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TIMING OF IMPLANTS USE IN BACKGROUNDING SYSTEM

by

Kylie M. Butterfield

A THESIS

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TIMING OF IMPLANTS USE IN BACKGROUNDING SYSTEM

Kylie M. Butterfield, M.A.S.

University of Nebraska, 2022

Advisor: James C. MacDonald

A study was conducted over two years to determine the interactions of winter rate of gain at a high gain (HG) of 0.91 kg and low gain (LG) 0.45 kg, and implant strategy in the backgrounding and subsequent effects in the finishing phases. There were three phases in this study, the winter phase (~148 days), the summer phase (~60 days) and the finishing phase (~120 days). This was a 2 x 3 factorial design. The first factor is a rate of gain at either 0.91 kg (HG) or 0.45 kg (LG). The next factor is the timing of implant where steers either receive an implant in the winter and summer phases (STRONG-IMP), an implant only in the summer phase (MED-IMP) or no implant in the winter nor summer phases (NO-IMP). Steers were either fed a HG (0.91 kg/d) of 30% MDGS, or a LG (0.45 kg/d) of 10% MDGS in smooth bromegrass hay diets, respectively. The experimental unit is the pen which consists of ten head. During the winter phase, STRONG-IMP steers were implanted with 36 milligrams (mg) of zeranol (Ralgro; Merck Animal Health) lasting around 90 days; all steers remained in the winter phase for 148 days. In the summer phase, steers grazed Smooth Bromegrass pasture and both MED-IMP and STRONG-IMP received an implanted with 40 mg of trenbolone acetate (TBA) and 8 mg of estradiol (Rev-G; Merck Animal Health) lasting 120 days. Eighty steers did not receive an implant during the winter nor summer phases (NO-IMP). Steers remain in the summer phase for approximately 56 days. In the finishing phase, all steers were given 200 mg of TBA and 40 mg

of estradiol (Rev-XS) lasting approximately 200 days. The steers remained in the feedlot for approximately 115 days. In the winter phase, there was a significant difference in the ending body weight (EBW), average daily gain (ADG) and gain to feed ratio (G:F) for the main effects of winter rate of gain and implant strategy ($P < 0.01$), with the HG and STRONG-IMP gaining the most at 0.89 kg/d, having the largest EBW and greatest G:F of 0.109. For the summer phase, there was a statistical difference for winter rate of gain and implant strategy ($P < 0.01$) of EBW. High gain and STRONG-IMP resulted in the largest EBW but did not gain the most over the summer phase. When comparing the treatments of HG verses LG, the LG treatments gained more than the HG during the summer. There was a significant difference for EBW in the finishing phase for both main effects ($P < 0.01$) with HG and STRONG-IMP being the greatest. Hot carcass weight (HCW) followed a similar trend to EBW with a statical difference for both main effects of winter rate of gain and implant strategy ($P < 0.01$) and the HG and STRONG-IMP weighing 416 kg, which is numerically 44 kg greater than the LG and NO-IMP in the winter nor summer phases. Supplementing at a high rate of gain during the winter backgrounding phase and implanting in the winter, summer and finishing phases results in the greatest total system gain and HCW.

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Introduction

Growth promoting factors have been utilized in the cattle industry since the 1940s, such as diethylstilbesterol (DES) started being used in the 1950s (Preston, 1999). From the 1940s to the 1970s the amount of beef produced in the U.S. grew proportionally with the number of beef cattle. From the 1980s until today the number of head of cattle decreased while the amount of beef production continued to increase (Preston, 1999). The goals of any beef producer is to increase the amount of beef produced while lowering input costs like feed. One option to increase muscle gain is through implants. While implants have been used in the beef industry throughout the years in multiple segments of beef production, the feedlot industry is the largest user of implants. On average implants increase between 15 to 40 dollars per head more as a financial advantage depending on gain when comparing those nonimplanted (USDA, 2000). The percent of cattle implanted in feedlots with 8,000 or fewer head was 89.5%, compared to feedlots with 8,000 or more head implanting 99.6% (USDA, 2000). Larger feedlots also more likely to implant cattle more than once when the cattle weighed 700lbs or less. If cattle entered the feedlot weighing 700lbs or more, they were less likely to get implanted twice because the life span was less to reach approximate slaughter weight (USDA, 2000).

Growth Promoters

Starting in 1954, DES was approved as the first growth promoter fed to cattle (Preston, 1999). In 1956, DES was approved for implant usage (Preston, 1999). Mitchell et al., 1959 used tritium-labeled DES in two steers to determine how the radioactivity of DES stayed in the tissue. One steer was cannulated in the bile duct while the other steers was not cannulated Both consumed a diet of alfalfa hay, ground shelled corn and soybean oil meal (Mitchell et al., 1959). The collection period was 11 days while collecting urine and feces at six hour intervals for the first 48 hours and then 12 hours intervals for the rest of the period. Bile from the cannulated steers was collected at 3 hour intervals for the first 48 hours and 6 hour intervals for the remainder of the period. On the 12th day of the period the non-cannulated steer was necropsied for samples of the muscle, liver, heart and kidney (Mitchell et al., 1959). In the non-cannulated steer, 46% of the radioactive of DES was found in the urine and feces, while the cannulated steer showed 51.1% f the radioactive of DES in the bile, urine and feces (Mitchell et al., 1959). There was not enough radioactive DES to be detected in the tissues sampled (Mitchell et al., 1959). This implies that a majority of the radioactive DES is excreted. In 1979 DES was banned for use in cattle when it was recognized that women who were pregnant and took DES to reduce unwanted abortions had a tendency to have cancer later in life, and their daughters also had an increase probability to have cancer (Veurink et al., 2005; Preston, 1999). Taking DES off the market opened up new opportunities and research to find new molecules and techniques for growth promoters.

In 1969, zeranol, an estrogen synthetic hormone, was approved for cattle (Preston, 1999). Calkins et al., 1985 compared intact males to steers when given zeranol. Zeranol increased average daily gain (ADG) of 1.54 kg/d in the growing phase compared to non-implanted cattle of 1.43 kg/d. Additionally, an increased yield grade (YG) of the zeranol implanted cattle of 3.57 with the non-implanted cattle of a YG of 2.85, with an increase in adjusted fat thickness for the zeranol implanted of 1.70 cm and the non-implanted of 1.21 cm (Calkins et al., 1986). The addition of zeranol improved performance and carcass traits for both intact males and steers. Cole et al., (1983) investigated the differences between yearling steers implant with zeranol to non-implanted steers with different protein sources. The non-implanted steers gained 1.08 kg per day compared to implanted steers, which gained 1.19 kg per day, over a 143 day period (Cole et al., 1984). In both of these studies, steers that were implanted with zeranol did gain more muscle over the trial period then those not implanted. Zeranol can be used to increase body weight (BW) and hot carcass weight (HCW) and is a reasonable option to help increase muscle growth responses.

Trenbolone acetate (TBA) was introduced in the beef industry in 1987, while the combination of TBA and estradiol (E2) was approved in 1991 with a ratio of 5:1 TBA:E2 (Preston, 1999). In 1991, Perry et al. implanted Holstein, Angus and crossbred beef steers with TBA:E2 while on a common feedlot diet comparing performance and carcass traits. The breeds of steers that showed the most difference for performance traits was the Angus while the Holsteins also gain more and had a large final body weight (FBW) (Perry et al., 1991). There was no difference in carcass traits across all breeds. This may indicate that TBA:E2 implants had different rates of gains between different breeds. Johnson et al., 1995 compared implanted steers with TBA:E2 (Revalor-S) to non-implanted steers on carcass traits over 143 days in the feedlot on a common feedlot diet. Final body weight and HCW did differ numerically with the implant steers having a FBW of 635 kg and HCW 394 kg and nonimplanted steers had a FBW of 601 kg and HCW of 368 kg (Johnson et al., 1996). The implanted steers had a carcass protein gain of 142 g/d with the nonimplanted steers having a 114 g/d ($P < 0.06$) over 143 days (Johnson et al., 1996). The combination of TBA:E2 is more common to use in the feedlot industry. Trenbolone acetate with estradiol is one of the major implants that is used across the United States for feedlot showing the largest muscle gain (Johnson et al., 1996; Preston, 1999).

Implants in Different Sectors of the Beef Industry

Implants have been used in the feedlot industry for many years. In more recent years, the use of implants has become more common in the backgrounding phase but are still rarely used in the preweaning phase. Backgrounding operations are slowly starting to implement implants into their practices. Brandt et al., (1995) compared two grazing systems with an implant verses a non-implanted control, and observed a numerical difference where implanted animals had a greater average daily gain (ADG). Depending on the type of grazing system steers will gain more if implanted then those not implanted (Brandt et al., 1995).

Implanted cattle in one phase of the beef industry usually means that the cattle will be implanted in the later phases of the industry if the cattle remain under the same owner. Roeber et al., 2000 compared using multiple implants in the grower and finishing phases with different brands of implants. The brands of implants compared were Merck Animal Health, Zoetis Incorporated and Elanco Animal Health Incorporated. The steers were either given no implants, implant in the grower/ no implant in the finisher, no implant in the grower/ implant in the finisher or implant in the backgrounding and implant in the finisher phase (Roeber et al., 2000). There was significant difference for increase HCW for those that were implanted for both phase of the study compared the control, which was the no implanted for both phases for the study. There was a significant difference with a pen by treatment effect ($P < 0.0001$; Roeber et al., 2000). This shows there are some benefits to implanting during the grower and finisher phases regardless of the brand of implant. Duckett and Andrae 2001 repeated a similar study with implanting in the preweaning, grower and finisher phases comparing Merck Animal Health, Zoetis Incorporated and Elanco Animal Health Incorporated. Overall, implanting steers in the preweaning phase increase ADG by 5%, 15% in the grower phase and 20% in the finisher phase (Duckett and Andrae, 2001). Simms et al., 1988 chose six different treatments to test implants in multiple phases of the beef industry. The treatments consisted of no implants, implanted two times in the finishing phase, implanted in the suckling or preweaning phase with two implants in the finishing phase, implanted in the backgrounding phase with to implants in the finishing phase, implanted in the preweaning and growing phase while receiving one implant in the finishing phase, implanted in the preweaning and growing phase while receiving two implants in finishing phase (Simms et al., 1988). All implants use contained the hormone zeranol. The breed of the steers used was a cross between Charolais and Simmental. There was no differences between preweaning calves that were implanted and not implants on ADG. During the backgrounding phase there was a significant difference between then no implant followed by an implant, implant and implant compared to the implant then no implant for ADG (Simms et al., 1988). For the finishing phase, there significant difference was between those not implanted at all and those who were implanted in different phases of the trial for ADG range from 1.29 kg/d receiving no implants and 1.41 kg/d receiving four implants (Simms et al., 1988). Implants in this trial resulted in differences in each phase when implanted verses not implanted. The implications for this trial are implants as an overall increase ADG, but may not be needed in every phase of the beef industry. However, more research needs to be done to determine the magnitude of impact that implants have on preweaning calves.

Implants in the grower and the finisher increase the BW and HCW compared to those that are not implanted in either phase regardless of the brand of implant. Implants in both the grower and finisher increase the value of the carcass and bring more dollars back to the producers when being sold into the finishing phase to a feedlot from the grower phase or when being sold to the packer from the finishing phase. The profit of ADG from implant for steers will outweighs the cost of the implant for both the grower and finisher phase.

Implants are an important factor for all sectors of the beef industry to increase muscle gain while decrease the overall cost of production. As shown in this review, the improvement of the understanding of types of implants as well as the timing greatly benefited the beef industry. Implants are proven to be a resourceful asset.

Mechanisms of Implants

Implants consist of one or more hormones combined within pellets to increase muscle gain in cattle. On a cellular level, to increase muscle gain the muscle cell must grow wider and longer (Johnson et al., 1996). When any animal is born, they are born with a set number of muscle cells. This type of growth is considered hypertrophy (Johnson et al., 1996). To work effectively implants are given in the middle third of the ear and in the middle of the ear (Merck Animal Health, De Soto, KS). There are two veins that run along the outer edge of the ear, this allows the implant to be released into those specific two veins to travel to the rest of the body to affect the muscle hypertrophy throughout the rest of the body. Implants are given in the ear because the ear is the first part of the animal the is cut off at harvest and does not go into the food supply (NASEM, 2016). The hormones in implants are encapsulated in either a sugar or polyene glycol to protect the hormones from environmental effects until entering the ear (Castillo et al., 1992). These encapsulation substances will dissolve in the ear to release the hormones into the blood. In addition to encapsulation, implants can have a coating to increase the release time of some of the pellets. For example, Revalor XS has four pellets that are not coated and start releasing immediately and are almost completely dissolved by day 70 of implant being in the ear, while the other six pellets are coated to begin releasing on day 70 (Intervet/Merck Animal Health, 2021). This can lengthen the impact of the implant to around 200 days total (Intervet/Merck Animal Health, 2021). These types of coating can be polyvinyl alcohol, schellac, bees wax, cellulose acetate butyrate, polylactic acid, ethyl cellulose, silicones and ethylene vinyl acetate (Castillo et al., 1992).

Hormones in implants are estrogen, testosterone, progesterone, zeranol, and trenbolone acetate (TBA; Meyer, 2001). Implants for cattle are made by three companies: Merck Animal Health, Zoetis Incorporated and Elanco Animal Health Incorporated. These companies have implants for calves, pasture cattle, feedlot cattle and heifer verses steer implants. These implant have different lengths and amount of hormones within them for longevity (Smith and Johnson, 2020; Table 1). The different longevity and potency are used in different areas of the beef industry. Most common use of longer lasting implants with a greater potency is in the feedlot sector. However, there is a growing trend to use implants in the preweaning and backgrounding sectors. In the feedlot sector, more steers have been implanted then heifer, especially since heifers are retained as replacement heifers in the herd. This results in an overall smaller number of heifers entering the feedlot compared to the number of steers entering the feedlot. Implanting heifer is becoming more common as more implants are specified for heifers.

