DIET AND MANAGEMENT STRATEGIES TO MITIGATE DECREASED FEED INTAKE ASSOCIATED WITH TERMINAL IMPLANT ADMINISTRATION IN FINISHING BEEF STEERS

BY

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THESIS ACCEPTANCE PAGE

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This thesis is approved as a creditable and independent investigation by a candidate for the master's degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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DEDICATION

I dedicate this thesis degree to my parents. Because of my parents, I have become the person I am today. Dad, thank you for pushing me to be better every day. Mom, thank you for always being my safe place to land. I love you both.

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LIST OF ABBREVIATIONS

ADG	Average Daily Gain
BRD	Bovine Respiratory Disease
CP	Crude Protein
DDGS	Dried Distillers Grains Plus Solubles
DM	Dry matter
DMI	Dry matter intake
DOF	Days On Feed
EBF	Empty Body Fat
G:F	Gain To Feed
HCW	Hot Carcass Weight
KG	Kilograms
NE	Net Energy
Neg	Net Energy for Gain
Nem	Net Energy for Maintenance
REA	Ribeye Area
USDA	United States Department of Agriculture
USDA YG1	Yield Grade 1

USDA YG2	Yield Grade 2
USDA YG3	Yield Grade 3
USDA YG4	Yield Grade
Volatile Fatty Acids	VFA

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ABSTRACT

DIET AND MANAGEMENT STRATEGIES TO MITIGATE DECREASED FEED INTAKE ASSOCIATED WITH TERMINAL IMPLANT ADMINISTRATION IN FINISHING BEEF STEERS

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Terminal implant administration in beef steers often leads to decreased feed intake, leading to less growth. Our objective was to identify diet and management changes that can mitigate this decrease in feed intake. Single-sourced Angus x Simmental steers (n=27, initial BW= 385.1 ± 30.8 kg) were utilized in a completely randomized trial to assess the effects of animal movement and increased forage inclusion on rumination and feed intake after re-implanting. Steers were initially implanted with Synovex Choice (100 mg trenbolone acetate and 14 mg estradiol benzoate; Zoetis, Parsippany, NJ), then re-implanted 88 d later with Synovex Plus (200 mg trenbolone acetate and 28 mg estradiol benzoate). Steers had been consuming the finishing diet for approximately 88 d at the time of re-implanting. Steers were allocated into one of three treatment groups: CON) remained on a 1.43 Mcal/kg NE_g diet and moved a shorter distance between the pen and working facility (0.43 km), ACT) remained on a 1.43 Mcal/kg NE_g diet and moved a longer distance (1.05 km) to simulate movement in a larger feedlot and ACT + DIET) fed a 1.32 Mcal/kg NE_g diet (increased forage inclusion) and travelled 1.05 km between the pen and working facility. Individual feed and water intake was collected using Insentec RIC feeders and waterers (Hokofarm, Marknesse, Netherlands). Individual rumination data was collected with SenseHub Beef (AllFlex Livestock Intelligence, Madison, WI). No significant differences among treatments were observed for overall dry matter intake, average daily gain, gain to feed ratio, or carcass traits. No treatment effect was observed for dry matter intake for 14 days post-reimplantation. A treatment by days on feed effect was observed for dry matter intake, where CON cattle consumed more feed than ACT + DIET on multiple days after reimplanting (P = 0.03). The ACT + DIET group ruminated ~65 minutes/day more (P = 0.02) than CON for 14 days after reimplantation. No differences in total water intake for 14 days (P = 0.38) or the cumulative period (P = 0.97) were observed. Activity (calculated number of minutes standing, walking, eating, drinking) was unaffected by reimplantation (P = 0.99). Increasing forage inclusion in the diet for 7 days after re-implantation did not mitigate feed intake depression, but increased rumination for multiple days after reimplanting. When reimplanting cattle, it is recommended to limit distance calves have to travel. Nutritional management strategies utilized in this experiment indicate that increasing forage inclusion increases rumination. Previous research suggests that increasing rumination decreases incidence of acidosis, however, further research must be conducted to determine the effects of increased forage inclusion on rumen pH post-reimplantation.

REVIEW OF LITERATURE

Introduction to Ruminant Nutrition

Cattle in finishing feedlots are fed high concentrate total mixed rations (TMR). The type of concentrate used is highly dependent on availability of commodities, geographical location, and economic value. Commonly used concentrates in feedlot diets are corn products, soybean meal, and dried distillers grains plus solubles (DDGS). Another key component of each TMR is forage, which is commonly ground alfalfa hay, silage, or straw. Forage serves as a physically effective fiber in the ration and is crucial in stimulating rumination and salivation. Salivation which provides a buffer in the rumen to maintain rumen pH amid diet changes and fluctuations in external environment (McAllister et al., 2020). High quality forage in a ration is often overlooked; however, forage is critical to rumen development and microbe maintenance (Lalman et al., 1993). Another critical element of feedlot diets is a well-formulated vitamin and mineral supplement. Vitamin and mineral blends are a small percentage of a ration but play a key role in balancing metabolic need. Protein is the most critical macronutrient that animals require for growth and development. Protein can come from feeds such as soybean, cottonseed, dairy-quality alfalfa, and many others. Protein can also come from urea and non-protein nitrogen sources that rumen microbes utilize to make microbial protein which feeds the animal (Lalman et al., 1993).

Feed processing increases availability of feed digested in the rumen. Feeds are commonly processed in the United States. Some methods for feed processing are ensiling, heat treating, mechanical processing, or a combination of these methods. Silage is a feed that has been fermented through an anaerobic cycle. Silage is made from harvesting a crop, such as corn without stalks, and placing the crop in a silage bag or covered bunker to create an anaerobic environment for microbes to break down the indigestible components of the feed (Le et al., 2016). Anaerobic microbes proliferate and break down the feed, increasing digestibility when fed. A large component of successful silage processing is proper storage and management (Ramirez et al., 2019). Improvements in silage management have allowed farmers to decrease spoilage and increase storage time by maintaining an anaerobic environment. Often, the most abundantly fed feedstuff on feedlots is corn. Corn naturally has a waxy hard coating on the outside, decreasing digestibility when fed in its whole form (Owens et al., 1997). Grains such as barley and wheat also have hard outer coatings. Smaller grains are more likely to pass through the rumen and intestines without being digested or utilized (Owens et al., 1997). Steam-flaking corn involves softening the corn by steaming, and then rolling the corn through a machine which crushes the corn kernel. This process creates a much larger surface area as the corn passes through the rumen, increasing availability to rumen microbes (Lardy 2018).

Acidosis : Metabolic Disease Associated with Feedlot Cattle

Acidosis is one of the most prevalent diseases in feedlot cattle. Acidosis is caused initially by a sharp decrease in rumen pH, which disturbs microbial populations (Galyean et al., 2002). Two types of acidosis occur in feedlot cattle. The first type is subacute, or subclinical acidosis, and the second type is acute acidosis. Clinical signs of acidosis are bloat, diarrhea, ruminitis, laminitis, polio encephalomalacia, and liver abscesses. Acidosis has detrimental effects on feed intake and efficiency. Change in feed intake is the primary sign of subacute acidosis. Cattle exhibit signs of subacute acidosis more subtly than acute acidosis. Acute acidosis needs to be treated quickly to prevent mortality (Hernandez et al., 2014). Acidosis also weakens the immune system, which predisposes cattle to developing laminitis, polio encephamalacia, and liver abscesses (Owens et al. 1998).

Finishing feedlot cattle consume high concentrate rations, with rations consisting of 70-90% concentrate. Grain and starch in feed is digested and converted to glucose. Glucose then undergoes glycolysis to create volatile fatty acids (VFA) for utilization within the body. Glycolysis creates pyruvate, which is used to synthesize VFAs. Two types of lactate, D-lactate and L-lactate are formed from pyruvate. Bacteria and other microorganisms create D-lactate and L-lactate, is a byproduct created from the conversion of pyruvate to VFAs. Accumulation of L-lactate due to rapidly increased consumption of starch causes rumen pH to become acidic and negatively affects rumen microbes (Muir et al., 1981). Decreased rumen health is directly associated with decreased intake and decreased rumination. Saliva is one of the key buffers for the rumen. Decreased rumination in turn decreases saliva production. Thus, if cattle stop eating feed due to metabolic upset (acidosis), saliva production, rumination, and dry matter intake all decrease. Recovery time from a single acidotic event must be considered (Huber, 1976). An incidence of acidosis may decrease dry matter intake (DMI) up to 10 d after the initial acidotic event.

Different bacteria are associated with different pH changes (Nagaraja et al., 2007). Rumen acidosis is associated with decreased populations of lactate-consuming (gram-negative) bacteria and increased populations of lactate-consuming (gram-positive) bacteria, in response to cattle ingesting toxic amounts of highly fermentable carbohydrates that change the rumen microbial population (Slyter 1975). Normal pH of ruminants consuming high-concentrate diets is between 5.5-5.6. *Streptococcus bovis* (gram-negative, *Lactobacillus* species) proliferates during the process of digestion and produces lactic acid. If lactic acid accumulates in the rumen, rumen pH decreases. If lactic acid accumulates in the rumen, gram-positive bacteria are not able to utilize lactic acid at the same rate this acid is being produced. Several examples of gram-negative bacteria are *Megasphaera elsdenii* and *Selenomonas ruminantium* (Nagaraja et al., 2007). When rumen pH is less than 5.5, gram-negative bacteria are destroyed, continuing the increase in lactic acid in the rumen and decrease of *Lactobacillus (*Constable 2022). If cattle are not consuming toxic amounts of highly fermentable carbohydrates, lactate-consuming bacteria will proliferate when lactate is abundant and will convert lactate to pyruvate (Owens et al., 1998). *Lactobacillus* species are also responsible for producing DL-lactate, which is the type of lactate that crosses into the bloodstream and causes metabolic acidosis when DL-lactate is too abundant (Hernadez et al., 2014). Metabolic acidosis is associated with long-term effects on immune and cellular function, and is fatal in severe cases (Constable 2022).

Feeding Behavior

Acidosis is primarily onset by inconsistencies in nutritional management. Adaptation to high-concentrate diets is important to ensure that microbial populations have developed to support high consumption of highly fermentable carbohydrates such as corn. Step-up diets are often part of a feedlot receiving protocol. Cattle that arrive at a finishing feedlot will be slowly adapted to the finishing diet over the course of several weeks, increasing concentrate every 7-10 days (Nagaraja et al, 2007). Irregular feed delivery, feed withdrawal, or both have detrimental effects on rumen microbiota, blood chemistry, and animal behavior. With inconsistent feed availability, cattle are more likely to have less frequent and longer feeding bouts. Acidosis can also occur with long-term feed withholding (Rabaza et al., 2020). Feed withholding causes cattle to gorge themselves when feed is delivered. Large intake of highly fermentable carbohydrates can be toxic and negatively affects rumen pH (Constable 2022). Effective nutritional programs provide a proper adaptation period to high-concentrate diets and practice consistent feeding strategies.

