

An evaluation of bunk space requirements for limit-fed growing heifers and feeding strategies
for beef × dairy steers

by

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Abstract

Two experiments were conducted to evaluate the effects of bunk management strategy and restrictive feeding regimen on receiving cattle growth, performance, liver abscess (LA) prevalence, and feedlot performance. One option when feeding newly arrived light-weight cattle is to limit- or program-feed energy-dense diets. Previous research demonstrated that limit feeding a high-energy diet during the receiving period improved feed efficiency, illness detection, and diet digestibility when compared with feeding high-roughage diets for ad libitum intake. When limit feeding, cattle feeders have questioned the need to increase bunk allotment per calf when compared with cattle fed for ad libitum intake. Previous research on bunk allotment for limit-fed cattle fed once daily has been conducted in small pen studies containing 4 to 14 cattle per pen. In Exp. 1, a total of 332 crossbred beef heifers were used in a randomized complete block design. Heifers were blocked by origin and then stratified by weight to pens containing 18 to 28 heifers per pen. Pens within block were randomly assigned 1 of 4 treatments, providing 15.2, 25.4, 35.6, or 45.7 cm of linear bunk per heifer, with 4 pens per treatment. Heifers were limit-fed once daily at 2.0% (dry matter basis) of body weight (BW) for 56 days. Bunk allotment did not affect ($P \geq 0.09$) final BW, average daily gain (ADG), dry matter intake, or gain to feed (G:F) among treatments. However, a quadratic effect ($P = 0.05$) was observed on the standard deviation of ADG within pen, with heifers allotted 35.6 cm of bunk space having a greater standard deviation than those allotted 15.2 or 45.7 cm of bunk space per heifer. In Exp. 2, program feeding strategy and roughage and tylosin phosphate inclusion were evaluated in beef $\times$ dairy (B $\times$ D) crossbred steers for growth performance, LA prevalence, and subsequent feedlot and carcass performance. A total of 529 B $\times$ D growing steers were used in a randomized complete block design. Steers were blocked by weight and stratified to pens within block by

individual arrival weight. Pens were randomly assigned to 1 of 5 treatments, with 8 pens/treatment. Treatments included diets formulated to provide 1.1 Mcal of NEg/kg DM fed for a targeted gain of 0.91 kg/d (HR), 1.32 Mcal of NEg/kg DM fed for a targeted gain of 0.91 or 1.36 kg/d (MRL and MRH, respectively), or a diet formulated to provide 1.41 Mcal of NEg/kg DM fed for ad libitum intake with or without tylosin phosphate (ALT and ALNT, respectively). Steers were fed once daily for 126 d, and at the conclusion steers were weighed by pen, and ultrasounded for LA. Steers were then shipped to a commercial feedyard and finished on a common diet in 1 of 5 pens, based on treatment, for 179 ± 12 d. Finally, steers were sent to a commercial packing plant where carcass data and LA prevalence and severity were collected. Growing phase final BW and ADG were greatest ($P \leq 0.04$) for ALNT and ALT, intermediate ($P \leq 0.04$) for MRH, and least ($P < 0.01$) for HR and MRL. Steers fed MRL and MRH had similar ($P \geq 0.20$) G:F compared with ALNT and ALT. Feeding MRH reduced ($P \leq 0.02$) LA prevalence by 62% compared with feeding ALNT and ALT. Liver abscess prevalence did not differ ($P = 0.80$) between ALNT and ALT at the end of the growing period. Steers fed HR, MRL, and MRH had greater ADG and G:F during the finishing period compared with ALNT and ALT. At the conclusion of the finishing phase, LA prevalence did not differ ($P = 0.28$) among treatments, but MRH tended ($P \geq 0.06$) to have a higher proportion of A+ adhered LA when compared with all other treatments. Overall, program feeding a moderately energetic diet resulted in similar feed efficiency during the growing period and improved performance and efficiency during the finishing period compared with feeding a high-energy diet for ad libitum intake. Programmed-fed steers had less LA prevalence at the end of the growing period but LA prevalence at harvest did not differ among treatments. In addition, feeding tylosin phosphate did not reduce LA prevalence at the end of the growing period or at harvest. Overall, these data

demonstrate the performance benefits to restrictively feeding cattle as well as possible mitigation strategy to LA development in the growing phase. Additionally, producers do not need to increase bunk space to implement these restrictive intake strategies in existing growing systems without compromising performance or animal health.

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Chapter 1 - Review of Literature

Introduction

Newly received light-weight cattle can pose a significant risk to cattle managers. Marketing and shipping stress can result in an 85% reduction in dry matter intake (DMI) (Hutcheson and Cole, 1986). Traditionally, high roughage receiving diets are fed to growing cattle to prevent over-fleshing (reduced frame size and excessive adipose tissue), promote rumen health, and reduce metabolic upsets. Typical receiving diets contain >30% roughage, <50% cereal grains, and 30 to 40% corn co-products (Samuelson et al., 2016). However, when DMI is low upon arrival, feeding high roughage diets can result in energy and protein deficiencies leading to detrimental effects on health and performance (Spore et al., 2018). An alternative to high roughage receiving diets for ad libitum intake is to restrict intake by limit- or program-feeding diets with greater dietary energy (Galyean, 1999). Restricting feed intake can improve feed efficiency, health detection, and bunk management when compared to cattle fed traditional diets for ad libitum intake (Galyean and Hales, 2023). Historically, increasing energy concentrations through cereal grains has been associated with increased respiratory morbidity (Lofgreen et al., 1975). However, due to similarities in the clinical signs for bovine respiratory disease and ruminal acidosis, it is possible cattle identified with respiratory disease were experiencing a digestive issue rather than a respiratory challenge (Richeson et al., 2019). In the last 30 years, the availability of low starch, highly fermentable fiber corn co-products has allowed producers to increase dietary energy with lesser risk of metabolic upset (Klopfenstein et al., 2008, Spore et al., 2019). Another concern when restricting intake of growing cattle is that bunk space allotment per animal might need to be increased due to bunk aggression leading to variation in gains within a pen. Current recommendations for cattle fed once daily are 45.7 to 55.9 cm/animal (FASS,

2020). However, studies have found that bunk allotments as low as 15.2 to 20 cm did not negatively impact cattle performance or weight variation in limit fed calves (Duncan et al., 2022; Gubbels et al., 2023).

Beef $\times$ dairy (B $\times$ D) crossbred cattle have become a common class of cattle fed in the U.S. Improvements in sexed semen have led to dairies breeding large proportions of their herd to beef semen. This has resulted in increased value for dairy producers from their calves, while filling a void in the U.S. beef system (McCabe et al., 2022). The U.S. cattle inventory is at the lowest level in 70 years, which has resulted in a reduced supply of feeder calves and volatile market conditions (Cowley et al., 2024). Compared with beef cattle, B $\times$ D cattle have similar average daily gain (ADG), greater DMI, and worse feed efficiency (Foraker et al., 2022), although wide variations can be observed in performance due to breed and genetic factors (Basiel and Felix, 2022). A primary concern with B $\times$ D cattle is their increased risk of liver abscess (LA). Liver abscesses account for a \$256 million loss to the beef industry each year through liver condemnation, carcass trim, and reduced live performance (Batista and Holland, 2022; Taylor et al., 2025). Liver abscesses are a multifactorial bacterial infection of the hepatic system. The most common bacteria isolated from LA is *Fusobacterium necrophorum*, although numerous other anaerobic bacteria can be found (Nagaraja and Lechtenberg, 2007). During events of ruminal acidosis, bacteria entered the portal vein through lesions on the ruminal epithelium. Once in the liver, *Fusobacterium necrophorum* creates an anaerobic environment by depositing toxins and enzymes to create a fibrin-encapsulated abscess (Emery et al., 1986; Tan et al., 1996).

The objectives of this review is to explore how alternative management strategies for growing cattle, such as restricting intake and program-feeding can affect the health and

performance of growing beef and B × D cattle, and additionally to discuss the impacts of liver abscesses on the beef industry, their formation, and strategies for control.

Restrictive feeding for newly received growing cattle

Purchasing weaned, light-weight calves and placing them in backgrounding or stocker systems has been advantageous to grow the calves' frame size, manage illness, and prepare cattle for the feedlot phase. Growing cattle are commonly offered ad libitum access to high roughage, low-energy diets to promote intake, minimize metabolic upset, and increase frame size (Murphy and Loerch, 1994; Lofgreen et al., 1975). Cattle entering the grow yard often experience high levels of stress due to marketing and transit. Increased stress can result in reduced intake, compromised ruminal function, and challenge the immune system (Loerch and Fluharty, 1999). Reduced intake and low dietary energy concentration could lead to a negative energy balance in receiving cattle (Spore et al., 2019). Early research found that increasing energy levels in receiving diets fed for ad libitum intake led to an increased percentage of calves treated for bovine respiratory disease, hastened physiological maturity, and excessive adipose tissue deposition (Lofgreen et al., 1975; Schoonmaker et al., 2001). Another method to feed growing cattle is to restrict intake while feeding a more energetically dense diet. This can be achieved by restricting feed by 5 to 15% of ad libitum or program feeding to target a specific rate of gain. Restricting intake has been shown to reduce intake variability, improve feed efficiency, simplify bunk management, ease the transition to finishing diets, reduce manure loads, and improve morbidity detection (Galyean, 1999).

Growing cattle diets

In young calves, forage inclusion in diets stimulates rumen development, papillae, and ultimately surface area of the rumen (NASEM, 2016). A survey conducted by Samuelson et al. (2016) of consulting nutritionists stated that receiving diets typically contain 30% or more roughage on a dry matter (DM) basis. Additionally, primary roughage sources reported by nutritionists were alfalfa, cottonseed hulls, and corn silage. A meta-analysis of six studies by Rivera et al. (2005) noted that increased roughage inclusion in rations, at the expense of cereal grain, has been associated with reduced morbidity, specifically digestive disorders and bovine respiratory disease complex. Authors added that increasing roughage in the diet by 20% reduces ADG by 0.18 kg, but decreases morbidity by 1.35%. However, increasing roughage inclusion beyond 40% can offset the benefits to morbidity and cattle performance (Rivera et al., 2005). However, forage availability is volatile depending on environmental conditions. Often producers will alter roughage inclusion rates in diets depending on forage and cattle prices. It is therefore important to balance the cost benefit and energetic dilution when adding roughage to growing diets.

Dietary energy is typically increased in diets by including cereal grains. Samuelson et al. (2016) found that 87.5% of respondents used corn, either steam-flaked or dry-rolled, as their primary grain. The second most common grain source was wheat (43.5% of respondents). The energy content of cereal grains is reliant on the starch content; available starch can be rapidly fermented by microbes in the rumen to produce organic acids and volatile fatty acids. In growing cattle, the rumen is still developing, and thus greater inclusions of rapidly fermentable starch can result in acidosis, leading to reduced intake and digestive upset (Owens et al., 1998). To reduce the chance of acidosis in receiving cattle, 82% of respondents to Samuelson et al. (2016)

reported less than a 50% inclusion rate of cereal grains in receiving diets. Although finishing diets are typically more than 70% cereal grains, this reduction in receiving cattle diets allows time for microbial adaptation and reduces the risk of acidosis.