Hormones entering the blood steam have many effects on the body. Hormones have direct and indirect effects, which means that the hormone can have a direct effect on muscle or the hormone can directly affect an organ to release another hormone to affect the muscle. Any estrogen and androgen hormones have direct effects on the rumen, kidney, skin, bone, liver, muscle, hypothalamus, pituitary and behavioral effects (Meyer, 2001). While indirect effects on the liver, bone muscle and fat. These hormones can travel to the hypothalamus, which will release growth hormone releasing hormone (GHRH). The GHRH stimulates the pituitary gland to release growth hormone (GH). Growth hormone has a positive effect on muscle, liver and bone to increase growth (Meyer, 2001). On a cellar level, when a hormone reaches a target cell, the cell in which the hormone has an effect, the hormone must attach to a receptor. Once the hormone and receptor are attached, this unit is called the hormone-receptor complex. This complex can travel through the cytoplasm to the nucleus to attach to the chromatin. By attaching to the chromatin, the activation of mRNA transcription is initiated (Sur and Chakravorty, 2016). The initiation is the signal to change or increase muscle growth.

Estrogens

The types of estrogen hormone in implants are estradiol-17B, a naturally occurring estrogen, and zeranol, a synthetic hormone (Meyer, 2001). Estradiol-17B's receptors are estrogen receptor-alpha (ER), ER-Beta and G-protein-related receptor (GPR30). Estradiol-17B directly stimulates GH secretion, GH receptor and insulin-like growth factor-1 in the muscle (Meyer, 2001; Kamanga-Sollo et al., 2008). In the blood stream, estradiol-17B moves to the target cell, enters the cytoplasm and attaches to either ER-a or ER-B. The receptors will move to the nucleus and attaches to estrogen response element (ERE). Within the nucleus there are four different types of pathways to signal the transcription. One is ERE-mediated, transcription factor with the estrogen receptor, non-genomic with the transcription factor or ligand- independent where the estrogen receptor is accompanied by a cofactor (Sur and Chakravorty, 2016).The events that result from the transcription are cell proliferation, osteogenic function and cell differentiation (Ho et al., 2018). Zeranol has a different affinity for binding to ER-a and ER-B then estradiol 17-B, but similar transcriptional effects (Meyer, 2001).

Testosterone

Testosterone's receptor is called androgen receptor in the muscle cell. When traveling to the target cell, testosterone attaches to a G-protein-linked receptor to have a direct effect on muscle hypertrophy, myonucleus with a direct effect on muscle hypertrophy, satellite cell which will cause proliferation. Proliferation causes myonuclear accretion and new myotubes can form, this results in muscle hypertrophy. Testosterone has a positive effect on muscle lineage while having a negative effect on adipogenic lineage (Kadi, 2008).

Trenbolone Acetate

Trenbolone acetate is a synthetic like testosterone properties as well as progesterone like properties. Trenbolone acetate has binding affinities for androgen receptors, progestin receptors and glucocorticoid receptors. Glucocorticoid when bond to its receptor will decrease the protein synthesis with an increase in catabolism of the amino acids and can cause protein degradation. Trenbolone acetate attaching to the glucocorticoid receptors blocks the protein degradation (Meyer, 2001; Kamanga-Sollo et al., 2008). The effects of progesterone within implants on metabolism are not completely known (Meyer, 2001).

Multiple Hormones in Implants

Some implants have more than one hormone. Most common is to combine estradiol and TBA. Combining these two hormones can help increase the number of bovine satellite cells, also known as muscle stem cell, IGF1 mRNA and estrogen receptors and androgen receptors within the muscle cells (Kamanga-Sollo et al., 2008; Smith et al., 2019). This can significantly increase muscle growth and result a great return to producers.

Goal of Backgrounding

Backgrounding is a method to increase body weight after weaning but before entering the finishing phase (Thomson and White, 2006; Bradford et al., 1978). There can be different ways to background cattle depending on the region. In the Midwest, backgrounding cattle can be fed a diet of hay with distillers as the protein supplement in a feedlot type system, be turned out on a pasture of grass, a crop field of corn residue or a type of cover crop. In the Texas Panhandle and some parts of Kansas, cattle can be placed on winter wheat pasture or in a feedlot system with the main feed ingredient being a forage base diet with some type of protein or energy supplement (Gill et al., 1993). These methods can also be combined to lengthen or shorten the backgrounding period. The shorter phase is for cattle after being weaned in the fall, which is the most common, can consist of a feedlot placement in the winter on a forage based diet, on a corn residue pasture, or a cover crop pasture consisting of oat, brassica or winter wheat pasture. The cattle will enter the finishing phase around April or May on a concentrate based diet. A longer backgrounding phase would have two different periods, one being the similar to the short phase and the other phase being turned out on perineal pasture such as bromegrass or kept for a longer time in the feedlot on a forage based diet before entering the finishing phase around July or August depending on the type of backgrounding allocated (Gill et al., 1993).

The purpose of backgrounding is to increase body weight of calves after weaning but before the finishing phase, this is profitable on a forage based diet by ensuring gain with a type of energy or protein supplementation. A main factor that holds the most importance is how cattle gain during this period with the amount of feed available, which is considered the gain to feed ratio. Brandt et al., 1995 used different lengths of grazing systems for backgrounding to determine which is the most profitable system in the plains of Kansas. Crossbred steers weighing around 272.4 kgs were allotted to treatments being either intensive-early stocking(70 days) or season long stocking(147 days) with an implant or no implant (Brandt et al., 1995). The intensive-early stocking gained less ($P < 0.05$) and had a smaller HCW ($P < 0.0001$) then those on the season long stocking system. However the return on dollars per head was greater for the season long grazing verses the intensive early stocking with no implant ($P < 0.0001$). Therefore making the season long grazing with no implant more profitable then the intensive early stocking with no implant (Brandt et al., 1995). Increasing the backgrounding period showed an increase in gain while possibly reducing the breakeven price of production (Shain et al., 1998).

Protein Supplementation in the Backgrounding Period

Ruminant diets, always have a source of forage and can grow and maintain body composition on a diet that is unsuitable for most animals. Ruminants are able to utilize low quality forage because of a unique symbiotic relationship with microorganisms within their rumen (Castillo-González et al., 2014).Ruminants, unlike pigs or humans, have four compartments to their stomach. The four compartments of a ruminants stomach are the rumen, reticulum, omasum and abomasum. Within the rumen, there are microorganisms that ferment feed (Burns, 2008).When ruminants consume forage, similar to humans or pigs, they do not have enzymes that break down cellulose or hemicellulose from fiber. Microorganisms are utilized to breakdown the fiber and create an end product that is readily available for the ruminant to convert into energy in the tricarboxylic acid cycle (TCA cycle; Russell and Dombrowski, 1980).

Microorganisms Relation to Protein

The microorganisms not only are able to breakdown fiber, they are also able to turn a feed that is low in protein quality to a protein that is metabolizable to the ruminant (Galyean, 1996). There are three different types of proteins that the ruminant uses to turn into metabolizable protein (MP). Metabolizable protein is protein that the animal can absorb and use within different parts of its body (Ouellet et al.,2002). The three protein sources that make up MP are rumen undegradable protein (RUP), rumen degradable protein (RDP) and bacterial crude protein (BCP; Galyean, 1996). Rumen undegradable protein is protein in the diet that is not degraded by the microbes in the rumen and is broken down in the abomasum to then be absorbed in the small intestine (Galyean, 1996). Rumen degradable protein is protein in the diet that the bacteria in the rumen degrade and use for their growth and maintenance (Blackburn, 1968).Bacterial crude protein is from bacteria that flows out of the rumen into the abomasum, where that protein is broken down, and then into the small intestine where the protein is absorbed (Spicer et al., 1986).

Determining Metabolizable Protein

Bacteria depend on RDP for growth and maintenance (Cotta and Hespell, 1986). If RDP is low, not meeting the requirements of the bacteria, microbes will not maintain normal biological function (Cotta and Hespell, 1986), the total bacterial population will decrease. The decrease in the bacterial population will result in the decrease of MP. To calculate MP from BCP, the total digestible nutrients (TDN) multiplied by microbial efficiency (the RDP requirement being met), which equals BCP production. Bacterial crude protein is 80% true protein and 80% digestible (Verite et al., 1979). Multiplying BCP true protein by the digestibility equals 0.64, which is the percent of MP within BCP. The BCP production is then multiplied by 0.64 to equal the total MP from BCP (Verite et al., 1979). Galyean (1996) derived the equation as:

TDN Intake* Microbial Efficiency= BCP Production* 0.64= MP from BCP

The other portion of the equation to determine the MP is from RUP. First, the total crude protein (CP) intake from the diet needs to be determined, which is multiplied by RUP of the diet and RUP digestibility. This determines the total MP from RUP. The MP form BCP is added to MP from RUP to get the total MP (Galyean, 1996). These equations were adapted from Galyean (1996).

CP* RUP of Diet* RUP Digestibility= MP from RUP

MP from BCP + MP from RUP= Total MP

Cattle diets are greatly composed greatly composed of different types of forages, understanding the impact of forages on the total MP is important when formulating diets to meet the requirements of cattle.

Microbial Protein Synthesis within the Rumen

Rumen degradable protein is a source of amino acid (AA) for the microorganism to meet the requirements, while another source of amino acids comes from nitrogen recycle that occurs within the rumen (Lapierre and Lobley, 2001).Bacteria degrade protein in a similar manner as animals, the use proteases that can be attached to the membrane or wall of the bacteria (Blackburn, 1968). Blackburn (1968) isolated a specific bacteria called *Bacteroides amylophilus* to determine the type of protease enzyme used for protein degradation. *Bacteroides amylophilus* protease enzyme that was isolated had similar enzymatic activity to that of trypsin, which allows access of AA for the bacteria (Blackburn, 1968). Trypsin is an enzyme within the small intestine that cleaves peptide bonds of basic AA (Locksley Trenholm et al., 1966).There are different bacteria that have specific proteases the target certain AA, *Bacteroides ruminicola* proteolytic enzyme degrades protein with an AA base of cystine, serine and aspartic acid (Hazlewood and Edwards, 1981). *Bacteroides amylophilus* and *Bacteroides ruminicola* proteolytic enzymes allow for bacteria without such enzyme access to AA for growth and development. This can be considered an important concept especially when evaluating the diet of bovine. Cotta and Russell (1982) compared bacteria viability at varying amounts of protein and glucose provide. Rumen bacteria was extracted from the rumen and placed in a media with microminerals to meet requirements. The bacteria showed a maximum production of protein when the ratio of AA to glucose was set at 12.5% (Cotta and Russell, 1982).

The microorganism are efficient when the protein source being feed is low in protein quality because of the nitrogen recycling that occurs within a ruminant (Bryant and Robinson, 1963). Nitrogen recycling occurs when ammonium (NH_4) travels to the liver from the rumen where it is converted to ammonia (NH_3) to travel back to the rumen (Lapierre and Lobley, 2001). The microorganisms are able to use the nitrogen from the ammonia to synthesize AA for maintenance and growth (Lapierre and Lobley, 2001). This nitrogen recycling can account for approximately 30 to 40% of the nitrogen fed will return to the rumen in cattle, with about 50% of the nitrogen returned to the rumen will be converted into AA (Lapierre and Lobley, 2001). Bryant and Robinson (1963) found that bacteria within the rumen cannot use the carbon efficiently that is with AA from the diet, however, they seem to synthesize AA from the nitrogen recycled more efficiently. The bacteria use the dietary protein to produce volatile fatty acids in addition to NH_3 and CO_2 before using the dietary protein to synthesize AA for themselves (Bryant and Robinson, 1963).

Protein from forages

Depending on the forage source impacts the amount of protein and energy available to the animal. Redfearn et al. (1995) compared the protein availability from cool season grasses and warm season grasses by incubating both grass types in the rumen of a cannulated steer and removing the bags at different hours of incubation. Three grasses were included in the study included: switchgrass, big bluestem (warm season grasses) and smooth bromegrass (cool season grasses; Redfearn et al., 1995). The warm season grasses differed in the amount of protein that was not degraded in compared to the protein degraded of cool season grasses. The warm season grasses ranged from 8% to 23% of protein that was not degraded by the rumen. The cool season grasses ranged from 25% to 60% of protein that was not degraded in the rumen (Redfearn et al., 1995). The degradation of these certain grass proteins can also depend on the maturity of the plant when eaten by a ruminant as well as how selective the animal is when grazing. Depending on the time of year and region effects whether cattle are grazing cool and warm season grasses. Cattle will mainly be grazing these grasses in the late spring, summer and early fall. However, in the winter producers normally turn to another source of forage such as hay. In the Midwest, sources of hay can include meadow hay, alfalfa hay, smooth bromegrass hay, and prairie hay. In addition to silages as a source of forage. Alfalfa hay has been known as a golden standard of hay as it has a crude protein disappearance in the rumen and duodenum is 81.24% to 93.82% compared to the grass hay at 71.70% to 93.43% and grass silage at 64.48% to 92.98% crude protein disappearance (Von Keyserlingk et al., 1996). These few forages had a crude protein degradability in the rumen and duodenum at around 90%, indicating that the forages protein is being used either by the microbes or being absorbed in the small intestine for the ruminant's use (Von Keyserlingk et al., 1996).

Supplementation on Low Quality Forage

During the backgrounding period cattle are normally consuming a forage based diet. There are many forage diets that are available for grazing cattle. The forage available should be able to support the nutritional need for the grazing animal. However, when the nutritional needs are not met, mainly protein and energy, supplementation may be needed, especially with growing animals.