In 2011, Moya et al. explored how feeding behavior and ruminal acidosis was affected by different ration presentations (free choice grain or TMR) and found that diet presentation did not affect cattle's ability to self-regulate consumption. Heifers that ate a TMR had smaller, more frequent meals. Even though cattle consumed TMR more consistently in smaller quantities compared to free choice treatments, VFA profiles were not significantly different between groups. Finishing feedlot cattle fed free choice diets containing barley grain self-regulated intake of diets that have a similar composition and ruminal fermentation profile to those fed a TMR (Moya et al., 2011). Feedlot cattle consume feed until their caloric and nutrient requirements are fulfilled. The mechanism of cattle eating to caloric satisfaction is referred to as chemostatic fill. Chemostatic fill regulates cattle's satiety signals. Chemostatic fill and physical fill work in together to create a balanced feeding cycle (Fisher, 1996). Physical fill is a limiting factor when cattle are young and rumen capacity is smaller due to body size. When cattle are young and on a low-energy, forage-based diet, they will consume a higher quantity of feed. As cattle grow closer to mature weight, and cattle are on high-energy, concentrate-based diet, their caloric needs are met with less quantity of feed. Results from the study presented above show that cattle self-regulate intake based on chemostatic fill. Frequency of smaller meals maintain consistent digestion and rumination, where the consumption of larger, more inconsistent meals creates influxes of glucose which create an imbalance of lactate, thus leading to acidosis (Owens et al., 1996)

Dry Matter Intake and Gain

Compensatory gain occurs when periods of restricted or decreased feeding occur. Severity of compensatory gain is more affected by severity than the duration of the DMI depression (Droulliard, 1991). Imposed compensatory gain was hypothesized to be an effective nutrition management strategy; however, effects on carcass traits were not favorable. Fat deposition requires time and consistency. Marbling is an intrinsic property of growth; periods of decreased DMI decrease marbling scores and backfat thickness (Sainz et al., 1995). Despite risk associated with compensatory gain, periods of decreased DMI can improve feed efficiency. If gain is not negatively affected by decreased DMI, temporary financial savings will occur due to decreased feed costs. However, if gain decreases with decreased DMI, calves will need more time on feed to reach terminal weight and fat thickness. Gain is largely related to composition of the carcass and frame size (Smith et al., 1977). Larger-framed calves have higher maintenance costs, thus require more feed to achieve gain. Smaller-framed calves require less feed for maintenance costs to be covered, thus will gain more efficiently (Caton et al., 2016). Periods of decreased DMI cannot be guaranteed to increase or decrease feed efficiency, due to situational differences. However, if gain is maintained despite restricted feed or decreased DMI, decreased intake may not be detrimental to income or overall growth performance.

Feedlot cattle rations typically contain 6-12% roughage (hay, silage) (Turgeon et al., 2016). Forage stimulates saliva production and increases rumination time, thus creating buffer for the rumen (Beauchemin, 1991). Inclusion of forage provides physically effective neutral detergent fiber (peNDF), which decreases incidence of acidosis (Chibisa et al., 2020). Increasing forage inclusion of feedlot diets decreased the incidence of acidosis, but imposed compromise in growth performance due to decreasing energy consumption. Corn silage inclusion (12%) in feedlot diets decreased but did not completely mitigate acidosis incidence. Type of forage does have an effect on rumen response. Koenig et al. (2020) tested effects of barley silage inclusion in feedlot diets to decrease incidence of acidosis, and found that acidosis incidence was unaffected, but the inclusion of barley silage decreased feed efficiency. Rumen pH or rumination was not measured. Limitations of current research on this topic result from lack of knowledge of how most major feed types effect rumen microbial population.

Use of Growth Promoting Technologies on Feedlots

Implants containing steroidal hormones with anabolic activity are used in cattle operations to maximize efficiency and decrease cost of production. Implants utilize naturally occurring hormones to support muscle accretion thus increasing growth performance. Implants are a tool used by producers to reduce the cost of feeding cattle by improving feed efficiency and improving quality and yield grades (Duckett et al., 2001). Implants are administered subcutaneously, in the upper two thirds of the cattle’s ear, and slowly release hormones that are encapsulated in pellets. Dosage and type of implant are dependent on age, body weight, type of feed, and determined finishing endpoint. Implants vary by dosage and hormones used depending on whether cattle are in the weaning, backgrounding, or finishing production phase. Most feedlots administer multiple implants to increase muscle accretion and delay fattening to increase harvest carcass weight of cattle at lower cost (Smith et al., 2022). Implants are available for beef and dairy cattle in all stages of life. Beef cattle will likely receive 4 implants in their lifetime in the USA if fed to a terminal endpoint within their first two years of life. Beef cattle used for breeding, replacement, or grazing purposes will likely receive fewer, less frequent implants. Dairy cattle fed to slaughter within the first two years of life will likely receive multiple implants in the USA as well. Though differences in composition and frame size pose relevant challenges for dairy cattle versus beef cattle, implants provide an option for maximizing muscle growth in all types of cattle.

Dosage and Type

Six commonly used implanted hormones estradiol-17β (estradiol), testosterone, trenbolone, zeranol, melengesterol acetate, and progesterone (Meyer, 2000). Hormones used in implants are naturally occurring and circulating in the body. Male and female animals have different baseline levels of circulating hormones depending on age and status of reproduction, i.e. intact/castrated, open/pregnant. Implants include one or a combination of hormones to stimulate genes responsible for muscle growth (Smith et al., 2019). When implants were first developed and introduced into the market in 1956, the dosage producing the largest effect on growth was unknown. Estrogen, progesterone, zeranol were the first hormones used in implants. In 1987, trenbolone acetate was approved to be used in combination with other hormones (Zobell et al., 2006). Today, dosage is based on stage of production. Estrogen increases lean muscle growth by stimulating an increase in growth hormone in both sexes. Estradiol-17β also increases protein deposition in skeletal muscle and decreases nitrogen excretion (Meyer, 2000). Estradiol alone increases average daily gain by 7% without the addition of other androgenic compounds (Grant et al., 1992). Estradiol is most effective in improving growth performance and carcass characteristics when used in combination with another androgenic compound such as trenbolone acetate. Therefore, one combination of hormones in modern implants is estradiol benzoate (EB) and trenbolone acetate (TBA) (Duckett et al., 2001).

The TBA and EB implants increase muscle accretion and delay fat deposition. Implanting with TBA and EB increased average daily gain (ADG) by 18% in the first 40 days, but implanting did not increase dry matter intake (DMI) in the same 40-day period (Dayton et al., 1996). Cattle that were implanted with TBA and EB were therefore more efficiently utilizing feed. Cattle implanted with a higher dosage of TBA and EB had higher average daily gain (ADG) and higher DMI (Smith et al., 2020). Administered together, implanting cattle with TBA and EB increases growth performance and average daily gain over the finishing feeding period. Implanting with TBA and EB may also improve feed efficiency.

Timing of Implants

Slaughter withdrawal is not required in the USA for implants used in beef production systems. The Food and Drug Administration (FDA) requires that labels for administration are followed according to timing of administration based on other implants cattle have received, thus regulating the dosage of compounds. The United States Department of Agriculture (USDA) guarantees that any animal slaughtered in the United States will be free of antibiotics. Steroidal implants contain naturally circulating hormones, so administration of implants is not regulated like antibiotics. Nevertheless, when considering implanting cattle, it is important to account for the time between implant to slaughter to guarantee that the dosage is correct over the entire duration of the feeding period. The time between implant administration to the time when the implant is no longer effective is known as implant payout, or the effective anabolic payout period. The two physical factors that affect implant payout period are 1) dosage of implant and 2) whether the implant is coated or non-coated. Coated implants include additional compounds such as lactose or cholesterol to create a time-release effect and these implants degrade more slowly over time. Non-coated implants only include anabolic compounds plus necessary ingredients and are primarily used in cattle that are going to be implanted more than once.

Approximately 80% of steers receive more than one implant from the backgrounding to finishing phase in the USA. Federal rules and regulations limit the dosage of compounds contained in a single dose of an implant. Reimplanting cattle after the effective anabolic payout period of the first implant ensures that cattle will continue to increase feed efficiency and delay fattening as cattle approach their terminal endpoint. Effective anabolic payout in low to moderate potency implants varies from 70-140 days. Best practice for maximizing utilization of the implant indicates that reimplanting should not occur before the anabolic payout has passed. Most commonly, cattle are reimplanted with a high potency implant that has an anabolic payout of 150-200 days. Typically, stocker calves received on a finishing feedlot will weigh between 270-360 kg, and the finishing phase will be 150-200 days long. If cattle will be in the feedlot for a longer duration than anabolic payout period of a single, coated implant, a reimplant program should be considered.

Impact of Reimplanting

Every processing event requiring labor, supplies, and facility usage has a financial and opportunity cost. The tradeoff of the opportunity cost is normally associated with the promise that the implant will increase growth performance and therefore increase income. The cost of labor, cost of operating the chute, and the implant itself are the largest costs to consider when reimplanting. A decrease in dry matter intake is often observed following reimplantation for up to 14 days. In commercial feed yards in Kansas, Nebraska, Iowa, and Texas, DMI for 10 days before and after a reimplant procedure was evaluated (*n* = 321 pens). The 47,000 cattle evaluated consumed an average of 0.2 kg less dry matter for 10 days following reimplantation. Sixty-one percent of the pens decreased DMI following reimplant, whereas 39% of pens did not differ or had increased DMI before and after the reimplant (Wallace et al., 2008). A more recent study also showed decreased DMI associated with reimplantation in heifers given a greater hormone dosage than single implant heifers, and despite depressed DMI, reimplantation had positive effects on live-basis growth performance such as carcass-adjusted average daily gain, feed to gain ratio, and carcass traits (e.g. backfat thickness, REA, and dressing %) (Merck Animal Health). Steers (*n* = 3179) were enrolled in a study that had two treatments (Treatment 1, extended-release, polymer-coated implants administered on arrival;

Treatment 2, non-coated implants administered on arrival and at 90 days). Treatment 2 decreased DMI by 0.45 kg for 10 days after reimplantation (P = 0.01). Treatment 2 consumed 0.34 kg on average less than Treatment 1 from reimplantation to harvest (P = 0.01). The study shows that reimplantation may decrease DMI, but the study does not investigate the factors that could lead to decreased DMI. Despite decreased DMI, growth performance was not affected.