In the last 30 years, the expansion of the ethanol and corn milling industries has allowed producers to utilize corn co-products such as wet or dried distillers' grains with solubles (DGS) and wet corn gluten feed (WCGF) as significant sources of protein in cattle diets (Klopfenstein et al., 2008). Additionally, corn co-products can provide significant amounts of energy in growing diets when inclusion rates exceed 15%. Due to the corn milling process, the protein, fat, phosphorus and fiber in corn gluten feed increases 3-fold (Klopfenstein et al., 2008). Therefore, contributions of protein and fiber in these products to dietary net energy is similar to that of starch in corn (Spore et al. 2019). Replacing portions of cereal grains with corn co-products replaces dietary starch with highly digestible fiber, allowing producers to increase dietary energy while reducing the risk of metabolic upset (Scott et al., 2003). Samuelson et al. (2016) reported 96% of nutritionists formulated receiving diets containing 20 to 40% corn co-products on a DM basis. Distillers' grains are the primary co-products of the ethanol industry. In 2025, the ethanol industry produced 16.49 billion gallons of ethanol (RFA, 2026), allowing a consistent supply of DGS for producers. Crude protein content of DGS can range from 25 to 32% (DM basis), with corn gluten feed having less crude protein ranging from 14 to 24% (DM basis), where 20 to 30% of the crude protein in corn gluten feed is rumen undegradable protein (Stock et al., 2000). A study conducted by Larson et al. (1993) noted when DGS was included at 40% of the diet at the expense of corn (DM basis) feed efficiency was improved by 25%. Additionally, the authors noted a 63% improvement in diet net energy for gain, when compared to corn. Nutrient

compositions of corn co-products can vary due to inconsistent milling, and updated ingredient samples are necessary when feeding these products (Weiss, 2004).

Performance of limit-fed cattle

Growing cattle limit-fed high energy diets prior to entering the feedlot are more efficient in the growing period and perform similar in the feedlot phase to cattle that were fed traditional growing diets (Galyean, 1999). Average daily gain is similar to cattle fed high roughage diets for ad libitum intake, whereas DMI is reduced. Thus, improvement in feed efficiency is observed for limit-fed cattle. Loerch (1990) observed improvements in feedlot ADG and feed efficiency when cattle were restricted by 30% of ad libitum intake.

Dry matter intake can be reduced during the first 1 to 3 weeks post shipping due to stress related to marketing, commingling, and transportation (Hutcheson and Cole, 1986). Hutcheson and Cole (1986) reported that DMI was reduced as much as 85% when comparing the first week of arrival with the third week. One strategy to mitigate reduced DMI, and subsequent reduced energy intake, is to increase the concentration of dietary energy while restricting intake (Spore et al. 2018). The use of feedstuffs containing highly fermentable fiber can reduce the risk of digestive upset without affecting immune function (Spore et al., 2018).

Scilacci et al. (2024) compared steers fed a diet formulated to contain 0.99 Mcal of NEg/kg fed for ad libitum intake with steers fed a diet formulated to contain 1.32 Mcal of NEg/kg restricted to 2.2% of body weight daily on a DM basis. At the conclusion of an 84-d growing period, steers fed for ad libitum intake tended to have increased body weight and ADG compared with limit-fed steers. However, limit-fed steers were 30% more efficient than steers fed for ad libitum intake.

Improved feed efficiency has consistently been found in the literature when restricting the intake of receiving cattle. Galvayan (1999) reported that feed restrictions of less than 15% can account for improved feed efficiency by approximately 0.6% for each 1% restriction. Daily gain increases in a nonlinear fashion as feed intake increases (Meissner et al., 1995). This suggests a state of diminishing returns; therefore, maximum feed efficiency may occur at less than ad libitum intake. Restricting intake reduces liquid passage rate, increases ruminal retention time, thus, improving diet digestibility (Spore et al., 2019). Scilacci et al. (2024) noted a 49.5% slower liquid passage rate when comparing heifers limit fed high energy diets to heifers offered ad libitum access to high roughage feed.

Benefits of restrictive-feeding in the growing phase can have added benefits to the finishing phase. Compensatory gain occurs when limit-fed cattle are transitioned to feedlot diets fed for ad libitum intake (Galvayan and Hales, 2023). Loerch and Fluharty (1998) compared steers limit-fed to gain 1.36 kg/d from 273 to 372 kg of body weight to steers offered ad libitum access to feed (period 1). All treatment groups were offered ad libitum access to feed from 372 kg of body weight to 535 kg (period 2). At the conclusion of the first period, steers program-fed had reduced ADG and DMI when compared with those offered ad libitum access to feed. Program fed steers had a 6% advantage in ADG over steers fed for ad libitum intake. However, at the conclusion of the study, steers had similar ADG as well as final body weight, requiring only five more days on feed (DOF). Daily DMI was 5% less for steers program fed, which the authors concluded was the result of compensatory growth. Cattle fed for restricted intakes can have improved feedlot performance without increases in DOF, making restricted feeding an economic benefit to cattle feeders.

Bunk space requirements for growing cattle

Bunk space allotment for cattle fed once daily is recommended to be 45.7 to 55.9 cm per animal for calves weighing 180 to 380 kg (FASS, 2020). However, a survey of consulting nutritionists conducted by Samuelson et al. (2016) found that the average bunk allotment of newly received cattle averaged 30.3 cm of bunk and ranged from 15.2 to 45.7 cm of bunk per animal. In an ad libitum feeding system, 15 cm of bunk allotment per animal is considered adequate (Zinn, 1989). Concerns over cattle aggression and weight variation within pens when restrictive feeding growing cattle have been noted (Zinn, 1989). However, recent research has found there to be no effect on performance of growing cattle when restricting bunk space to as low as 20 to 25 cm per head, when fed once daily (Duncan et al., 2022; Gubbels et al., 2023). Another concern with restricting bunk allotment is within pen variation, possibly due to variability in cattle aggression (Longenbach et al., 1999). The standard deviation is a metric to identify within pen variation. Gubbels et al. (2023) did not observe a difference in the standard deviation of average daily gain when restricting bunk allotment from 40 cm to 20 cm for feedlot heifers program-fed to gain 1.36 kg/d. Additionally, Duncan et al. (2022) observed a similar response when limit feeding growing steers 2.0% of BW daily in bunks allotting 25 to 64 cm of space per steer. However, Harrison and Oltjen (2021) observe a greater variation in steers restricted to 20 cm of bunk space when compared with 87 cm; in this study cattle were fed to a slick bunk management system, and the authors concluded that restricting bunk space led to increased activity at the bunk and less efficient cattle. These studies were conducted on pens containing 12 to 14 cattle per pen. Further research on large pen application and cattle performance and aggression is needed (Harrison and Oltjen, 2021).

Growth and performance of growing beef × dairy cattle

Beef × dairy (B × D) crossbred cattle entering the feedlot have increased in recent years. This increase can be attributed to a reduced feeder calf population and advancements in the dairy industry. The use of sexed semen by dairy producers on high performing females has led to an increased use of beef semen on the remaining cows. Since 2017, beef semen sales in the United States have increased by 242% (NAAB, 2024). Historically, dairy bull calves have been viewed as a by-product of dairy production. Crossbred B × D calves have greatly increased the value dairy producers receive for calves. McCabe et al. (2022) found B × D male calves created a \$34.58/45.36 kg BW advantage when compared with straightbred male dairy calves. Holstein dairy cows represent a large proportion of the U.S. dairy industry, and most research has been performed on crossbreds sired by Angus, Charolais, and Simmental beef sires crossbred with Holstein or Jersey dams (Basiel and Felix, 2022). Some beef breed associations have developed tools to identify ideal sires for breeding dairy dams. Performance and carcass characteristics can differ depending on dam and sire breeds as well as genetic potential (Basiel and Felix, 2022).

A survey conducted by Foraker et al. (2022) analyzing feedlot closeout and carcass data was collected from Midwest and High Plains facilities to compare beef and B × D cattle. The authors concluded there was no difference between the two classes of cattle on final body weight, DOF, or ADG. However, DMI between straight bred dairy cattle and B × D cattle appears to be similar but, are both greater than traditional beef breeds (Berry, 2021). Thus, B × D cattle were less efficient than beef breeds, but more efficient than dairy breeds. These findings are to be expected as the energy requirements for dairy animals are higher due to frame size and internal organ mass (Barry, 2021). Carcass metrics collected by Foraker et al. (2022) demonstrated B × D cattle have lower hot carcass weight, smaller ribeye area, and greater

amount of carcass trim compared to beef breeds. The authors noted that B × D cattle represent a greater proportion of upper 2/3 choice and prime carcasses when compared with beef cattle. Marbling of B × D carcasses is consistent with that of Holsteins, which have historically had better marbling when compared with native beef cattle.

Liver abscesses

Liver abscesses (LA) develop as a result of bacteria translocating from the rumen to the liver. They are commonly associated with high grain feeding of finishing cattle. Liver abscesses account for an annual loss of \$162 to \$378 million to the beef industry (Taylor et al., 2025).

Liver abscesses are graded on a severity scale of A- (one or two small LA or scars), A (2 to 4 small LA), or A+ (multiple small LA, or 1 or more large LA). Severe LA can become adhered to the diaphragm or possibly rupture, resulting in heavy trim (Herrick et al., 2024). Carcasses with A+ adhered or open LA can reduce carcass value by 5.0 to 6.4% from condemned livers, reduced hot carcass weights, and reduced dressing percentage (Herrick et al., 2023). Additionally, losses to live performance have been noted. Net energy for maintenance can increase by 4% when LA are present, LA can impair feed utilization, resulting in poor feed efficiency (Batista and Holland, 2022). The beef industry has become more concerned with LA in recent years, as the rate of LA has increased from 12% in 2012 to 32.5% in 2021 (Grimes et al., 2024). Influx of B × D cattle in feedlots, longer DOF, and heavier carcasses could all contribute to a greater rate of LA.

Liver abscess etiology

The primary catalyst for LA development is the acidosis-rumenitis interaction. This occurs when cattle experience acidosis, leading to rumenitis, creating lesions in the rumen epithelium. Bacteria are then translocated from the rumen through the portal vein and deposited

in the liver. Liver abscesses are polymicrobial infections with the most common bacteria being *Fusobacterium necrophorum* (Nagaraja and Lechtenberg, 2007). Other bacterial species have been isolated from LA including *Trueperella pyogenes* and *Bacteroides* sp. In recent work Amachawadi and Nagaraja (2015) have also isolated *Salmonella enterica*, the first aerobic bacterium that has been isolated from a LA. This discovery has led to a theory that hind gut acidosis may also play a role in the breakdown of the large intestine mucosal barrier to allow *Salmonella enterica* to enter the portal vein. However, *F. necrophorum* possesses the most virulence.