In the Midwest, it is very common to supplement cattle using distillers grains. It is an easy and readily available source of protein and energy. While there are many other by products that can be used to supplement cattle as well such as corn gluten meal and soybean meal. Steers grazed cornstalks and then fed bromegrass hay in the winter period with corn gluten feed being the protein and energy supplement (Downs et al., 1998). The steers were supplemented at either a low rate of gain at 0.32 kg/d or high rate of gain at 0.77 kg/d. Steers allotted the lower supplementation rate gained less per day then those allotted the higher rate of gain, in addition to, the higher rate of gain had a greater ending body weight ($P < 0.05$; Downs et al., 1998). Distillers grains has been used as a supplementation asset for many years, and is a byproduct of the ethanol industry. Studies were compiled over years in eastern Nebraska, Nebraska sandhills, southeastern Kansas and the Kansas Flint Hills supplementing distillers grains. The forage source on these eight studies was bromegrass pasture, native range, silage, alfalfa hay and grass hay. All those that were supplemented with distillers grains gained more than those not supplemented. However, the steers in Kansas, especially those in the Kansas Flint Hills gained significantly more at 1.28 kg/d and southeastern Kansas 0.96 kg/d compared to the Nebraska studies gaining anywhere from 0.77 to 0.99 kg/d (Klopfenstein et al., 2007).

Types of Distillers as a Supplementation Source

A decades long debate of whether dried distillers grains (DDGS), wet distillers grains (WDGS), or modified distillers grains (MDGS) is the best for protein and energy to supplement to cattle during the finishing phase (Ham et al., 1994; Firkins et al., 1985). When comparing DDGS to WDGS, feeding high levels of DDGS, cattle gained 1.71 kg per day, while feeding wet distillers byproducts, cattle gained 1.69 kg per day (Ham et al., 1994). Where the gain to feed ratio was much more efficient when feeding wet distillers byproduct being 0.158 and high levels of DDGS being 0.145 ($P < 0.05$; Ham et al., 1994). The type of distillers grains did not seem to have an effect on final body weight when comparing all three distillers grains for Nuttelman et al., 2011. However, the type of distillers grains does seem to effect the dry matter intake and feed to gain ratio. Wet distillers grains had a lower dry matter intake at 11.26 kg/d with a feed to gain ratio at 6.06, MDGS with 11.99 kg/d dry matter intake with feed to gain being 6.33 and DDGS of 12.30 kg/d dry matter intake with feed to gain being 6.67 ($P < 0.01$) (Nuttelman et al., 2011). Wet distillers seems to be the obvious choice to be supplementing on low quality forage, but the consistency also needs to be taken into consideration. Wet distillers grains is 30-35% dry matter, which makes handling it hard as it is a watery consistency. Modified distillers grains is 45-52% dry matter, which is easier to handle then WDGS (Buckner et al., 2011). Dry distillers grains is 90% dry matter (NESAM, 2016).

Supplementation of distillers grains is very different when used in foraged based grazing or confined backgrounding system. For diets consisting of high forage, whether backgrounding in a dry lot or backgrounding in a pasture, MDGS or DDGS is mostly like the more reasonable choice for supplementing protein or energy on low quality forage as they are easier to handle then WDGS. Modified distillers grains increases the feed efficiency of the animal when compared to DDGS, resulting in MDGS being the more obvious choice in supplement in a dry lot situation when there is a bunk available for MDGS to fed out of (Gillespie-Lewis et al., 2016; Boundurant et al., 2018). Griffin et al., (2012) used multiple studies to compared supplementation of DDGS to no supplementation when grazing a native rangeland, perennial grasses or a dry lot. There was a significant difference for those not supplemented at all and supplemented at 1.2 kg/d in FBW and ADG. The final body weight for the non-supplemented steers was 376 kg, while the supplement steers at 1.2 kg/d was 409 kg in the pasture studies with the confinement resulting in an overall lower FBW (Griffin et al., 2012). Dried distillers grains may be more reasonable to supplement on a pasture based backgrounding operation because of the high dry matter content (NESAM, 2016). The type of distillers grains used to supplement backgrounding cattle may depending on the operation facilities and goals, but supplementing either MDGS or DDGS will result in greater gains then those not supplement (Gillespie-Lewis et al., 2016; Griffin et al., 2012).

Compensatory Gain

Compensatory gain is the idea of cattle being on a low plane of nutrition and having a lower average daily gain on this diet will compensate gain when being fed on a higher plane of nutrition (Klopfenstein and Milton, 1999; Hornick et al., 2000). Compensatory gain is achieved when moving from a backgrounding phase (lower plane of nutrition) to a finishing phase (high plane of nutrition). Knowing this, compensatory gain is still not well understood and even harder to predict (Klopfenstein and Milton, 1999). Klopfenstein and Milton, (1999) compared mutliple studies evaluating compensatory gain. All calves on a decresed plane of nutriton showed an increase compensation percentage from 40% to 80% (Klopfenstein and Milton, 1999). The type of forage for grazing during the backgrounding phase (bromegrass verses sandhills range) had no effect on the compensation percentage. The britsh and conitental breeds were compared to see which breed compensated better. However, there was no signficant difference in compensation with both breeds compensating at about 53% (Klopfenstein and Milton, 1999). The main factor effecting compensatory gain was the days on a lower plane of nutrion. A full grazing period is consisdered to be around 130 days which showed a increased compenstation when compared to a 53 day grazing period. The plane of nutrition is decreased for a long peroid of time there will be no compesatory gain (Hornick et al., 2000). Between all the studies comapaired most showed about 55% compensation rate when cattle were on a decreased plane of nutrition (Klopfenstein and Milton, 1999).

Performance

Cattle are on high plane of nutrition, will have peak of compensatory gain at about 50 days on feed then slowy decrease gain to match those that did not have to compensate (Hornick et al., 2000). When entering the finishing phase steers with the lower plane of nutrition enter the feedlot at a smaller weight, resulted in decreased maintenance requirements (Wright and Russel, 1991). Wright and Russel, 1991 compaired feeding steers at a higher and lower feeding levels, where the lower feeding level at slaughter had an increase in muscle and a decrease in fat compared to those fed at a higher feeding level, which can be expected as known that fat in deposited after muscle in growth patterns. The lower feeding level of steers had not reach the point in their growth to put on fat (Carstens et al., 1991). Neither live weight nor the hot carcas weight of these steers were not signifancantly different (Wright and Russel, 1991). Coleman and Evens, 1968 looked at compensatory gain comparing Chalios and Angus breeds with age being a factor of younger or older steers. Overall, steers with a lower plane of nutrition compensated ($P < 0.05$) then those not on a restricted diet (Coleman and Evens, 1968). There was no difference between breeds at compensetory gain. However, the age of the steers did show difference in overall feed to gain. The younger steers had a better feed to gain ratio then older steers ($P < 0.05$; Coleman and Evens, 1968). There is no signifcant difference in bos taurus breeds nor age of animal where comparing compensatory gain (Coleman and Evens, 1968).

Steers were fed either a forage diet or a concentrate diet, while all the steers on the forage diet were fed ad libitum, the steers on the concentrate diet were fed either ad libitum or limited intake during the growing phase (Sainz et al., 1995). In the finishing phase, phase steers were all fed a concentrate diet at either ad libitum or limited intake. Steers were harvested in a serial harvest in a total of four groups. The ending body weight for the steers fed a forage diet weighed less then the concentrate both at ad libitum ($P < 0.001$), which is expected, compared to the concentrate limited intake resulted in an ending body weigh inbetween the two other treatments (Sainz et al., 1995). When comparing gut fill among treatments, the forage ad libitum was greatest because of physical fill controls intake, where the concentrate diets will be controled by chemostratic control of intake. Carcass characteristics including marbling ($P < 0.05$), backfat (P

< 0.001), and hot carcass weight where the greatest in the concetrate ad libitum, concentrate limited intake in the middle and forage ad libitum intakes as the lowest treatment (Sainz et al., 1995). Steers that were on the both of the concentrate had the best gain to feed at 0.173 (ad libitum) and 0.176 (limited intake) compaired to the forage ad libitum (Sainz et al., 1995).

Metabolic Changes

When on a low plane of nutrition diet or restriction of nutrition diet, animals experience metabolic changes. Cabaraux et al., (2003) restricted food to doubled-muscle Belgian Blue bulls and evaluated the metabolic changes over the feeding period with compensatory gain. Multiple blood plasma measurements were taken looking at insulin-like growth factor 1 (IGF-1), urea, glucose, creatinine, thyroxine (T4), alpha-amino nitrogen, non-esterified fatty acids and tri-iodothyronine (T3). The bulls that were on restricted diet had a decrease in blood glucose and urea, high levels of creatinine and unchanged levels of alpha-amino nitrogen (Cabaraux et al., 2003). When diet restriction in young steers blood urea remained the same, decreased IGF-1 and increased growth hormone (Hayden et al., 1993). This response of GH may be the biological response of compensatory gain when fed a non-restrictive diet in addition to an increase in IGF-1 and insulin with a non-restrictive diet (Hayden et al., 1993). Carstens et al., 1991 evaluated crossbred weaned steers with a restricted feed intake diet to determine compensatory gain with those on a non-restricted diet or *ab libitum* diet. The steers were resticted for 189 days. Steers were separated into different groups of growth restriction and then harvested. The groups was grown from 245kg to 350kg, 350kg to 420kg and lastley from 420kg to 500kg (Carstens et al., 1991). The ending body weight and HCW did not differ (R^2=0.96), which is a result of compensatory gain from the restricted group. However, the carcass for the restricted steers resulted in a high protien and water percentage and less fat when compaired to the non-restricted group (Carstens et al., 1991).

Heifers were restriced in a similar fashion to the previous studies by Yambayamba et al., 1996 with a restictrion of 95 days. Blood plasma was taken from the heifers at mutliple time points throughout the feeding period to evaluate GH, T4, T3, IGF-1, NEFA, glucose, blood urea nitrogen, insulin and 3-methyl histidine (3-MH). On day 48, there was difference in the blood plasma for the restricted heifers. The resitricted heifers had a decrease in everything. However, NEFA and GH increased ($P < 0.05$) while 3-MH remained the same as the non-restriced heifers throughout the feeding period. The blood urea nitrogen degrease less then the other blood components, which conversely is different then the findings of Hadyen et al., 1993 (Yambayamba et al., 1996). Hayden et al. (1993) found the blood urea nitrogen was increase after a period of restriction on steers. The differences in blood urea nitrogen between these two studies may be a result of gender differences (Yambayamba et al., 1996; Hayden et al., 1993). The restricted heifers had a major decrease in IGF-1 comparied to the non-restricted heifers (Yambayamba et al., 1996). After the reintroduction of the non-restricted diet to the restricted heifers the all blood plasma components the were measure retured to the same levels as the original non-restricted heifers but GH was greatly increased, which leveled off by day 31 of reintroduction (Yambayamba et al., 1996). On day 10 of reintroduction, T3 and T4 were significantly decrease ($P < 0.05$) and then on day 31 returned to level of the orginal non-restricted heifers. Increased GH and decreased T3 and T4 may have been a contributing factors to compensatory gain of these heifers (Yambayamba et al., 1996).

Twelve steers were allocated to a restrictive or *ad libitum* diet for 80 days (Jones et al., 1990). Then all steers were fed an *ad libitum* diet for 60 days following. Measurements taken were total nitrogen, urea nitrogen, creatinine, and N- methyl histidine (N-MH) from the urine. The creatinine nor N-MH was significantly different. However, the total nitrogen and urea nitrogen was less in the restricted animals then the *ad libitum* animals ($P < 0.05$; Jones et al., 1990). This could be an indication that there is a higher nitrogen recycling in restricted steers then those not restricted which can coincide with research done by Hayden et al. (1993) resulting in higher blood urea nitrogen (Jones et al., 1990).

There are many metabolic changes that occur when animals are in a diet restriction. There is an increase in GH and blood urea nitrogen in steers but not in heifers while a decrease in IGF-1 (Hayden et al., 1993; Yambayamba et al., 1996; Cabaraux et al., 2003). These changes could be the result of compensatory gain after reintroducing a non-restrictive diet. However, the specific mechanism for these changes are still unknown and could be further research to determine the exact cause of compensatory gain.

Economics

Compensatory growth can be beneficial by reducing the total cost of input. During a restriction period, reducing the cost of feed by providing less feed to the animal, while getting better gain in the finishing period. Jordan et al., 2000 looked at feeding wet corn gluten feed at a high gain, high/low gain, low/high gain, and low gain to yearling steers during a winter period to determine the lowest breakeven cost. The lowest breakeven costs resulted in was the high gain and the low/high gain. The low/high gain resulted in compensatory gain during the high gain portion of the study with the breakeven being $64.63 per 45.4 kg (Jordan et al., 2000).

Compensatory gain can be a used as a strategy to increase animal performance while decreasing input feed cost. Cattle can be on a restricted diet, whether that be intake driven or nutrient driven, and still make up for the gain when reintroduced to a non-restricted diet. However, the exact mechanism is still unknown in which compensatory gain occurs but can be used to reduce the total breakeven for producers.

Implant use in the Background System

Growth promoting strategies have been around for years as the goal is to profit. One of the growth promoting technologies is implants. An implant is a type of hormone that influences the growth of muscle.. The part of the cattle industry that mainly uses implants is the feedlot industry. However, there has been research done that show the positive impact the implanting cattle during the backgrounding phase.

Brandt et al., (1995) at Kansas State University studied how the effect of implanting when cattle are grazing for the summer impact on the finishing phase. They started out with 144 head of bos taurus crossbred steers. There were two different types of grazing systems that were being used during this study. The first was intensive-early stocking (IES) and the second was season-long grazing (SLG). The implant that was used for this study was Synovex-S. For the intensive-early stocking steers, they grazed pasture for only 70 days before moving into the finishing phase. For the season-long grazing steers, they grazed for 147 days before moving into the finishing phase (Brandt et al., 1995). Once the steers entered the finishing phase, all the steers received another implant of Synovex-S. When evaluating the results, the steers in the intensive grazing system gained more per acre compared to the season-long grazing system. Even though the intensive-early grazing system gained more per acre, it was the season-long grazing system that ended the grazing phase with more total pounds of beef produced because they were allocated to graze for an additional 77 days longer then that of the intensive-early grazing system (Brandt et al., 1995). The intensive-early grazing steers that were implanted showed improved average daily gain compared those not implanted. The season-long grazing steers that were implanted also showed increased average daily gain compared to the non-implanted steers. However, the spread was not as large compared to the intensive-early grazing system. When looking at the results of the finishing phase, the IES had a higher average daily gain compared to the SLG. However, the SLG steers were still the larger animal with more total pounds of beef. The implanted during the pasture phase had no impact on the on the finishing phase. The carcass data is what seemed to be the most intriguing. The SLG implanted steers had the largest carcass and increased dressing percentages compared to the non-implanted. The IES steers had a lower overall carcass weight then the SLG and the implanted steers had a lower dressing percentage then the non-implanted steers. Implanting steers during a pasture phase system does improve the ADG in an intensive grazing system, but does not improve the ADG in a season long- system (Brandt et al., 1995). The most numerically profitable treatment was the SLG with no implant, but the IES implanted steers was the next most profitable being only two dollar less then the SLG with no implant ($P < 0.05$; Brandt et al., 1995).

