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Forages and Technology Management in Growing and Finishing Beef Cattle Systems

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FORAGES AND TECHNOLOGY MANAGEMENT

IN GROWING AND FINISHING BEEF CATTLE SYSTEMS

by

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FORAGES AND TECHNOLOGY MANAGEMENT

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A systems study evaluated the effects of an implant [25.7 mg estradiol (Compudose; Elanco Animal Health)] at two rates of gain (LOW: 0.45 kg/d and HIGH: 0.9 kg/d) applied during the winter backgrounding phase in drylot and winter grazing systems and its effects on subsequent phases of production. HIGH supplementation with an implant during the winter backgrounding phase in the drylot system yielded the greatest ending body weight (EBW) during the summer backgrounding phase (P = 0.04). LOW supplementation, without an implant, improved summer backgrounding average daily gain (ADG; P = 0.05) while achieving similar carcass adjusted final body weight and hot carcass weight (HCW) as those wintered at HIGH with an implant. In the dormant meadow winter backgrounding system, additional supplement yielded increased winter and summer EBW and ADG (P <0.10). Administering an implant to calves grazing dormant meadows during the winter backgrounding phase with variable levels of supplement intake had no effect on performance (P > 0.16).

A feedlot study compared the effects of a direct-fed microbial feed additive to no feed additive on performance and liver abscess rates in finishing beef cattle. The DFM technology used in this study was developed to reduce the abundance of *Fusobacterium necrophorum* and *Streptococcus bovis* in the rumen. Feeding this specific DFM at 1

billion bacterial cells/steer daily to finishing beef cattle did not significantly affect performance, carcass characteristics, liver abscess rate, or the severity of liver abscesses.

Rumen undegradable protein (RUP) values of crested wheatgrass (CWG) have not been well established. Knowing the amount of RUP available to cattle grazing CWG throughout the grazing season can help producers calculate MP supply and aid supplementation decisions throughout the grazing period. An experiment evaluated the forage value of crested wheatgrass harvested from Western Nebraska over a two-year period (2019-2020). The study found that crude protein decreased throughout the growing season while RUP % CP increased. The RUP content of CWG may range from 0.8% to as high as 1.21% of DM throughout the grazing season. RUP digestibility is less than 50% of RUP resulting in digestible RUP being less than 0.5% of DM.

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CHAPTER 1 - REVIEW OF LITERATURE

Introduction

The purpose of this literature review is to provide information to the reader about current knowledge of backgrounding systems and development strategies such as implant technologies or targeting specific rates of gain. The overarching goal of this review is for the reader to value each strategy, know how they are applied in current industry practices, and why it is important to understand how these strategies affect subsequent phases of production.

Direct Fed Microbials

Liver abscesses are a major concern for the beef cattle industry and negatively impact cattle performance as well as value to the producer, packer, and consumer. Abscesses in the liver of animals occur as a result of entry, growth, and establishment of pyogenic bacteria (Nagaraja and Lechtenberg, 2007). Ruminal lesions resulting from acidosis usually are accepted as the predisposing factors of liver abscesses (Nagaraja and Lechtenberg, 2007). In the past, feeding the antibiotic, tylosin, as a prophylactic (fed as a preventative method) has effectively reduced the occurrence of liver abscesses in cattle fed a diet high in readily fermentable carbohydrates. With concerns of antibiotic resistance in medically important drugs, the Food and Drug Administration (FDA) banned the use of tylosin as a growth promotant, and now requires veterinarian approval in compliance with the Veterinarian Feed Directive (VFD). Due to the public concerns with antimicrobial resistance and the challenges associated with acquiring a VFD, the industry is seeking natural effective alternatives. It was suggested by Krehbiel et al., (2003) that direct fed microbials (DFM) may be utilized to reduce the risk for acidosis and metabolic acidosis which could potentially reduce the occurrence of liver abscesses without the need of a VFD. This review of the literature explains current industry challenges with liver abscesses, how they are formed, the primary uses of DFM in the industry today, and how they may potentially be used as a probiotic means of liver abscess prevention.

