. Ad libitum intake and 70%-restricted steers had similar ADG. Feed conversion was improved by 30% for the 70% restricted corn-based diet compared to corn-silage fed ad

libitum. Moreover, a 10% improvement in feed conversion was observed for steers fed the 80% restricted corn-corn silage diet compared to the steers fed ad libitum. Dry matter digestibility was improved by 36 and 11% for the 70 and 80% restricted intake levels, respectively, compared to the ad libitum steers. The author postulated that the improvements in digestibility may have been the result of a reduced rate of passage allowing for increased residence time in the digestive tract. He also stated that the improvements in efficiency occurred when an all-concentrate diet was fed at restricted levels compared to restricted diets with moderate energy levels. The reduction in dry matter digestibility for the 80%-restricted level compared to the 70%-restricted level may have been the result of adding grain to a high-fiber diet which may have caused negative associative effects on fiber digestion. Daily gains, overall dry matter intakes, feed conversion and carcass characteristics of these steers fed a common finishing diet were not affected by the growing period diet.

Wertz et al. (2001) evaluated the effects of length of intake restriction during the growing period on growing-finishing performance. Heifers were assigned to one of four treatments: dry corn gluten feed and corn fed ad libitum (DCGF-corn), DCGF-corn limit-fed for 42 d (42-DCGF-corn), DCGF-corn limit-fed for 84 d (84-DCGF-corn), and DCGF-corn limit-fed for 126 d (126-DCGF-corn). Limit-fed treatments during the growing period were fed at 80% of the DMI by heifers fed ad libitum. After limit-fed treatments of 42 and 84 d were complete, heifers remained on a growing diet fed ad libitum until the 126 d growing period was complete. Following the growing period, heifers were fed a common feedlot diet and were fed to a target 12th-rib backfat thickness of 1.0 cm. Heifers that were limit-fed 42-DCGF-corn had similar ADG to heifers fed ad libitum throughout the growing phase. However, heifers fed 84-DCGF-corn had slower gains than those fed ad libitum but were similar to those heifers fed 42-DCGF-

corn. Heifers that were limit-fed for 84 d had the most desirable feed efficiency during the

growing period. Heifers that were limit-fed for 84 d compensated for the earlier, slower

growing period in the latter 42 days of growing, and by the end of the growing period, heifers

limit-fed for 42 or 84 d had achieved similar ADG. Limit-feeding during the growing period

beyond 84 d did not improve feed efficiency and seemed only beneficial when the feeding

period was less than 84 d. In this experiment, heifers that were limit-fed then switched to an ad

libitum diet were able to compensate for modest weight gains early in the growing period.

Average daily gain in the feedlot increased linearly as length of restriction during the growing

phase increased; however, feed efficiency was not affected. Average daily gain for heifers

limit-fed for 84 d or less were similar and heifers limit-fed for the entire 126 d growing period

had 6.7% less ADG and 4.3% less desirable feed efficiency. Marbling scores for 42 and 84 d

limit-fed treatments were greater than heifers fed ad-libitum for 42 d during the growing

period. Additionally, hot carcass weight, marbling score, and quality grade increased linearly

as length of intake restriction increased. The authors postulated that this was the result of the

longer days on feed that were necessary for the 84 and 126 d limit-fed heifers to reach their

target backfat end point.

Hicks et al. (1990) conducted a study on finishing steers and heifers fed at programmed

rates of gain and evaluated potential reasons for increased feed efficiency. As expected, a

control group of cattle fed ad libitum had greater ADG than limit-fed steers. Feed efficiency,

however, was improved in the cattle that were limit-fed. The authors found that available NE

and ME content of the diet was increased in limit-fed treatments because the DE component of

the diet had increased due to slower passage rates and improved digestion. Heat increment may

have been decreased in limit-fed animals due to less metabolic activity, decreased physical activity of the animal, and smaller visceral organ mass.

Hicks et al. (1990) postulated on four reasons why feed efficiency in limit-fed cattle is improved. Firstly, they considered that liver size was highly correlated with maintenance energy requirements of an animal. Limit-fed steers may have smaller livers (Rust et al., 1986) and a static supply of feed intake can reduce the metabolic changes to that organ compared to ad libitum feeding. Conversely, Hicks et al. (1990) were not able to demonstrate a change in liver size by limit-fed cattle compared to ad libitum-fed cattle Secondly, they considered that limit-fed cattle may have a decreased maintenance requirement due to altered behavior patterns which, in turn, alter their energy expenditures. Mobility of limit-fed cattle may be reduced because they are adapted to a less active routine compared to when feed is available ad libitum. Thirdly, they considered that diet digestibility may be increased during limit-feeding. Digesta moves slower through the gastrointestinal tract thereby allowing the body greater opportunity to digest and absorb the nutrients. Fourthly, feed efficiency may be improved due to decreased waste from spillage, spoilage, or weather loss because limit-fed animals consume available feed at a greater rate than cattle fed ad libitum.

Plegge (1987) reported on restricting the intake of feedlot cattle using slight DMI restriction of 92 and 96% of ad libitum intake. He found that slight restrictions in DMI had tendency to lower ADG but since the degree of restriction was so small, feed efficiency was improved slightly. It was also observed that the metabolizable energy (ME) yield of the diet was increased when feed was restricted due to increased digestion and slightly lower maintenance energy requirements.

Sainz (1995) reported on the effects of restricted DMI on feed efficiency. He suggested that an optimum restricted feeding level may be 12-15% below ad libitum intake. He also reported that digestion increases with limit-feeding, resulting in increased nutrient supply and that restricted animals may have a lower maintenance requirement.

Cattle grown under restricted-DMI management systems may have reduced maintenance requirements, resulting in greater accretion of lean tissue than fat. In limit-feeding scenarios that maintain energy and protein intake that is similar to that by ad libitum fed animals, feed efficiency is improved and these animals may experience similar or greater ADG as the ad libitum fed animals (Loerch 1990; Schmidt et al., 2005; Clark et al., 2007).

Drager et al. (2004) reported on the effects of the severity of caloric restriction and its effects on cattle performance and carcass characteristics in a feedlot. Treatments were ad libitum, 75% of ad libitum for 65 d then 95% of ad libitum for 65 d (AL85), 80% of ad libitum for 65 d and then ad libitum for 65 d (AL90), and then 85% of ad libitum for 65 d then 105% of ad libitum for 65 d (AL95). The ad libitum fed treatment and the AL95 limit-fed treatment had greater gains than the other treatments. Overall carcass-adjusted ADG was greater for the ad libitum fed steers than steers in the limit-fed treatments. Overall feed efficiency did not differ between treatments. Hot carcass weights were greater for the ad libitum fed steers than the other treatments. Marbling score was also greater for ad libitum fed steers than for restricted steers. Fat thickness, however, decreased linearly as the degree of limit-feeding increased. This study did not maintain a constant net energy intake across treatments which is why greater ADG was observed for ad libitum fed animals. This was also the reason why hot carcass weights and marbling scores were greater for the ad libitum fed steers.

Meissner et al. (1995) reported on the relationship between feed intake, ADG, and feed efficiency in order to address the question of whether or not faster gaining cattle have greater feed intakes. They contended that lower dry matter intake of slow growing steers resulted in improved feed efficiency, whereas faster growing steers experienced decreased feed efficiency because of greater intakes. The authors postulated that fast growing steers may have a greater maintenance requirement and their relatively high intakes may have resulted in more fat accretion. The authors concluded that increasing intake will not necessarily increase ADG and that optimum intake levels for the greatest efficiency may fall below ad libitum.

Murphy and Loerch (1994) evaluated the effects restricted-feeding of growing-finishing steers on performance and carcass characteristics. Steers were fed an all-concentrate diet at ad libitum or 90 or 80% of ad libitum DMI. Nitrogen intake, but not NE, was kept constant across all treatments. They found that a decrease in daily feed intake led to a reduction in daily gain during the 84-day growing phase for steers restricted to 90 and 80% of ad libitum intake. The calculated NE_m of restricted steers increased 2.2 and 6.9% for steers restricted to 90% and 80% of ad libitum intake, respectively; moreover,, the calculated NE_g increased 2.5 and 8.1% for steers restricted at 90% and 80% of ad libitum, respectively. The authors postulated that reduced NE_m expenditure may be caused by reduced size of visceral organ mass, reduced physical activity, increased diet digestibility, and reduced feed wastage. Feed efficiency during this experiment was not affected by restricting DMI. These researchers found that T_3 tended to decline linearly as DMI level was decreased. This was interpreted to suggest that limit-fed steers may have inherently lesser metabolic activity.

Rossi et al. (2001) reported the effects of days on feed in response to varying restricted DMI strategies and varying rates of programmed gain on performance and carcass traits.