Duckett and Andrae (2001) at the University of Georgia look at implants and the impacts it has on different sections of the beef industry. When looking at calves that were implanted, they gain around 5% to 6% more than those not implanted when implanted at about 45 days of age (Selk, 1997). The implants that have been approved during this time to be used in calves is 10mg of estradiol benzoate with 100mg of progesterone or 36 mg Zeranol. However, when looking at steers implanted verses heifers implanted, the heifers showed a larger response from being implanted to those who were not implanted. For stocker cattle, there are different type of implants approved for stockers/ backgrounding systems depending on where they are housed. When cattle are backgrounded in a feedlot system or in a grazing system cattle can be implanted with 20mg of estradiol benzoate and 200mg of progesterone or 25.7 or 43.9 mg of estradiol (Duckett and Andrae, 2001). If cattle are backgrounded on a pasture for a grazing system cattle can be implanted with 8 mg of estradiol and 40 mg of TBA. Overall the steers that are implanted during the backgrounding phase had a greater average daily gain. Implanting steers in the finishing phase is a common practice to achieve maximum average daily gain along with high energy diets to get the largest carcass possible with the most pounds of beef.

Platter et al. (2003) at Colorado State University looked at how repeating implant effected carcass traits. There were five hundred fifty steers that were allocated to this study being placed into ten different treatment groups. These steers come from a variety of different backgrounds. The steers were calved and weaned in Wyoming, Texas and Idaho. Calves were split up into groups on whether they got implant during different phases of the beef industry. These phases are which were implanted at are branding, weaning, backgrounding, feedlot entry and re-implant in the feedlot. At branding the implant that was given was Synovex-C, which contains 10 mg of estradiol benzoate and 100 mg of progesterone. At weaning, the implant that was given was Ralgro, which contains 36 mg of zeranol. Another Ralgro or Synovex-S was given at backgrounding. Synovex-S contains 20mg of estradiol benzoate and 200 mg of progesterone. Upon entry of the finishing phase the steers either got implanted with Synovex-S or Revalor-S. Revalor-S contains 24 mg of 17-*B*-estradiol and 120mg of TBA. For the re-implant, Synovex-S or Revalor-S was given again (Platter et al., 2003). The implications for this study were that the steers implanted throughout all the phases of the study had tougher meat compared to those with fewer implants. Producer may prefer less implant to improve the quality of meat.

Brazle (1998)from Kansas State University looked at the effects of how implanting during the backgrounding phase effected heifers during the finishing phase. The was two hundred fifty-eight heifers that were assigned to three different treatments. The first treatment was a control with no implants. The second treatment the heifers were given Component E-H. The third and final treatment was the heifers were implanted with Ralgro. The heifers grazed native grass land for 74 days before entering the finishing system (Brazle, 1998). Upon entry into the finishing system all heifers receive an Synovex-H. The heifers were also re-implanted at day 70 of being in the feedlot with Finaplix-H. The heifers stayed in the feedlot for a total of 120 days before going to be harvested at a packer plant (Brazle, 1998). The Component E-H heifers had a higher rate of gain the grazing phase compared to the control and Ralgro heifers. Subsequently, the control heifers showed compensatory gain during the finishing phase with the highest average daily gain. The hot carcass weights for the controls were similar to that of the Component E-H with the highest hot carcass weight and the Ralgro with the lowest hot carcass weight. For the ribeye area, the control was the largest once again (Brazle, 1998). The type of implant does affect the amount of gain on heifers. However, no matter the implant, heifers will gain more if implanted verses non-implanted heifers.

Multiple Implants and Effect on Finishing Phase

The use of implants in every phase of the industry have been assumed to negatively impact the implant in the finishing phase. However, research has shown that multiple implants have a positive effect on the implant in the finishing phase (Gentry et al., 2020). The goal of any producer in the beef industry is to grow any cattle efficiently with least cost input. Implants have been able to help producers achieve this over the years.

Recently, the idea of an aggressive implant program in the backgrounding and finishing phases has become more common for producers to use. Especially, when smaller cattle are entering the finishing phase. An aggressive implant program is when an animal is given multiple implants over different sectors of the industry. Gentry et al., (2020) compared large and smaller framed animals with aggressive and non-aggressive implant programs. The thought behind this study is that the smaller framed animals entering the feedlot need an aggressive implant program to increase growth to match that of large framed animals. This could result in both large and small framed animals finishing at similar weights and fat thickness. Implants used are Synovex S, which consist of 20 mg of estradiol benzoate and 200 mg progesterone, and Synovex Choice, 14 mg of estradiol benzoate and 100 mg of TBA (Zoetis Inc.) for the first experiment, while the second experiment used Revalor-S, 24 mg estradiol benzoate and 120 mg of TBA (Merck Animal Health, De Soto, KS). There was no significant differences in the backgrounding phase of the experiment. There was a significant difference during the finishing phase in dry matter intake and gain to feed ratio ($P < 0.01$), with the smaller framed animals eating less while gaining more. The carcass adjust results showed that the larger framed animal had a greater final body weight ($P < 0.01$) and greater average daily gain compared to the smaller framed animals ($P < 0.01$; Gentry et al., 2020). This results that implanting smaller framed steers benefit from aggressive implant programs. Especially, when compared to nonimplanted animals.

Implants and Nutrition

Implants are a great tool to increase muscle gain but when combine with an nutritionally balance diet it can improve profit greatly. Hermesmeyer et al., (2000) used a two by three by two factorial design to compare ad libitum intake verses restricted, Revalor-S, 24 mg estradiol benzoate and 120 mg of TBA (Merck Animal Health), Synovex-Plus 28 mg estradiol benzoate with 200 mg of TBA (Zoetis Inc.) and no implant, and one centimeter (cm) of back fat verses 1.4 cm of back fat. Feeding cattle at an ab libitum intake being implanted had a greater gain to feed ratio with a greater average daily gain ($P < 0.05$; Hermesmeyer et al., 2000). Those on ad libitum diet, implanted and finished at 1.4 cm of back fat had a greater hot carcass weight ($P < 0.05$; Hermesmeyer et al., 2000). There was no significant difference between the implants used.

Implanting cattle that are on an ab libitum intake diet and finishing at 1.4 cm of back fat is the most profitable for producers when compared to a restricted diet with no implant and finishing at one cm of backfat (Hermesmeyer et al., 2000).

Conclusion

Implants are an important factor in increase muscle growth not only in the finishing phase but as well as the backgrounding phase. The potency of the implant in addition to the hormone type and longevity are important factor in the determination of which implant to use in which phase of the beef industry. The different hormones have different biological effect on the animal to promote muscle growth by increasing the growth curve for the individual animal. Multiple implants over each phase have become popular to use especially for the backgrounding phase. Not only are implants important for the backgrounding phase but also is the diet for a growing animal. Backgrounding diets are a majority forage based compared to finishing diets that are concentrate based. In the backgrounding phase, low quality forage can be used as a cheap source of diet, but depending on the forage source supplementation of protein and energy may be need. In the Midwest, distillers grains and corn gluten feed may be reasonable sources to supplement protein and energy. Distillers grains are readily available to producers as supplement. Depending on the operation the type of distiller gains, WDGS verses MDGS verses DDGS, will be taken into consideration if the cattle are in a feedlot or pasture based system. In result, the object of this experiment are to determine the interaction of wintering ADG and implanting strategy during the winter backgrounding and summer grazing periods on compensatory gain, animal performance and carcass characteristics

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Table 1.1 Implants Longevity and Potency (NASEM, 2016)

Company	**Implant Name**	**Androgenic (mg)**	**Estrogenic (mg)**	**Progesterinic (Mg)**	**Steer vs. Heifer**	**Feedlot, Stocker, Calves**	**Days**
Merck	Ralgro		36 Zeranol	-	Both	All	90
	Revalor- G	40 TBA	8	-	Both	Stocker	120
	Revalor- H	140 TBA	14	-	Heifer	Feedlot	120
	Revalor- IH	80 TBA	8	-	Heifer	Feedlot	120
	Revalor- S	120 TBA	24	-	Steer	Feedlot	120
	Revalor- IS	80 TBA	16	-	Steer	Feedlot	120
	Revalor- 200	200 TBA	20	-	Both	Feedlot	120
	Revalor- XS	200 TBA	40	-	Steer	Feedlot	200
Elanco	Component E-H	200	20	-	Heifer	Feedlot	140
	Component E-S	200 TBA	200	-	Steer	Feedlot	140
	Component TE-H	140 TBA	14	-	Heifer	Feedlot	140
	Component TE200	200 TBA	20	-	Both	Feedlot	90
	Component TE-S	120 TBA	24	-	Steer	Feedlot	90
	Component TE-IS	80 TBA	16	-	Steer	Feedlot	120
	Component TE-IH	80 TBA	8	-	Heifer	Feedlot	120
Zoetis	Synovex C	-	10	100	Both	Calves	120
	Synovex H	200 Testosterone Propionate	20	-	Heifer	Feedlot	120
	Synovex S	-	20	200	Steer	Feedlot	120
	Synovex Choice	100 TBA	14	-	Steer	Feedlot	120
	Synovex Plus	200 TBA	20	-	Steer	Feedlot	120
	Synovex One Feedlot	200 TBA	28	-	Steer	Feedlot	200

Chapter II: Timing of Implant Use in the Backgrounding System

K. M. Butterfield*, Z. C. Carlson*, B. C. Troyer*, J. Xiong*, M. M. Norman*, B. L. Nutteleman†, G. E. Erickson*, M. E. Drewnoski*, J. C. MacDonald*

*Department of Animal Science, University of Nebraska- Lincoln, 68583

†Merck Animal Health, 66018

Abstract

In this study, 240 (initial BW= 247 kg, SD= 6 kg YR 1; BW= 255 kg, SD= 11 kg YR 2) weaned steers per year were placed in the pens (winter phase) and fed one of two backgrounding diets consisting of either Smooth Bromegrass hay and 10% MDGS (low gain supplementation) targeting 0.45 kg of average daily gain (ADG; LG) or Smooth Bromegrass hay and 30% MDGS (high gain supplementation) targeting 0.91 kg of ADG (HG). The experimental unit was pen with ten head per pen. This 2-year study was designed as a 2 x 3 factorial with the first factor as winter rate of gain targeting 0.45 kg ADG (LG) or 0.91 kg ADG (HG), and the second factor as implant strategy. Implant strategies included 1) 36mg zeranol implant (Ralgro; Merck Animal Health, De Soto, KS) during the winter phase and 40 mg of trenbolone acetate (TBA) with 8 mg of estrodiol (Rev-G; Merck Animal Health, De Soto, KS) in the summer phase (STRONG-IMP), 2) no implant during the winter phase and Rev-G during the summer phase (MED-IMP) or

3) no implant during the winter and summer phases (NO- IMP). The steers remained in the winter phase for 148 days, followed by 56 days on bromegrass pasture during the summer phase. In the finishing phase, all steers were placed in a feedlot on a common feedlot diet receiving 200 mg TBA and 40 mg estradiol (Rev-XS; Merck Animal Health, De Soto, KS). The steers remain were fed for approximately 115 days targeting an equal fat development. There were no interactions between the rate of gain and implant strategy ($P = 0.15$) during the winter period. For HG and LG steers gained 0.92 and 0.58 kg/d respectively ($P < 0.01$) and the use of zeranol increase ADG by an average of 0.08 kg/d (11%; $P < 0.01$). In the summer, LG steers gained more ($P < 0.01$) than HG0.70 kg/d vs. 0.53 kg/d respectively. Additionally, the MED-IMP and STRONG-IMP did not differ but gained more than NO-IMP (0.55, 0.65, and 0.65 kg/d for NO-IMP, MED-IMP and STRONG-IMP respectively; $P = 0.02$) suggesting the summer implant improved gain by 18%. Differences in initial BW and ADG during the summer period resulted in a tendency for an interaction in ending BW ($P = 0.10$). For HG steers, the STRONG-IMP strategy resulted in 24 kg of additional BW compared to the MED-IMP and NO-IMP strategies ($P < 0.01$). For LG steers, the MED-IMP and STRONG-IMP implant strategies resulted in 8 additional kg of BW over the NO-IMP strategy ($P < 0.01$). This may suggest implants result in more cumulative BW gain when steers are backgrounded at a higher rate of winter gain. Interestingly, when no implants were used in the system, the LG steers compensated 24% during the summer. When implants were used, the degree of compensation for LG steers was 4-7%, perhaps summer implants decrease the amount of compensatory gain when steers are backgrounded at HG. During the finishing phase, HG resulted in 36 kg more ending BW than

LG steers (P < 0.01) while the STRONG-IMP strategy resulted in 36 kg additional ending BW over NO-IMP (P < 0.01). The additive effects of utilizing a STRONG-IMP program with HG resulted in 73 kg heavier ending BW than steers receiving NO-IMP during the backgrounding phases with LG. Supplementing to achieve at a greater ADG in the winter phase and implanting both during the winter and summer phases increases overall body weight compared to those supplemented at a lower gain and not implanted.

Keywords: backgrounding systems, compensatory gain, equal fatness, grass supply, implant strategy

Introduction

In the beef industry, steroidal implants have been an important part of increasing efficiency of growth in cattle. Feedlots have been the greatest user of implants, but it is becoming more common to use implants in the preweaning and backgrounding phase of production (USDA, 2000). Implants increase ADG and EBW, potency and longevity of the implant affect the magnitude of the implant on ADG and EBW when compared to those not implanted (Roeber et al., 2000; Duckett and Andrae, 2001). Simms et. al (1988) evaluated six different implant strategies in multiple phases of the beef industry and concluded that implants increase ADG compared to those not implanted. Therefore, implant strategies need to be evaluated within the context of production systems rather than independent production phases.