Liver Abscesses

Liver abscesses are not identified nor measured within the commercial industry until after harvest when livers can be physically inspected. Abscessed livers are condemned and may require additional trim to the carcass. For research purposes, the liver from each animal is scored based on the occurrence and size of the abscess(es). The scores range from 0, A-, A, and A+: an animal that has a liver with no abscesses or scarring receives a score of 0 and a liver with one or more large abscesses with inflammation is assigned A+. A liver assigned A+ is considered a severe liver abscess and is condemned. Animals with severe liver abscesses are estimated to pose an annual economic loss of $15,873,456 simply in unrealized liver value and can have reduced daily gains by up to 5.2% or reduce dressing percent by 1.7% (Hicks et a., 2011). Cattle with liver abscesses that receive a score of A- or A do not show any measurable impact on carcass yield or performance (Montgomery et al., 1985). One study reported that performance of animals with severe liver abscesses (A+) varied from little to no effect to as much as an 11% decrease in average daily gain and a 9.7% reduction in feed efficiency

(Brink et al., 1990). Liver abscesses are a concern for all producers within the feedlot industry because the prevalence has large variability which make it difficult to assess for improvement. The prevalence of liver abscesses may vary regionally, but range anywhere from 1% to 95% (Nagaraja and Lechtenberg, 2007) with the average incidence around 20.3% (Batista and Holland, 2022). The large variability in prevalence may be associated with the many factors that may influence acidosis. Ruminal lesions resulting from acidosis usually are accepted as the predisposing factors of liver abscesses (Nagaraja and Lechtenberg, 2007).

Liver Abscesses Pathology

Liver abscesses are formed from the colonization of facultative anaerobic bacteria within the liver. The facultative anaerobes can survive in the presence of oxygen or in an anaerobic (oxygen deprived) environment; however, they prefer an anaerobic environment. These bacteria are naturally occurring in the rumen but are able to escape into portal blood circulation when the rumen epithelial become keratinized and crack (otherwise known as rumenitis). The rumen epithelial tissue may be compromised due to several reasons, most of which are driven by increased organic acid (lactic acid and volatile fatty acids) production and accumulation in the rumen from rapidly fermentable feeds (high grain) resulting in acidosis which eventually damage the protective surface of the ruminal wall (Nagaraja and Lechtenberg, 2007). As previously described, damage to the rumen epithelial wall allows pathogenic bacteria to escape the rumen and migrate into portal circulation (Rezac et al., 2014). Once reaching the liver via portal circulation, the facultative anaerobes get entrapped in the portal capillary system of the liver leading to infection and abscess (Nagaraja and Lechtenberg, 2007) when they establish an anaerobic environment. Nagaraja and Chengappa, (1998) summarized the pathology described above simply as the acidosis-rumenitis-liver abscess complex (Figure 1.1).

Almost all studies have concluded that *Fusobacterium necrophorum*, a ruminal bacterium, is a primary causative agent and *Trueperella* (formerly *Arcanobacterium*) *pyogenes* is the secondary pathogen for liver abscess formation (Amachawadi & Nagaraja 2016).

Acidosis Defined

Liver abscesses are considered generally as a sequel to ruminal acidosis and rumenitis in cattle fed diets high in readily fermentable carbohydrates and low in roughages (Amachawadi & Nagaraja 2016). Acidosis has been defined by Stock et al., (2000) as an array of biochemical and physiological stresses caused by rapid production and absorption of ruminal organic acids and endotoxins when an animal over consumes a meal of readily fermentable carbohydrates.

There are different degrees of severity to acidosis; sub-acute and acute. In acute acidosis, the animal may be sick to the point of death or may have impaired some physiological function, like absorption (Stock et al., 2000). Animals suffering with sub-acute acidosis rarely show symptoms. If re-occurring, sub-acute acidosis may cause damage to the rumen epithelial tissue. Although acidosis is not defined by ruminal pH alone, levels of severity are often observed to have a ruminal pH within a certain range. Cattle with sub-acute acidosis are commonly observed to have a rumen pH between 5.6 and 5.0 whereas cattle suffering acute acidosis are often observed to have a pH below 5.0. Sub-acute ruminal acidosis is caused by a rapid rate of volatile fatty acid (VFA) production while, for acute acidosis, the pH depression is often associated with an increase in lactic acid (Penner, 2014).