Treatments were applied in a 2 x 2 factorial arrangement with two control treatments of ad

libitum feeding for 168 d and ad libitum feeding for 203 d. Limit-fed treatments were fed a

programmed rate of gain for the first 78 kg of BW for both 168 and 203 d followed by a greater

programmed rate of gain for the next 124 kg of BW. They found that when programming

intakes for greater rates of gain, observed ADG that was 29% greater than predicted. Feed

efficiency was also 20% greater for steers on a programmed rate of gain compared to ad libitum

fed steers. During the growing phase and the finishing phase, backfat measurements recorded by

ultrasound were greater for calves fed ad libitum than calves with restricted intakes; however, as

length of limit-feeding increased from 168 d to 203 d, backfat increased linearly for limit-fed

calves.

Schmidt et al. (2005) conducted a study where finishing steers were fed at restricted DMI

levels of 80 or 90% of ad libitum while the net energy and metabolizable protein intakes were

maintained similar to that of steers fed ad libitum. Steers fed at 80% of ad libitum had greater

ADG than steers fed ad libitum or 90% of ad libitum. The gains of the limit-fed treatments were

113 and 110% greater than predicted for steers fed at 80 and 90% of ad libitum, respectively.

The authors pointed out that potential DMI of a given diet decreased as its energy density

increases, therefore, the steers fed the 80% diet may have been functionally near ad libitum

intake. Moreover, the authors postulated that the energy yield of the limit-fed diet may have

been greater than that predicted by net energy equations due to a lower passage rate and increase

in digestibility.

In this study, gain efficiency was greater by limit-fed steers than by steers fed ad libitum.

Given this observation, maximum feed efficiency might occur at a level that is below ad libitum

intake, particularly if energy yield of the diet is high. The authors' concluded by saying that

energetic values of feeds in a limit-feeding scenario are possibly greater than those predicted by NRC (2000) equations.

Similar results to this study were observed by Knoblich et al. (1997), Loerch and Fluharty (1998), and Rossi et al (2001) where predicted ADG for a programmed rate of gain was underestimated by NRC (2000) equations. Predictive equations that use the California Net Energy System were predicated on an ad libitum feeding system.

Reinhardt et al. (1998) conducted a trial that compared the performance of Holstein steers fed whole or processed corn in limit- or full-fed growing-finishing systems. The study was conducted as a 3 x 2 + 2 factorial arrangement of a randomized complete block design. Treatment factors in the growing phase included a corn-silage-based diet (SIL), a limit-fed whole corn (WCLF), and a limit-fed steam-flaked corn (SFLF). Finishing phase diets were based on full-fed whole- or steam-flaked corn. The study included two positive-control treatments which consisted of full-feeding of whole-corn and full-feeding of steam-flaked corn. Limit-fed diets were fed to achieve daily cattle gains of 1 kg/d.

Throughout the growing phase, steers that were fed SFLF and WCLF improved feed conversion by 7.0 and 4.3%, respectively, compared to steers fed SFFF and WCFF. Steers that were fed SFLF had greater feed conversion than steers that were fed WCLF. Daily gains for steers fed the WCLF and SFLF were greater during the growing period than positive controls; moreover, limit-fed steers had the greatest gains after being switched to a full-fed diet. The steers fed WCLF and SFLF converted feed more efficiently during the subsequent finishing period than steers fed SIL during the growing period.

When examining the overall feeding period (i.e., growing and finishing), limit-fed steers that were fed high-grain diets were more efficient than steers fed silage. Daily gains, however,

of SFLF and WCLF were 26 and 36% less, respectively, than that of their respective positive

controls. Steers that were fed SFFF throughout the entire trial gained the fastest and steers that

were fed WCLF during the growing phase and then switched to WCFF during the finishing

phase gained the slowest; all other treatments had similar ADG. On average, steers that were

full-fed throughout the entire feeding period achieved the target slaughter weight 17 d sooner

than steers limit-fed during the growing period. Steers that were full-fed throughout the entire

feeding period, tended to have more external fat at slaughter and increased marbling.

Löest et al. (2001) reported effects of using soybean hulls as a primary ingredient in

forage-free diets for limit-fed growing heifers. The limit-fed treatments were a roughage-based

diet fed at 2.75% of BW, a corn-based diet fed at 1.5% of body weight, a corn-based diet fed at

2.25% of body weight, a soybean hull-based diet fed at 1.5% of body weight, and a soybean hull

based diet fed at 2.25% of body weight. Heifers limit-fed the soybean hull-based diets gained

29% less than heifers limit-fed the corn-based diets. Furthermore, the heifers limit-fed the

soybean hull-based diets were 27% less efficient than the heifers limit-fed the corn-based diet.

All heifers that were fed soybean hull-based diets had lesser ADG than those that were fed the

roughage-based diet. In spite of that, the gain:feed ratio for both heifers fed roughage-based

diets and soybean hull-based diets were similar because the heifers fed soybean hulls consumed

38% less feed.

Reinhardt et al. (1998) measured the digestion of Holstein steers fed whole or processed

corn in limit- or full-feed growing-finishing systems. Trial periods consisted of a 10 d adaptation

period, with ad libitum intake, to a whole- or rolled-corn diet, followed by a 6 d collection

period; subsequently there was a 5 d adaptation to a restricted intake that was 85% of ad libitum

followed by 6 d of collection. This process was repeated for an alternate corn processing

treatment. Limit-feeding tended to reduce ruminal starch digestibility by 14%. Ruminal VFA concentrations and pH were not different shortly after feeding in either limit- or ad libitum treatments. Immediately before feeding, VFA concentrations were greater and pH was less in full-fed calves than in limit-fed calves. There was no effect of corn processing method on ruminal VFA and pH. There was also no difference in corn processing method on liquid dilution rates.

Löest et al (2001) observed the effects of limit-feeding using used soybean hull-based and corn-based diets as treatments. Diet digestibility was determined by collecting refused feed and fecal samples over a 48 hour period during a growing study. Soybean hull-based diets were less digestible (i.e., DMD) than corn-based diets. Heifers that were fed soybean hull-based diets and corn-based diets at 1.5% of BW had similar DMD to heifers fed the same diets at 2.25% of BW. The calculated NE_m and NE_g concentrations in the diets used for the limit-fed animals were slightly lower than predicted from NRC (2000) net energy equations. The authors speculated that limit-fed animals may have smaller visceral organ mass as a consequence of slower passage rates and greater diet digestibility.

In the study conducted by Wertz et al. (2001), the nutrient disappearance of heifers fed at restricted intakes during a growing period was measured. Overall average OM disappearance was improved for all restricted DMI treatments fed ad libitum. Digestion of DM and gross energy were improved when diets were limit-fed to heifers in this trial.

Montgomery et al. (2004) fed wet corn gluten feed at different intake levels to observe its effects on diet digestibility and ruminal passage rates. Treatments consisted of diets with steam-flaked corn, alfalfa hay, and either 0 or 40% wet corn gluten feed (WCGF) fed either ad libitum or limited to 1.6% of BW. They reported that limit-feeding in this trial decreased apparent OM

and neutral detergent fiber (NDF) digestibility. Within the first 4 hours post-feeding, ruminal pH was decreased, while NH_3 and VFA concentrations increased. Conversely, 12 h post-feeding, pH had increased and NH_3 and VFA concentrations had decreased. Meanwhile, steers fed ad libitum had a continual decrease in ruminal pH and an increase in NH_3 and VFA concentration up till 12 hours post-feeding. The authors postulated that, because limit-fed animals rapidly consumed their diet, this may have led to the decrease in pH, the increase in NH_3 and VFA concentrations, and the decrease in OM and NDF digestion. Ruminal acetate concentrations of the limit-fed treatment increased rapidly within 4 hours post-feeding but later decreased. This was associated with decreased ruminal propionate concentrations and increased acetetate:propionate ratio. Rates of in situ dry matter disappearance were not affected by DM intake. The authors suggested that multiple feedings of a limit-fed diet may be beneficial when diets contain highly fermentable, starchy products.

Clark et al. (2007) conducted two trials that evaluated the effects of dry matter intake restriction on diet digestion, energy partitioning, phosphorus retention, and ruminal fermentation by beef steers. In experiment 1, crossbred steers were fed 1 of 3 dietary treatments consisting of ad libitum dry matter intake (AL), intake restricted to 90% of ad libitum dry matter intake (IR90), and intake restricted to 80% of ad libitum dry matter intake (IR80). Experiment 2 compared AL and IR80. Intake of NE_m, NE_g, MP, and phosphorus were similar across treatments. During both experiments, fecal output was less for the IR80 steers than the AL steers by approximately 40%. Furthermore, DMD by IR80 steers was greater compared to the AL steers. Urinary and gaseous energy losses were similar between all treatments in experiment 1; however, IR80 steers in experiment 2 had lesser fecal and gaseous energy loss and tended to have greater urinary energy loss than AL. Steers fed AL had greater VFA concentrations than

the IR80 steers. The IR80 and the AL steers had similar VFA concentrations at 0.25, 4, and 8 hours post-feeding, however, the IR80 steers had lower VFA concentration at 12, 16, 20, and 24 hours post-feeding.