In addition to implants, backgrounding strategies can impact subsequent animal performance and carcass characteristics at harvest. Two studies determining the effects of different rates of gain in the backgrounding phase showed that targeting a higher rate of gain equal to or above 0.72 kg/d can be beneficial in achieving a larger final body weight at the end of backgrounding. However, targeting a rate of gain of only 0.50 kg/d did not result in additional final BW compared to a rate of gain of 0.28 kg/d during the winter period (Klopfenstein et al., 2000). Gillespie (2016) evaluated the differences in gain of spayed heifers supplementing at 0.91 kg DM (LO) or 2.3 kg (HI) DM of MDGS in a winter backgrounding phase. The heifers on a HI supplementation gain significantly more ($P < 0.01$) and had a greater ending BW ($P < 0.01$) then those supplemented LO (Gillespie-Lewis et al., 2016). These two studies concluded that supplementing to achieve a gain greater than 0.60 kg/d increase ending BW compared to lower supplementation strategies.

While targeting a greater rate of winter gain and implanting have both been shown to increase weight gain, it is unclear if backgrounding ADG and implant strategy interact in a stocker cattle production system. Therefore, the objective of this study was to determine the interaction of wintering ADG and implanting strategy during the winter backgrounding and summer grazing periods on compensatory gain, animal performance and carcass characteristics. We hypothesis the implanting strategy and backgrounding rate of gain interact to effect compensation and animal performance in subsequent phases of production.

Materials and Methods

All animal handling and experimental procedures were approved by the University of Nebraska-Lincoln's Institution Animal Care and Use Committee. Animals were housed at University of Nebraska Eastern Nebraska Research and Extension Center near Mead, NE.

Upon arrival, steers were weighed, individually identified, vaccinated to prevent *Heamophilus somnus* (Sumobac, Zoetis, Inc.; Kallamazoo, MI), bovine respiratory syncytial virus, parainfluenza 3, infectious bovine rhinotracheitis and bovine viral diarrhea type I and II (Bovi-Shield Gold 5, Zoetis, Inc., Kalamazoo, MI), and given an injection of doramectin for parasite control (Dectomax, Zoetis, Inc.). Steers were then revaccinated approximately 14 days after arrival for *Mannhemia haemolytica* (One Shot Bovi-Sheild Gold, Zoetis, Inc.) and *Heamophilus somnus* (Ultrabac-7, Zoetis, Inc.). Steers were backgrounded for a 30-day period before starting the experiment as a part of receiving.

The experiment was repeated over two years. In each year of the experiment, 240 crossbred steers were selected by weight from a larger pool of cattle received at a similar time. The average weight was 247 kg (SD= 6 kg; November 26th) for year 1, and 255 kg (SD= 11 kg; December 3rd) in year 2. There was a total of 480 head assigned to the experiment over the two years. The experiment utilized a yearling production system with three different phases: a winter growing, a summer grazing phase and finishing phase. The treatment design was a 2 x 3 factorial design with steers stratified by BW and experimental units of ten head per pen upon entry into the winter phase, and experimental units were then blocked by pasture location for the summer phase. Once steers were assigned to experimental units (pen), they remained in the same experimental group for the entirety of the experiment. There were six treatments arranged in a 2 x 3 factorial with four replicates per treatment each year (n = 8). The first factor was winter ADG, targeting 0.91 kg/d (HG) or 0.45 kg/d (LD). The second factor included three implant strategies implemented during the winter growing phase and summer grazing phase. Implant treatments included 1) no implants in the winter or summer (NO-IMP), 2) no implant in the winter phase followed by 40 mg of trenbolone acetate (TBA) and 8 mg of estradiol (Rev-G; Merck Animal Health, De Soto, KS) during the summer phase (MED-IMP), or 3) 36 mg of zeranol (Ralgro; Merck Animal Health) during the winter phase followed by Rev-G in the summer grazing phase (STRONG-IMP). During the finishing phase, all steers received 40 mg of estradiol and 200 mg of TBA (Revalor XS; Merck Animal Health, De Soto, KS) and were all fed a common feedlot diet.

Winter Phase

Steers were limit fed for five days at 2% of BW with a diet of 50% alfalfa hay DM and 50% Sweet Bran DM (Cargill Corn Milling, Blair, NE) before and after each phase (Watson et al., 2013). Steers were weighed for two consecutive days to account for gut fill on 0 d and 1 d of winter phase (Stock et al., 1983). Steers were assigned to either HG treatment diet consisted of 30% modified distillers grains (MDGS), 66% bromegrass hay and 4% supplement (DM basis)with urea targeting 0.91 kg of ADG, while the LG treatment was 10% MDGS, 86% bromegrass hay, and 4% supplement (DM basis) with urea targeting 0.45 kg ADG (Table 1). All diet percentages are on a dry matter (DM) basis. Steers were fed twice a day to manage bulkiness of the diet with feed being delivered by a truck mounted mixer and delivery unit (Roto-Mix, Dodge City, KS). Steers were fed for ad libitum intake with ad libitum access to water. Feed bunks were evaluated daily at 0530 h to determine feed refusals resulting in minimal amount of feed left in bunk at time of feeding 915 h. Feed refusals were collected as needed and were weighed, subsampled then dried at 60^{o}C in a forced air oven for 48 h to determine DM for total DM refused weight. Diet ingredient samples were taken on a weekly basis, composited monthly, ground through a 1-mm screen (Thomas-Wiley Mill) for DM analysis in 100^{o}C oven for 24 h, organic matter (OM) analysis in an ash oven at 600^{o}C for 6 hours and CP analysis on a nitrogen analyzer (FlashSmart N/Protein Analyzer CE Elantech, Inc. Lakewood, NJ). Year 1 started on November 26th, 2019. Year 2 started on December 3rd, 2020. Implant checks were performed on d 22 (December 17th, 2019) YR 1 of the trial and d 20 (December 22nd, 2020) YR 2. Steers were poured for lice on d 45 YR 1 with gamma-cyhalothrin 0.5% (Standguard; Elanco Animal Health) at 15 milliliters (mL) and on d 63 YR 2 with diflubenzuron 3% and permethrin 5% (Clean-Up II; BAYER) at 22 mL. The steers remained in the winter phase for 148 days in both YR 1 (April 21st, 2020) and YR 2 (April 29th, 2021). From November 2019 to April 2020, the temperatures ranged from an average low in January of -7.83^{o}C and an average high in April of 18.61^{o}C for YR 1. From November 2020 to April 2021, the temperatures ranged from an average low in February of -16.72^{o}C and an average high in April of 19.00^{o}C for YR 2.

Summer Phase

Steers were turned out on Smooth Bromegrass (*Bromus inermis*) pastures for the summer grazing phase. Pastures were fertilized with 45.4 kg per 0.405 hectare of nitrogen in both years. In YR 1, steers were limit fed for 14 days YR 1 to give pastures adequate time for growth after fertilization due to cool temperatures. In YR 2, the steers were limit fed for six days. In both years, the limit-fed diet consisted of 50% Sweet Bran (Cargill Corn Milling, Bair, NE) and 50% alfalfa hay at 2% of BW. For YR 2 steers were limit fed for six days with the same limit fed diet as YR 1. The steers were weighed for two consecutive days to account for gut fill, on d 0 and d 1 of summer phase (May 4th and May 5th for YR 1; May 6th and May 7th for YR 2; Waston et al., 2013; Stock et al., 1983). The steers assigned to MED-IMP and STRONG-IMP were implanted with Rev-G (Merck Animal Health). Experimental units (pens of 10 steers) were blocked by treatment to pastures. Blocks one and two were turned out on d 1 (May 5th) YR 1. Blocks three and four were turned out d 2 (May 6th) YR 1. In YR 2, blocks three and four were turned out d 1 (May 6th), while blocks one and two were turned out on d 2 (May 7th). For fly control, steers received a fly tag with the active ingredients lambda cyhalothrin 6.8% and pirimiphos-methyl 14% (Double Barrel VP, Merck Animal Health) for YR 1 before being turned out. For year 2 steers were poured with 36 mL of Normectin before being turned out and received a fly tag at implant check (6/2/2021). Each pen of cattle were allotted 2.43 hectares, resulting in 0.243 hectares per head. Steers had ad libitum access to water. There were three 0.81-hectare strips per pasture that each group was rotated through. Once the group grazed through all three strips it was considered a cycle. There was a total of three cycles YR 1 and four cycles YR 2. The first cycle was five days of grazing on each strip for both years. The second cycle was seven days YR 1 and six days YR 2 of grazing on each strip. In the third cycle, the first two rotations were seven days, and the final rotation was three days in YR 1. The third cycle for YR 2 were seven-day rotations. The fourth cycle for YR 2 was three-day rotations. Rotation lengths depended on the amount of grass available. The reason that the YR 1 grazing season was shorter was because limited amount of rainfall in April and the concern of over grazing resulted in minimal amount of grass leading to the decision to pull the cattle off grass earlier in YR 1 than YR 2. For every rotation the cattle were fed 0.227 kg of DM per head of Sweet Bran to rotate them easier (Cargill Corn Milling, Bair, NE). The steers grazed the bromegrass for a total of 51.5 days on average YR 1 and 60.5 days for YR 2. Between both years the steers grazed for an average of 56 days. Steers were pulled of grass on June 26th, 2020 in YR 1 and July 6th, 2021 in YR 2. From May 2020 to Jun 2020, the temperatures ranged from an average low in May of 9.3^{o}C and an average high in June of 32.3^{o}C with a total average rain fall of 7.26 cm for YR 1 (National Weather Service, 2021; Table 10). From May 2021 to July 2021, the temperatures ranged from an average low in May of 9.9^{o}C and an average high in June of 31.9^{o}C with a total average rain fall of 9.98 cm (National Weather Service, 2021; Table 10).

Biomass Analysis

Before steers were turned out, pre-grazed biomass samples were taken two inches from the ground to determine the amount of grass available. For each rotation, pre-grazed and post-grazed biomass samples were taken in duplicated on the day of rotation with 0.33 square meters frames 2 inches from the ground totaling 96 samples per rotation. Samples were dried at 60^{o}C in a forced air oven for 48 h to determine DM. Samples were ground through a 2-mm screen (Model 4 Thomas-Wiley Mill, Swedesboro, NJ) and DM was analyzed in 100^{o}C oven and organic matter (OM) was analyzed in an ash oven. Samples were composited by cycle. Pre-grazed cycles were ground through 1-mm screen for in vitro OM digestibility (AOAC, 1999; method 4.1.03). In vitro OM digestibility procedures (McDougall, 1948; Tilley and Terry, 1963;

Mertens, 1993) were modified by adding 1 g/L urea to the buffer. In vitro OM digestibility was evaluated on pre-grazed cycles 2 and 3 composites for YR 1 and all the cycles for YR 2. Rumen fluid was collected from two ruminally canulated steers on a diet of 70% bromegrass hay and 30% dry distillers grains. The tubes incubated for 48 hr in a 37^{o}C water bath and filtered through 22 micrometer filter paper and dried in the 100^{o}C oven (Whatman Grade 541; Cytiva, Marlborough, MA). The filter paper was then placed in crucibles to be ash in the muffle at 600^{o}C for a minimum of 6 h (AOAC, 1999; method 4.1.10). There was a total of five hay standards with known in vivo digestibility's, which were used to adjust the values of the pre-grazed bromegrass samples (Stalker et al., 2013).

Carcass Based Performance

Carcass based performance was evaluated by marketing 24 hd at the end of the grazing period and measuring carcass data. The purpose of these steers was to establish dressing percentage and carcass traits of steers entering the feedlot, and to determine if these characteristics were influenced by experimental treatment. These 24 steers were separate from the 240 head, were assigned to one of the six treatments (n = 6 for each year) and were treated the same as the 240 hd each year. They were housed in two pens, based on winter rate of gain treatments, during the winter phase, and all 24 steers were housed in a single pasture during the summer. A 3-strip rotation was utilized, like the experimental pastures. Steers remain on the bromegrass pasture for an average of 56 days between the two years. The steers were then pulled off the pasture and limit fed 50% Sweet Bran and 50% alfalfa for 12 days (Waston et al., 2013; Cargill Corn Milling, Bair, NE). They were then weighed for three consecutive days. Steers were shipped on the third weigh day to a commercial abattoir (Greater Omaha, Omaha, NE) to be harvested. Hot carcass weight was recorded on the day of harvest, and dressing percentage was calculated. Hot carcass weight and ADG was corrected using the carcass adjusted calculation.

Finishing Phase

Steers entered the feedlot and were limit-fed for five days at 2% of BW with a diet of 50% alfalfa hay and 50% SB (Cargill Corn Milling, Blair, NE; Waston et al., 2013). Steers were consecutively weighed for two days to account for gut fill on 0 d and 1 d of the finishing phase (Stock et al., 1983). All steers were given the same implant strategy of 40 mg of estradiol and 200 mg of TBA (Revalor XS; Merck Animal Health, De Soto, KS) Year 1 start date for the finishing phase was July 2nd, 2020. Year 2 steers were drenched with 21 mL of fenbendazole (SafeGuard; Merck Animal Health, De Soto, KS) for a dewormer. Steers were fed a common feedlot diet of high moisture corn (HMC) 51%, SB (Cargill Corn Milling, Blair, NE) 40%, corn stalks 5% and supplement 4% (Table 8). Before being fed a finishing diet the steers were on a step-up program of four steps. Step 1 was day 1 through day 5 consisting of HMC 30%, SB 50%, corn stalks 16% and supplement 4%. Step 2 was day 6 through day 10 consisting of HMC 35%, SB 50%, corn stalks 11% and supplement 4%. Step 3 was day 11 through day 15 consisting of HMC 40%, SB 45%, corn stalks 11% and supplement 4%. Step 4 was day 16 through day 21 consisting of HMC 45%, SB 40%, corn stalks 11% and supplement 4% (Table 8). Steers were fed once a day ad libitum with feed being delivered by a truck mounted mixer and delivery unit (Roto-Mix, Dodge City, KS). Steers had ad libitum access to water. Feed bunks were evaluated on a day basis at 0530 h to determine feed refusals resulting in minimal amount of feed left in bunk at time of feeding 1001 h. Feed refusals were weighed and subsampled then dried at 60°C in a forced air oven for 48 h to determine DM for total DM refused weight. Diet ingredient samples were taken on a weekly basis, composited monthly for DM analysis in 100°C oven for 24 h, ash analysis in an ash oven and CP analysis on a nitrogen analyzer.