Fusobacterium necrophorum is a rod-shaped gram-negative bacterium, and it is a natural inhabitant of the rumen. In the rumen, *F. necrophorum* metabolizes lactic acid and protein (Tadepalli et al., 2009). The concentration of *F. necrophorum* in the rumen has been found to be 10^5 to 10^6 /g. Cattle on grain-based diets have a greater concentration than cattle on foraged based diets, due to increased production of lactate during starch fermentation (Berg and Scanlan, 1981). *F. necrophorum* can be found free-floating in the rumen, attached to feed particles, or adhered to the rumen wall. During periods of increased lactic acid production and ruminal pH below 5.5, *F. necrophorum* concentration decreases (Coe et al., 1999). However, colonization of the ruminal epithelial tissue may have already taken place, and a low pH may not affect adhered *F. necrophorum* populations (Amachawadi and Nagaraja, 2022). During extended times of low ruminal pH, the ruminal epithelium can develop lesions that allow *F. necrophorum* to escape into the portal vein. *Fusobacterium necrophorum*, an anaerobe, must overcome an oxygen rich environment in the hepatic system. To do so, leukotoxin and endotoxic lipopolysaccharide protect it from phagocytosis, and additionally the release of cytolytic products such as lysosomal enzymes and oxygen metabolites destroys phagocytes (Emery et al., 1986; Tan et al., 1996).

Several virulence factors have been identified: leukotoxin, endotoxin, hemolysin, hemagglutinin, protease, and adhesin (Nagaraja et al., 2005). Nagaraja et al. (2005) also noted that the leukotoxin secreted is a novel protein, specifically targeting the leukocytes of ruminants. This creates a fibrin-encapsulated abscess, resulting in an anaerobic environment.

Control of Liver Abscesses

Reducing the risk of acidotic events is important to reducing LA prevalence. Proper management practices such as diet adaptation, increasing roughage concentration, consistent feed delivery, and accurate feed calls are important to maintain ruminal balance (Nagaraja and Chengappa, 1998). Antibiotics are the most common way to prevent the development of LA. Six antibiotics are approved for the prevention of LA in feedlot cattle: bacitracin methylene disalicylate, chlortetracycline, oxytetracycline, neomycin sulfate in combination with oxytetracycline, tylosin phosphate (TP), and virginiamycin (Amachawadi and Nagaraja, 2016). Other methods have also been researched, including vaccines, essential oils, pre- and probiotics, phytochemicals, and enzymes (Meyer et al., 2009). However, these strategies have not shown a significant reduction in LA prevalence and severity when compared with antibiotics (Broadway et al., 2024).

Two vaccines have previously been approved to reduce LA but are no longer commercially available. Fusogard (Elanco, Greenfield, IN), an *F. necrophorum* bacterin and Centuron (Merck, Rahway, NJ) a leukotoxoid. In a study conducted by Fox et al. (2009), 1,307 feedlot cattle were randomly assigned to one of 3 treatments groups: Fusogard, Centuron, and no vaccine (control). Cattle were fed for 238 days a diet containing 73% steam flaked corn and 13% roughage. Total LA prevalence was 56% with 39% being A+ severity. The use of the LA

vaccines did not reduce the incidence of LA or the severity of LA. Length of the feeding period could have contributed to poor efficacy of the vaccines (Amachawadi and Nagaraja, 2016).

Currently, TP is the leading antibiotic used to control of LA formation (Broadway et al., 2024). Tylosin phosphate is a feed-through macrolide antibiotic, commonly fed for the entire feeding period at a rate of 60 to 90 mg/animal daily. The mode of action of TP is an inhibitory effect on *F. necrophorum* in the rumen and possibly in the liver (Nagaraja and Lechtenburg, 2007). A meta-analysis concluded that feedlot cattle not being fed TP had a 30% risk of LA compared with an 8% risk when being fed TP (Wileman et al., 2009). However, even when TP is fed, 12 to 18% of feedlot cattle are reported to still develop LA (Reinhardt and Hubbert, 2015). Tylosin phosphate may not completely eliminate the risk of LA infections for three possible reasons: (1) other bacteria populations may increase when *F. necrophorum* is reduced, and cause infection; (2) antimicrobial resistance may develop; and (3) the rate at which TP is fed may not provide sufficient concentration to eliminate all *F. necrophorum* (Nagaraja and Chengappa, 1998).

Because TP is medically important for humans, recent research has focused on the reducing TP during the finishing period. A study conducted by Linneen et al. (2023) concluded feeding TP for the first 75% or last 83% of DOF produced similar LA prevalence to heifers fed TP continuously for 163 days. They also noted that reducing the use of TP for less than 80% increased the prevalence of LA by 30% compared with heifers fed TP for the entire finishing period. Feitoza et al. (2025) administered TP for the first 30 or 60 d of a 160-d feeding period. During the transition to finishing diets cattle are at a greater risk for ruminal acidosis, thus feeding TP at this time could be critical to control LA. However, at the conclusion of the feeding period, no differences in LA prevalence were observed among steers fed TP for the first 0, 30, or

60 d. Further research is needed to identify the optimal timing and duration for administering TP to reduce its use in cattle.

Liver abscesses in crossbred beef×dairy cattle

Liver abscess prevalence of dairy breeds has historically been greater than that of beef breeds (Nagaraja et al., 1996). This has been associated with increased DOF, greater intakes, and increased risk of digestive upset. The LA prevalence of B × D has been reported to be intermediate (40 to 60%) to beef and dairy breeds, although a greater variation has been observed (Foraker et al., 2022). Grimes et al. (2024) evaluated a carcass database (n=1,156,204) to identify LA status by breed; beef (n=990,648), B × D (n=36,972), and Holstein (n=129,164). The authors identified B × D cattle to have a significantly greater proportion of LA when compared with Holstein or beef cattle with LA prevalence of 50.18, 39.24, and 23.02%, respectively. Along with LA prevalence, B × D cattle have an increased rate of severe LA (>A+) when compared with the other breeds. The authors are unclear as to why B × D cattle have a higher rate of LA when compared with Holsteins, but they identified wide genetic variation and inconsistent management practices across calf ranches as possible sources.

Conclusion

Balancing intake, performance, and health of newly received growing cattle can be difficult for cattle managers and nutritionists. Cattle experiencing stress from marketing and transport will consume less, be at an increased disease risk, and possibly enter a negative energy balance. Increasing the energy density of the diet, while restricting intake, can reduce the risk of digestive upset without adversely affecting morbidity. Restrictive feeding can offer benefits to cattle efficiency, health detection, and manure and bunk management. Producers who may transition to restrictive feeding can maintain bunk space similar to cattle fed for ad libitum intake

without negatively impacting cattle performance or variation. Liver abscesses result in significant losses to the beef industry each year. Beef $\times$ dairy cattle represent a significant proportion of the beef industry, and they perform similarly to beef cattle but are less efficient due to greater intakes. Understanding the metabolic and genetic disposition for B $\times$ D cattle to develop more LA than beef or dairy cattle requires further research. Management strategies to reduce the risk of acidosis and rumenitis, and antibiotics such as TP, are currently the best way to manage LA.

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**Chapter 2 - Restricting Bunk Space Allotment to 15 or 25
Centimeters per Head has Minimal Effects on Growth Performance
in Limit-fed Growing Heifers**

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Abstract

Objective: Our objective was to evaluate the effects of bunk allotment on growth performance of receiving beef heifers limit fed a diet based on high-energy corn and corn co-products, in pens that contained 18 to 28 heifers.

Materials and Methods: Beef heifers (291 ± 15.5 kg; $n = 332$) were used in a randomized complete block design. Heifers were blocked by origin, stratified by individual arrival weight, and assigned to pen within block. Pens were randomly assigned to 1 of 4 treatments, with 4 pens per treatment, that provided 15.2, 25.4, 35.6, or 45.7 cm of linear bunk per heifer. Heifers were limit fed a highenergy diet once daily at 2.0% of BW (DM basis) for 56 d. Individual BW were measured on d 0 and 56. Pen BW were measured weekly and used to adjust feed delivered for the following week.

Results and Discussion: Bunk allotments of 15.2, 25.4, 35.6, or 45.7 cm per heifer did not affect final BW, ADG, DMI, or G:F. At feeding, 43%, 62%, 79%, and 96% of heifers in the pen had access to the feed bunk when allotted 15.2, 25.4, 35.6, and 45.7 cm of linear bunk per heifer, respectively. The SD of ADG within the pen did not differ among feed bunk sizes.

Implications and Applications: Bunk allotments as low as 15.2 to 25.4 cm per heifer can be used without negatively influencing growth performance of growing beef heifers of about 290 to 360 kg of BW that are limit fed a high-energy diet at 2.0% of BW (DM basis) once daily in pens that contained 18 to 28 head.

Key words: bunk space, growing cattle, limit feeding

Introduction

Limit feeding newly received beef cattle a high-energy diet during the growing period can improve feed efficiency without negatively influencing animal health compared with feeding a high-roughage diet for ad libitum intake (Wagner et al., 1990; Spore et al., 2018, 2019; Scilacci et al., 2024). Despite this, many cattle feeders have voiced concerns that bunk space requirements may be greater for limit-fed cattle compared with those fed for ad libitum intake. The Guide for the Care and Use of Animals in Agricultural Research and Teaching recommends 45.7 to 55.9 cm of bunk be allotted for cattle that weigh 180 to 380 kg and are fed once daily (FASS, 2020); however, a survey of consulting feedlot nutritionists indicated that the minimum bunk allotment for newly received cattle averaged 30.3 cm of bunk per head but ranged from 15.2 to 45.7 cm of bunk per head (Samuelson et al., 2016). Feed bunks represent a significant investment for cattle feeders and currently cost approximately \$77 per linear meter (Croell Inc., Dodge City, KS, personal communication). If bunk allotments must be increased for limit-fed cattle relative to cattle fed for ad libitum intake, expected improvements in feed efficiency and costs savings associated with limit feeding may not outweigh the cost of additional bunks.

Several experiments have evaluated bunk space requirements for limit-fed cattle and have demonstrated that bunk allotments as low as 12.7 to 25 cm of linear bunk per head are sufficient for cattle limit fed once daily (Zinn, 1989; Gunter et al., 1996; Duncan et al., 2022; Gubbels et al., 2023). One limitation of previous experiments is that all were conducted in small pens (range: 4 to 14 cattle per pen). Larger pen sizes could result in more aggression at the feed bunk in comparison with pens with fewer cattle. Overconsumption by aggressive calves and underconsumption by nonaggressive calves could potentially increase variation in growth performance among cattle within a pen. In addition, we are only aware of one experiment that

has evaluated bunk space requirements for limit-fed growing heifers (Gubbels et al., 2023). Therefore, the objective of our experiment was to determine whether bunk allotments of 15.2, 25.4, 35.6, or 45.7 cm of linear bunk space per heifer in pens that contained 18 to 28 heifers affect growth performance and variation of growing calves limit fed a high-energy diet based on corn and corn co-products.