The authors noted that as DMI decreased, digestibility of the diet increased. Digestible energy intake was increased for the IR80 steers because fecal energy loss was less than IR90 and AL steers. Urinary energy output was greater and gaseous energy losses were less for IR80 steers, which led to similar ME intakes across all three treatments. Ruminal VFA concentrations were similar at 0.25, 4, and 8 h after feeding across all treatments; however, ruminal VFA concentrations were lower for the IR80 steers at 12, 16, 20, and 24 h after feeding. The authors presumed that this was the result of the restricted steers consuming their feed within 4 h of feed delivery while the AL steers consumed their feed over a 23-h period so the authors postulated that the rate of ruminal fermentation may have slowed after 8 h due to a lack of continuous input of feed substrate.

Heat increment describes heat loss associated with product formation, fermentation, waste formation, and waste excretion, among other things. In the study by Clark et al. (2007), IR80 steers produced 40% less fecal dry matter and had lesser total ruminal VFA concentrations 8 h after feeding compared to the AL steers. This may be an insight into the mechanism whereby animals maintained on a limit-feeding regime have a lesser heat increment than animals fed at ad libitum DMI .

Basal metabolism is another factor that contributes to losses from heat increment. Sainz and Bentley (1997) evaluated visceral organ mass and cellular growth in steers fed ad libitum or steers fed at 70% of DMI of the ad libitum fed steers. They found that steers that were limit-fed had smaller livers and that this was highly correlated with dietary energy yield as well as amino

acid availability. Cell numbers in the livers of limit-fed animals and full-fed animals were similar; however, cell size was greater in full-fed animals. They also found that small intestine weight was less in limit-fed steers compared to full-fed steers. The authors concluded that visceral organs are a major contributor to whole-animal energy expenditure. When cell sizes are smaller, visceral organs expend less energy to perform basal metabolic functions, thereby decreasing heat increment.

Summary of Restricted Feeding

Restricted feeding can be a cost-effective feeding strategy. In general, limit-fed animals will have improved feed efficiency and improved DM digestibility. Under certain feeding conditions when ME intakes are held constant and DMI is varied, improvements in ADG have been observed. Carcass characteristics tend not to suffer as a result of restricted feeding. In spite of that, days on feed may be increased in some situations. Several authors have speculated that limit-fed animals have a lesser maintenance requirement per unit of metabolic BW than animals fed ad libitum; however, no studies have examined complete energy balance in limit-fed cattle. Limit-fed animals may have a smaller heat increment than ad libitum-fed animals for several reasons: lesser visceral organ mass, lesser heat of waste production and excretion, lesser heat of fermentation, or altered fermentation end-products. Whether or not the excess available energy is diverted to either maintenance or gain is unclear.

In studies where energy intake is held constant between limit-fed and full-fed animals, , programmed feeding strategies have underestimated gain. This may occur because NRC (2000) predictive equations are based on previous research where animals were fed ad libitum and they may not take into consideration the improvements in digestion that occur in limit-fed animals. Therefore, the nutrient content of the feed given may also be underestimated.

Compensatory Growth

The ability of animals to compensate from periods of malnutrition in terms of weight gain was a term defined by Bohman (1955). In general, the degree of compensatory gain that will occur is based on several factors: age of the animal, severity of nutrient restriction, and quantity of feed available during the subsequent feeding period. Bohman (1955) performed a study analyzing early- and late-cut hay consumption on beef cattle. The cattle were allowed to consume the different hay types during the winter months, and then moved to grazing on an open range in the spring. Cattle in this study that consumed the late-cut were nutritionally deprived of various nutrients but were able to compensate for this loss by rapid gains during the grazing period.

Berg and Butterfield (1976) reviewed the concepts of various growth stages regarding cattle production. They concluded that certain factors that are involved with the growth curve of cattle are more influenced by weight than by age. Compensation in animals results in an increase in muscle mass towards a point of normal, muscle-bone relationship. Fat deposition will approach the same level if a sufficient period of compensation is allowed. The authors stated that an animal whose growth has been retarded will be of similar shape to its normal counterpart as long as feed supplies are sufficient to avoid bone depletion in the body.

Owens et al. (1993) stated that animals that undergo realimentation following periods of restricted growth will experience superior growth rates compared to their animal companions whose growth rate was not restricted. They described compensatory growth as a period of muscle hypertrophy and the degree of compensation will be greater following periods of caloric rather than protein restriction. However, compensation in terms of weight gain will depend on

other underlying factors such as age at which restriction began, the severity of the restriction, duration of the restriction, the realimentation diet, length of time that realimentation diet is fed, and breed type. The authors also concluded that compensatory growth can only alter body composition during growth and has very limited effect on body composition at maturity.

Drouillard and Kuhl (1999) summarized compensatory gain as the period of time when an animal is recovering from nutritional deprivation. However, other environmental stressors (i.e. extreme temperatures, disease, plant toxins, parasites, etc.) could also influence the degree of compensatory gain an animal may experience. Within the beef industry, compensatory gain represents a redistribution of value that many operations depend on to represent a margin of profit. Compensatory gain should be utilized to minimize input costs and reduce overall production costs, particularly during grazing, a period of low input costs, and subsequent finishing, a period of high input costs. Cattle producers will prefer to enhance this mechanism to increase slaughter weights without substantially affecting the percentage of body fat deposition when cattle are slaughtered.

Lofgreen and Kiesling (1985) evaluated the effects of receiving and growing diets on compensatory gains of stressed calves. They used grower calves and placed them in 1 of 3 dietary treatments that were hay alone diet, hay and a protein supplement, and a 75% concentrate diet. These diets were fed in the receiving phase for 28 d and then realimented to an 85% concentrate diet for the remainder of a 196 d growing-finishing period. Calves that were fed the 75% concentrate diet had the greatest ADG, consumed the most feed, and required less feed per unit of gain than the other two treatments. Calves fed hay and a protein supplement consumed more feed, gained more weight, and required less feed per unit of gain than those calves fed hay alone. During the finishing phase, calves receiving hay and hay and a protein supplement

exhibited similar gains. During the finishing phase, calves receiving hay alone had the greatest gains. Calves fed the 75% concentrate diet that exhibited the greatest degree of compensatory growth earlier in the receiving phase; and also had larger carcass weights and a greater dressing percentage.

Drouillard et al. (1991) evaluated the effects of restricting NE and MP during the growing period on compensatory growth. ADG during the restricted growing phase for both MP and NE restricted were similar; however, the degree of compensatory growth that the animal experienced was greater for NE restricted than MP restricted animals. Upon realimentation, liver weights were greater for NE restricted animals than MP restricted animals. Furthermore, finishing performance was similar for NE and MP restricted steers for 77 d. Longer durations of finishing resulted in the performance of NE restricted animals being greater than MP restricted animals.

Abdalla et al. (1988) fed Holstein steers three different diets that were protein deficient, protein sufficient, or energy restricted to evaluate compensatory growth. In the same study, the authors conducted a second experiment and kept two dietary treatments the same with the exclusion of the energy restricted diet from the first experiment. They observed greater gains and improvements in feed efficiency calves that were re-alimented regardless of timing of restriction and whether they were limited in protein or energy. The authors concluded that the compensatory growth that the calves experienced was due to both an increase in DMI and an increase in the efficiency of ME. They also concluded that regardless of whether an animal is underfed energy or protein, realimentation to a higher plane of nutrition will result in compensatory gain.

In a previously mentioned study by Sainz et al. (1995), animals experiencing malnutrition prior to a realimentation diet typically have lower fat deposits within carcass tissues; however, still maintain a similar protein level in EBW as ad libitum fed steers. After re-alimentation had begun and steers had started the finishing diet, DMI of limit-fed steers was greater ad libitum throughout the growing-finishing period. However, upon realimentation to a higher plane of nutrition, malnourished steers had lower maintenance requirements and numerically higher protein:fat proportions in weight gain. The change in NE_m requirements was the major factor in determining the degree of compensatory gain that an animal will experience. Upon conclusion of the finishing phase, realimented steers had less carcass fat deposits and more internal, non-carcass fat deposits.