Steers were ultrasounded between the 12th and 13th rib to estimate back fat on d 1, d 57 and d 89 of the finishing phase. These ultrasounds were to determine the time to ship cattle to be harvested at a commercial abattoir (Greater Omaha, Omaha, NE) aiming for an average 1.27 cm of backfat. Steers were shipped in two different groups depending on the results of the ultrasounds. The first group that was shipped on day 111 in the evening was the HG and STRONG-IMP, HG and MED-IMP, HG and NO-IMP, and LG and NO-IMP YR 1 (October 20th, 2020). Final live BW was recorded on the day shipped. The second group was shipped on day 117 in the evening was the LG and MED-IMP and LG and STRONG-IMP YR 2 (October 22nd, 2020). Hot carcass weight (HCW) was recorded on the day of harvest. The initial HCW was subtracted from the final HCW and then divide by the days on feed the get HCW average daily gain. Longissimus muscle area (LM area), 12th rib back fat thickness, dressing percentage and marbling score were recorded after a 48-h chill. Final BW, G:F and ADG were carcass adjusted using HCW with a 62% dressing (average dressing percentage). Initial HCW of the finishing phase was calculated using the average dressing percentage of the carcass-based performance steers that were harvested at the end of the summer phase. Hot carcass weight ADG was calculated using the dressing percentage from the carcass-based performance and multiplying that by the initial BW to get the initial HCW when entering the finishing phase.

Average daily gain of HCW was calculated by subtracting the initial HCW from the final HCW and divided by days on feed for the finishing phase.

Lab Analysis of Diets (Both Winter and Finishing Phases)

The ingredients for both the winter and finishing phase diets were combined into phase composite ingredients. Ingredient samples were collected weekly and ground through a 1-mm screen using a Wiley (Model 4 Thomas-Wiley Mill, Swedesboro, NJ). After being ground, samples were composited by month and then composited by phase. All composites were analyzed for DM, OM and CP. Dry matter was analyzed by weighing up 0.5 g of sample in crucible and place it in a 100^{o}C oven for 24 h. Organic matter was analyzed in a similar way by weighing up 0.5 g of sample, placing it in crucible and put it in a muffle furnace for a minimum of 6 h at 600^{o}C (AOAC, 1999; method 945.05). The winter phase bromegrass hay was analyzed for neutral detergent fiber (NDF) by weighing 0.5 g of bromegrass hay, adding 100 ml NDF solution with the addition of 0.5 ml alpha-amylase, refluxing for an hour, filtering through a 22 micrometer filter paper and dried in the 100^{o}C oven (Whatman Grade 541; Cytiva, Marlborough, MA; Van Soest et al., 1991). The filters were weighed and used to calculate NDF percent (Van Soest et al., 1991).

Statical Analysis

Grower, summer and finishing performance data (BW, ADG, DMI and G:F) and carcass data (HCW, REA, Back Fat and Marbling) were analyzed using the MIXED procedure of SAS (SAS) Inst., Inc., Cary, N.C.) as a 2x3 factorial design with pen as the experimental unit. Blocking was used to assign treatment group to pasture. Biomass DM and in vitro OM digestibility data were evaluated using the MIXED procedure of SAS as a 2X3 factorial design. The effects of time were evaluated using covariate regression with Julian date as the covariate for the analysis of biomass DM and in vitro OM. Significance was set at $P < 0.05$, while tendencies were declared between $P > 0.05$ and $P < 0.10$. The main effects were evaluated for significance if interactions were not significant. Year was considered a random effect.

Results and Discussion

Winter

There were no interactions of winter rate of gain by implant strategy on winter performance ($P > 0.15$), so main effects will be discussed. Initial body weight was not impacted by treatment ($P > 0.34$), and the average initial BW was 251 kg (Table 2.3).

Steers receiving HG during the winter had greater ADG and EBW compared to LG steers by design. The ADG for LG and HG was 0.57 and 0.92 kg/d, respectively ($P < 0.01$; Table 2.3). The LG steers gained slightly more than the targeted 0.45 kg/d whereas the HG steers gained close to the targeted gain of 0.91 kg/d. As a result, the steers on the LG treatment had an average ending BW of 336 vs. 387 for HG steers ($P < 0.01$; Table 2.3). This result reflects the targeted rates of gain during the winter and was expected. These data agree with Boundurant et al., (2018) and Gillespie-Lewis et al., (2016). Boundurant et al., (2016) compared low, medium and high gains from increasing amounts of supplement to heifers grazing corn residue. Average daily gain increased similarly to the current study with low gain of 0.69 kg/d, medium gain at 0.74 kg/d and high 0.89 kg/d ($P < 0.01$; Boundurant et al., 2016). On average, the LG treatment for the current study was less than the Boundurant et al. (2016) low gain treatment perhaps because Boundurant et al., (2016) utilized heifers grazing corn residue with supplementation of MDGS. For the current study, the high gain supplementation of ADG averaged 0.92 kg/d, slightly greater than Boundurant et al., (2018). For the winter phase of Gillespie-Lewis et al. (2016), the low gain supplementation of MDGS resulted in an ADG of 0.38 kg/d and a high gain supplementation ADG was 0.62 kg/d for heifers grazing corn residue and brome grass pasture ($P < 0.01$). The Gillespie-Lewis et al., (2016) ADG results were lesser than both the current study and the Boundurant et al., (2016) study. However, all three studies were significantly influenced by supplementation, or dietary energy concentration. Winter rate of gain also impacted DMI ($P < 0.01$) where HG resulted in 0.80 kg greater DMI than LG steers (8.14 vs. 8.94 kg/d for LG and HG steers, respectively; Table 2.3). Interestingly, Loy et al., (2007) supplement heifers with DDGS and hay compared to the control of no supplementation. The supplemented heifers ate more as a percentage of BW basis then the control ($P < 0.01$). Additionally, G:F was improved by 45% for HG vs. LG (0.103 vs. 0.071 for HG and LG, respectively; $P < 0.01$).

The metabloizble protein (MP) requirements differed for the low gain verses the high gain requirements. Urea was used to meet the rumen degradeable protien requirements for both the low and high gain treatments . The MP requirements for the LG was 372 g/d and the HG was 515 g/d (Table 2.3). The MP supply for the LG was 456 g/d and for the HG was 885 g/d resulting in a MP balance of 85 for the LG and 376 g/d for HG (NASEM TAMU- UNL model). It appears that no treatments were deficient in MP.

The use of the Ralgro implant during the winter period increased both ADG and ending BW. During the winter phase, the only treatment that received a Ralgro implant was the STRONG-IMP treatment. Neither the NO-IMP nor the MED-IMP treatments received an implant during the winter phase. The addition of Ralgro during the winter backgrounding phase increased ADG by 11.4% (0.81 kg/d vs. 0.72 kg/d for steers with and without a Ralgro implant, respectively) which is reflected in an additional 12 kg of ending BW for STRONG-IMP vs. the average of NO-IMP and MED-IMP (Table 2.3). Implant strategy did not significantly affect DMI (P = 0.11). In the current study, steers receiving the Ralgro implant (STRONG-IMP) ate 0.27 kg more than the average of NO-IMP and MED-IMP, a 3% increase, which is a numerical increase but not statically different. Implant strategy did affect G:F, with STRONG-IMP steers having a 7% increase in G:F compared to the average of NO-IMP and MED-IMP steers (P < 0.01; Table 2.3). These results are similar to previous observations (Simms et al., 1988). Samber et al., (1996) evalutated multiple implant strategies including a Ralgro treatment as the initial implant. Similar to the current study, those implanted with Ralgro resulted in increased ADG and greater G:F (P < 0.05) compared to no implanted (Samber et al., 1996). In addition, Brazle, (1998) evaluted a Ralgro implant verses a control of no implant for grazing heifers, where the use of Ralgro increased ADG (P < 0.10). The current study refects the past studies of implanting with Ralgro resuting in increased ADG and greater G:F.

Summer

The initial body weights of the summer phase differed from the ending body weights of the winter phase due to the fact that the steers were limited fed for 14 days for the first year and 6 days for the second year before being turned out to the bromegrass pastures. There were no interactions of winter rate of gain by implant strategy for the initial BW (*P* = 0.15) or ADG (*P* = 0.55; Table 2.4). The differences in initial BW due to winter rate of gain and implant strategy reflected treatment effects during the winter phase. Both winter rate of gain (*P* < 0.01) and implant strategy (*P* = 0.02) affected ADG during the summer grazing period.

Steers on LG during the winter phase gained more than HG steers during the summer phase (0.70 vs. 0.53 kg/d for LG and HG, respectively; *P* < 0.01). This difference in summer ADG represents classic compensatory gain (Klopfenstein and Milton, 1999; Hornick et al., 2000) and is similar to previous observations of Boundurant et al. (2018) and Gillespie-Lewis et al. (2016) with the LG cattle compensating in the summer. Steers receiving the LG treatment were on a restricted plane of nutrition during the winter phase consuming a diet of 10% MDGS and bromegrass hay, then when moving to bromegrass pastures, the LG steers were then on a higher plane of nutrition. During the winter phase, the LG steers are biologically decreasing their maintenance requirements on the lower plane of nutrition (Wright and Russel, 1991). The steers on the HG treatment consumed a diet of 30% MDGS and bromegrass hay during the winter phase. Therefore, the LG steers compensated during the summer phase while the HG steers did not compensate. This is similar to the observations of Klopfenstein and Milton (1999) where steers on a low plane of nutrition compensated at approximately 53%. In the current study, the LG compensated at 22% when no implants were used (NO-IMP strategy).

The use of Rev G during the summer phase increased (*P* = 0.02)summer ADG by 17% (0.55, 0.65, and 0.65 kg/d for NO-IMP, MED-IMP, and STRONG-IMP, respectively *P* = 0.02).

The added ADG due to Ralgro during the winter phase did not impact ADG during the summer phase. However, the differences in initial BW and ADG during the summer phase resulted in a tendency for an interaction of winter rate of gain and implant strategy for ending BW ($P = 0.10$). Steers fed HG maintained a greater BW at the end of the summer phase for all implant treatments. The STRONG-IMP strategy for the HG steers had greater ending BW than any other treatment. The MED-IMP and NO-IMP treatments had similar ending BW for HG steers. For LG steers, the MED-IMP and STRONG-IMP treatments had similar ending BW, which were greater than the ending BW for NO-IMP. The interaction in winter rate of gain and implant strategy for HG and LG steers suggests that steers receiving Ralgro during the winter phase maintained increased BW at the end of the summer phase when fed a greater plane of nutrition during the winter. Implant strategy appeared to impact the degree of compensation during the summer. Steers fed LG during the winter compensated 24% during the summer when no implants were administered (NO-IMP strategy). However, when REV-G was administered during the grazing season, the percent compensation was only 4-7% (MED-IMP and STRONG-IMP, respectively; Table 2.4).

Biomass

Smooth bromegrass is a cool season grass with an optimal growth temperature of around 22^{o}C (Vogel and Moser, 1957). During the first year of the study the bromegrass had a slow growth because of little rainfall of 2.24 cm and a low temperature averaging 1.2^{o} C and a high temperature of 18.6^{o} C (NWS, 2021; Table 2.8). In the second year, forage growth in April improved with 4.39 cm of rainfall and an average low of 4.17^{o} C and a high of 19.0^{o} C (NWS, 2021; Table 2.8). Resulted in a shorter grazing season for year one with the steers being pulled off June 26th compared to July 6th for year two. The pre-graze biomass was not significantly different for the main effects of winter rate of gain (P = 0.98) and implant strategy (P = 0.74) and no significant difference of winter rate of gain by implant interaction (P = 0.98). For the post-graze biomass estimates, there were no significant differences for the main effects of winter rate of gain (P = 0.46) and implant strategy (P = 0.42) and no significant interaction of winter rate of gain by implant strategy (P = 0.98). These data suggest that while steer BW differed by treatment, forage availability was similar across treatments. However, while there were no differences for biomass, there were differences in the quality of the forage for organic matter digestibility (OMD). There was an interaction (P < 0.01) for winter rate of gain and implant strategy for OMD of pasture sample. Steers implanted with Ralgro and Rev-G (STRONG-IMP) had a greater OMD with LG being 62.8% and HG being 63.9% (Table 2.5). Steers background with LG and the MED-IMP strategy had the lowest average forage quality (59.9% OMD) with all other treatments being intermediate.

Carcass Based Performance

The purpose of the 24 steers per year that were marketed following the summer grazing phase was to evaluate if the winter rate of gain and implant strategies impacted dressing percentage of steers at feedlot entry so that carcass gain during the finishing period could be evaluated. There was a significant difference for the HCW of the main effects of winter rate of gain (P < 0.01) and implant strategy (P < 0.01), but no interaction (P = 0.27). The HG resulted in a HCW of 197, 190 and 208 kg for the NO-IMP, MED-IMP and STRONG-IMP, while the LG was 164, 174,187 kg for the NO-IMP, MED-IMP and STRONG-IMP. However, there were no differences for dressing percentage ($P > 0.23$) and the numerical means ranged from 0.50 to 0.52 (Appendix 2.9). Therefore, the overall average DP of 0.51 was used to estimate HCW for all steers entering the finishing phase to predict HCW gain over the finishing phase.