Steers (n = 200 pens) were implanted and observed for 10 days after reimplantation. Treatments included a control, increasing distance travelled (an additional 805 m), and restricting feed and water for 4 hours after reimplantation. Rumination, activity, and dry matter intake were recorded. Restricting access to feed and water did not subsequently affect DMI, but increasing distance travelled associated with reimplantation decreased dry matter intake (Helmuth et al., 2022). Decreased DMI following a reimplantion event may decrease income and should be considered when implementing implant strategies. If cattle decrease DMI in response to reimplantation and the event negatively affects overall growth performance and carcass traits, reimplantation is not the most economical option for producers. The same tradeoff is considered when reimplanted calves perform similarly to calves that receive one implant. Data suggests that a single, high potency implant at receiving into the feedlot can be as effective as a multiple-implant program if cattle respond to the reimplanting event negatively or neutrally (Parr et al., 2011). If cattle do not respond to reimplanting with increased ADG and improved carcass traits (e.g. HCW, REA), the reimplantation event will not provide producers with return on investment.

Locomotion

Locomotion refers to the distance an animal travels during a given period. An animal’s activity level is largely related to comfort associated with facilities (e.g., flooring, spacing). Cow comfort on dairies affects milk production, conception rates, dry matter intake, and lameness. For 50 years, the dairy industry has attempted to increase cow comfort by improving grooving in pavement, installing rubber matting for traction, managing ice in poor weather conditions, and other management strategies to ensure well-being of animals. Most dairy cattle operations are indoors, and the cattle live on concrete. Extended bouts of standing, walking, and running on concrete decreases cow’s comfort and increases risk of lameness (Kougioumtzis, 2014). Increasingly, beef production systems have transitioned to concrete pens and monoslope barns with concrete flooring. Concrete flooring is an economical and durable option for flooring, that is also more sanitary because concrete can be easily cleaned. When considering the alternative of mud in group housing, concrete is a better option for cleanliness and appearance. The dairy industry has recognized the importance of locomotion for cow health and production. Unlike the dairy industry, the feedlot industry primarily focuses on pen stocking density, water access, and ease of use for feeding and cleaning equipment (Boyer et al., 2017). The housing of feedlot cattle in the finishing phase, whether cattle are housed on concrete or in a dirt pen, is not conducive to high activity levels.

Impacts of Locomotion

Metabolic needs vary based on body size and level of activity. Small-framed (n = 13) and large-framed (n = 15) cows were compared to analyze differences in grazing behaviors, diet intake, and energy costs of activity based on different body conformations. All cattle were equipped with global positioning systems (GPS), activity monitors, and heart rate monitors. Partitions of time were compiled to determine how much time each day cattle spent walking, lying down, grazing, and walking without grazing. Distance travelled was also collected. Smaller-framed cows travelled more distance per day, grazed more per day, and had lower costs for locomotion, compared to larger framed cows (Aharoni, 2009). A similar experimental design was repeated one year later to test if using a larger plot size would affect locomotion. The cost coefficients for standing, grazing, and horizontal locomotion were similar to those cattle grazing the smaller plot size. Therefore, if given the opportunity, cattle tend to travel long distances compared to staying in one area or confined space. Even though cattle travelled father distances, the cost coefficients for standing, grazing, and horizontal locomotion were similar to those cattle grazing the smaller plot size. Heat production was measured based on heart rate and measurement of oxygen consumption per heartbeat. Heat production was equated to energy cost coefficients for activity. Cattle also had a less severe physiological response (energy cost) to travel if they were smaller frame size, based on heart rate and activity monitors (Brosh et al., 2010). Thus, a moderate-framed, lightly conditioned calf that just came off pasture would be less affected by having to travel long distances than a finishing feedlot steer accustomed to minimal travel.

Behavioral Markers Across Species

Quantified behavioral data in livestock raising operations has been difficult to collect. Development of tracking technologies such as collars, radio frequency identification tags (RFID), and video scanning tools has given indication of how housing affects locomotion in different species such as cattle, horses, sheep, and broilers. The distance livestock travel in a day, whether they are free-range, on pasture, or in a pen is related to their feeding behavior and socialization patterns. Grazing animals travel much longer distances/day to meet caloric needs and to travel to water. Behavioral data collection can be used for assessing welfare and sickness. Video is the most effective way to measure behavioral activity, location, and movement in broilers in large production settings (Doornweerd et al., 2022). The RFID-systems are effective for measuring the same parameters in color-marked broilers but are ineffective in non-color-marked broilers. Behavioral data collection will be especially helpful in broiler raising, as pathogens spread very quickly in confinement-raised poultry operations. The RFID-sensors have proven that high activity early in broilers life has been associated with improved leg health and did not have negative effects on body weight gain (Van der Sluis, 2022).

Differences in activity, locomotion, and growth performance in post parturient cows housed on pasture or in a dry lot were examined. Visual observations of lameness and locomotion scores were recorded. Housing cows in drylots increased BW, BCS, and milk production, but resulted in poorer locomotion scores and increased lameness treatments (P = 0.02) compared to cows on pasture (Hofer et al., 2021). Similar effects were observed when two treatment groups of cow-calf pairs were housed separately, either in a dry lot setting or on pasture. The study concluded that dry lot housing improved BW, body condition score, and milk production of cows, and improved BW and ADG in pre-weaned calves than pasture calves. However, pasture calves had higher ADG and feed efficiency than dry lot calves in the feedlot receiving phase (Myerscough et al., 2022). Comparisons can be drawn between locomotion early in life between broilers and dry lot versus pasture calves. Research has not been completed to determine if locomotion of pasture-raised beef cattle would affect leg muscle growth and health long-term. However, data from these studies indicate that pasture-rearing stimulates more activity.

Conclusions

Helmuth et al. 2022 is currently the only peer-reviewed study that investigated the probable reasons for DMI decrease post-reimplantation. Locomotion negatively impacted DMI for 10 days post-reimplantation and overall growth performance. Based on evidence that reimplantation decreased DMI associated with increased locomotion, management strategies should be implemented to decrease locomotion associated with reimplantation. Helmuth et al. also imposed a treatment where cattle that increased locomotion (travelled an additional 805 m), also were restricted from feed and water for 4 hours, and received a bolus of *Megashaera eisdenii. Megashaera eisdenii* is a gram-negative bacteria which consumes lactate (refer to Chapter 1, Section 2). Overall, the control group, which travelled to the pen to be reimplanted then returned to the home pen, tended to have the highest DMI for the entire study (P = 0.02). The introduction of a bolus intended to mitigate acidosis did not prove to be an effective management strategy to mitigate decrease DMI post-reimplantation. The study did not measure rumination, rumen pH, or other nutritional management strategies.

Use of implants is an important management strategy in beef production in the USA. Especially in the finishing feedlot phase, implant administration is critical to maintaining feed efficiency and delaying fattening. When considering implant program options, location of processing facility should be considered to decrease the distance calves need to travel to be reimplanted. Current data suggests that having cattle travel 805 m on a feedlot will have detrimental effects on DMI. A single, coated implant option that will cover the duration of the finishing feeding phase will be more effective, if the distance calves have to travel to the processing facility to be reimplanted meets or exceeds 805 m. Data from the same study proves that reimplanting cattle improves growth performance and carcass traits, further confirming established data that reimplantation is economically profitable for feedlot cattle in the finishing phase. No nutritional management strategies are established for mitigating decreased DMI at time of reimplantation. Proper feed processing, ration formulation, and feed delivery are all important management strategies that should be prioritized consistently, but especially in response to reimplantation, as its effects are still relatively unknown. Our study will test effects of reimplantation on DMI when cattle travel 1.05 km, and determine if basic management nutritional strategies could be implemented at time of reimplantation.

The study discussed in Chapter 2 will address our two objectives. Objective 1 will investigate whether increased locomotion at time of reimplantation has a negative effect on DMI. Objective 2 will investigate the effects of increasing forage (oat hay) by 10% in the diet at time of reimplantation. Our hypothesis is that increased locomotion will negatively impact DMI, and that increasing forage will increase rumination thus mitigating the effects of acidosis.

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INTRODUCTION

The use of implants in US beef production is an important management practice to improve average daily gain (ADG), increase dry matter intake (DMI), and delay fattening (Smith et al., 2020 Smith et al., 2022; Johnson et al., 1996). Calves are often implanted multiple times from the weaning phase to the finishing phase. In 2013, 4 out of 5 (79.8%) steers placed in the feedlot weighing less than 317 kg received more than one implant (APHIS, 2013). Traditionally, the decision to administer multiple implants between backgrounding and finishing phases is largely based on frame size of cattle and average daily gain, which predicts how long cattle will be on feed before harvesting. Smaller cattle require more time on feed to reach their terminal endpoint, because it is desired to allow them to reach their potential for frame size before optimum muscle growth and fattening occur.

Costs associated with reworking cattle are labor, cost to operate the chute, cost of the implant, increased locomotion, and time away from feed (Wallace et al., 2008). Physiological effects of locomotion on DMI are unknown in cattle operations, but evidence of decreased DMI post reimplantation is clear. The effects of reimplanting on DMI were observed in finishing feedlots (n = 321 pens; 47,000 cattle) across Kansas, Nebraska, Iowa, and Texas (add citation). Sixty-one percent of pens evaluated had decreased DMI following reimplantation for 10 days, whereas 39% of pens did not differ or had increased DMI before and after a reimplant event (Wallace et al., 2008). A more recent study also showed decreased DMI associated with reimplantation in heifers given a greater hormone dosage than single implant heifers, and despite depressed DMI, reimplantation had positive effects on live-basis growth performance such as carcass-adjusted average daily gain, feed to gain ratio, and carcass traits (Merck Animal Health, 2020). In 2022, Helmuth et al. concluded that increased locomotion associated with reimplantation decreased DMI for a 10-day period and for the rest of the feeding period (P = 0.01). Restricting access to feed and water did not subsequently affect DMI, but increasing distance travelled associated with reimplantation decreased DMI (Helmuth et al., 2022).