Materials and methods

The Kansas State University Institutional Animal Care and Use Committee reviewed and approved all animal handling and animal care practices used in our experiment (protocol #4650).

Heifer Management

A total of 332 British × Continental crossbred heifers (initial BW of 291 ± 15.5 kg) were purchased in Texas, Kansas, and Missouri and transported to the Kansas State University Beef Stocker Unit (Manhattan, KS) between March 1, 2023, and March 10, 2023. A randomized complete block design was used with pen as the experimental unit. Heifers were blocked by origin (3) and stratified by individual arrival BW to pens within block. Two blocks were stratified across 4 pens and contained 19 or 28 heifers per pen. One block was stratified across 8 pens and contained 18 heifers per pen. Within block, pens were randomly assigned to 1 of 4 bunk allotment treatments: 15.2, 25.4, 35.6, or 45.7 cm of linear bunk per heifer. This provided a total of 16 pens with 4 pens per treatment. Before the start of the experiment, each bunk was measured, and both ends of each bunk were marked with concrete bunk dividers. In addition, portable corral panels were fastened along the bunk line so heifers could only access their designated bunk allotment. All pens were soil surfaced, were identical in size ($18.2 \text{ m} \times 15.2 \text{ m}$), and contained a concrete bunk apron ($18.2 \text{ m} \times 3.7 \text{ m}$) and one automatic water tank (Lil' Spring

3000; Miraco Livestock Water Systems, Grinnell, IA) that was located along the fence near the center of the pen.

At arrival (d -1), heifers were individually weighed in a hydraulic squeeze chute (Silencer, Moly Manufacturing Inc., Loraine, KS) and assigned an individual visual identification ear tag. After processing, cattle were randomly assigned to pens (18 to 28 heifers per pen) and offered prairie hay at 1% of BW (DM basis) and ad libitum access to water overnight. The following day (d 0) heifers were reweighed individually, assigned a pen ear tag, treated for internal (Valbezen; Zoetis, Kalamazoo, MI) and external (Clean-Up II; Elanco, Greenfield, IN) parasites, and allocated to their respective treatment pen. Heifers were fed the experimental diet (Table 1) once daily beginning at 0700 h using a Roto-Mix feed wagon (Model #414-14B; Roto-Mix, Dodge City, KS) for 56 d. On d 0, heifers were fed at 1.5% of average pen BW (DM basis). The following day, feed allocations were increased to 2% of BW daily (DM basis), where they remained for the duration of the experiment. Pen weights were measured weekly (d 0, 14, 21, 28, 35, 42, 49, and 56) and were used to adjust weekly feed calls. At the completion of the 56-d feeding period, heifers were individually weighed.

Heifer Feeding Behavior

Feed bunks were evaluated daily at 3 h after feeding using the feed bunk scoring system adapted from Boyles et al. (2003; Table 2). Bunks were assigned a score of 1 to 6 based on the amount of feed that remained. A score of 1 represented an empty bunk with no feed residue remaining, whereas a score of 6 indicated greater than 30% of feed delivered that day remained. In addition, the proportion of heifers that were eating at the feed bunk was measured weekly at feeding and 2 h after feeding. Measurements were recorded by 2 trained observers and were evaluated in the order that pens were fed. Duncan et al. (2022) reported that limit-fed steers

consumed almost all their daily feed within 3 h of delivery; therefore, we decided to evaluate the proportion of heifers at the bunk 2 h after feeding to minimize the chance of a slick bunk.

Feed Analysis

Individual feed ingredient samples were collected once weekly. A subsample of each ingredient sample was dried in a forced-air oven at 105°C for 48 h and used to determine diet DM. At the completion of the experiment, weekly ingredient samples were composited and sent to a commercial laboratory for nutrient analysis (SDK Laboratories; Hutchinson, KS). Ingredient samples were analyzed for DM, OM (100 – ash; AOAC International, 1999), CP ($N \times 6.25$; AOAC International, 1999), NDF (Van Soest et al., 1991), ADF (Van Soest et al., 1991), calcium (Bowers and Rains, 1988), and phosphorus (AOAC International, 1999; procedure 965.17).

Statistical Analysis

Growth performance data were analyzed as a randomized complete block design using the MIXED procedure in SAS (SAS 9.4, SAS Institute Inc., Cary, NC). The model included treatment as a fixed effect and block as a random effect. Treatment effects were evaluated using orthogonal, polynomial contrasts. Intake and performance data from dead heifers were removed before analysis. The proportions of heifers at the bunk at feeding and 2 h after feeding were analyzed as a binomial proportion of the total pen head count using the GLIMMIX procedure of SAS. The model included treatment as a fixed effect and block as a random effect; treatment effects were evaluated using orthogonal, polynomial contrasts. Bunk score data were analyzed as repeated measures using the MIXED procedure of SAS. The model included fixed effects of treatment, day, and treatment $\times$ day and a random effect of block. Day served as the repeated term, and the subject was pen. The covariance structure was compound symmetry as determined

by Akaike information criterion statistics. No treatment $\times$ day interactions were observed ($P = 1.00$); therefore, main effects of treatment on bunk scores are discussed. Significance was declared at $P \leq 0.05$ and tendencies at $0.05 \leq P < 0.10$.

Results and discussion

Heifer Performance

Growth performance data are presented in Table 3. At the conclusion of the 56-d feeding period, final BW did not differ ($P = 0.23$) among heifers allotted 15.2, 25.4, 35.6, or 45.7 cm of linear bunk space per heifer. Similarly, bunk allotment did not affect ($P \geq 0.17$) ADG, DMI, or G:F. Our results agree with those of Zinn (1989), who reported no improvement in growth performance when bunk space was reduced from 60 to 15 cm per animal in feedlot steers programmed to gain 1.22 or 1.45 kg/d. Similarly, Gubbels et al. (2023) observed no differences in final BW, ADG, DMI, or G:F in growing heifers allotted 20.3 or 40.6 cm of linear bunk per head that were programmed to gain 1.36 kg/d for a 109-d period. Additionally, Gunter et al. (1996) and Duncan et al. (2022) demonstrated no improvements in growth performance when limit-fed steers were allotted 12.7 to 35.6 cm or 25.4 to 63.5 cm of bunk per animal, respectively. Although growth performance did not differ statistically, there was a numeric trend for ADG to be lesser for heifers allotted 35.6 cm of bunk per head compared with heifers allotted 15.2, 25.4, and 45.7 cm of bunk per head. Reasons for numerically lesser performance for heifers allotted 35.6 cm of bunk are unclear. The overall incidence of respiratory morbidity and mortality in our experiment was low (Table 3). In total, 5 heifers were treated once for bovine respiratory disease: 1 from the 15.2-cm treatment, 1 from the 45.7-cm treatment, and 3 from the 35.6-cm treatment. In addition, 1 heifer from the 35.6-cm treatment was treated a second time for respiratory illness 4 d after the initial treatment. The 3 calves treated for respiratory disease in the

35.6-cm treatment gained 0.07 kg/d on average. If these heifers were not included in the analysis, ADG for the 35.6-cm treatment increased from 0.99 to 1.03 kg/d. Regardless, final BW, ADG, DMI, and G:F were similar among heifers allotted 15.2, 25.4, or 45.7 cm of linear bunk per heifer, which suggests that providing additional bunk space to limit-fed heifers is not necessary to optimize growth performance. One concern associated with bunk space requirements for limit-fed cattle is how bunk allotments may affect the variability of weight gain within a pen. We observed a quadratic effect ($P = 0.05$; Table 3) of bunk allotment on the SD of ADG where heifers allotted 35.6 cm of bunk had greater variation in weight gain within the pen compared with those allotted 15.2, 25.4, or 45.7 cm of bunk. Similar to ADG, when the 3 heifers treated for respiratory disease that were allotted 35.6 cm of bunk were removed from the analysis, the SD of ADG decreased from 0.39 to 0.35 kg/d (quadratic effect: $P = 0.12$; data not shown). Zinn (1989), Duncan et al. (2022), and Gubbels et al. (2023) reported no difference in within-pen SD of ADG in limit-fed cattle allotted as little as 15, 25.5, or 20.3 cm of linear bunk per head, respectively. In contrast, Gunter et al. (1996) observed a linear decrease in the SD of ADG with decreasing bunk allotments. Our observed lack of variation in weight gain for heifers allotted 15.2, 25.4, or 45.7 cm of bunk suggests that variation of gain within a pen does not increase when both feed and bunk allotment are restricted. One difference between our experiment and those previously discussed is the use of heifers rather than steers. As heifers reach sexual maturity, they may begin mounting one another, which could potentially affect growth performance when both feed and bunk allotments are limited. Gubbels et al. (2023) reported no differences in growth performance between heifers allotted 20.3 or 40.6 cm of linear bunk per head; however, heifers in that experiment were supplemented with melengestrol acetate. In our experiment, heifers were not supplemented with melengestrol acetate, but no signs of riding within the pen were observed,

suggesting that our heifers were likely not cycling. Overall, it appears that restricting bunk allotment affects limit-fed steers and heifers similarly; however, studies simultaneously evaluating the effects of bunk allotment on both steers and heifers could provide more definitive results.

Heifer Feeding Behavior

To determine how bunk allotment influenced the number of heifers that could eat at one time, the proportion of heifers consuming feed at the bunk was determined at feeding and 2 h after feeding. As expected, the proportion of heifers that could simultaneously access feed increased linearly ($P < 0.01$; Table 4) as bunk allotment increased. Overall, 43%, 62%, 79%, and 96% of heifers within each pen could access the feed bunk at feeding for heifers allotted 15.2, 25.4, 35.6, and 45.7 cm of bunk per head, respectively. Similar to our results, Lake (1986) reported that 55% and 75% of the pen could reach the feed bunk when cattle were allotted 22.9 or 30.5 cm of bunk per head, respectively. Based on visual observations, aggressive heifers would eat initially in pens where bunk space was restricted; however, these heifers would consume their initial meal and then allow less aggressive heifers access to feed. The proportion of heifers eating at the bunk 2 h after feeding also increased linearly ($P < 0.01$; Table 4) as bunk allotment increased. At 2 h after feeding, 29%, 30%, 38%, and 36% of heifers within each pen were at the feed bunk for heifers allotted 15.2, 25.4, 35.6, and 45.7 cm of bunk per heifer, respectively. Duncan et al. (2022) reported that limit-fed steers tended to consume feed more quickly as bunk allotment was reduced; however, in our experiment, bunk scores measured 3 h after feeding did not differ ($P = 0.71$; Table 4) among treatments. Overall, it appeared that all heifers had adequate access to feed, and this is further supported by the lack of a difference in the variation of ADG within pens.