Drouillard et al. (1991) evaluated the changes in body composition and visceral organ size during restricted and compensatory growth following restrictions of MP or NE in lambs. Weights of liver, stomach complex, and intestines were less in lambs in response to NE and MP restrictions. Upon realimentation, liver and stomach complex weights increased and intestinal weights seemed to increase for the first 14 d of realimentation and then reached a plateau thereafter. Liver and intestinal mass were sensitive to changes in the availability of absorbable nutrients while the stomach complex mass changes were more affected by changes in energy density of the diet. The authors provided estimates of oxygen consumption in the present study which were indicative of in vivo rates of metabolism. Restricted lambs, regardless of type of restriction, had almost a 40% decrease in oxygen uptake by liver tissue. This is an indication that the maintenance requirements of previously restricted animals do have lower maintenance energy requirements. The maintenance energy level of these animals will remain low even into

the early stages of realimentation because less energy is needed to maintain the animal's body and more energy can be emphasized for gain.

Turgeon et al. (1986) studied the effects of three different diets on lambs that were programmed for slow, medium, and rapid growth rates. Lambs that were fed under the slow and medium growth rate regime were switched to the rapid growth rate after the lambs attained 30 kg of BW. As growth rate increased, EB water decreased curvilinearly and percentage of fat increased curvilinearly. EB protein and ash decreased linearly as growth rate increased. Nutrition of an animal will alter body composition and animals growing at faster rates were fatter at any given BW and as animals neared maturity, the composition changed towards less protein and more fat accretion. Animal maturity is defined at the point when fat accretion surpasses protein accretion within the body. In this study, ME and retained energy decreased linearly as growth rate from the growing period increased. Heart weights and gastro-intestinal tract weights increased linearly as growth rate increased during the growing period. The authors concluded that compensatory gain will occur in two stages. First, protein accretion will increase followed later by an increase in fat deposition. They also concluded that nutrition can be used to modify the composition of an animal's gain; a slow growth rate will decrease fat deposition consequentially leading to greater rates of protein accretion.

Carstens et al. (1991) observed the physical and chemical components of the empty body during compensatory growth in beef steers by conducting a serial slaughter technique on steers and slaughtering those steers at approximately 325 kg BW, 420 kg BW, 475 kg BW, and 500 kg BW. Treatments were a continuous feeding regime (CON) and a restricted/compensatory growth (CG) feeding regime where steers were restricted to grow at 0.45 kg/d. At 189 d growth restriction, CG steers were realimented to ad libitum intake. After the period of restriction, the

CG steers from weight 325 kg to 420 kg gained faster than the CON steers and when steers were slaughtered at 500 kg, ADG was greater for the CG steers, however, DMI was similar. The authors observed larger empty body weights (EBW), hot carcass weights, and full body weights in the CON steers than in the CG steers. At 325 kg, CG steers had heavier EBW, whereas at 500 kg, the CG steers had lighter EBW than the CON steers. The growth coefficient for the liver was greater for the CG steers than CON steers. At 450 kg of EBW, liver weights were less in the CG steers than the CON steers. The authors postulate that this may be indicative of the higher growth rate maintained by the CG steers throughout the realimentation period. Liver mass of the CG steers increased by 40% during the first 45 d of realimentation. They also observed that non-carcass protein and water accretion was greater for the CG steers than the CON steers during the realimentation period. Lipid accretion was reduced in non-carcass tissues and carcass tissues of CG steers while EBW and ash were greater in CON steers. Furthermore, the authors concluded that restricting growth altered the partitioning of nutrients available for growth with more protein and water and less fat being deposited in non-carcass and carcass tissues during compensatory growth.

Higher accretion rates that occur during the realimentation period are reflective of hypertrophy of the visceral organs. Hypertrophy is abnormal enlargement of cells within an organ or system that can take place following a change in metabolic rate of nutritional input. The authors suggest that this mechanism plays an obligatory role during compensatory growth. During compensatory growth, NE_g requirements are reduced as a result of changes in the efficiency of the animal and in particular the consequence of hypertrophy of visceral organ cells. Since protein accretion requires four times less energy than fat accretion in the body

consequentially, more protein and water is deposited in bodily tissues at a rapid rate during compensatory growth.

Sainz and Bentley (1997) conducted an experiment designed to examine the mechanisms of compensatory gain, particularly regarding visceral organ size and cell numbers in ad libitum and limit-fed steers. They found that liver cell size increased during a period of compensatory gain and realimentation and not numbers. Hypertrophy is the mechanism responsible for the changes that the liver underwent during compensatory growth. However, small intestinal mass, during this experiment, was increased which hyperplasia may be the mechanism responsible. Hyperplasia is the abnormal increase in cell numbers in an organ usually in response to huge flux in nutrients following periods of starvation.

Di Marco et al. (1987) evaluated the role of hypertrophy and hyperplasia and their contributions toward the growth in cattle. They found that hypertrophy did occur in the muscle cells of cattle experiencing compensatory growth because muscle mass had increased 151 times while DNA increased only increased 35 times. This suggested to the authors that muscle size is increasing and is proportionally larger than the increment in DNA found in the muscle cells. They concluded that during rapid stages of growth of an animal, as bodily protein increased sixfold, DNA will presumably increase twofold. Their study also revealed that hypertrophic growth is most important in postnatal growth, particularly in muscle tissue, while hyperplasic growth is dominant in prenatal development.

Yambayamba et al. (1996) conducted a study that evaluated the hormonal status, metabolic changes, and resting metabolic rate of beef heifers experiencing compensatory growth. Growth hormone (GH) concentrations were greater on during early realimentation previously restricted heifers compared to heifers previously fed ad libitum and by d 31, GH levels had fallen

to a level similar to that of the control heifers. There was also a rapid increase in insulin levels

of restricted heifers during the initiation of realimentation and, by d 10, insulin levels had fallen

to a level similar to that of the control heifers. During the initiation of realimentation thyroid

hormone levels were lower for previously restricted heifers but by d 31, had risen to a level

similar to the ad libitum fed heifers.

The authors stated that, although no experimental evidence is available to support the role

GH may play in compensatory growth, this study suggests that a strong correlation exist between

the rapid growth of compensation and the elevated levels of GH at the initial phase of

realimentation. The rapid influx of insulin during the initiation of realimentation is functionally

related to the stimulation of amino acid transport, slowing of amino acid oxidation, a decrease in

protein degradation, which, in turn, will have a direct effect on protein synthesis. This rapid

increase in insulin may be a signal for the initiation of anabolic processes. Insulin, along with

GH, may work synergistically to favor the uptake of glucose and amino acids by organ systems

for the synthesis of new tissue. Lower levels of thyroid hormone early in realimentation

followed by a rise later during realimentation indicate that the resting metabolic rate of the

previously restricted heifers was lower than ad libitum fed heifers, allowing for more energy to

be put towards gain. However, later during realimentation, resting metabolic rate had increased

to levels similar to that of heifers previously fed ad libitum. Blood urea nitrogen levels were

lower for restricted heifers early on during realimentation but later increased to similar levels as

the control heifers. This suggests that previously restricted heifers were more efficient in

nutrient utilization and nitrogen efficiency which, may have led to the improvements in feed

efficiency that occur during compensatory growth. The authors concluded that it may be more

efficient to restrict weaned animals for a period of time to allow for compensatory growth prior to feeding animals ad libitum.

Summary of Compensatory Growth

Compensatory growth in an animal is a physiological phenomenon that will depend upon not only on the age of the animal, but the severity of restriction the animal was exposed to and the subsequent plane of nutrition the animal is moving towards. An animal that is experiencing compensatory growth will undergo noticeable changes increases in DMI and ADG as well as improvements in feed efficiency.

The degree of compensatory gain that cattle will experience is more reliant on weight; however, maturity and age of the animal is an intermediate factor. At a certain age in an animal's lifetime, there is a particular, normal muscle:bone relationship. Therefore, if an animal's growth has been retarded and then moves to a higher plane of nutrition, muscle deposition will attempt to approach that normal muscle:bone relationship that its counterpart of a different weight but similar age that was originally fed on a higher plane of nutrition at ad libitum.

Studies have shown that when MP and NE are restricted, animals will experience compensatory growth. Also, as previously mentioned, restricted animals possess smaller visceral organ size; however, once restricted animals are realimented, organ systems experience rapid growth during early realimentation. The mechanisms responsible for the rapid growth in the body are hypertrophy and hyperplasia. Muscle and liver cells will expand in size with small increases in cell numbers, which is an example of hypertrophy. Cells' sizes have shown larger increases in mass and DNA concentration having smaller increases. Liver mass is known to

increase nearly 50% during the first month of realimentation. Intestinal growth is a result of hyperplasia or a rapid increase in cell numbers.