Fluctuations in feeding due to a disruption in body homeostasis and increased locomotion at reimplantation may lead to decreased DMI. Cattle must consume consistent, small meals to maintain VFA production and rumen microbial populations. Rumination in between meals stimulates saliva production and rumen motility for digestion. Rapid consumption of highly-fermentable carbohydrates, commonly found in feedlot finishing diets, can be toxic if lactic acid accumulates in the rumen. Acidosis is caused by a rapid decrease of rumen pH due to accumulation of lactic acid. Rumen pH may be affected by feed type, frequency of feeding bouts, weather, and rumination (Owens et al., 1998). Forage stimulates saliva production and increases rumination time, thus creating buffer for the rumen (Beauchemin, 1991). Inclusion of forage provides physically effective neutral detergent fiber (peNDF), which decreases incidence of acidosis (Chibisa et al., 2020).

It is unknown which factors related to reimplantation have a negative effect on cattle. Factors to consider are locomotion, time away from the pen, and feeding behavior after reimplantation. Increasing forage in the diet after reimplantation may decrease acidosis incidence, leading to less or no reduction in DMI. Our hypothesis was that increased locomotion will negatively impact DMI, and that increasing forage will increase rumination thus mitigating the effects of acidosis. This study investigated two objectives. Objective 1 investigated whether increased locomotion at time of reimplantation affected DMI, water intake, growth, rumination, or carcass characteristics. Objective 2 investigated the effects of increasing the diet forage concentration by 10% for 7 d following reimplantation.

MATERIALS AND METHODS

Animals

South Dakota State University Institutional Animal Care and Use Committee approved experimental procedures. The experiment utilized Angus and Simmental x Angus steers (*n* = 27) sourced from the South Dakota State University Cow Calf Education and Research Facility in Brookings, South Dakota. Calves were born on site and never left the facility, from birth to their terminal shipment. Between 1-2 months of age, in April 2020, calves were processed and received vaccinations. At this processing, cattle were vaccinated against clostridial species *Clostridium Chauvoei, Septicum, Novyi, Sordellii, perfringens types C & D, and Moraxella bovis* (Alpha 7; Boehringer Ingelheim Health Inc., Duluth, GA). Cattle were also vaccinated against respiratory diseases caused by Bovine Respiratory Syncytial Virus (BRSV), Infectious Bovine Rhinotracheitis (IBR) virus and Parainfluenza 3 (PI_3) virus (Inforce 3; Zoetis Animal Health, Parsippany, NJ), and treated with a parasiticide to control roundworms, lungworms, grubs, and mites commonly found on cattle on pasture (Long Range; Boehringer Ingelheim Health Inc., Duluth, GA). In August 2020, cattle were processed again before weaning. At this processing, cattle were vaccinated against viral papillomas warts (Wart Vaccine;

Colorado Serum Company, Denver, CO) and respiratory diseases caused by BRSV, IBR, PI3, Bovine Respiratory Virus Types 1 and 2, and *Mannheimia haemolytica* (Bovi-Shield One Shot; Zoetis Animal Health, Parsippany, NJ).

Cattle were weaned in September 2020. At weaning, cattle were re-vaccinated against blackleg-causing clostridial *species Chauvoei, Septicum, Novyi, Sordellii and perfringens Types C & D* (Ultrabac 7; Zoetis Animal Health, Parsippany, NJ). At weaning, calves also received boosters of wart vaccine and Bovi-Shield One Shot and were vaccinated against *Mycoplasma bovis* bacteria (Myco-B One Dose, American Animal Health Inc., Grand Prairie, TX). Cattle underwent fence-line weaning, which is proven to be a smooth transition for both cows and calves, allowing physical and audible contact between pairs without the ability for the calf to nurse (Price et al., 2003). Weaned calves were kept on pasture and provided a pellet comprised of 50% dried distillers grains with solubles and 50% soybean hulls as well as a mineral supplements. Calves were processed again on November 12, 2020, weighed, castrated via banding, received a tetanus vaccination, and were assigned electronic identification transponders (Allflex Livestock Intelligence, Dallas, TX). Calves were weighed every 45-days from November 2020-March 2021. After March 2021, cattle were weighed every 28 days.

Calves were moved into a single pen in an open front monoslope building which contained 12 Insentec automated watering and feeding units (Insentec RIC, Hokofarm, Marknesse, Netherlands). Four identical pens (total 17,725 ft^2) comprise the monoslope building. Each pen included outdoor space and a covered area where the Insentec feeding and watering systems (roofed area equals 1,145.2 ft^2). The Insentec feeding system is effective in measuring the disappearance of feed and water (Chapinal et al., 2007). An adaptation period is required for cattle to adapt to the feeders. Calves had a 14-day adaptation period to the feeding bunks on this trial. For 7 days, they had access to all bunks; then they were assigned to specific bunks based on treatments.

Experimental Design

Three treatments were applied in a randomized complete block design with animal as experimental unit. On March 26, 2021, calves were weighed before feeding and implanted with Synovex Choice [100 mg of trenbolone acetate (TBA) and 14 mg of estradiol benzoate (EB); Zoetis Animal Health, Parsippany, NJ]. Calves were affixed with a transponder to continuously monitor rumination and activity data (SenseHub Beef, Allflex Livestock Intelligence, Madison, WI). All treatments received a uniform diet until the time of reimplant. Calves received their second implant (terminal) which was Synovex Plus (200 mg of TBA and 28 mg of EB; Zoetis Animal Health, Parsippany, NJ) on June 21, 2021 (93 days from initial implant). The observation period began on the day of reimplantation (June 21, 2021) and is considered day 1 of data collection.

Treatments consisted of the following: (9 steers per treatment group): 1) CON: reimplanted on day 1 and then returned to their home pen immediately 2) ACT: reimplanted on day 1, walked 1.05 km and held in holding pen without access to food or water for 4 hours, and 3) ACT + DIET: reimplanted on day 1, walked 1.05 km and held in holding pen without access to food or water for 4 hours, followed by diet adjustment to increase forage by 10%. Processing began at 8:00 am prior to feeding and cattle on ACT and ACT + DIET treatment groups returned to their home pen at 12:00 pm. Calves assigned to treatments ACT and ACT + DIET travelled from their home pen to and from the processing facility on concrete and a dirt road. The CON group travelled 0.43 kilometers. On the day of processing, calves in the ACT + DIET treatment group received an altered diet that increased forage and decreased net energy for gain (NE_g) (Table 2.1). This diet was provided to the ACT + DIET cattle when they returned to their home pen and continued for 7 days at which time the cattle were fed their original finishing diet.

All steers on treatments ACT and ACT + DIET were determined to be sound before and after the walking event. Steers were not treated for bloat or other diseases throughout the duration of the experiment. One steer in CON group was eliminated from the experiment in July due to chronic acidosis. That data is not included in overall growth performance analyses. However, the animal did not exhibit symptoms during the 14-day period after reimplanting, thus data from that period is included in data analysis during the first 14-day window. At the 28-day mark after each implanting event, ears were palpated to ensure that implants were intact and infection had not developed. After initial implant, all implants were intact and no irritation around implant sites was detected. Seven days after reimplantation, three steers had developed inflammation at the implant site, but implants were intact. The inflammation was gone at 28-days post-reimplant without treatment.

Dietary Management

Feed bunk management on the Insentec system varies greatly compared to a pen-based, slick-bunk management feeding style. Feed bunks were managed to provide *ad libitum* feed to animals. Bunks were evaluated at 8:00 am each day and adjustments were made based on how much feed was left. Bunks were targeted to always have 3 kg or less of feed refusals. Weekly ingredient samples were taken to assess dry matter and nutrient content of the diet. Feed samples were weighed and then dried in a 60º C oven. Feed samples were closely monitored to ensure that a true value of dry matter was obtained. Once dry weight of feed was recorded, dry matter of diet was calculated by dividing dry weight by original weight. The difference between the two weights was the measurement of diet water that does not contribute to overall feed intake. Dry matter intake was calculated by determining overall dry matter percentage of the diet, then determining individual total intake for each 24 day period and multiplying dry matter % by total feed intake.

Data Collection

Daily individual dry matter intake, water intake, rumination, and activity data were collected. Individual feed and water intake were collected using the Insentec RIC feeding system (Ahlberg et al., 2016). The pen was equipped with 12 Insentec RIC feed bunks and 2 Insentec RIC water units. However, only 9 feed bunks were used for this experiment to allow for a uniform average stocking density per feeder. Three bunks were assigned to each treatment, and three steers were assigned to each bunk (n = 27 steers, 3 treatments, 9 steers/treatment, 3 bunks/treatment, 3 steers/bunk). Cattle assigned to a bunk were within the same treatment group. Insentec feeding bunks operate by reading animal's ear tags, lowering the gate, measuring weight of feed at the start of the bout, then measuring weight of feed at the end of the bout, and recording duration of the bout. Cattle activate feeding gates by placing their ear in proximity of an EID reader, then breaking a light beam with their head. If the animal has been given permission to eat from that feeder, the gate lowers, time and weight of feed are recorded and again recorded once feeding bout has ended. The gate serves to limit which calves have access to each bunk, thus allowing treatments to be assigned with different diets. The gate will only lower when the calves assigned to the correct treatment group are attempting to gain access. In this experiment, three bunks were assigned to each treatment. The Insentec watering system works almost identically. For this experiment, water intake and duration was collected; however, no treatment was assigned within the Insentec watering system. The Insentec watering system is supplied by Brookings Municipal water supply.

As-fed feed and water intake was collected from the Insentec system on a per-head basis. Intakes were evaluated for outliers or errors (calves attempting to eat out of bunks from an incorrect treatment group) and these data were excluded. Liquid water intake (L) and as-fed feed intake were calculated for each day of the feeding period. Total water intake was calculated by combining the water proportion of as-fed intake (determined when DMI was calculated) with liquid water intake in liters. Rumination and activity were calculated based on time (minutes) within a 24 hr period using SenseHub Beef monitoring tags (AllFlex Livestock Intelligence, Madison, WI). Each calf was equipped with an individual monitoring tag.

Cattle were processed through a hanging Silencer chute (Moly Manufacturing, LLC, Lorraine KS). The chute is also equipped with a TruTrest XR5000 scale (readability: .91 kg; TruTest Inc., Mineral Wells, TX).