Conclusion

Newly received beef cattle are typically allotted a minimum of 30.3 cm of bunk per head and are traditionally fed high-roughage diets for ad libitum intake. Limit feeding a more energetically dense diet can improve feed efficiency; however, bunk space requirements for limit-fed receiving cattle are not well defined. In our experiment, allotting 15.2, 25.4, 35.6, or 45.7 cm of bunk per head allowed 43%, 62%, 79%, and 96% of heifers within the pen access to the feed bunk at feeding. Final BW, ADG, DMI, and G:F did not differ among treatments, and restricting bunk allotment to as low as 15.2 cm of bunk per head did not increase variation in weight gain within the pen of beef heifers of 290 to 360 kg of BW during the 56-d experiment. Overall, these data suggest that bunk allotments do not need to be increased above the current industry standard for growing cattle limit fed a high-energy diet in pens containing 18 to 28 head.

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Tables

Table 2.1 Composition of experimental diet fed to heifers allotted 15.2, 25.4, 35.6, or 45.7 cm of linear bunk space per heifer and limit-fed at 2.0% of body weight (dry matter basis) once daily

Item,	% DM
Ingredient	
Dry-rolled corn	39.5
Supplement ¹	7.5
Wet corn gluten feed ²	40.0
Warm-season grass hay	13.0
Nutrient Composition	
Dry matter, % as is	75.9
Organic matter	94.9
Crude protein	14.8
Neutral detergent fiber	25.7
Acid detergent fiber	9.5
Calcium	0.80
Phosphorus	0.53
Calculated Composition ³ , Mcal/kg	
NEm	1.95
NEg	1.31

¹ Supplement pellet formulated to contain (dry matter basis) 9.2% Ca, 5.26% NaCl, and 338 mg/kg monensin. Supplement ingredients: 71.01% wheat middlings, 22.72% calcium carbonate, 5.26% NaCl, 0.39% soybean oil, 0.18% Rumensin 90 (Elanco; Greenfield, IN), 0.11% zinc sulfate, 0.08% manganese sulfate (32% Mn), 0.06% vitamin E premix (500,000 IU/kg), 0.05% copper sulfate, 0.10% selenium premix (0.99% Se), 0.008% ethylenediamine dihydriodide (EDDI) premix (9.2% EDDI), and 0.043% vitamin A (600,000 IU/g).

² Sweet Bran (Cargill Corn Milling; Blair, NE).

³ Net energy of maintenance (NEm) and net energy of gain (NEg) were calculated using NASEM (2016) tabular values of diet ingredients.

Table 2.2 Feedbunk scoring system used to evaluate the effects of allotting 15.2, 25.4, 35.6, or 45.7 cm of linear bunk space per heifer on feeding behavior of heifers limit-fed at 2.0% of body weight (dry matter basis) once daily¹

Score	Bunk Description
1	Empty Bunk; no feed residue remaining
2	Empty Bunk; evidence of fine feed particles
3	A few feed clumps and fine feed particles in the bunk
4	<15% of feed in bunk
5	15 to 30% of feed in bunk
6	>30% feed in the bunk

¹ Adapted from Boyles et al. (2003).

Table 2.3 Effects of bunk space allotment on growth performance and health of limit-fed growing heifers¹

Item,	Bunk space allotment, cm				SEM ²	<i>P</i> -value	
	15.2	25.4	35.6	45.7		Linear	Quadratic
Number of pens	4	4	4	4			
Number of heifers	82	82	83	83			
Morbidity, head ³	1	0	3	1			
Mortality, head	1	1	0	0			
Body weight, kg							
Day 0	298	297	297	297	12.0	0.09	0.72
Day 56	360	357	353	358	13.7	0.29	0.14
Average daily gain, kg/d	1.10	1.07	0.99	1.09	0.060	0.48	0.12
Standard deviation of							
average daily gain ⁴ , kg/d	0.26	0.31	0.39	0.29	0.039	0.30	0.05
Dry matter intake, kg/d	6.58	6.59	6.56	6.58	0.266	0.70	0.88
Gain:feed, kg/kg	0.167	0.163	0.151	0.165	0.0084	0.45	0.10

¹ Heifers were allotted 15.2, 25.4, 35.6, or 45.7 cm of bunk per head and limit-fed at 2.0% of body weight daily (dry matter basis) for 56 d.

² Standard error of the mean with pen as the experimental unit.

³ Number of heifers treated for bovine respiratory disease.

⁴ Standard deviation of average daily gain was calculated for each pen using gains of individual heifers.

Table 2.4 Effects of bunk space allotment on proportions of cattle eating and bunk scores¹

Item,	Bunk space allotment, cm				SEM ²	<i>P</i> -value	
	15.2	25.4	35.6	45.7		Linear	Quadratic
Bunk count ³ , %							
At feeding	42.8	62.0	78.8	96.0	2.03	< 0.01	< 0.01
2 h after feeding	28.5	29.9	37.8	36.1	3.87	< 0.01	0.39
Bunk score ⁴	3.0	2.8	3.5	3.0	0.54	0.76	0.76

¹ Heifers were allotted 15.2, 25.4, 35.6, or 45.7 cm of bunk per head and limit-fed at 2.0% of body weight daily (dry matter basis) for 56 days.

² Standard error of the mean.

³ Proportion of the pen eating out of the feed bunk.

⁴ Determined 3 hours post-feeding as described by Boyles et al. (2003). Treatment × day: *P* = 1.00; Treatment: *P* = 0.71; Day: *P* < 0.01.

Chapter 3 - Effects of feeding strategies on Performance and Liver

Abscess Prevalence of Growing Beef × Dairy Steers

Abstract

Our objective was to evaluate the effects of beef × dairy steer growing strategies on performance and liver abscess (LA) prevalence at the end of the growing period, and on subsequent feedlot performance, carcass characteristics, and LA prevalence and severity at harvest. Beef × dairy steers ($n = 529$; 295 ± 20.5 kg) were used in a randomized complete block design. Steers were blocked by weight and stratified to pens within block by individual arrival weight. Pens were randomly assigned to 1 of 5 treatments, with 8 pens/treatment. Treatments included diets formulated to provide; 1.1 Mcal of NEg/kg DM fed for a targeted gain of 0.91 kg/d (HR), 1.32 Mcal of NEg/kg DM fed for a targeted gain of 0.91 or 1.36 kg/d (MRL and MRH, respectively), or a diet formulated to provide 1.41 Mcal of NEg/kg DM fed for ad libitum intake with or without tylosin phosphate (ALT and ALNT, respectively). Steers were fed once daily for 126 d. Liver abscess prevalence was determined by ultrasound on d 0 and 126. Steers were then shipped by treatment to a commercial feedlot and penned by treatment (5) for 179 ± 12 d. Steers were fed a common commercial finishing diet at the feedlot to determine the effects of growing strategy on subsequent performance. Growing phase final BW and ADG were greatest ($P \leq 0.04$) for ALNT and ALT, intermediate ($P \leq 0.04$) for MRH, and least ($P < 0.01$) for HR and MRL. Steers fed MRL and MRH had G:F similar ($P \geq 0.20$) to ALNT and ALT. Feeding MRH reduced ($P \leq 0.02$) LA prevalence by 62% compared with feeding ALNT and ALT. Liver abscess prevalence did not differ ($P = 0.80$) between ALNT and ALT at the end of the growing period. Steers fed HR, MRL, and MRH had greater ADG and G:F during the finishing period compared with

ALNT and ALT. At the conclusion of the finishing phase, LA prevalence did not differ ($P = 0.28$) among treatments, but MRH tended ($P \geq 0.06$) to have a higher proportion of A+ adhered LA when compared with all other treatments. Overall, program feeding a moderately energetic diet resulted in similar feed efficiency during the growing period and improved performance and efficiency during the finishing period compared with feeding a high-energy diet for ad libitum intake. Programmed fed steers had less LA prevalence at the end of the growing period but LA prevalence at harvest did not differ among treatments. In addition, feeding tylosin phosphate did not reduce LA prevalence at the end of the growing period or at harvest.

Key words: program feeding, liver abscess, beef $\times$ dairy crossbred, growing strategy

Introduction

The U.S. cattle herd is currently at its lowest level in 70 years (USDA NASS, 2025). Due to low feeder calf numbers and advancements in sexed semen, there has been an increase in the proportion of beef $\times$ dairy (B $\times$ D) crossbred cattle entering the feedlot. An estimated 12 to 15% of all cattle harvested in the U.S. are B $\times$ D crossbred cattle (Mitchell and Burdine, 2024). The influx of B $\times$ D calves began with the dairy industry's increased use of sexed semen, allowing producers to breed dairy cows with low genetic potential to beef sires to create a calf with a greater value. Since 2017, beef semen sales in the United States have increased by 7 million units per year (NAAB, 2024). Compared with traditional dairy calves entering the feedlot, B $\times$ D calves have greater average daily gains and feed efficiencies (Basiel and Felix, 2022). Compared with native beef cattle, B $\times$ D cattle have similar average daily gains, but are less feed-efficient (Schwab et al., 2024). Due to the dairy influence, B $\times$ D calves can reach larger frame and carcass sizes compared with native beef cattle but must stay on feed longer to reach common carcass fat endpoints. Typically, B $\times$ D calves are bottle fed in individual hutches until weaning; they are then started on texturized feed and commingled into large pens. As a result, B $\times$ D cattle spend more time consuming high-starch diets than native beef cattle.

One issue associated with B $\times$ D cattle is their increased susceptibility to developing liver abscesses (LA; Grimes et al., 2024). Liver abscesses result in an annual loss of \$162 to \$378 million to the beef industry, which come in the form of decreased live performance, liver condemnation, carcass trim, and processing delays (Taylor et al., 2025). The accepted theory of LA formation in cattle is the translocation of *Fusobacterium necrophorum* from the rumen to the portal vein as a result of ruminal acidosis and rumenitis (Nagaraja and Chengappa, 1998). Cattle in the feedlot are transitioned to diets containing high levels of fermentable starch. Bacteria

rapidly ferment this starch resulting in a buildup of acid in the rumen. The increased acid load damages the rumen epithelium, resulting in breakdown of the protective barrier that allows bacteria to enter the portal vein and be deposited in the liver, thus forming LA (Broadway et al., 2024). A common approach to reducing LA is the use of tylosin phosphate. Tylosin phosphate is a macrolide antibiotic that is fed at a rate of 60-90 mg/animal daily. It is used as early as 90 d of age and fed for the duration of confined feeding. More than 50% of beef cattle in the U.S. are fed tylosin phosphate (Stapleton et al., 2021). This antibiotic must be administered under a veterinary feed directive due to its medically important human application; this has led to research aimed at reducing the duration cattle are fed tylosin phosphate.

The objective of the current study was to evaluate the effects of roughage inclusion, feed intake, and tylosin phosphate inclusion on growing phase performance and LA prevalence at the conclusion of the growing phase. Additional objectives were to determine the effects of growing strategy on finishing phase performance, carcass quality, and LA severity of steers at harvest.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee reviewed and approved all animal handling and animal care practices used in our experiment. All animal procedures were conducted in accordance with the Guide for the Care and Use of Animals in Agricultural Research and Teaching (FASS, 2020).