Finishing Performance and Carcass Characteristics

The finishing results are from YR 1 only. Steers were marketed by treatment based on ultrasound fat estimates collected at 60 and 90 days on feed. The LG MED-IMP and LG STRONG-IMP treatments were on feed for 117 days whereas the remainder of the treatments were on feed for 111 days. There were no differences in 12th rib fat ($P > 0.22$) and the average fat thickness ranged from 1.25 to 1.37 cm, or YG ($P > 0.19$; Table 2.7). Additionally, dressing percentage was not affected by treatment ($P = 0.25$). All treatments exhibited dressing percentages between 60 and 61%.These dressing percentages are lower than the national average of 63% (Campbell, 2016; Radunz, 2012). Nevertheless, we conclude that steers were marketed at similar fat endpoints. There were no interactions due to winter rate of gain and implant strategy for finishing performance ($P > 0.52$; Table 2.6) or carcass characteristics ($P > 0.24$; Table 2.7). Therefore, main effects are presented.

Steers receiving HG during the winter phase entered the finishing phase weighing 51 kg more than LG steers (418 vs 368 kg for HG and LG, respectively; $P < 0.01$; Table 2.6). There were no differences in ADG, DMI, or G:F due to winter rate of gain ($P > 0.22$), so the differences in BW persisted through the finishing period, with HG steers having 36 kg more final BW than LG steers (660 vs. 624 kg for HG and LG, respectively; $P < 0.01$; Table 2.6), and 22 kg more HCW (402 vs. 381 kg for HG and LG, respectively; *P* < 0.01; Table 2.7). Bondurant et al (2016) did not show a difference in HCW (*P* =0.67) for the first year but there was a difference in HCW (*P* =0.04) for the second year increasing linearly from the low gain to the high gain. In additional to increasing weight throughout the production system, HG steers also had carcasses with slightly greater longissimus muscle area (89.8 vs. 86.8 cm^2 for HG and LG, respectively; *P* < 0.01; Table 2.7). and marbling scores (522 vs. 466 for HG and LG, respectively; *P* < 0.01; Table 2.7). Similarly, Gillespie- Lewis et al., (2015) reported no difference for DMI nor G:F but there was a difference in ADG (*P* = 0.05).

Implant strategy also influenced finishing and carcass characteristics. Final BW was 625, 642, and 660 for NO-IMP, MED-IMP, and STRONG-IMP, respectively (Table 2.6). The STRONG-IMP strategy had greater FBW compared to NO-IMP (*P* = 0.01) and tended to be greater than MED-IMP (*P* = 0.10). The NO-IMP and MED-IMP strategies did not differ in FBW (*P* = 0.33). The HCW for all implant strategies tended to differ (*P* < 0.07) with NO-IMP, MED-IMP, and STRONG-IMP having HCW of 381, 391, and 403 kg, respectively. The differences in final BW and HCW were a reflection of differences in initial BW (*P* = 0.03) since finishing ADG was not influenced by implant strategy (*P* = 0.44). Dry matter intake was affected by implant strategy during the backgrounding phases. The DMI for STRONG-IMP, MED-IMP, and NO-IMP was 12.5, 12.9, and 13.3 kg/d, respectively. The STRONG-IMP strategy had a greater DMI during the finishing phase than did the NO-IMP strategy (*P* < 0.01) while the MED-IMP strategy was intermediate. There were no differences in G:F during the finishing period as a result of implanting strategy during the backgrounding phases. The STRONG-IMP also resulted in greater longissimus muscle area in steers (90.3 cm^2; *P* = 0.02) compared to either the MED-IMP (87.4 cm^2) or the NO-IMP (87.3 cm^2) strategies.

The effects of winter rate of gain and implant strategy appear to be additive, with the largest HCW resulting from the HG and STRONG- IMP (416 kg) while the least HCW was generated from LG an NO-IMP (372 kg). The LG HCW ADG was 1.18, 1.14, and 1.12 kg/d, with HG being 1.30, 1.36 and 1.41 kg/d for NO-IMP, MED-IMP and STRONG-IMP respectively (Table 2.7). The HCW ADG was not influenced by implant strategy during the backgrounding phases (*P* = 0.77). However, the HG winter rate of gain resulted in a HCW ADG which was greater than the LG treatment (1.15 vs. 1.36 kg/d for LG and HG, respectively; $P < 0.01$; Table 2.7). There was no significant difference in YG among treatments.

Conclusion and Implications

The HG had a greater ADG and ending BW than those supplemented at LG during the winter phase. In addition, regardless of the plane of nutrition implanting with Ralgro increases ADG and EBW in the winter phase compared to not implanting. During the summer phase, steers previously fed LG had a greater ADG than HG. Suggesting the LG experienced compensatory gain during the summer phase. Across both previous winter gain treatments, implanting with REV-G in the summer phase increased gain compared those not implanted. The HG and STRONG-IMP resulted in the greatest ADG and EBW in the finishing phase but there was no interaction. The HG and STRONG-IMP also ended with the greatest HCW. When comparing the HG verses LG and NO-IMP, MED-IMP and STRONG-IMP, the treatment that resulted in the greatest gain over the entire trial was the HG and STRONG-IMP. The implant strategy and winter rate of gain had additive effects to increase animal performance over the winter, summer and finisher phases.

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TABLES

Table 2.1. Diet Composition as a percent of diet DM for winter phase.

	Treatments[1]	
Item	LG	HG
Ingredient Composition,[4] %		
MDGS	10.0	30.0
Bromegrass Hay	86.0	66.0
Supplements[2,3]	3.0	3.5
Urea	1.0	0.5
Nutrient Composition %		
DM	94.0	93.6
OM	92.6	93.1
CP	11.4	13.3
NDF	61.1	46.9

[1]Treatments = 10% MDGS (Low Gain 0.45 kg ADG) or 30% MDGS (High Gain 0.91 kg ADG).
[2] Supplement for low gain includes fine ground corn (1.3227%), limestone (1.2%), tallow (1%), salt (0.3%), beef trace mineral (0.05%; containing 10% Mg, 6%Zn, 4.5% Fe, 2% Mn, 0.05% Co, 0.5% Cu and 0.3% I), vitamin A-D-E (0.015%; containing 1,500 IU of vitamin A, 3,000 IU of vitamin D and 3.7 IU of vitamin E per gram), rumensin-90 (0.0123%).
[3] Supplement for high gain includes fine ground corn (1.7127%), limestone (1.31%), tallow (1%), salt (0.3%), beef trace mineral (0.05%), vitamin A-D-E (0.015%), rumensin-90 (0.0123%).

Table 2.2. Diet composition of finishing step up diets and final finishing diet as a percent of diet DM.

Ingredients[1]	Step 1 (d 1-5)	Step 2 (d 6-10)	Step 3 (d 11-15)	Step 4 (d 16-21)	Finisher
HMC	30.0	35.0	40.0	45.0	51.0
Sweet Bran	50.0	50.0	45.0	40.0	40.0
Corn Stalks	16.0	11.0	11.0	11.0	5.0
Supplement[3]	4.0	4.0	4.0	4.0	4.0

[1]Ingredients as a % DM basis.
[2]Cargill Corn Milling, Blair, NE.
[3]Supplement includes fine ground corn (1.8782%), limestone (1.63%), tallow (0.1%), salt (0.03%), beef trace minerals (0.05%; containing 10% Mg, 6%Zn, 4.5% Fe, 2% Mn, 0.05% Co, 0.5% Cu and 0.3% I), vitamin A-D-E (0.015%; containing 1,500 IU of vitamin A, 3,000 IU of vitamin D and 3.7 IU of vitamin E per gram), rumensin-90 (0.0123%).
[4] Nutrient composition of finishing diet is DM= 94.28%, OM= 93.04%, CP= 14.97%.
[5] All treatments received the same diet in the finishing phase

Table 2.3. Winter performance of yearling steers developed at two rates of gain during the winter under different implant strategies

	Treatments[1]									
	LG			HG			SED	*P*-Value[2]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	148	148	148	148	148	148				
Initial BW, kg	251	251	251	251	251	251	0.36	1.0	0.46	0.34
Ending BW, kg	331	336	340	381	382	399	4.56	<0.01	<0.01	0.15
ADG, kg	0.54	0.58	0.61	0.88	0.89	1.00	0.031	<0.01	<0.01	0.15
DMI, kg	8.17	7.95	8.31	8.85	8.85	9.13	0.22	<0.01	0.11	0.76
G:F	0.066	0.074	0.073	0.100	0.100	0.109	0.004	<0.01	<0.01	0.15
$MP_{rep.}$ (g/d)	371	372	373	501	517	527				
$MP_{sup.}$ (g/d)	457	457	457	885	885	885				
MP_{bal} (g/d)	86	84	83	384	368	376				

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.
[3] Metabolizable Protein (MP) was calculated using the NASEM TAMU- UNL model.

[4]Implant strategy signifcantly differs for EBW, ADG and G:F. STRONG-IMP had to greatest EBW, ADG and G:F with MED-IMP being the intermidate EBW, ADG and G:F and NO-IMP resulting in the smallest EBW, ADG and G:F.

Table 2.4. Summer performance of yearling steers developed at two rates of gain during the winter, under different implant strategies

	Treatments[1,2]						SED	*P*-Value[3]		
	LG			HG						
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant[5]	Winter Gain * Implant
DOF	56	56	56	56	56	56				
Initial BW, kg	335	341	345	386	386	403	4.59	<0.01	<0.01	0.15
Ending BW, kg	371	374	383	410	417	437	6.00	<0.01	<0.01	0.10
Compensation, %[4]	24	4	7	-	-	-				
ADG, kg	0.65	0.74	0.70	0.45	0.55	0.59	0.04	<0.01	0.02	0.55

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2] Means in the same row with a the same subscript are similar ($P > 0.05$)

[3]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[4]Compensation was calculated by subtracting both the winter initial and summer initial BW from the EBW of the corresponding phase. Then, subtracting the winter total gain from the summer total gain and dividing it by the winter total gain.

[5]Implant strategy signifcantly differs for IBW, EBW and ADG. STRONG-IMP had to greatest IBW, EBW and ADG with MED-IMP being the intermidate IBW, EBW and ADG and NO-IMP resulting in the smallest IBW, EBW and ADG.

Table 2.5. Organic matter digestibility (OMD) and clipped biomass from pastures grazed by steers developed at two rates of gain during the winter under different implant strategies

	Treatments[1]						SED	*P*-Value[3]		
	LG			HG						
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
ODM%	61.2[bc]	59.9[c]	62.8[ab]	61.1[bc]	60.7[bc]	63.8[a]	0.9	0.83	0.06	<0.01
Biomass										
Pre (kg/ha)	2506	2645	2495	2670	2586	2586	135	0.98	0.74	0.98
Post (kg/ha)	2211	2251	2083	2171	2120	1935	92	0.46	0.42	0.98

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2] Means in the same row with a the same subscript are similar (P>0.05)

[3]P-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

Table 2.6. Carcass Adjusted finishing performance of yearling steers developed at two rates of gain during the winter under different implant strategies (YR1 only).

	Treatments[1,2]									
	LG			HG			SED	*P*-Value[4]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	111	117	117	111	111	111				
Initial BW, kg	367	366	370	408	414	433	9.57	<0.01	0.03	0.11
Final BW[3], kg	599	616	627	630	647	671	11.8	<0.01	<0.01	0.69
ADG[3], kg	2.11	2.14	2.21	2.02	2.12	2.15	0.06	0.15	0.06	0.74
DMI, kg	12.6	12.9	13.12	12.3	12.8	13.4	0.36	0.93	0.02	0.49
G:F[2]	0.167	0.165	0.169	0.164	0.166	0.161	0.005	0.24	0.97	0.50

[1] All treatments received the same implant of 200 mg TBA and 40 mg of estradiol (Rev-XS; Merck Animal Health, De Soto, KS) and are fed the same common finisher diet during the finishing phase.

[2]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[3]Final body weight, ADG and G:F adjusted using the average dressing percent of 62%.

[4]P-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[5]Implant strategy signifcantly differs for IBW, EBW, ADG and DMI. STRONG-IMP had to greatest IBW, EBW, ADG and DMI with MED-IMP being the intermidate EBW, ADG and G:F and NO-IMP resulting in the smallest IBW, EBW, ADG and DMI.

Table 2.7. Carcass characteristics of yearling steers developed at two rates of gain during the winter under different implant strategies (YR1 only).

	Treatments[1,2]									
	LG			HG			SED	*P*-Value[5]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
Dressing %	60.34	61.27	60.2	61.28	61.48	61.47	0.012	0.25	0.75	0.81
HCW, kg	372	381	389	390	401	416	7.18	<0.01	<0.01	0.70
HCW[3] ADG, kg	1.18	1.14	1.12	1.30	1.36	1.41	0.104	<0.01	0.77	0.64
LM area, cm^2	86.9	85.2	88.2	87.6	89.5	92.4	1.68	<0.01	0.03	0.24
Back fat, cm	1.25	1.35	1.32	1.25	1.32	1.37	0.091	0.87	0.22	0.80
Marbling[4]	479	452	467	516	524	526	24.45	<0.01	0.82	0.61
Calculated YG[6]	3.21	3.33	3.30	3.22	3.30	3.35	0.09	0.90	0.19	0.79

[1] All treatments received the same implant of 200 mg TBA and 40 mg of estradiol (Rev-XS; Merck Animal Health, De Soto, KS) and are fed the same common finisher diet during the finishing phase.
[2]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)
[3] HCW ADG was calculated by multiplying the IBW in the finishing phase by the dressing percent of 24 steers marketed at feedlot entry, then subtracting that number from the HCW and dividing that by the days on feed.
[4]USDA marbling scores. 400= small, 500= modest, 600=moderate.

[5]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.
[6]Calculated: 2.5+ (6.635 x 12^{th} rib fat thickness, cm) – (2.06 x LM area, cm^2) + (0.2 x 2.5 KPH fat, %) + (0.0017 x HCW, kg) (KPH fat is assumed as 2.5 %; Boggs and Merkel, 1993).
[7]Implant strategy signifcantly differs for HCW and REA. STRONG-IMP had to greatest HCW and REA with MED-IMP being the intermidate HCW and REA and NO-IMP resulting in the smallest HCW and REA.