Malnourished animals have been shown to have a decrease in the oxygen uptake by observing thyroid hormone concentrations. This signifies a slower metabolic rate in these animals; however, when restricted animals are realimented to a higher plane of nutrition, organ size is still small and oxygen uptake is still lower than the animals' full-fed counterparts. Therefore, compensatory growth occurs at its highest degree during early realimentation when a massive influx of nutrients, resulting from higher DMI, is supplied to metabolically slower animals. The visceral organs are still small; therefore, maintenance energy requirements are lower for these animals until these animals attain their normal weight. This rapid growing period is dependant upon pre- and post-nutritional plane. Also, research has shown that an increase in insulin concentrations in the blood may be responsible for the increased anabolism that is occurring during compensatory growth.

Burning Pastures in the Flint Hills, Kansas

McMurphy and Anderson (1965) performed a study that evaluated burning the Flint Hills Range to ascertain the benefits of maintaining Native Tallgrass Prairie species and its potential to improve livestock performance during grazing. Native species in this region are typically big bluestem (*Andropogon gerardi*), little bluestem (*Andropogon scoparius*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and sideoats grama (*Bouteloua curtipendula*) and can be affected by seasonal burning. The authors assigned four, 44 acre pastures that were fenced for a burning-grazing trial where previous winter, early spring, mid-spring, and late spring burning had taken place. Those pastures were compared with an unburned pasture of 60 acres. Yearling steers were placed in each of the pastures with a

moderate stocking rate of 5.0 acres per animal unit on May 1 and removed on October 1. Total

moisture in a 5-foot soil profile was less in the early spring and mid-spring burned pastures. In

regards to forage production, the unburned pasture produced more forage than early-spring

burned or winter-burned pastures. Dominant species of the prairie changed with burning

procedures. Little bluestem tended to increase in burned pastures but this effect could have been

weather related. Big bluestem generally became the dominant species in winter-burned and late

spring burned pastures. This was beneficial because big bluestem is a palatable grass and an

increase in this species was beneficial to early grazing. Earlier burning tended to be detrimental

to indiangrass and late spring burning reduced Kentucky bluegrass. Burning, overall, removed

protective mulch from pervious herbage, increased water runoff, and allowed seedlings of

invasive species to establish themselves; however, if adequate fuel is available, burning can

remove those seedlings. The authors recommended burning to increase the presence of big

bluestem, control Kentucky bluegrass, Japanese brome, and buckbrush, and improve beef cattle

gains early in grazing.

Owensby and Anderson (1967) conducted a study that evaluated the time of spring

burning on herbage yields in pastures grazed by steers throughout the growing season. The

author used three, 44 acre pastures that had been annually burned since 1950 in early spring

(March 20), mid-spring (April 10), and late spring (May 1) and used a 60 acre unburned pasture

as a control. Each pasture was stocked at one animal unit to five acres. Steers were placed on

pastures on May 1 and removed on October 1. The author concluded that early and late spring

burning decreased herbage yield following grazing and over an 8-year period, early spring

burning continuously gave the lowest herbage yield. The author recommended that late spring

burning would yield the best forage yield and maintain a better range condition compared to early spring burning.

Svejcar (1989) conducted a study that analyzed animal performance and diet quality influenced by burning the Tallgrass Prairie. Two adjacent pastures, 37 and 53 hectares in size, were split at random in half and assigned to either a burned or control treatment. Each pasture was stocked at 1.5 hectares per calf from 13 June to 11 October, 1984 and 19 May to 16 October 1985. Esophageally-fistulated heifers were used to assess forage quality of the pastures. Average daily gain was greater on burned pastures compared to unburned pastures during late May and early July. During the latter part of the grazing season, ADG was similar between the two treatments. In vitro organic matter digestion tended to be slightly higher on burned pastures. Crude protein, tended to be higher on all sampling dates on unburned pastures. The author concluded that burning was beneficial for improving ADG during early part of the grazing season because this coincides with the active growth of the most dominant species of the Tallgrass Prairie. The author also suggested that stocking rates can potentially be increased during early grazing to take advantage of the increased growth.

Intensive Early Stocking

Smith and Owensby (1978) performed a study to determine if bluestem range could be stocked at twice the normal rate for the first half of the growing season in order to maximize the use of high quality early season forage and still maintain the stand and vigor of the native range. They used three pastures; one unburned pasture stocked at 1 yearling to 3.3 acres, a burned pasture stocked a 1 yearling to 3.3 acres, and a burned pasture stocked at 1 yearling to 1.67 acres. The burned pastures were burned in late April and yearling calves were placed on pasture on May 1 and removed from pasture July 15. Steers intensively grazed had greater ADG than on

the regular stocked unburned and burned pastures. Forage reserves were lower for the intensively stocked pasture during the growing season, but after calves were removed from the pasture, reserves were restored before frost occurred.

Owensby et al. (1977) looked at the carbohydrate and nitrogen reserve cycles for continuous and intensive early stocked pastures on the Flint Hills Range.   Their objective was to determine if the two stocking methods could dramatically affect carbohydrate and nitrogen reserve cycles of big bluestem. Two, 60-acre pastures in the Flint Hills Range were used in this study. Thirty-six steers were grazed on one, 60-acre pasture from May 1 to July 15. The stocking rate was 2.5 acres per animal unit. Another 60 acre pasture was grazed by eighteen steers from May 1 to October 1. Stocking rate was 5.0 acres per animal unit and each pasture had been burned in late April for the previous ten years. Total nonstructural carbohydrate (TNC) reserves were lower throughout the grazing season on the intensive early stocked pasture. Stocking rate had no apparent affect on nitrogen reserves cycles in this study. The authors' conclusions were that intensive early stocking can be used to maximize beef production on native range without damaging the plant community because active growing species will continue to conduct TNC storage even after cattle have been removed from pasture.

Nutritive Value of Flint Hills Pastures

Rao et al. (1973) observed the seasonal changes in the nutritive value of bluestem pastures. In this study they used esophageally-fistulated steers to obtain grazed forage samples to determine to the nutritive value of grazed forage and to measure energy and crude protein of Flint Hills Range during the summer growing season. Individual esophageal samples were taken from each animal monthly during the months of June to October. Protein of the forage on the range declined from 8.84% in June to 5.12% in October. In vitro organic matter digestibility

declined as the summer months progressed. From this research, the authors concluded that

protein becomes limiting in mid-July and energy becomes limiting in late August. Furthermore,

utilization of the available protein and energy would be beneficial if grazing takes place early in

the growing season.

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CHAPTER 2 - Effects of Restricting Dry Matter Intake to Stocker Calves and its Subsequent Effects on Grazing, Feedlot Performance, and Carcass Characteristics

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Introduction

Stocker operators prepare young, disease-prone calves for entry into the finishing segment of the beef industry. This is accomplished by utilizing various forages, feedstuffs, and grain by-products for maximum voluntary intake, which allows for efficient and desirable gains (Murphy and Loerch, 1994; Blasi et al., 2000). Previous research has shown that desirable production efficiency occurs when the DMI level is below ad libitum intake (Clark et al., 2007). Restricting intake can be advantageous to stocker operators (Galyean, 1999). This feed management strategy allows for a slower rate of feed passage in the gut thereby promoting increased diet digestion and perhaps reducing the amount of feed required to reach a predetermined end-point (Loerch, 1990; Reinhardt et al., 1998; Clark et al., 2007). It is unknown what extent of compensatory gain occurs when calves are limit-fed prior to introduction to native grass pastures of excellent nutrient composition. The objectives of this experiment were to evaluate three different limit-feeding strategies in a drylot scenario and their effects on subsequent grazing and finishing performance.

Materials and Methods

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The procedures used in our study were approved by the Kansas State University

Institutional Animal Care and Use Committee.

Crossbred, weanling calves, (n = 329; 191± 5.52 kg) were received at the Kansas-State

University Beef Stocker Unit (KSU-BSU) in February 2007. Upon arrival, calves were

weighed, assessed for sex status (bull vs. steer), and tagged. Calves were penned randomly and

fed prairie hay overnight. Twenty four hours after arrival, calves received a metaphylactic

dose of antibiotic (Draxxin®), they were vaccinated for clostridial and viral diseases, and they

were de-wormed. Bulls were castrated and evenly distributed among all pens. All animals

were initially offered a high-forage receiving diet (Table 2.1).