Growing Phase

A total of 529 B × D crossbred steers (initial body weight [BW] = 295 ± 20.5 kg) were purchased in Texas and transported to the Kansas State University Beef Stocker Unit on March 20, 2024 and used in a 126-d growing study. Steers were placed in pens containing 12 to 14 steers and limit fed a common growing diet at 2.2% of BW (dry matter [DM] basis) for 5 days.

On d -1, steers were individually weighed in a hydraulic chute (Silencer, Moly MFG, Lorraine, KS) and given a visual identification ear tag. Steers were blocked by weight (heavy and light) and stratified by individual BW within block. The following day, steers were assigned to pens containing 12 to 14 steers, given a pen ear tag, and treated for internal parasites (Safe Guard, Merck, Rahway, NJ) and external parasites (Clean-Up II; Elanco, Greenfield, IN). Within block, experimental treatments were randomly assigned to 1 of 20 pens for a total of 40 pens or 8 pens/treatment. Treatments included diets (Table 3.1) formulated to provide 1.1 Mcal of NEg/kg DM fed for a targeted gain of 0.91 kg/d (HR), 1.32 Mcal of NEg/kg DM fed for a targeted gain of either 0.91 or 1.36 kg/d (MRL and MRH, respectively), or a 1.41 Mcal of NEg/kg DM fed for ad libitum intake with or without tylosin phosphate (ALT and ALNT, respectively). Only the ALT treatment received tylosin phosphate (Tylovet, Huvepharma, Peachtree City, GA) fed at a rate of 90 mg/animal/d. Pens were identical in size (9.1 m × 15.2 m) with a packed soil floor, a concrete bunk apron (9.1 m × 3.7 m), and an automatic water tank (Lil' Spring 3000; Miraco Livestock Water Systems, Grinnell, IA) that provided ad libitum access to water. Feed offerings for the program-fed diets were calculated using a spreadsheet programmed-gain calculator (Galyean, 2019). On d-0 steers program-fed received all of their calculated daily call. Steers fed for ad libitum intake on d-0 received 2.2% of BW and were stepped up daily by 0.2% until they reached ad libitum intake. Orts for steers fed for ad libitum intake (ALT and ALNT) were targeted at 10% of the previous day's feed delivery. All diets were fed once daily beginning at 0700 h using a feed wagon (Model # 414-14B, Roto-Mix, Dodge City, KS). Pen weights were measured using a pen scale (Rice Lake Weighing System, Rice Lake, WI) on d 0 and once weekly for 42 d, and every 2 wk thereafter. Pen weights were used to adjust feed calls for the diets targeting specific gains (HR, MRL, and MRH) to monitor growth performance across all

treatments. On d 126, steers were fasted for 12 h to equalize differences in gut fill and then pen weights and individual BW weights were measured. Growth performance was determined using d 0 and d 126 pen weights.

Liver Abscess Prevalence

On d 0 and 126, steers were shaved on the right side from the 9th to 13th rib. Isopropyl alcohol (70%) was applied to the hide, and each intercostal space was examined using a convex, portable ultrasound scanner (Clarius C3HD3VET convex scanner, Vancouver, BC, Canada) to identify the presence of LA. Ultrasounds began between the 12th and 13th rib and moved dorsal to ventral until the liver was no longer in view. Moving forward, each intercostal space was evaluated until reaching the 9th rib. Steers were identified as either negative (no LA) or positive (LA), no determination of quantity or severity was made with the ultrasound. Liver abscess prevalence was calculated for each pen as the number of steers positive for LA divided by the total number of steers and multiplied by 100%.

Finishing Phase

At the conclusion of the 126-d growing period, the steers were shipped to a commercial feedlot in south central Kansas where they were finished for 179 ± 12 d. Initial BW were determined using final BW of the growing period with a 4% shrink applied. Final BW were determined using truck weights at the feedlot, prior to shipping to the packing facility. Steers were assigned to 1 of 5 pens according to treatments (HR, MRL, MRH, ALT, ALNT) applied during the growing phase. Within treatment, light and heavy blocks were placed together in the same finishing pen. Each pen was fed a series of 4 common step-up rations (Table 2). Steers were fed the first ration for 5 d then stepped up every 3 d, reaching the finishing ration on d 15. All diets contained tylosin phosphate fed at a rate of 90mg/animal/d. On d 45 steers were given

an implant of either Synovex Choice, Synovex One, or Synovex Plus (Zoetis, Parsippany, NJ). Steers fed ALNT and ALT received Synovex Plus, steers fed HR and MRL received either Synovex Plus or Synovex Choice, and steers fed MRH received either Synovex Choice or Synovex One. Implant protocol was determined based on the anticipated pen projections, and as a result treatments were administered different implant protocols. Steers were fed lubabegron (Experior, Elanco, Indianapolis, IN) for the last 35 d (HR, MRH, and ALT) or 42 d (MRL and ALNT) on feed. At the conclusion of the finishing phase, steers were shipped to a commercial packing plant in Dodge City, KS. Steers were shipped by treatment on January 20, 2025 (HR, MRH, and ALT) or February 10, 2025 (MRL and ALNT). The variations among treatments in implant strategies, the number of days steers were fed lubabegron, and the total days on feed are confounding factors that may have influenced finishing performance and carcass data. Outcomes of the growing and finishing phase were averaged to identify total performance.

Carcass Characteristics and Liver Abscess Score

At the processing plant, carcass characteristics and LA severity were collected by a trained team (BCRC, West Texas A&M University). Carcass characteristics (ribeye area, marbling score, and ribfat thickness) were measured by plant camera. Quality grade was recorded by a USDA professional at the plant. Yield grade was calculated using methods described by Grimes et al. (2024); both sides of the carcass were calculated separately using camera data observed by trained university personnel from the BCRC. Livers were scored on size and number of LA present (Brown et al., 1975). Livers were scored as; A- = 1 to 2 small LA or inactive scars, A = 1 or 2 large LA or multiple small LA, A+ = multiple large LA, A+ adhesion (A+AD) = liver adhered to part of the diaphragm or gastrointestinal tract or both, A+open (A+OP) = open abscess).

Feed Analysis

Individual feed ingredient samples were collected once weekly, and 100 g of each sample was dried in a forced air oven at 105°C for 48 h to determine diet DM. At the conclusion of the study, ingredient samples were composited and sent to a commercial laboratory for nutrient analysis (SDK Laboratories; Hutchinson, KS). During the finishing phase a total mixed ration (TMR) feed sample was collected at the feed bunk directly after feeding. Five samples were collected from each step-up ration, then once monthly during the finishing phase. Feed samples collected on the same day were composited using 100 g from each feed bunk. Composited TMR samples were sent to a commercial laboratory for analysis (SDK Laboratories; Hutchinson, KS). Ingredient and TMR samples were analyzed for DM, OM (100-ash; AOAC International, 1999) CP ($N \times 6.25$; AOAC International, 1999), NDF (Van Soest et al., 1991), ADF (Van Soest et al., 1991), calcium (Bowers and Rains, 1988), and phosphorus (AOAC International, 1999: procedure 965.17).

Statistical analyses

Growing phase

Growth performance data were analyzed as a randomized complete block design using the MIXED procedure in SAS (SAS 9.4, SAS Institute Inc., Cary, NC). The model included treatment as a fixed effect and block as a random effect. Any steers that died during the study were removed and the data was adjusted to exclude their data. Liver abscess prevalence was analyzed as binomial proportions using the GLIMMIX procedure in SAS with a model that included a fixed effect of treatment and a random effect of block.

Finishing phase

Pen level growth performance data during the finishing phase were not analyzed due to confounding factors mentioned above as well as loss of repetition. Carcass data was analyzed by placing data into original growing phase pens to calculate means. Hot carcass weight, marbling, ribeye area, rib fat, and calculated yield grade were analyzed using the MIXED procedure in SAS. The model included treatment as a fixed effect, block as a random effect, and initial growing phase BW as a covariate. USDA quality grade, LA prevalence and severity were analyzed as binomial proportions using the GLIMMIX procedure. For all measurements statistical significance was declared at $P \leq 0.05$ and tendencies declared between $0.05 < P \leq 0.10$.

Results and Discussion

Growing Phase Performance

Growth performance data are presented in Table 3.3. At the conclusion of the 126-d growing study, final BW and ADG were least ($P < 0.01$) for HR and MRL, intermediate ($P \leq 0.04$) for MRH, and greatest ($P \leq 0.04$) for ALT and ALNT. Steers fed HR, MRL, and MRH exceeded their respective targeted gain values across all three program-fed treatments. HR steers gained 1.22 kg/d against a target of 0.91 kg/d, MRL steers gained 1.17 kg/d against a target of 0.91 kg/d, and MRH steers gained 1.50 kg/d against a target of 1.36 kg/d. The degree to which program fed steers exceeded targeted gains is likely due to the use of unshrunk BW entered into the program gain calculator. Given the considerable dairy influence in these cattle, differences in body composition and visceral organ proportions, could result in the programmed gain calculator over energy available for gain when compared with beef cattle. The NASEM system was developed primarily around beef breeds, and the programmed gain calculator operates on tabular NEg values and beef cattle maintenance coefficients that may not adequately capture the

metabolic characteristics of B × D cattle. This would result in B × D cattle underperforming targeted gains. Proctor et al. (2024) demonstrated that performance-adjusted NE values calculated from live performance data can differ from tabular formulated values, underscoring the need for breed-specific calibration when applying net energy systems to non-traditional cattle types.

Dry matter intake was least ($P \leq 0.01$) for MRL, intermediate ($P \leq 0.01$) for HR and MRH, and greatest ($P \leq 0.01$) for ALT and ALNT. When compared with ad libitum-fed steers, DMI was 31.7, 20.6, and 10.6% less for MRL, HR, and MRH, respectively. By design, as energy increased in the program-fed diets, DMI required to reach the targeted gain also decreased. The ad libitum treatments consumed 3.26 and 1.09 kg more DM than MRL and MRH, respectively. Despite this, gain:feed did not differ ($P \geq 0.20$) among those 4 treatments. Steers fed MRL treatment consumed 31.7% less DM than ad libitum fed steers yet achieved similar feed efficiency. This is due to greater paNEg and improved diet digestibility when intake is reduced. Scilacci et al. (2024), reported that limit-fed heifers receiving 1.32 Mcal NEg/kg DM at 85% of ad libitum intake achieved 47% greater gain:feed than heifers offered a 0.99 Mcal NEg/kg DM diet for ad libitum intake. The current study did not observe an increase in feed efficiency when steers were program fed, however, MRL steers were offered a less energetically dense diet, but maintained a similar feed efficiency to ad libitum fed steers. The convergence of feed efficiency across DMI levels in the present study underscore how reduced dietary energy density can offset the advantage of greater intake when intake is restricted.