Statistical Analysis

One steer (from treatment group CON) was removed from the study on day 50 due to mortality. Two animals were excluded from carcass-based statistical analysis due to inconsistencies in recording of electronic identification (EID) tags at slaughter. Steers were randomly assigned to treatments before the study began. The study was a completely randomized design and the linear model included treatment as a fixed effect and block as a random variable. Individual animals were experimental unit for all analyses. A Kenward-Roger estimation of degrees of freedom structure was used to estimate fixed effects because of small sample size. The autoregressive covariate structure for the random effect of day was determined to be the best fit for the model based on the smallest AIC value. The model, DF structure, and covariate structures were the same for all parameters that were tested. The dependent variables DMI, total water intake, rumination and activity were analyzed using PROC MIXED in SAS 9.4 (SAS Inst. Cary, NC). Effects in the model included fixed effect of treatment and random effects of day and treatment x day interaction. Carcass-adjusted final body weight, carcass traits and growth performance were dependent variables analyzed using PROC GLIMMIX in SAS 9.4 because these dependent variables were not normally distributed (SAS Inst. Cary, NC). Initial shrunk body weight was used as a covariate for analyzing growth performance. Otherwise, the same fixed and random effects were included in these models. A baseline average for each parameter was calculated using data from 7 days before the study started. Baseline was used as a covariate for its respective dependent variable, i.e., average DMI (day -7 through day 0) for DMI d 0-70.

Significance was determined to be $P \leq 0.05$ and tendencies were determined to be between $P \geq 0.06$ and $P \leq 0.10$.

Growth performance, rumination, activity, DMI, and water intake were evaluated for two time periods. Day 1-14 was evaluated by least square means using repeated measures in PROC MIXED with fixed effect of treatment and random effect of day. Mean separations were analyzed using preplanned contrasts: 1) CON vs. ACT (to evaluate effects of increased locomotion), 2) CON vs. ACT + DIET (to evaluate effects of increased locomotion and increasing effective fiber inclusion), 3) ACT vs. ACT + DIET (to evaluate effects of increasing effective fiber inclusion to mitigate effects of acidosis).

RESULTS AND DISCUSSION

Two time periods were investigated: days 1-14 and days 1-70 post-reimplantation. Days 1-14 post reimplantation were investigated to determine short-term effects of reimplantation on DMI, water intake (diet water and liquid water), rumination, and activity (Table 2.3). Days 0-70 were investigated to determine longer-term effects of reimplantation on DMI, water intake (diet water and liquid water), rumination, activity, growth performance, and carcass traits (Tables 2.4, 2.5, 2.6).

Dry Matter Intake

Dry matter intake increased as days on feed increased, likely a response to increasing BW ($P < 0.0001$) (Fig. 2.1). Figure 2.2 depicts a days on feed effect ($P <$ 0.0001), no treatment effect, and a treatment by days on feed interaction effect ($P = 0.04$) on DMI from days 1-14. Though no treatment effect was observed for the 14 day period post-reimplantation, biological differences in DMI were noted. The CON group consumed 1.21 kg more DM than the ACT + DIET group, and the ACT group consumed 1.38 kg more DM than the ACT + DIET group for the 14-day period post-reimplantation. No overall treatment by days on feed effect on DMI from day 1-70 (*P* = 0.24) post-reimplantation was observed.

Mean separations between treatment groups were estimated for DMI for the 14-day period following the implanting event (Table 2.9). The ACT and ACT + DIET groups received the same treatment of walking 1.05 km, and the ACT + DIET treatment group received a diet change of increased forage inclusion for 7 days after reimplantation. On day 1, the day that treatments were applied, the ACT group consumed 2.11 kg more DM (*P* = 0.04) than the ACT + DIET treatment group. On day 2, the CON treatment group consumed 2.12 kg more than the ACT + DIET treatment group (*P* = 0.06) and no significant difference between ACT and ACT + DIET was observed. On day 4, the CON treatment group consumed 3.27 kg more dry matter than the ACT + DIET treatment group (*P* = 0.02). No significant differences between CON and ACT, or ACT and ACT + DIET were observed on day 4. On day 5, the CON treatment group consumed 2.83 kg more DM than ACT (*P* = 0.04) and 3.03 kg more than ACT + DIET (*P* = 0.024). On day 6, CON consumed 3.37 kg more DM than ACT + DIET (*P* = 0.008). On day 7, no significant differences in DMI were observed between treatments. Day 7 was the last day of diet change for ACT + DIET. The ACT + DIET treatment group returned to the finishing diet on day 8 (Table 2.2). The ACT treatment group consumed 2.12 kg more than ACT + DIET on day 8 (*P* = 0.04), and no differences in DMI were observed among other treatments. On day 9, ACT + DIET consumed 3.4 kg less DM than CON (*P* =

0.003) and 3.65 less DM than ACT. Similar effects are observed on day 10, where ACT + DIET still consumed less than CON (*P* = 0.02) and ACT (*P* = 0.02), respectively. The DMI among treatment groups was not different from days 11-14.

Investigating DMI by day illustrates the effects of the treatments. The CON group consistently consumed the highest amount of DM and was less variable over the 14-day period post-reimplantation. The ACT + DIET treatment group fluctuated the most, indicating that increasing roughage increased variation of DMI. Decreased DMI does not mean decreased ADG or even decreased feed efficiency. In fact, decreased DMI often improves feed efficiency. Decreased DMI does, however, pose the risk of metabolic illness and reduced fat deposition. Periods of decreased DMI mean that cattle are partitioning energy towards only maintenance instead of maintenance and gain (Smith et al., 1977). Extended periods of DMI depression result in less energy being used for muscle growth and fat deposition, leading to more days on feed and decreased intramuscular fat deposition (marbling). Though there were differences in DMI on individual days, there was no treatment effect observed; thus indicating that treatment did not have an overall effect on DMI in this study.

Rumination

Rumination follows similar trend lines as dry matter intake when means across treatment groups are analyzed. A treatment by days on feed effect was not observed for cumulative average rumination (*P* = 0.162) (Fig. 2.3). A treatment by days on feed interaction (*P* = 0.022) was observed for the 14-day period post-reimplantation, thus, least square means between treatment groups were compared (Fig. 2.4) (Table 2.8). For three days post-implant, no differences in rumination among treatments were found. On day 4, ACT + DIET ruminated significantly more minutes in a 24 hr period than CON (*P* = 0.033). A 65.2-minute decrease in rumination for ACT treatment calves relative to the ACT + DIET treatment group was observed; however, this difference was not statistically significant. On day 5, ACT ruminated more than CON (*P* = 0.035) and ACT + DIET ruminated more than CON (*P* = 0.024). On day 6, ACT tended to ruminate more than CON (*P* = 0.06). No significant differences in rumination between day 6-11 were found.

When cattle are ruminating, buffer is being created to stabilize the rumen environment. Saliva from rumination is a primary buffer to counteract changes in rumen pH. Rumination is a marked behavioral factor that changes when acidosis onsets (DeVries et al., 2009). Rumination decreased in dairy cows in treatment groups that were being challenged with acute acidosis. Rumination was measured to determine if acidosis incidence increased after reimplantation, and if decreased rumination is associated with certain treatment. On day 4-6 post-reimplantation, the CON treatment group consumed more DM and ruminated less minutes than the ACT + DIET treatment group, which consumed the least amount of DM among treatment groups and ruminated the most minutes among treatment groups. Though increasing forage in the diet did not increase DMI, rumination was increased. Increasing forage in a diet increases the neutral detergent fiber (NDF) and increases rumination and saliva production (Beauchemin, 1991). Increasing forage in the diet was hypothesized to mitigate DMI depression by buffering the rumen, and while DMI decreased for the ACT + DIET treatment group on multiple days, increased minutes of rumination on several days suggests less acidosis risk.

Water Intake

Water intake includes diet water and raw water intake in liters. No treatment by days on feed effect on total water intake (diet water plus liquid water) for the entirety of the feeding period was observed from day 1-70 (Fig. 2.5). A treatment effect ($P = 0.07$) and DOF effect ($P = 0.0001$) on water intake from day 1-14 was observed (Fig. 2.6). No treatment by days on feed effect for water intake was observed from day 1-14 ($P = 0.38$).

Activity

Activity was calculated by collecting total of minutes of the day spent eating, standing, walking, and drinking (Lee et al., 2021). Activity did not differ among treatments for the cumulative feeding period ($P = 0.99$) (Fig. 2.7). No differences among treatments were detected when performing mean comparisons for d1-14 after reimplantation (Fig. 2.8). Activity was not found to be statistically different in this study. However, differences in activity may have been exhibited if the calves were on pasture. If calves are on pasture, they are traveling as they graze and they must travel to water. Calves on pasture will naturally have more active minutes per day than feedlot calves, due to the confinement feedlot calves are under in a pen. The calves in this study had minimal distance to travel from the feeding bunk, waterers, and the resting area of the pen.

Growth Performance

Table 2.3 depicts values for growth performance. Initial body weights were not significant among treatments ($P = 0.53$). No difference in ADG among treatments after reimplantation from day 1-14 was observed ($P = 0.75$). No significant treatment effect was observed on final shrunk BW (*P* = 0.72). No significant difference in average daily gain was observed among treatments for the finishing period after implanting (*P* = 0.76). Treatment was not significantly different for G:F ratio for 14 days after reimplantation (*P* = 0.51). Gain to feed ratio was also not significantly different among treatments for the duration of the feeding period after implanting (*P* = 0.91).

Carcass Traits

Carcass traits were not significantly affected by treatment (Table 2.5). Hot carcass weights were not significantly different (*P* = 0.89). Dressing percentage, rib fat, REA, marbling scores, and calculated yield grade were all unaffected by treatment overall. No significant differences in quality (*P* = 0.76) or yield grade (*P* = 0.87) distribution were observed based on treatment (Table 2.6).

Concluding Discussion

Reimplantation in feedlot cattle has been proven to increase feed efficiency and delay fattening (Smith et al., 2022). The positive effects of the implants are more potent if a detrimental effect is not associated with reimplantation, such as decreased DMI, rumination, or activity. A loss of income is associated with decrease in DMI is post-reimplantation, considering the cost of labor and implants, and risk associated with metabolic disease such as acidosis. This study significantly observed decreased DMI associated with reimplantation, specifically in the treatment groups that travelled a longer distance.

Objective 1 was to determine if locomotion (walking two groups an additional 1.05 km) had a detrimental effect on cattle’s response to reimplantation. Treatment effects on DMI were not observed for 14 days post-reimplantation, but a treatment by days effect was observed, where the CON group consumed more feed than ACT and ACT + DIET on multiple days. However, due to no treatment effect being observed for 14 days post-reimplantation, we cannot conclude that increasing distance travelled in the ACT and ACT + DIET groups negatively effected DMI. Similarly, no treatment effects were observed for water intake or activity. Rumination was different among treatments due to the imposed diet change, but the change cannot be contributed to increased locomotion. Locomotion is known to have a detrimental effect on cattle, and this detrimental effect is greater as BW increases (Brosh et al., 2010). Based on data that proceeded this study, locomotion following reimplantation may be more detrimental to performance measures as BW increases. However, evidence from this study does not indicate that increased locomotion had a detrimental effect.