Following processing, all calves were arranged in a randomized complete block design

involving 3 blocks of 8 pens each with 2 replications of each treatment within each block. Pen

served as the experimental unit for performance measurements; there were 13-15 steers in each

pen. All steers were allotted 61 cm of bunk space. Three previous rounds of cattle

(approximately 900 head total) at the KSU-BSU achieved an average ad libitum DMI of 3.00%

BW. Therefore, treatment DMI restrictions were based on this figure. The restricted DMI

treatments consisted of 2.50% of BW, 2.25% of BW, and 2.00% of BW. Steers were fed two

step-up, grower rations (Table 2.1) for 18 d before initiation of the trial. Steers were weighed

on d 15; sufficient protein and energy were provided to achieve an ADG of 1.40 kg/d, 1.28

kg/d, and 1.14 kg/d for calves restricted to a DMI of 2.50%, 2.25%, and 2.00% of BW,

respectively (NRC, 2000). Feed delivery was then determined for the three restricted

treatments for the next 15 d. Ad libitum fed steers were fed on a slick-bunk management

scheme developed under the KSU bunk scoring system. No feed remaining in the bunk was

noted 0; <1 was nearly no feed remaining in the bunk; < 3, 5, 5-10, and 10-15 corresponded to

the approximate pounds of feed remaining in the bunk. Feed delivery was adjusted prior to feeding to account for refused feed. Upon initiation of the trial, steers were fed their respective treatment amount for 45 d in 2 equal feedings (0700 and 1600 h). Upon conclusion of the trial period, all steers were fed ration 3 (Table 2.1) at 2.00% BW to reduce the variation in gut-fill for 5 d. Dry matter intake was calculated based on ADG from previous 15 d intervals and adjusted on d 30, 45, and 62. Final weights were collected on d 67.

Grazing

On d 67, steers were de-wormed and implanted with Ralgro® and placed on burned, Flint Hills, tallgrass pasture for 90 d. Steers were organized into a balanced incomplete design such that all treatments were equally represented across 13 paddocks. Paddocks were stocked at 281 kg live weight per hectare. Body weights were collected on d 45 after the initiation of grazing. Following d 90, cattle were placed in their previous pens for 5 d and fed the receiving ration at 2.00% BW (Table 2.1) to reduce the variation in gut-fill at the conclusion of the grazing period. Hand-clipped forage samples were taken during May, June, early-July, and mid-July (Table 2.2).

Feedlot

Steers were sorted by body weight into one of four groups based on expected finishing date and were shipped to Hays, Kansas (Hays Feeders; division of Pratt Feeders Inc.). Each group was placed into a separate pen and fed a common feedlot diet. Entire pens were harvested when average steer BW reached 545 kg. Feedlot performance and carcass merit were measured on 263 of 329 steers; 66 identification tags were lost during processing at the slaughter facility.

Statistical Analysis

The GLM procedure (SAS Inst. Inc., Cary, NC) was used to determine that there was no interaction between treatment and block during the drylot backgrounding portion of the experiment. This allowed for the pens within a treatment to be merged and equally distributed among paddocks. The PROC MIXED procedure, with receiving treatment as the main effect, was used to analyze final weights and ADG for both the backgrounding and grazing periods. Feed efficiency was also analyzed during the backgrounding period. Treatment means were calculated using the LSMEANS option and means were separated using LSD when protected by a significant ($P < 0.05$) F-test. Statistical significance was determined to occur at $P < 0.05$. Feedlot performance (i.e., ADG and final live weight) and carcass characteristics were evaluated using a general linear model (PROC GLM) . Days on feed was used as the response variable and entry weight into the feedlot was used a covariate. The relationship between each treatment and days on feed was evaluated using Chi-Square (PROC FREQ).

Results

Backgrounding

The effect of restricting DMI on growing cattle during the backgrounding period are presented in Table 2.3. Restricting DMI during the backgrounding period decreased ($P < 0.001$) ADG by 27, 32, and 49% for the 2.50%, 2.25%, and 2.00% BW treatments, respectively, compared to ad libitum fed steers. Steers restricted to 2.00% BW had 30 and 25% lesser ($P < 0.001$) ADG than steers fed at 2.50 and 2.25% BW, respectively. Upon conclusion of the backgrounding period, BW of steers fed at 2.50 and 2.25% BW was not different. Furthermore, final BW at the end of the backgrounding period was greatest ($P <$

0.001) for ad libitum fed steers; steers fed 2.00% BW had the lowest ($P < 0.001$) final BW. Actual DMI of the ad libitum-fed steers fed in this study was 3.08% of BW.

All steers were weighed at 14-d intervals to ensure that DMI of each respective treatment level was maintained. Average daily gain improved over time for each feeding treatment (Figure 2.2); however, observed ADG was significantly less ($P < 0.05$) than the programmed rate of gain as calculated using NRC (2000). Gain efficiency for steers was improved ($P < 0.05$) for steers fed ad libitum. All other treatments had similar G:F ($P > 0.05$).

Daily feed costs associated with ad libitum, or 2.50, 2.25, and 2.00% BW were 1.03, 0.84, 0.75, and 0.63 $/head/trt/d, respectively (Figure 2.1). These figures were calculated based on total feed consumed (i.e., Ration 3) during limit-feeding. Step-up diets and feeding to eliminate the variation in gut fill were not included.

Grazing

Grazing performance data is presented in Table 2.4. Initial grazing BW for ad libitum, 2.50, 2.25, and 2.00% BW was 267, 255, 254, and 240 kg, respectively. In general, steers that were fed at restricted DMI during the backgrounding period exhibited compensatory gain during the grazing period. Ad libitum fed steers had similar BW as steers fed 2.50 and 2.25% BW during the first 45 d of the grazing period; however, these three treatments had greater ($P < 0.001$) BW than steers fed 2.00% BW. During the last 45 d of the grazing period, ADG for restricted steers was 0.93, 0.93, and 0.94 kg/d for steers fed 2.50, 2.25, and 2.00% BW, respectively, and was greater ($P < 0.05$) than that of ad libitum fed steers (0.85 kg/d). Final BW for ad libitum, 2.50, and 2.25% BW was greater ($P < 0.01$) than that of steers fed 2.00% BW. Average daily gain for the 90-d grazing period was less ($P < 0.05$) for ad libitum fed steers than for all other treatments; ADG was similar for steers fed 2.50, 2.25, and 2.00% BW.

Total weight gain for steers during the grazing period was 89, 94, 96, and 97 kg for ad libitum, 2.50, 2.25, and 2.00% BW, respectively.

Feedlot

Feedlot performance is presented in Table 2.5. No treatment differences ($P > 0.10$) were observed in final live weight because steers were marketed at a common target weight (545 kg) within a pen. No treatment differences were observed in ADG regardless of days on feed (DOF) nor were there differences in hot carcass weight, dressing percentage, marbling score, 12th rib backfat thickness, USDA quality grade, or USDA yield grade. Conversely, DOF during finishing was influenced ($P < 0.05$) by backgrounding treatment.

At 140 DOF, there were fewer ($P < 0.001$) steers fed at 2.00% BW during backgrounding than those fed ad libitum during backgrounding. In addition, steers fed 2.00% BW during backgrounding were represented more frequently ($P < 0.05$) than ad libitum fed steers in the 160-DOF harvest group. There were no other differences between treatments. Numerically, there were more 2.00%-BW steers marketed at 179 DOF than ad libitum fed steers; however, observations were too few to perform statistical analyses due to lost identification tags on a majority of the steers in that harvest group.

Discussion

Backgrounding

Average daily gain during the backgrounding period was greater for animals that were fed ad libitum. Animals with greater DMI may also have greater maintenance requirements (Zinn, 1986 and Murphy and Loerch, 1994). Similar studies by Choat et al. (2002), Loerch (1990), Murphy and Loerch (1994), and Wertz et al. (2001) have shown that animals offered feed ad libitum had greater ADG than animals whose intakes were restricted. Since ADG was

greater for ad libitum fed steers, this resulted in heavier BW at the end of the backgrounding

period. Loerch (1990) restricted the DMI of calves for 85 d and observed similar ADG to calves

that were fed ad libitum. However, other researchers (Reinhardt et al., 1998; Wertz et al., 2001)

fed for more days during the growing period and reported similar outcomes to the present study.

In this study, ADG improved as the feeding period progressed for all restricted DMI

treatments (Figure 2.2). Rossi et al. (2001) limit-fed calves by varying the programmed rate of

gain until the calves reached a certain target weight and then increased the rate of gain to a

higher level (1.13 kg/d for the first 78 kg of BW; 1.36 kg/d for the remaining 124 kg of BW).

They reported that observed ADG was 29% higher than the predicted rate of gain among limit-

fed cattle. Conversely, Knoblich et al. (1997), Loerch and Fluharty (1998), reported that

expected ADG was less than observed ADG among limit-fed cattle.

Most studies that have investigated limit feeding progressively restricted DMI of a single

diet; therefore, NE intake decreased as DMI decreased. Schmidt et al. (2005) restricted DMI of

cattle, while maintaining NE intakes similar to those of ad libitum-fed cattle. They reported that

limit-fed steers had greater ADG than full-fed steers when DMI was restricted to 80% of DMI

but nutrient intake was similar. These authors suggested limit-feeding in this fashion allowed

improved feed efficiency and similar carcass characteristics as steers fed under traditional

feeding practices.