The primary purpose of the growing period is to add frame size and promote lean tissue accretion prior to entering the finishing phase. Historically, this is accomplished through high-roughage diets fed for ad libitum intake. However, feed efficiency and cost of gain can be

improved when growing cattle are fed higher energy diets at controlled intakes (Debord et al., 2024; Scilacci et al., 2024; Spore et al., 2019). In the present study, gain:feed was the lowest ($P < 0.01$) for HR compared with all other treatments, which did not differ ($P \geq 0.20$) from one another. Steers fed HR required 10% more feed per unit of gain than MRL, MRH ALNT, and ALT. The comparatively poor feed efficiency of HR steers is consistent with their diet having the lowest dietary energy but intermediate DMI (Table 3.1). Gain:feed was similar among MRL and MRH, although performance adjusted net energy (paNE) was greater for MRL than MRH. Greater intake for MRH than for MRL may have lowered the paNE by reducing diet digestibility, whereas the greater intake of MRH than MRL may have offset the difference in energy by allowing the cattle to use more of their energy for gain rather than for maintenance

Performance adjusted net energy values (Table 3.3) were derived from live performance metrics using equations from Proctor et al. (2024) and Zinn et al (2008). The performance adjusted net energy for maintenance (paNE_m) and gain (paNE_g) was greatest ($P < 0.01$) for MRL, intermediate ($P \geq 0.42$) for MRH, ALNT, and ALT, and lowest ($P \leq 0.05$) for HR. The MRL treatment had greater paNE than all other treatments, which may reflect the combined effect of reduced intake and improved diet digestibility. However, for all treatments paNE_m and paNE_g values were below tabular formulated values across all treatments, which has been noted in the literature (Galyean et al., 2023). With data from pens containing a large number of cattle, formulated and observed NE values have strong correlation. However, Galyean et al (2023) noted when cattle are fed in smaller pens the accuracy of tabular values to predicted observed NE values is only around 40%. This could contribute to the discrepancy in observed vs formulated net energy values in the current study.

Average daily gain of steers fed ALNT did not differ ($P = 0.34$) from those fed ALT (1.72 vs. 1.70 kg/d; Table 3.3), indicating that tylosin phosphate inclusion in the ad libitum diet did not influence growing phase performance. Tylosin phosphate is labeled for the reduction of LA caused by *F. necrophorum*. Potter et al. (1985) reported a growth performance benefit associated with tylosin phosphate that was attributed to an 18% reduction in LA prevalence. Liver abscesses impair hepatic function, reduce metabolic efficiency, and can increase NEm requirements by approximately 4% (Batista and Holland, 2022). Additionally, a meta-analysis conducted by Young et al. (2026) did not observe an improvement in feed efficiency for feedlot cattle fed tylosin phosphate during the entire feeding period when compared with cattle that never received tylosin phosphate. In the current study, LA prevalence at d 126 did not differ ($P = 0.80$) between ALT and ALNT indicating that tylosin phosphate did not reduce LA formation during the growing phase when steers were fed a high-energy diet for ad libitum intake. The absence of a tylosin effect in these steers is consistent with findings from Müller et al. (2018), who reported no effect of tylosin phosphate on finishing performance or LA prevalence when comparing continuous, pulse-dosed, and no-tylosin treatments. However, A meta-analysis concluded by Wileman et al. (2009) that feedlot cattle not being fed tylosin phosphate had a 30% risk of LA compared with an 8% risk when being fed tylosin phosphate.

Finishing Phase Performance

Finishing phase performance was not analyzed statistically due to only having one replication per treatment and confounding management factors at the commercial feedlot. Descriptive statistics are presented in Table 3.5. Final BW were greatest for steers fed MRL, intermediate for steers fed MRH and ALNT, and lowest for steers fed HR and ALT during the growing phase. Increased days on feed for MRL and ALNT likely contributed to MRL having

the greatest and ALNT having greater final BW when compared with ALT. Using final BW and calculating to similar days on feed of 180 d, the difference in final BW is reduced from 70 kg to 40 kg. Adjusted final BW were greatest for MRL and MRH, intermediate for HR and ALNT, and lowest for ALT. Average daily gain was greatest for steers fed MRL and least for steers fed ALT, 1.68 and 1.10 kg/d respectively. The observed improvement in ADG is likely due to compensatory growth. Compensatory gain is often observed during ad libitum feeding of cattle that were previously program fed (Galyean and Hales, 2023). Dry matter intake was greatest for steers fed HR, MRL, and MHR than steers fed ALNT and ALT during the growing phase. Rossi et al. (2001) observed effects similar to ours following periods of program feeding, where DMI during the finishing period was greater for program-fed steers compared with steers fed a diet for ad libitum intake. Overall gain:feed was 0.15, 0.17, 0.15, 0.14, and 0.12 for HR, MRL, MRH, ALNT, and ALT respectively. The program-fed steers (HR, MRL, and MRH) were more efficient during the finishing phase compared with steers that had been fed a high-energy diet for ad libitum intake (ALNT and ALT) prior to finishing. Sainz et al. (1995) observed steers entering the feedlot that had been limit fed had a 17% reduction in net energy for maintenance requirements compared with steers offered the same diet for ad libitum intake. Steers fed ALNT and ALT likely entered the feedlot with increased maintenance requirements, increased visceral mass, and more advanced physiological maturity resulting in poorer feed efficiency (Rossi et al., 2001). Additionally, the ALNT and ALT steers on average entered the feedlot with a 52% greater LA prevalence compared with HR, MRL and MRH steers. Batista and Holland (2022) reported that LA can impair feed utilization, resulting in a reduction in feed efficiency.

The combinations of growing and finishing observed outcomes resulted in HR, MRL, and ALT being 1.4 kg/d and MRH and ALNT being 1.5 kg/d. Dry matter intake was greatest for

steers fed MRH, ALNT, and ALT and lowest for steers fed HR and MRL, DMI was 9.5, 9.4, 9.6, 9.1, and 8.6 respectively. Thus, resulting in the greatest gain:feed for steers fed MRL, MRH, and ALNT, and lowest for steers fed HR and ALT during the growing period. However, the effects of extended days on feed for MRL and ALNT could have influenced our final outcomes. Across the entire study growing strategy had little impact on steers performance.

Liver Abscess Prevalence

Liver abscess data from both the growing and finishing phases are presented in Table 3.4. There were no LA present at the beginning of the experiment. At the conclusion of the 126-d growing phase, feeding MRH resulted in a 62% lower ($P \leq 0.02$) LA prevalence compared with feeding ALT or ALNT. Steers fed HR and MRL had numerically less ($P \leq 0.14$) LA prevalence compared with ALNT and ALT treatments and did not differ ($P \geq 0.48$) from steers fed MRH. The use of roughages, corn co-products, and controlled intake of cereal grains can help to maintain normal ruminal pH. This could aid in the prevention of acidosis, thereby reducing the risk of LA formation. Similarly, the use of program feeding can reduce the number of meals per day resulting in less time the animal could be exposed to subacute acidosis. Additionally, LA prevalence did not differ ($P = 0.80$) between steers fed ALNT and steers fed ALT; this data suggest the use of tylosin phosphate during the growing phase did not influence LA prevalence.

The limitations of ultrasound could influence results. Thompson et al. (2025) reported the accuracy of ultrasounding LA on cattle of a similar BW (593 kg) was 73.02%, while the sensitivity was only 5.56%. Sensitivity is the ability of the diagnostic test to designate an animal with a disease as positive. Ultrasonography can be limited by the body wall depth, rib cage, and visceral organs (Broadway et al., 2024). Thompson et al. (2025) reported that steers with a larger BW, fat thickness, and circumference resulted in a lower ultrasound sensitivity when compared

to lighter weight cattle; therefore, they concluded the likelihood of detecting a true negative is higher than detecting a true positive LA.

Prevalence of LA at harvest did not differ ($P = 0.28$) among treatment. Liver abscess prevalence was 31.9, 39.5, 43.5, 46.2, and 38.4% for HR, MRL, MRH, ALNT, and ALT, respectively. Although feeding HR, MRL, and MRH decreased LA prevalence at the end of the growing period, these data demonstrate those benefits did not carry over into the finishing phase. Abscesses detected at the conclusion of the growing phase may have healed. It has been reported in models that an abscess can form and resolve within 21 d (Broadway et al., 2024). This process leads to an increase in liver scars. Feeding high-concentrate diets in the finishing phase has a greater impact on condemned liver prevalence when compared to high-concentrate diets in the growing phase (Loerch and Fluharty, 1998). Grimes et al. (2024) reported that B×D cattle at slaughter have a mean LA prevalence of 50.18%. Our results were lower for all treatment groups. Severity of LA A-, A, or A+ did not differ ($P \geq 0.30$) among treatments; however, MRH tended ($P \geq 0.06$) to have greater A+ adhesion severity compared with HR, MRL, and ALNT. Although it is unclear if feeding strategy in the growing phase affected this, these carcasses would have resulted in the most trim.

Carcass Characteristics

Carcass data is presented in Table 3.6. Hot carcass weight was greatest ($P < 0.01$) for MRL, intermediate ($P = 0.84$) for MRH and ALNT, and least ($P = 0.62$) for HR and ALT. Total carcass weights were 475, 454, 453, 439, and 435 kg for MRL, MRH, ALNT, HR, and ALT, respectively. Increased days on feed for the MRL and ALNT likely resulted in improved carcass weight. Rib fat was greatest ($P = 0.40$) for MRL and MRH, intermediate ($P = 0.34$) for HR and ALNT, and smallest ($P = 0.11$) for ALT. Our results would align with Scilacci et al. (2024) who

found heifers restricted to 2.20% of BW daily during the growing phase had greater rib fat thickness when compared with heifers offered a high roughage diet for ad libitum intake. Ribeye area was largest ($P = 0.56$) for steers fed MRL and ALNT and smallest ($P \geq 0.34$) for HR, MRH, and ALT treatments. A possible explanation could be cattle fed MRL and ALNT being fed lubabegron for an extra 7 d as well as increased days on feed. Wendler et al. (2025) observed a 3 cm² increase in ribeye area when days on feed increased by 14 or 28 d when compared with steers fed for 198 d and lubabegron was administered for the same length. Additionally, Edmonds et al. (2024) observed a 3cm² improvement when lubabegron was fed an additional 28 days at a rate of 5.5 mg/kg of DM. Marbling score was greatest ($P \geq 0.12$) for MRL, MRH, and ALNT and lowest ($P = 0.99$) for HR and ALT. Increased marbling score has been found to be more influenced by hot carcass weight than by growing strategy (Lancaster et al., 2014), and we observed a strong relationship between marbling score and hot carcass weight. Steers fed MRL and ALNT tended to have an increased ($P = 0.20$) prevalence of prime quality carcasses, whereas HR, MRH, and ALT had a lower ($P \geq 0.26$) prevalence of prime carcasses. There were no differences among treatments for choice ($P = 0.34$) or select ($P = 0.18$) quality grade carcasses.

Conclusion

Steers fed a program-fed a moderately energetic diet during the growing period had feed efficiencies similar to steers fed a high-energy growing diet. Additionally, Liver abscess prevalence at the conclusion of the growing period was less for program fed steers. In addition, LA prevalence at the end of the growing period was not affected by addition of tylosin phosphate to the high-energy growing diet, suggesting that feeding tylosin phosphate prior to the finishing phase may not be useful. Program feeding during the growing period improved weight gain and

feed efficiency during the finishing period. However, when combining steer performance of the growing and finishing phase there was little difference between the treatment groups.