The secondary objective was to determine if increasing forage intake mitigated the reduction in DMI following reimplantation. Treatment group ACT + DIET ruminated more than the other two treatment groups and decreased DMI on multiple days for 14 days post-reimplantation. The dry matter of the ACT + DIET group's diet was significantly lower, which would require increased saliva production (McCallister et al., 2020). With the addition of 10% oat hay, physically effective fiber was significantly increased, thus increasing buffering in the rumen and mitigating acidosis incidence. The ACT + DIET treatment ruminated more for 14 days immediately post-reimplantation, indicating that increased forage increased rumination. No treatment effect was observed for performance measures or carcass characteristics for the ACT + DIET treatment group, indicating that increasing forage by 10% was neither beneficial or detrimental to gain for the duration of the study. In combination with results from DMI data, we conclude that increasing inclusion of physically effective fiber increased rumination and did not negatively affect DMI overall.

Helmuth et al. (2022) completed a similar experiment. Treatments applied on the day of reimplantation included a control group (PCON), a group that was restricted from feed and water for 4 hours (RES), a group that travelled 805 m (LOC), a group that travelled 805 m and was restricted from feed and water for 4 hours (RES+LOC), and a group that travelled 805 m, was restricted from feed and water for 4 hours, and received a bolus of a lactate-utilizing bacteria (LACT). Increasing locomotion decreased DMI and growth performance. Helmuth et al. (2022) did not measure rumination or water intake.

Practical applications of this study are to limit locomotion associated with the reimplantation event. Calves to be reimplanted should travel the shortest distance possible, less than 0.805 km and time calves spend away from the pen should be minimal. Decreasing NEg by increasing forage by 10% is not recommended. The results of the study related to the ACT + DIET treatment group suggest that changing the diet increased rumination, but does not improve overall growth performance or carcass traits. Thus, it is not recommended to change feedlot cattle's diets at reimplantation.

No significant differences among treatments were observed for overall dry matter intake, average daily gain, gain to feed ratio, or carcass traits. No treatment effect was observed for dry matter intake for 14 days post-reimplantation. A treatment by days on feed effect was observed for dry matter intake, where CON cattle consumed more feed than ACT + DIET on multiple days after reimplanting (P = 0.03). The ACT + DIET group ruminated ~65 minutes/day more (P = 0.02) than CON for 14 days after reimplantation. No differences in total water intake for 14 days (P = 0.38) or the cumulative period (P = 0.97) were observed. Activity (calculated number of minutes standing, walking, eating, drinking) was unaffected by reimplantation (P = 0.99). Increasing forage inclusion in the diet for 7 days after re-implantation did not mitigate feed intake depression, but increased rumination for multiple days after reimplanting. When reimplanting cattle, it is recommended to limit distance calves have to travel. Nutritional management strategies used in this experiment indicate that increasing forage inclusion increases rumination. Previous research suggests that increasing rumination decreases incidence of acidosis, however, further research must be conducted to determine the effects of increased forage inclusion on rumen pH post-reimplantation.

REMARKS

Overall, reimplantation did not affect calf performance during the finishing phase. To truly determine the effects of locomotion associated with the reimplantation event, similar treatments would need to be repeated with the addition of one group that never leaves the pen for reimplantation. The additional group would receive one coated implant containing enough steroidal compounds to suffice for the entire feeding period. That group may be called a true control, as this group would not be impacted by locomotion following reimplantation. Measuring rumen pH in response to reimplantation would have been beneficial. Often, it is difficult to detect subclinical acidosis in large pens, where intake is variable due to a variety of reasons, e.g. locomotion, feed delivery differences, weather. Rumen pH monitors could monitor the effects of reimplantation on rumen health. Finally, a larger sample size of cattle per treatment would be advantageous. With nine steers per treatment group, statistical power was low. Fortunately, steers were healthy and responded well to treatments; thus, power was not further reduced. Repeating this study with multiple distances for cattle to travel at reimplantation would test whether distance cattle travelled affects performance. When cattle traveled 0.85 km, cattle decreased DMI for up to 10 days after reimplantation (Helmuth et al., 2022). Future work will need to be done to establish the least distance cattle will travel and not exhibit a DMI depression, to quantify realistic recommendations for producers.

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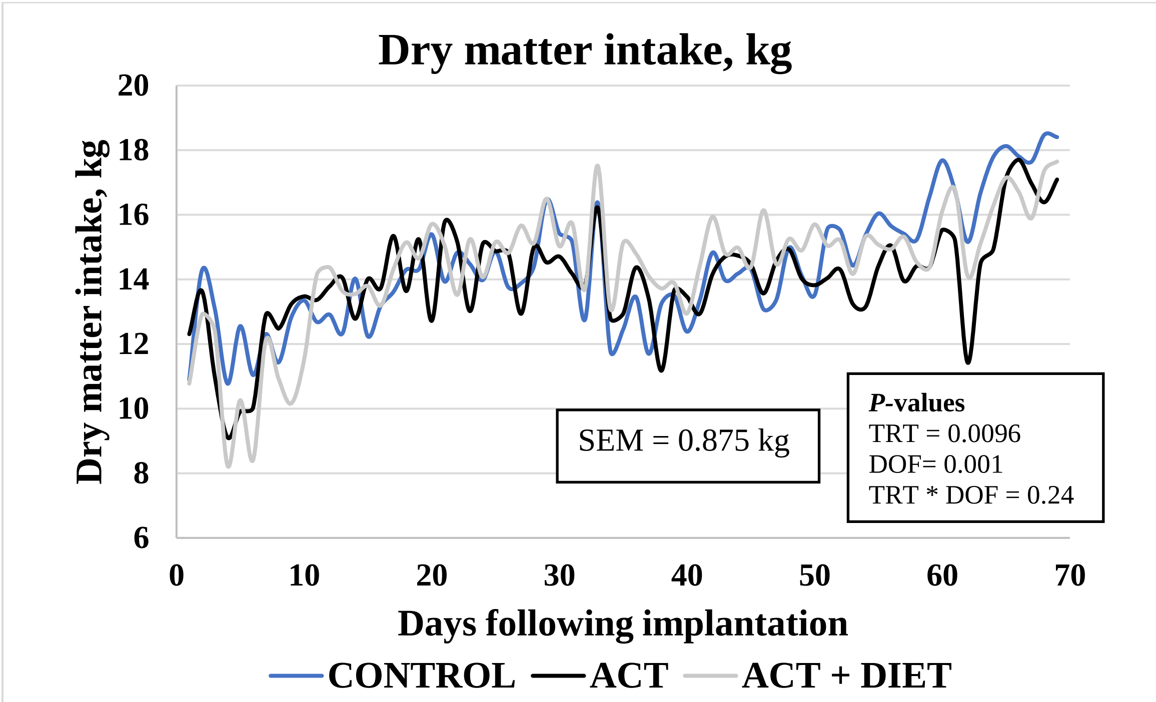

Figure 2.1. Dry matter intake (kg) in finishing beef steers d 1-70 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

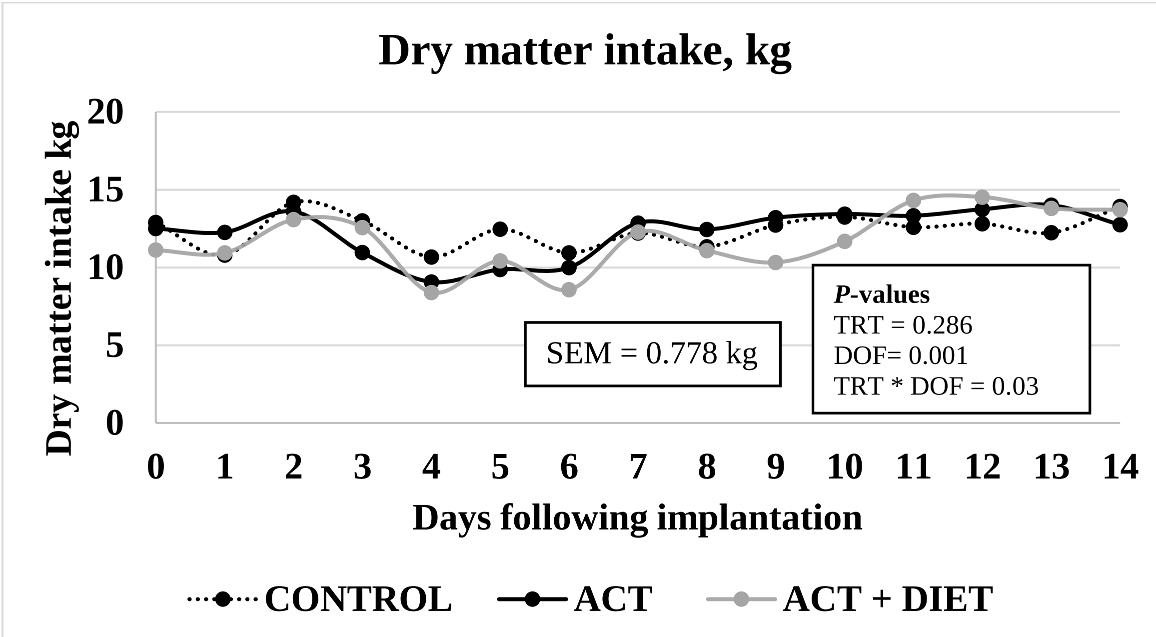

Figure 2.2. Effects of locomotion and diet change (10% increased forage) on dry matter intake (kg) in finishing beef steers d1-14 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