In our study, ME intakes were not held constant; therefore, limit-fed steers had lower

ADG than ad libitum fed steers. Since the observed ADG in this study was less than the expected

ADG and other studies have published results where programmed rates do not accurately predict

actual ADG (Knoblich et al., 1997; Loerch and Fluharty, 1998; Rossi et al., 2001; Schmidt et al.,

2005), this provides reason to believe that NRC (2000) energetic equations may not accurately

predict ADG in limit-fed situations. Ferrell et al. (1986) stated that limit-fed animals may have lesser visceral organ mass than full-fed animals and that visceral organ mass is highly correlated with maintenance requirements. Plegge (1987) also explained that limit-feeding of a given diet may increase the amount of NE available for gain due to lower maintenance energy requirements. Conversely, Hicks et al. (1990) concluded that liver size could not be used to explain improvements in feed efficiency by limit-fed animals.

In our study, feed efficiency was higher for ad libitum fed steers; however, it was unclear why feed efficiency of steers with restricted DMI. It is possible that insufficient time (45 d) was allowed for the restricted steers to adapt to their nutritional regime. Similar results were also observed by Knoblich et al. (1997) when steers fed at a programmed rate of gain for 32 d had lesser ADG and similar feed efficiency to steers fed at the same programmed rate of gain but for a longer duration.

Costs associated with feeding the steers in each treatment can be found in Figure 2.1. No statistics were performed on this data; however, feeding at a restricted DMI appeared less expensive than feeding steers ad libitum. Clark et al. (2007) reported that steers restricted to 80% of ad libitum intake had greater dry matter digestibility compared to ad libitum-fed steers which led to less fecal output. Costs of manure handling and removal were not considered in calculating production costs in our study.

Grazing

Steers that were fed at 2.00% BW during the backgrounding period had greater ADG during the first 45 d of grazing. This level of compensatory gain was inversely proportional to the degree of nutrient restriction during the backgrounding period. Owens et al. (1993) explained that the level of compensatory gain that an animal will experience is dependant on

numerous factors such as age, the quality of feed available during the realimentation period, the length of the realimentation period, and the severity of nutrient restriction that the animal experienced.

Sainz et al. (1995) noted that animals experiencing compensatory gain have greater DMI, but at the beginning of realimentation, may possess a lower maintenance requirement. Carstens et al. (1991) found that visceral organ mass, particularly the liver, increased by 40% during the first 45 d of realimentation compared to animals experiencing little to no compensatory gain. Drouillard et al. (1991) found that visceral organ mass had the greatest increase during the first 14 d of realimentation and then size reached a plateau thereafter. These studies may explain why ADG was greater during the first half of the grazing period in our study. During the first 45 d of grazing, the steers fed at 2.00% BW had the greatest ADG and steers fed ad libitum had the lowest. During the second 45 d of the grazing period, all steers had similar ADG, indicating that compensation had occurred during the early phase of the grazing period. At the conclusion of the 90 d grazing period, steers assigned to DMI-restricted treatments during the backgrounding period had greater ADG overall than full-fed steers. After the first 45 d of grazing, steers that were fed 2.50 and 2.25% BW had similar BW as steers fed ad libitum. The degree of compensation of the 2.00% BW steers was insufficient to attain BW similar to that of other treatments at the conclusion of the grazing period.

Feedlot

No differences were observed between treatments regarding ADG, hot carcass weight, dressing percent, marbling score, 12th rib backfat thickness, USDA quality grade, or USDA yield grade between the pens. Loerch (1990) and Wertz et al. (2001) reported similar results. Conversely, there was a relationship between DOF and DMI, which was interpreted to suggest

that a restricted feeding regime may increase days to a targeted harvest endpoint. Steers that were fed ad libitum were more likely to be harvested with fewer DOF than steers restricted to 2.00% of BW during backgrounding. Reinhardt et al. (1998) reported that growing steers fed ad libitum finished 17 d sooner than steers with restricted intakes. Wertz et al. (2001) also found that heifers that were limit-fed required more days on feed to reach a predetermined endpoint. The 2.00% BW level of restriction intake may have been too severe to allow steers to compensate during the time prior to slaughter. Feeding levels restricted to at 2.50 and 2.25% BW may prove to be optimal for stocker cattle prior to grazing that will allow for decreased feed costs, improved gains during grazing and an acceptable time to reach a harvest endpoint.

Implications

The manipulation of feed intake can be economically advantageous to stocker cattle growers. Restricting DMI of a high-energy diet to 2.25-2.50% BW will reduce feed costs prior to grazing. Gains may be low when starting on feed, however, within two to three weeks, feed efficiency will improve and gains will increase. After release to high-quality pastures, calves will compensate for lesser gains observed in the drylot with greater gains on pasture providing there is sufficient dry matter available. Based on the results of this study, limit-feeding prior to grazing will reduce feed cost, maintain normal sale weights at the end of the grazing season, and not impact feedlot performance; however, if dietary intake is restricted too severely, days on feed may be increased.
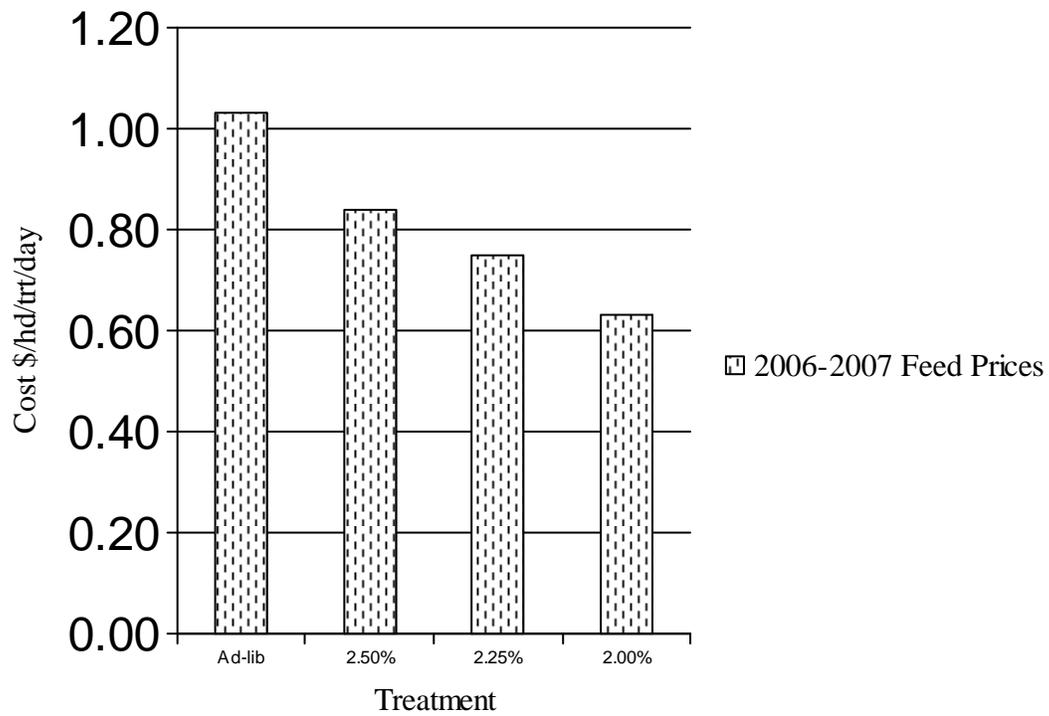
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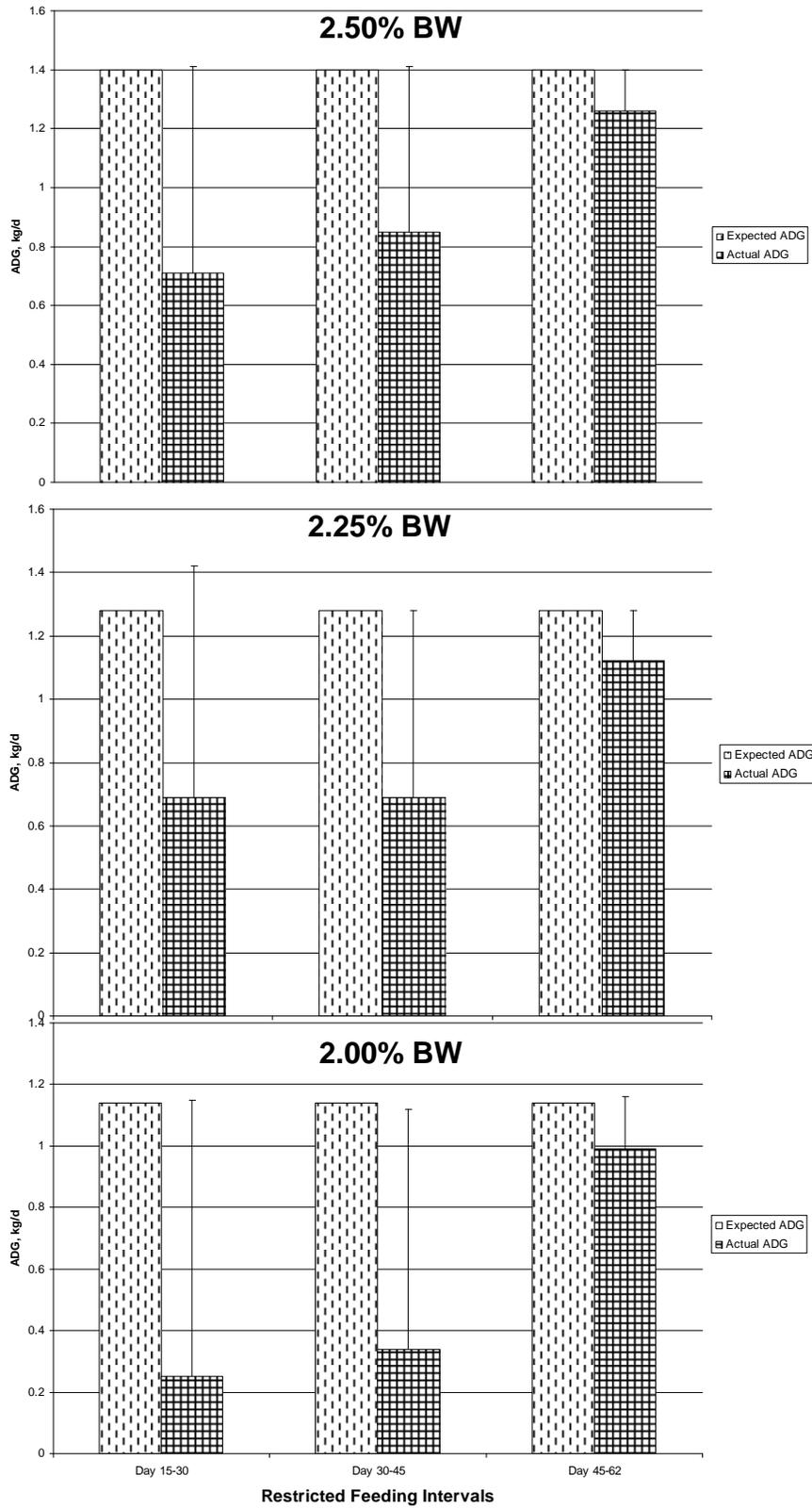
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Figure 2.1 Daily feeding costs *