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Tables

Table 3.1 Growing phase experimental diets

Item	Treatments ¹				
	HR	MRL	MRH	ALNT	ALT
Ingredient, %DM					
Dry rolled corn	24.37	41.37	41.37	58.91	58.91
Sweet Bran ²	40.00	40.00	40.00	30.00	30.00
Warm season grass hay	30.00	13.00	13.00	7.00	7.00
Control supplement ³	5.63	5.63	5.63	4.09	-
Tylosin supplement ⁴	-	-	-	-	4.09
Nutrient composition ⁵ , % of DM					
Dry matter, % as is	76.96	76.04	76.04	78.55	78.55
Organic matter	93.40	94.43	94.43	95.64	92.88
Crude protein	14.94	15.62	15.62	14.39	13.92
Neutral detergent fiber	33.23	24.64	24.64	19.37	18.52
Acid detergent fiber	17.04	11.08	11.08	8.12	7.88
Calculated composition ⁶ , Mcal/kg					
NE _m	1.90	2.07	2.07	2.14	2.05
NE _g	1.10	1.32	1.32	1.41	1.41

¹ HR: formulated to contain 1.1 Mcal of NE_g/kg DM and fed to achieve 0.91 kg of gain/d; MRL: formulated to contain 1.32 Mcal of NE_g/kg DM and fed to achieve 0.91 kg of gain/d; MRH: formulated to contain 1.32 Mcal of NE_g/kg DM and fed to achieve 1.36 kg of gain/d; ALNT: formulated to contain 1.41 Mcal of NE_g/kg DM and fed for ad libitum intake without tylosin phosphate; ALT: formulated to contain 1.41 Mcal of NE_g/kg DM and fed for ad libitum intake with tylosin phosphate fed at a rate of 90 mg/animal/d.

² Branded wet corn gluten feed, (Cargill Corn Milling; Blair, NE).

³ Supplement formulated to contain (DM basis) 11.29% crude protein, 0.63% phosphorus, 4.7% salt, 0.73% potassium, 3.41% fat, and 474 mg/kg monensin (Rumensin; Elanco, Greenfield, IN).

⁴ Supplement formulated to contain (DM basis) 10.57% crude protein, 0.62% phosphorus, 4.7% salt, 0.68% potassium, 3.41% fat, 474 mg/kg monensin (Rumensin; Elanco, Greenfield, IN), and 213 mg/kg tylosin phosphate (Tylovet 100; Huvepharma, Peachtree City, GA).

⁵ Nutrient analysis conducted by SDK Laboratories (Hutchinson, KS).

⁶ NE_m: net energy for maintenance, NE_g: net energy for gain; calculated using NASEM (2016) tabular values of diet ingredients.

Table 3.2 Finishing phase diet composition

Nutrient composition, % of DM ²	Rations ¹				
	10	20	30	40	50
Dry matter, % as is	81.6	81.3	80.1	76.9	78.1
Organic matter	88.9	92.4	92.5	94.3	94.9
Crude protein	12.2	17.0	13.9	12.9	13.5
Neutral detergent fiber	29.4	23.3	20.6	15.7	12.8
Acid detergent fiber	21.1	16.5	12.6	10.9	7.0
NE _m , Mcal/kg ³	1.85	2.04	2.14	2.21	2.34
NE _g , Mcal/kg ³	1.17	1.31	1.41	1.50	1.61

¹ 10: arrival ration, 20: second step-up ration, 30: third step-up ration, 40: fourth step-up ration, 50: finishing ration

² Nutrient analysis conducted by SDK Laboratories (Hutchinson, KS).

³ NE_m: net energy for maintenance, NE_g: net energy for gain; calculated using NASEM (2016) tabular values of diet ingredients

Table 3.3 Effects of growing strategy on performance of growing beef × dairy steers

Item,	Treatment ¹					SEM ²	<i>P</i> -value ³
	HR	MRL	MRH	ALNT	ALT		
No. of pens	8	8	8	8	8		
No. of steers	106	105	106	107	105		
Body weight, kg							
Initial	294.9	295.4	295.4	294.9	295.2	10.84	1.00
Final	449.0 ^a	442.7 ^a	484.2 ^b	512.1 ^c	508.8 ^c	8.034	< 0.01
Average daily gain, kg/d	1.22 ^a	1.17 ^a	1.50 ^b	1.72 ^c	1.70 ^c	0.029	< 0.01
Dry matter intake, kg/d	8.18 ^b	7.04 ^a	9.21 ^c	10.31 ^d	10.30 ^d	0.105	< 0.01
Gain: feed kg/kg	0.150 ^a	0.166 ^b	0.163 ^b	0.167 ^b	0.165 ^b	0.002	< 0.01
Feed: gain kg/kg	6.69 ^a	6.03 ^b	6.16 ^b	5.98 ^b	6.08 ^b	0.104	< 0.01
paNE _m , Mcal/kg DM ⁴	1.62 ^c	1.79 ^a	1.67 ^b	1.68 ^b	1.66 ^{bc}	0.016	< 0.01
paNE _g , Mcal/kg DM ⁴	1.01 ^c	1.16 ^a	1.06 ^b	1.06 ^b	1.05 ^{bc}	0.014	< 0.01

¹ HR: formulated to contain 1.1 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRL: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRH: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 1.36 kg of gain/d; ALNT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake without tylosin phosphate; ALT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake with tylosin phosphate fed at a rate of 90 mg/animal/d

² Largest standard error of the mean

³ Treatment main effect

⁴ Performance adjusted net energy for maintenance and gain determined using equations from Proctor et al. (2023) and Zinn et al. (2008)

^{a, b, c, d} Within row, means with unlike superscripts differ (*P* < 0.05)

Table 3.4 Liver abscess prevalence during the growing phase and subsequent liver abscess prevalence and severity at slaughter

Item	Treatment ¹					SEM ²	P-value ³
	HR	MRL	MRH	ALNT	ALT		
Growing phase no. of steers	106	105	106	107	105		
Growing phase no. of pens	8	8	8	8	8		
Finishing phase no. of steers	103	105	106	105	102		
Finishing phase no. of pens	1	1	1	1	1		
Grower LA prevalence, % ⁴							
Day 0	0	0	0	0	0	-	-
Day 126	10.38 ^{ab}	11.43 ^{ab}	7.55 ^a	20.56 ^b	19.95 ^b	3.907	0.05
Finishing LA prevalence, % ⁵	31.90	39.54	43.52	46.20	38.42	6.126	0.28
Finishing LA severity, % ⁶							
A-	11.97	18.32	13.26	21.62	14.15	4.052	0.30
A	4.86	5.72	5.61	2.89	4.03	2.602	0.86
A+	1.98	1.92	3.77	4.90	6.06	1.902	0.45
A+/adhered	8.14 ^x	8.78 ^x	19.93 ^y	10.91 ^x	12.15 ^{xy}	4.750	0.06
A+/open	7.92	4.81	4.72	6.86	2.02	2.248	0.39

¹ HR: formulated to contain 1.1 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRL: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRH: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 1.36 kg of gain/d; ALNT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake without tylosin phosphate; ALT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake with tylosin phosphate

² Largest standard error of the mean

³ Treatment main effect

⁴ Liver abscess prevalence during the growing phase = (steers positive for at least one LA / total head count in pen) × 100

⁵ Liver abscess prevalence during the finishing phase = (steers positive for at least one LA / total headcount of the treatment group) × 100

⁶ A- = 1 to 2 small LA or inactive scars, A = 1 or 2 large LA or multiple small LA, A+ = multiple large LA, A+/adhesion = liver adhered to part of the diaphragm or gastrointestinal tract or both, A+/open = open abscess).

^{a, b} Within row, means with unlike superscripts differ ($P < 0.05$)

^{x, y} Within row, means with unlike superscripts tend to differ ($0.05 < P \leq 0.10$)

Table 3.5 Means for growth performance during the finishing phase

Item	Treatment ¹				
	HR	MRL	MRH	ALNT	ALT
Finishing phase no. of steers	103	105	106	105	102
Days on feed	170	191	170	191	170
Body weight, kg					
Initial	431.0	425.3	464.6	491.5	488.6
Final	690.2	746.0	718.8	719.3	676.2
Adjusted final ²	704.6	727.4	733.2	704.4	687.0
Average daily gain, kg/d	1.52	1.68	1.49	1.18	1.10
Dry matter intake, kg/d	9.98	10.15	9.71	8.47	8.85
Gain: feed kg/kg	0.152	0.166	0.153	0.139	0.124
Feed: gain kg/kg	6.56	6.04	6.52	7.17	8.04

¹HR: formulated to contain 1.1 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRL: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRH: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 1.36 kg of gain/d; ALNT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake without tylosin phosphate; ALT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake with tylosin phosphate

² Adjusted final body weight for a common days on feed of 180 d

Table 3.6 Effects of growing strategies during the growing phase on finishing beef × dairy steers carcass outcomes

Item	Treatment ¹					SEM ²	<i>P</i> -value ³
	HR	MRL	MRH	ALNT	ALT		
Finishing phase no. of steers	103	105	106	105	102		
Hot carcass weight, kg	439 ^c	475 ^a	454 ^b	453 ^b	435 ^c	15.29	< 0.01
Ribfat, cm	1.50 ^b	1.76 ^a	1.69 ^a	1.43 ^{bc}	1.30 ^c	0.066	< 0.01
Ribeye area, cm ²	92.56 ^b	98.69 ^a	92.98 ^b	97.66 ^a	94.26 ^b	2.02	< 0.01
Marbling score ⁴	521 ^b	572 ^a	541 ^a	555 ^a	522 ^b	17.06	0.05
Calculated yield grade	3.09 ^b	3.33 ^a	3.36 ^a	2.87 ^b	2.70 ^{bc}	0.116	< 0.01
USDA quality grade, %							
Prime	6.0 ^y	19.4 ^x	10.4 ^y	12.8 ^{xy}	10.2 ^y	0.033	0.06
Choice	90.0	79.6	83.0	81.4	81.6	0.039	0.34
Select	2.0	0.9	6.5	3.8	7.0	0.033	0.18

¹ HR: formulated to contain 1.1 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRL: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 0.91 kg of gain/d; MRH: formulated to contain 1.32 Mcal of NEg/kg DM and fed to achieve 1.36 kg of gain/d; ALNT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake without tylosin phosphate; ALT: formulated to contain 1.41 Mcal of NEg/kg DM and fed for ad libitum intake with tylosin phosphate

² Largest standard error of the mean

³ Treatment main effect

⁴ Marbling score: 300 = Slight⁰, 400 = Small⁰, 500 = Modest⁰

^{a, b, c} Within row, means with unlike superscripts differ ($P < 0.05$)

^{x, y} Within row, means with unlike superscripts tend to differ ($0.10 \leq P < 0.05$)