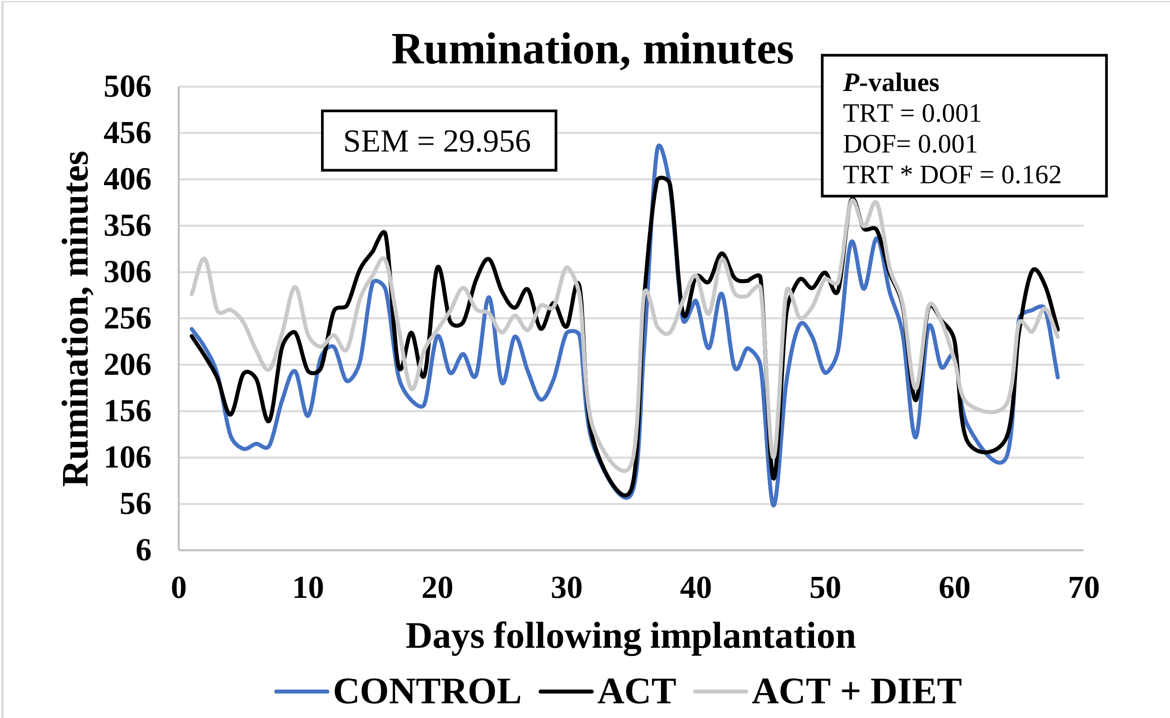

Figure 2.3. Cumulative average rumination (minutes) in finishing beef steers from d1-70 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

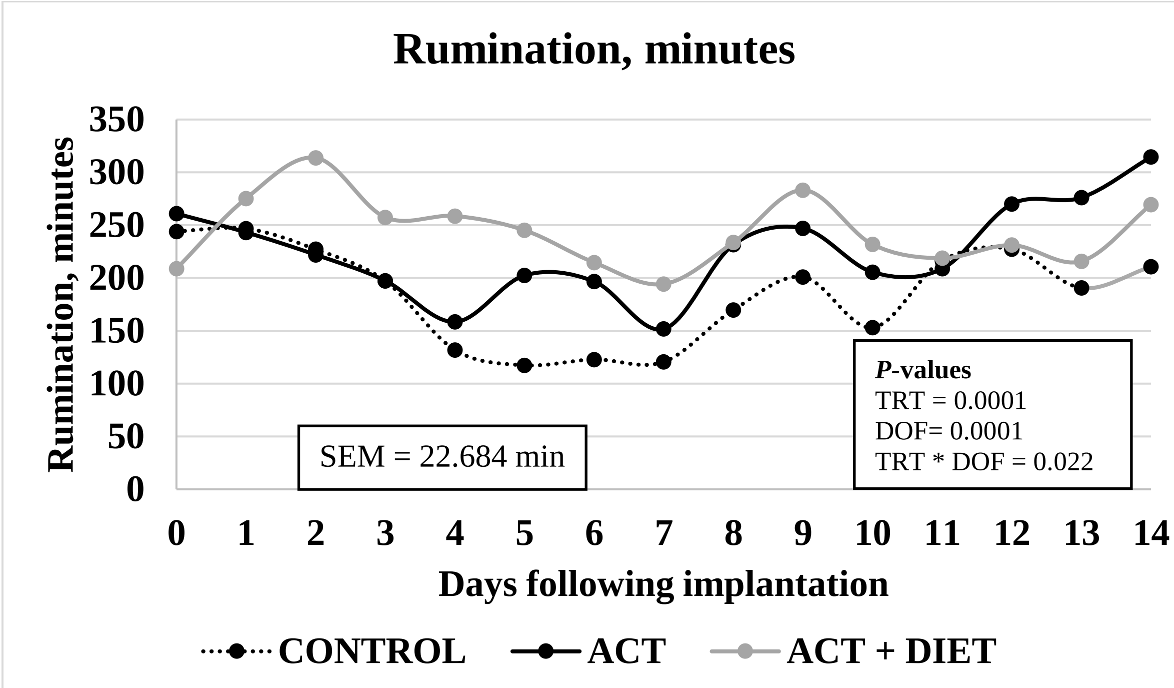

Figure 2.4. Effects of locomotion and diet change (10% increased forage) on rumination (min) in finishing beef steers from d1-14 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

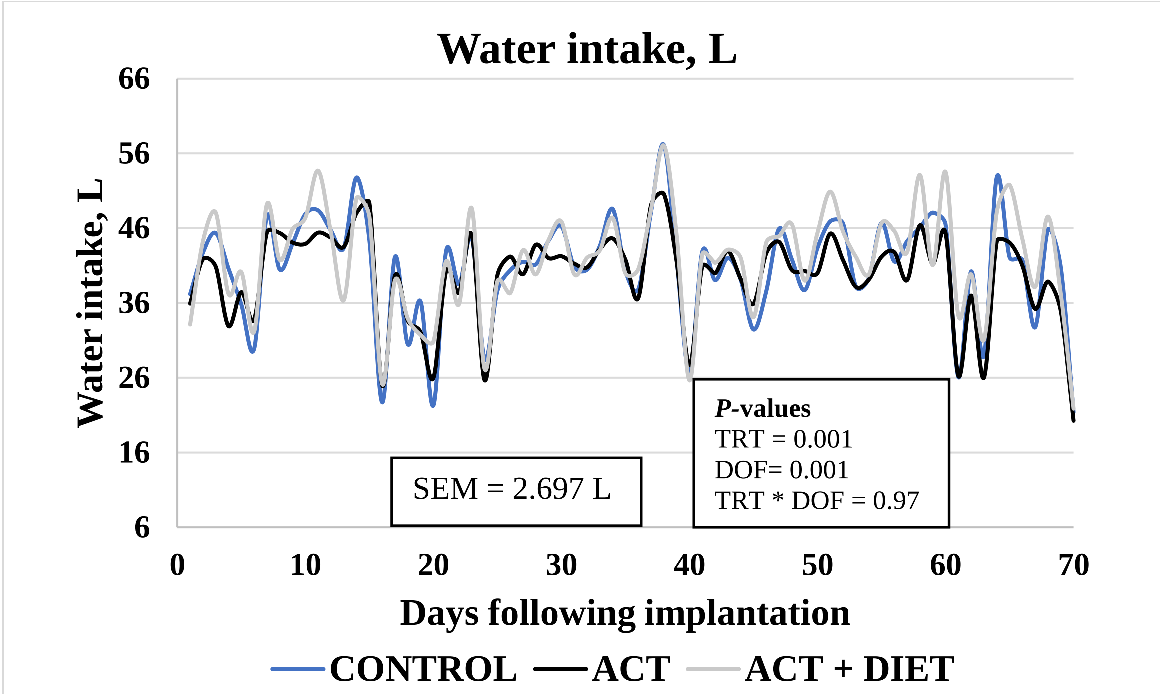

Figure 2.5. Cumulative total water intake (L) in finishing beef steers from d1-70 post terminal implant administration. Water intake (L) includes diet water and raw water intake. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

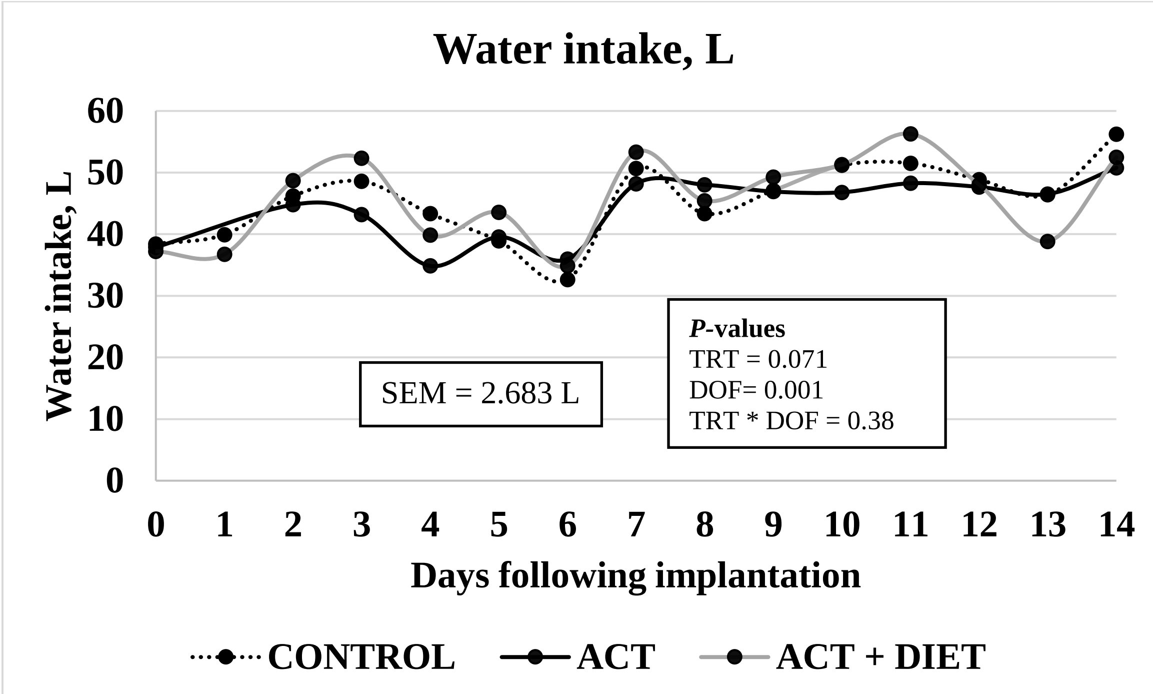

Figure 2.6. Effects of locomotion and diet change (10% increased forage) on water intake (L) in finishing beef steers from d1-14 post terminal implant administration. Water intake (L) includes diet water and liquid water intake. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