- Costs based on total, as-fed intake for each treatment for 2006-2007 feed prices as received by the KSU-BSU including all three rations.

Figure 2.2 Difference between expected and observed ADG of backgrounding treatment

Table 2.1 Composition of diets for receiving calves during the backgrounding period

Item	Receiving Ration[a]	Ration 2[b]	Ration 3[c]
Ingredient	% Diet Composition		
Dry rolled corn	30.00	30.67	36.76
Wet corn gluten feed	28.00	35.96	36.76
Alfalfa hay	23.00	15.49	15.01
Prairie hay	16.00	15.19	8.47
Mineral supplement	3.00	2.70	3.00
Composition	% Dry Matter Basis		
Dry matter	78.21	75.65	76.20
Crude protein	16.07	16.54	16.21
Crude Fat	3.87	4.46	4.58
Calcium	1.06	0.83	0.84
Phosphorus	0.46	0.51	0.51
Potassium	1.18	1.03	1.07
NE_M (Mcal/kg)	0.43	0.45	0.46
NE_G (Mcal/kg)	0.28	0.31	0.32
Ration Cost*, $/ton	107.56	107.83	111.53

* Costs/ton of DRC: $152; WCGF: $60; Alfalfa: $140; Prairie Hay: $80; Mineral Suppl.: $180.

[a] Receiving ration fed for 9 days following arrival of steers.

[b] Ration 2 fed for 6 days following receiving ration.

[c] Ration 3 fed for remainder of backgrounding phase.

Table 2.2 Nutritional composition of paddocks during the grazing period

Item, %	May[1]	Early June[2]	Late June[3]	July[4]
	Forage Sample Month			
Moisture	71.10	66.36	62.45	57.02
Crude protein	15.86	9.83	10.83	8.42
Crude fat	2.80	2.35	2.58	2.97
Ash	10.40	7.43	7.30	8.22
NDF	49.88	57.26	50.88	58.41
ADF	28.45	36.05	29.05	33.94
Lignin	4.96	5.69	5.05	5.80
Calcium	0.45	0.43	0.65	0.56
Phosphorus	0.24	0.12	0.14	0.10
Potassium	2.27	1.33	1.36	1.11

[1] Hand-clipped forage samples collected May 14

[2] Hand-clipped forage samples collected June 5

[3] Hand-clipped forage samples collected June 25

[4] Hand-clipped forage samples collected July 9

Table 2.3 Performance of ad libitum and restricted DMI treatments during the backgrounding period

		Receiving Treatment*			
Item	Ad libitum	2.50	2.25	2.00	SEM
No. head	83	81	81	82	-
Initial wt., kg	191	190	191	191	0.50
Final wt., kg	267^a	255^b	253^b	241^c	9.31
Overall gain, kg	76	65	63	50	10.66
ADG, kg/d	1.42^a	1.04^b	0.97^b	0.73^c	0.12
Gain:Feed	0.23^a	0.20^b	0.19^b	0.17^b	0.06

* Receiving Treatments: steers fed ad libitum; 2.50% body weight: steers fed at 2.50% of body weight; 2.25% body weight: steers fed at 2.25% of body weight; 2.00% body weight: steers fed at 2.00% of body weight.

[a-c] Means within a row lacking common subscript differ ($P < 0.05$).

Table 2.4 Performance of ad libitum and restricted DMI treatments during the grazing period

| Item | Receiving Treatment* | | | | |
	Ad libitum	2.50%	2.25%	2.00%	SEM
Turnout wt.[1], kg	267[a]	255[b]	253[b]	241[c]	9.31
Mid-grazing wt.[2], kg	315	305	305	293	9.0
Final grazing wt.[3], kg	355[a]	350[a]	350[a]	339[b]	9.61
Overall wt. gain, kg	89	94	96	98	3.86
D 1-45 grazing ADG[1], kg/d	1.06[a]	1.10[ab]	1.14[ab]	1.17[b]	0.10
D 48-90 grazing ADG[2], kg/d	0.85	0.93	0.93	0.94	0.10
Overall ADG, kg/d	0.95[a]	1.02[b]	1.04[b]	1.05[b]	0.08

*Receiving Treatments: steers fed ad libitum; 2.50% body weight: steers fed at 2.50% of body weight; 2.25% body weight: steers fed at 2.25% of body weight; 2.00% body weight: steers fed at 2.00% of body weight

[a-c] Means within a row lacking a common superscript differ ($P < 0.05$).

[1] Turn out May 1;

[2] Mid-grazing weight collected June 15.

[3] Final grazing weights collected July 27.

Table 2.5 Chi-Square analysis of days on feed during the feedlot period

% of Background Treatment by Days on Feed[1]			
Treatment*	**140**	**160**	**179**[2]	**SEM**
2.00% BW	15.25[a]	74.58[a]	10.17	-
2.25% BW	29.23[ab]	61.54[ab]	9.23	-
2.50% BW	33.33[ab]	57.58[ab]	9.09	-
Ad libitum	42.47[b]	56.16[b]	1.37	-
Carcass characteristics[†]	**140**	**160**	**179**	**SEM**
Live wt., kg	594.8	583.9	545.5	25.90
ADG, kg/d	1.55	1.47	1.30	0.13
Hot carcass wt., kg	370.4	359.1	336.8	17.10
Dressing, %	62.28	61.52	61.73	0.39
Yield grade	2.44	2.45	2.21	0.14
Marbling	386.5	423.3	443.7	29.99
Backfat	0.47	0.45	0.39	0.04
Ribeye area	12.42	12.63	12.25	0.19
Quality grade	440.5	474.2	500	29.84

* Receiving Treatments: Free Choice: steers fed ad libitum; 2.50% body weight: steers fed at 2.50% of body weight; 2.25% body weight: steers fed at 2.25% of body weight; 2.00% body weight: steers fed at 2.00% of body weight

[†] Average carcass characteristics analyzed for individual DOF

[1] Chi-Square analysis conducted to indicate representation of each treatment within a column

[2] DOF 179 data was reported with too few observations to account for statistical significance

[a,b] Means within a column, treatment differs ($P < 0.001$)

[3] Marbling scores reported as Trace: 200; Slight: 300; Small: 400; Modest: 500; Moderate: 600; Abundant: 700

[4] Quality grade reported as 200-300 Standard; 300-400 Select; 400-600 Choice; >600 Prime