Table 2.8. Average high and low temperatures (°C) and average precipitation (cm) over the course of two years for the study (Lincoln, NE) (NWS, 2021).

	Temperature (°C)						Precipitation (cm)		
	Low	High	Low	High	Low	High			
Item	2019	2019	2020	2020	2021	2021	2019	2020	2021
January			-7.83	1.89	-6.94	3.39		3.28	3.89
February			-7.5	6.78	-16.72	-5.61		0.33	1.85
March			0.56	13.11	-0.06	19.5		4.24	0
April			1.22	18.61	4.17	19.00		2.24	4.39
May			9.33	20.33	9.94	21.83		11.43	3.20
June			19.00	32.28	17.5	31.94		5.33	11.33
July			20.28	31.61	18.5	31.33		13.18	4.39
August			17.17	30.67				3.23	
September			10.56	25.61				4.12	
October			2.56	16.83				1.02	
November	-3.72	9.67	-1.56	14.67			3.63	3.28	
December	-6.06	6.56	-7.78	5.94			6.53	3.05	

FIGURES

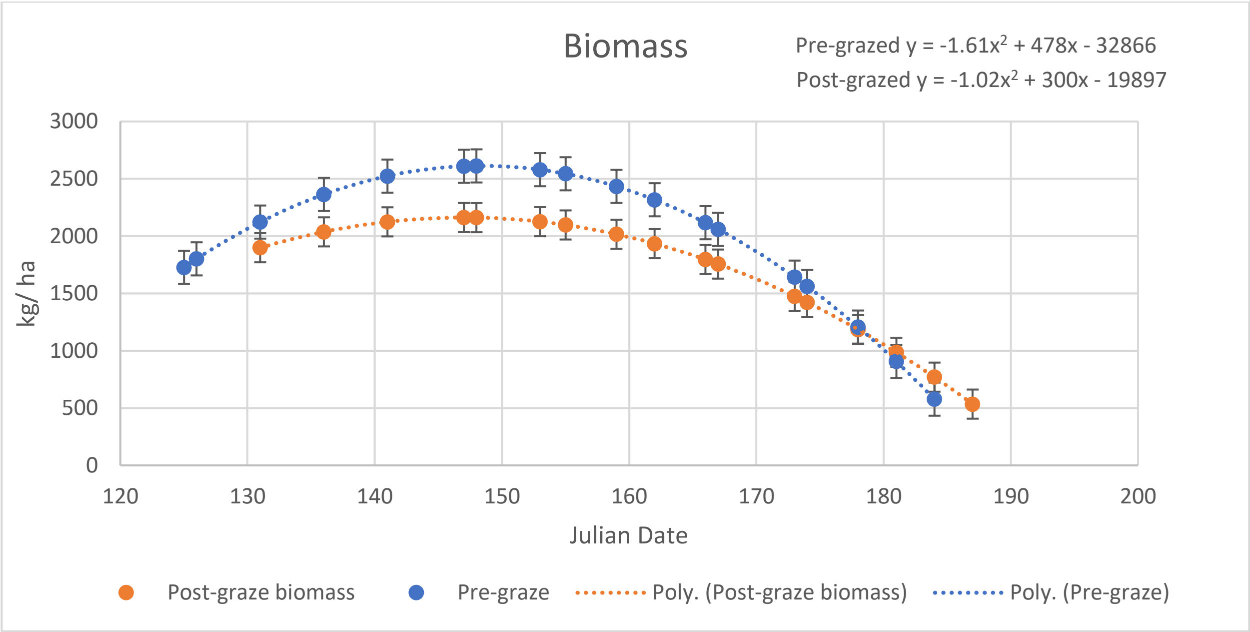

Figure 1. Pre and post grazed biomass of smooth bromegrass in kilograms per hectare over the grazing season by Julian date.

Appendices

Appendix 2.1. Winter performance of yearling steers developed at two rates of gain during the winter under different implant strategies for YR 1

	Treatments[1]									
	LG			HG			SED	P-Value[2]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	148	148	148	148	148	148				
Initial BW, kg	247	247	247	247	247	247	0.46	0.89	0.87	0.69
Ending BW, kg	320	320	325	375	376	391	6.00	<0.01	0.04	0.36
ADG, kg	0.49	0.49	0.53	0.87	0.88	0.97	0.04	<0.01	0.05	0.45
DMI, kg	8.08	8.04	7.99	8.67	8.99	9.22	0.63	<0.01	0.54	0.29
G:F	0.061	0.061	0.066	0.100	0.097	0.105	0.01	<0.01	0.15	0.86

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[3]Implant strategy signifcantly differs for EBW and ADG. STRONG-IMP had to greatest EBW and ADG with MED-IMP being the intermidate EBW and ADG and NO-IMP resulting in the smallest EBW and ADG.

Appendix 2.2. Summer performance of yearling steers developed at two rates of gain during the winter, under different implant strategies YR 1

Item	Treatments[1] LG NO-IMP	LG MED-IMP	LG STRONG-IMP	HG NO-IMP	HG MED-IMP	HG STRONG-IMP	SED	P-Value[3] Winter Gain	Implant	Winter Gain * Implant
DOF	51.5	51.5	51.5	51.5	51.5	51.5				
Initial BW, kg	326	326	331	381	382	397	6.00	<0.01	0.04	0.36
Ending BW, kg	367	366	370	407	414	433	7.43	<0.01	0.03	0.11
ADG, kg	0.80	0.78	0.76	0.50	0.62	0.67	0.07	<0.01	0.43	0.14

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2] Means in the same row with the same subscript are similar (P>0.05)

[3]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[4]Implant strategy signifcantly differs for IBW and EBW. STRONG-IMP had to greatest IBW and EBW with MED-IMP being the intermidate IBW and EBW and NO-IMP resulting in the smallest IBW and EBW.

Appendix 2.3. Carcass Adjusted finishing performance of yearling steers developed at two rates of gain during the winter under different implant strategies (YR1 only).

	Treatments[1,2]									
	LG			HG			SED	*P*-Value[4]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	111	117	117	111	111	111				
Initial BW, kg	367	366	370	408	414	433	9.57	<0.01	0.03	0.11
Final BW[3], kg	599	616	627	630	647	671	11.8	<0.01	<0.01	0.69
ADG[3], kg	2.11	2.14	2.21	2.02	2.12	2.15	0.06	0.15	0.06	0.74
DMI, kg	12.6	12.9	13.12	12.3	12.8	13.4	0.36	0.93	0.02	0.49
G:F[2]	0.167	0.165	0.169	0.164	0.166	0.161	0.005	0.24	0.97	0.50

treatments received the same implant of 200 mg TBA and 40 mg of estradiol (Rev-XS; Merck Animal Health, De Soto, and are fed the same common finisher diet during the finishing phase.

atments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during vinter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol ıg the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck nal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

al body weight, ADG and G:F adjusted using the average dressing percent of 62%.

'alue: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of ant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and ant strategy treatment during the winter and summer phases.

›lant strategy signifcantly differs for IBW, EBW, ADG and DMI. STRONG-IMP had to greatest IBW, EBW, ADG and [with MED-IMP being the intermidate EBW, ADG and G:F and NO-IMP resulting in the smallest IBW, EBW, ADG DMI

Appendix 2.4. Carcass characteristics of yearling steers developed at two rates of gain during the winter under different implant strategies (YR1 only).

	Treatments[1,2]									
	LG			HG			SED	*P*-Value[5]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
Dressing %	60.34	61.27	60.2	61.28	61.48	61.47	0.012	0.25	0.75	0.81
HCW, kg	372	381	389	390	401	416	7.18	<0.01	<0.01	0.70
HCW[3] ADG, kg	1.18	1.14	1.12	1.30	1.36	1.41	0.104	<0.01	0.77	0.64
LM area, cm^2	86.9	85.2	88.2	87.6	89.5	92.4	1.68	<0.01	0.03	0.24
Back fat, cm	1.25	1.35	1.32	1.25	1.32	1.37	0.091	0.87	0.22	0.80
Marbling[4]	479	452	467	516	524	526	24.45	<0.01	0.82	0.61
Calculated YG[6]	3.21	3.33	3.30	3.22	3.30	3.35	0.09	0.90	0.19	0.79

[1] All treatments received the same implant of 200 mg TBA and 40 mg of estradiol (Rev-XS; Merck Animal Health, De Soto, KS) and are fed the same common finisher diet during the finishing phase.
[2]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[3] HCW ADG was calculated by multiplying the IBW in the finishing phase by the dressing percent of 24 steers marketed at feedlot entry, then subtracting that number from the HCW and dividing that by the days on feed.
[4]USDA marbling scores. 400= small, 500= modest, 600=moderate.
[5]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.
[6]Calculated: 2.5+ (6.635 x 12th rib fat thickness, cm) – (2.06 x LM area, cm^2) + (0.2 x 2.5 KPH fat, %) + (0.0017 x HCW, kg) (KPH fat is assumed as 2.5 %; Boggs and Merkel, 1993).
[7]Implant strategy signifcantly differs for HCW and REA. STRONG-IMP had to greatest HCW and REA with MED-IMP being the intermidate HCW and REA and NO-IMP resulting in the smallest HCW and REA.

Appendix 2.5. Winter performance of yearling steers developed at two rates of gain during the winter under different implant strategies YR 2

Item	Treatments[1]						SED	P-Value[2]		
	LG			HG						
	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	148	148	148	148	148	148				
IBW (kg)	255	255	255	256	255	255	0.59	0.20	0.48	0.77
EBW (kg)	342^{d}	353^{c}	357^{c}	388^{b}	388^{b}	406^{a}	3.32	<0.01	<0.01	0.012
ADG (kg)	0.59^{d}	0.66^{c}	0.69^{c}	0.90^{b}	0.89^{b}	1.02^{a}	0.02	<0.01	<0.01	0.012
DMI (kg)	8.23	7.80	8.64	9.05	8.75	9.06	0.32	<0.01	0.06	0.48
G:F	0.072	0.086	0.080	0.099	0.102	0.113	0.004	<0.01	<0.01	0.03

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[3]Implant strategy signifcantly differs for EBW, ADG and G:F. STRONG-IMP had to greatest EBW, ADG and G:F with MED-IMP being the intermidate EBW, ADG and G:F and NO-IMP resulting in the smallest EBW, ADG and G:F.

Appendix 2.6. Summer performance of yearling steers developed at two rates of gain during the winter, under different implant strategies YR 2

	Treatments[1]									
	LG			HG			SED	P-Value[3]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	60.5	60.5	60.5	60.5	60.5	60.5				
IBW (kg)	345^{d}	355^{c}	359^{c}	391^{b}	390^{b}	409^{a}	3.26	<0.01	<0.01	0.01
EBW (kg)	374^{d}	389^{c}	398^{c}	414^{b}	420^{b}	440^{a}	4.26	<0.01	<0.01	<0.01
ADG (kg)	0.49	0.70	0.63	0.39	0.49	0.51	0.05	<0.01	<0.01	0.33

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2] Means in the same row with a the same subscript are similar (P>0.05)

[3]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[4]Implant strategy signifcantly differs for IBW, EBW and ADG. STRONG-IMP had to greatest IBW, EBW and ADG with MED-IMP being the intermidate IBW, EBW and ADG and NO-IMP resulting in the smallest IBW, EBW and ADG.

Appendix 2.7. Performance of carcass based performance yearling steers during the winter phase

	Treatments									
	LG			HG			SED	P-Value[3]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	148	148	148	148	148	148				
IBW (kg)	238	239	238	239	239	239	1.11	0.29	0.93	0.87
EBW (kg)	324	328	328	380	362	387	7.46	<0.01	0.07	0.05
ADG (kg)	0.53	0.54	0.55	0.90	0.78	0.94	0.05	<0.01	0.70	0.06

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

Appendix 2.8. Performance of carcass based performance yearling steers during the summer phase

Item	Treatments[1]						SED	P-Value[3]		
	LG			HG						
	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
DOF	56	56	56	56	56	56				
IBW (kg)	316[c]	320[c]	320[c]	373[a]	355[b]	379[a]	7.44	<0.01	0.06	0.0475
EBW (kg)	325	335	364	377	370	396	13.20	<0.01	<0.01	0.41
ADG (kg)	0.31	0.44	0.82	0.22	0.45	0.41	0.14	0.04	<0.01	0.08

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2] Means in the same row with a the same subscript are similar (P>0.05)

[3]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[4]Implant strategy signifcantly differs for EBW and ADG. STRONG-IMP had to greatest EBW and ADG with MED-IMP being the intermidate EBW and ADG and NO-IMP resulting in the smallest EBW and ADG.

Appendix 2.9. Carcass characteristics for carcass based performance yearling steers

	Treatments[1]									
	LG			HG			SED	P-Value[2]		
Item	NO-IMP	MED-IMP	STRONG-IMP	NO-IMP	MED-IMP	STRONG-IMP		Winter Gain	Implant	Winter Gain * Implant
HCW (kg)	164	174	187	197	190	208	7.97	<0.01	<0.01	0.27
Dressing, %	50.62	51.75	51.12	51.97	51.45	52.09	0.01	0.23	0.88	0.41

[1]Treatments = 10% MDGS (LG= Low Gain 0.45 kg ADG) or 30% MDGS (HG= High Gain 0.91 kg ADG) applied during the winter phase, NO-IMP= no implant, MED-IMP = no implant during the winter, 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health), STRONG-IMP= 36 mg of zeranol during the winter (Ralgro; Merck Animal Health) and 40 mg of TBA and 8 mg of estradiol during the summer (REV- G; Merck Animal Health)

[2]*P*-Value: Winter Gain= effect of supplementing at LG verses HG over two years during the winter phase, Implant= effect of implant strategy treatment during the winter and summer phases, Winter Gain* Implant= effect of winter gain treatment and implant strategy treatment during the winter and summer phases.

[3]Implant strategy signifcantly differs for HCW. STRONG-IMP had to greatest HCW with MED-IMP being the intermidate HCW and NO-IMP resulting in the smallest HCW in the LG treatment, but NO-IMP had a greater HCW in the HG than the MED-IMP. STRONG-IMP still had the greatest HCW in the HG.