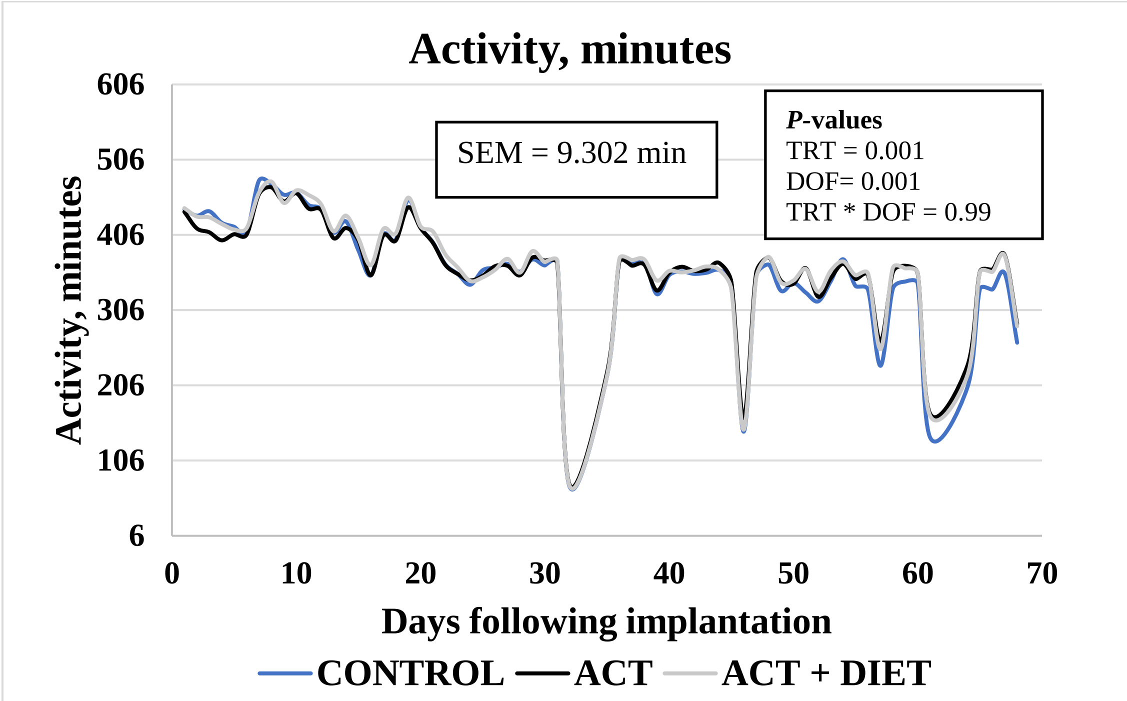

Figure 2.7. Cumulative average activity (minutes) finishing beef steers from d1-70 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

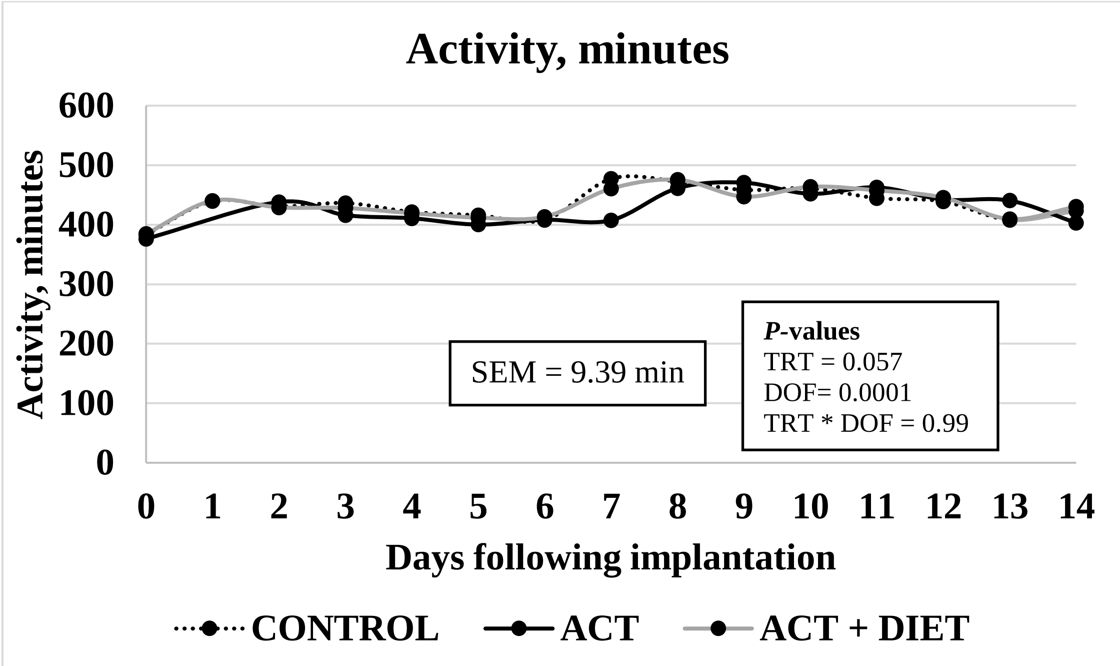

Figure 2.8. Effects of locomotion and diet change (10% increased forage) on average activity (min) in finishing beef steers from d1-14 post terminal implant administration. Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

Table 2.1. Diet composition (DM basis)

	Diet	
Item	Finishing	ACT+ DIET[a]
Dry rolled corn, %	61.5	33.85
Dried distillers grains, %	20.00	20.00
Oat hay, %		10.00
Corn silage, %	12.00	29.65
Liquid supplement, %[b]	6.50	6.50
Dry matter, %	82.22	72.22
Crude protein, %	14.52	14.42
NDF, % of DM[c]	7.85	17.37
NE_m, mcal/kg[d]	2.112	1.914
NE_g, mcal/kg[e]	1.43	1.38

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

[b] Liquid supplement: formulated to add monensin sodium to diet DM and vitamins and minerals to meet NASEM (2016) requirements

[c] Neutral detergent fiber

[d] Net energy for maintenance

[e] Net energy for gain

Table 2.2. Effect of implanting event on growth performance, dry matter intake and water intake in finishing beef steers d1-70

	Treatment				
Item	CON	ACT	ACT + DIET	SEM	*P* - value
Steers, *n*	9	9	9	--	--
Days on feed	70	70	70	--	--
Initial shrunk body weight (BW), kg[b]	556	569	550	6.62	0.53
Final shrunk BW, kg	680	674	672	7.75	0.72
Average daily gain (ADG), kg	1.66	1.72	1.60	0.152	0.76
Dry matter intake (DMI), kg	14.03	13.89	14.32	0.875	0.001
Gain to feed (G:F)[c]	0.123	0.113	0.116	0.007	0.67
Water intake, L[d]	44.34	42.69	44.67	2.69	0.97

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

[b]Initial and final body weights pencil shrunk 4% to account for gastrointestinal tract fill

[c] ADG/DMI

[d] Total water intake = diet water + raw water intake

Table 2.3. Effect of implanting event on d1-14 growth performance, dry matter intake and water intake in finishing beef steers

	Treatment				
Item	CON[a]	ACT	ACT + DIET	SEM	*P*-value
Steers, n	9	9	9	--	--
Days on feed	14	14	14	--	--
Initial shrunk body weight (BW), kg[b]	556	569	550	6.62	0.53
Final shrunk BW, kg	574	574	577	6.99	0.85
Average daily gain (ADG), kg	1.28	1.06	1.39	0.165	0.75
Dry matter intake (DMI), kg	12.49	12.66	11.2	0.284	0.29
G:F[c]	0.101	0.081	0.024	0.013	0.51
Water intake, L	46.06	44.29	46.50	2.683	0.001

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

[b] Pencil shrunk 4% to account for gastrointestinal tract fill

[c] ADG/DMI

Table 2.4. Effect of implanting event on activity and rumination in finishing beef steers.

	Treatment				
Item	CON[a]	WN[a]	WY[a]	SEM	*P*-value
Steers, *n*	9	9	9	--	--
d1-14					
Rumination, minutes	181	223	246	10.13	0.001
Activity, minutes	438	431	438	0.617	0.06
d1-70					
Rumination, minutes	215	258	257	29.956	0.001
Activity, minutes	357	361	365	9.302	0.06

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

Table 2.5. Effect of implanting event on carcass traits of finishing beef steers

	Treatment				
Item	CON[a]	ACT	ACT + DIET	SEM	*P*-value
Steers, *n*[b]	8	8	8	--	--
Hot carcass weight (HCW), kg	428	428	422	10.13	0.89
Dressing, %[c]	62.99	62.68	63.42	0.617	0.70
Rib fat, cm	1.76	1.75	1.80	0.136	0.97
Rib eye area, cm^2	101.37	96.09	97.14	3.35	0.51
Marbling score[d]	550	542	625	44.02	0.36
Calculated yield grade	3.25	3.51	3.45	0.265	0.78

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

[b] One steer was euthanized prior to shipping cattle. Two steers were removed due to incorrect data collection from EID tags at the slaughter facility

[c] HCW/final BW (shrunk 4%)

[d] 400 = $Small^{00}$ (USDA Low Choice)

Table 2.6. Effect of implanting event on United States Department of Agriculture Quality and Yield Grade distribution of finishing beef steers

	Treatment				
Item	CON[a]	WN[a]	WY[a]	SEM	P-value
Steers, *n*[b]	8	8	8	--	--
Quality Grade					
Choice, %	66.67	85.71	62.50	--	0.76
Prime, %	22.22	0.00	25.00	--	
Select, %	11.11	14.29	12.50	--	
Yield Grade					
YG 1, %	11.11	0.00	0.00	--	0.87
YG 2, %	11.11	14.29	25.00	--	
YG 3, %	55.56	85.71	50.00	--	
YG 4, %	22.22	0.00	25.00	--	

[a] Treatments: CON = cattle were implanted and returned to pen, ACT = cattle were implanted and walked 1.05 km, ACT + DIET = cattle were implanted, walked 1.05 km and received higher forage inclusion for 7 days after reimplantation

Table 2.7. Mean separation of dry matter intake (kg) means for 14 days post-reimplantation in finishing beef steers

Day	Control	ACT	ACT + DIET
1	12.45	11.20	10.34*
2	14.59	13.78	12.48*
3	13.40	11.98	11.13
4	11.08	9.25*	7.81
5	12.86*	10.56*	9.82
6	11.34	10.17*	7.97*
7	13.04	12.61	11.68
8	12.62	11.74	10.49*
9	13.38	13.13*	9.73*
10	13.65	13.62*	11.08*
11	13.72	13.51	12.99
12	13.94	13.93	13.22
13	14.19	13.21	12.63
14	14.33	13.12	12.92

* $P \leq 0.05$, significant difference between treatments

Table 2.8. Mean separation of rumination (minutes) means for 14 days post-reimplantation in finishing beef steers

Day	Control	ACT	ACT + DIET
1	251	259	256
2	231	237	294
3	201	213	238
4	136	174	236*
5	122	218*	226*
6	127	212*	195
7	125	167	174
8	174	214	247
9	205	262	263
10	157	221	212
11	220	224	199
12	231	285	211
13	194	292*	195
14	215	330*	250

* $P \leq 0.05$, significant difference between treatments