Etiology of Acidosis

Acidosis in cattle is caused by excessive ingestion of feeds which are rich in readily available carbohydrates (Elam et al., 1976). When feeds with readily available carbohydrates enter the rumen, a rapid concentration increase in free glucose occurs. Glucose is liberated from starch by amylase, but whether this elevated concentration is simply a result of more rapid hydrolysis or of a reduction in the rate of glucose utilization by ruminal microbes is not clear (Owens et al., 1998). The high concentration of free glucose within the rumen has several affects; first, the osmolarity of the rumen concentration may change which can damage rumen epithelial tissues by removing water from their plasma membrane forcefully. Second, several bacterial species proliferate in the presence of free glucose such as *Streptococcus bovis (S. bovis)*. *S. bovis* is a lactic acid producing (LAB) organism commonly present within the rumen. As such, when fermentable carbohydrates are abundant, *S. bovis* increases in population and increases lactic acid production. The third effect of a high concentration of free glucose in the rumen is explained well by Owens et al., (1998); other opportunistic microbes, including coliforms and amino acid decarboxylating microbes, may thrive in the rumen of cattle fed concentrated diets and produce, during lysis, and release endotoxins or amides. In response to the endotoxins, histamine is released which may cause vasoconstriction and increase blood pressure. If endotoxins and histamine are released over an extended duration and blood pressure remains elevated, cattle may show symptoms such as laminitis.

As microbes in the rumen ferment free glucose, the concentration of bacterium species that make up the microbial population will shift. Volatile fatty acids are produced as a byproduct of microbes fermenting free glucose. These VFAs have a pH of approximately 4.8. As microbes ferment more free glucose, more VFAs can accumulate in the rumen which buffer the pH closer to 4.8. Typically, concentration of VFA in the rumen do not accumulate high enough to have a drastic reduction in the overall pH of the rumen, but it can occur (Owens et al., 1998). The rumen has several methods of absorption in order to remove the VFAs from the rumen as the concentration rises and overall rumen pH declines. Volatile fatty acids are primarily absorbed through the villi of the rumen wall and enter the bloodstream for transport. As VFAs are absorbed, the overall concentration in the rumen is reduced and thus increases the ruminal pH returning it to a stable state.

Keep in mind that *S. Bovis,* a major LAB, proliferate in the presence of free glucose at a low pH (~5.4 or lower). In such cases, *S. bovis* proliferates and there is an increased amount of lactic acid being produced within the rumen. Lactic acid produced from microbes have a pH of approximately 3.8 which make it more potent to the rumen pH than VFA (Owens et al., 1998). However, there are also lactic acid utilizing bacteria (LUB) within the rumen which synthesize lactic acid and can help in the response to stabilize pH. Unfortunately, lactic acid utilizing bacteria are sensitive at lower pH environments and can become impaired if rumen pH decreases too far. The rumen pH may decrease below the LUB tolerable threshold either because of rapid VFA production and relatively slow VFA absorption, lactic acid being produced at a greater rate than the LUB are able to utilize it, or a combination. Without functional LUB at a low pH, the lactic acid may accumulate uncontrolled, and the pH can decrease further below a pH of 5.

As rumen pH decreases or the amount of time spent below a pH of 5.6 increases, the greater the risk of rumen epithelial tissues becoming keratinized and cracking, thus allowing microbes and other rumen contents to enter the portal blood. The damage to rumen epithelial tissues can also be due to a combination of events such as a decrease in osmolarity of the epithelial cells or certain bacterial virulence factors. Virulence factors from some bacteria include a leukotoxin which is cytotoxic to the neutrophils, hepatocytes, macrophages, and possibly the ruminal epithelial cells (Nagaraja and Lechtenberg, 2007). The virulence factors of *Fusobacterium necrophorum* also play a critical role in the penetration and colonization of the ruminal epithelium (Nagaraja and Chengappa 1998).

As a result of a compromised rumen epithelial wall and absorption into the portal blood, blood pH is reduced, and the liver is one of the last remaining mechanisms to synthesize the lactic acid. The liver is slow to synthesize D+ lactate and therefore is slow to stabilize the blood pH. At this point, metabolic acidosis has set in, and the animal’s body is responding to the low blood pH by panting to remove carbon dioxide as a means to remove hydrogen ions from the blood to increase pH. Metabolic acidosis is a last resort for the body and typically occurs after all other methods of absorption have been saturated. Often times, metabolic acidosis results in death.

Previous Methods to reduce the occurrence of liver abscesses

Common methods to reduce the occurrence of liver abscesses are based on nutritional management, vaccines, and antimicrobial feed additives (Nagaraja and Lechtenberg, 2007). There are many ways to manage acidosis using nutritional management such as proper selection of grain processing techniques, selection of grain sources, increasing fiber inclusion, or feed delivery techniques. These management strategies have proven to effectively help reduce the occurrence of liver abscesses but many result in decreased amount of readily fermentable carbohydrates within the diet which tends to reduce performance.

In the past, the prophylactic use of the antibiotic tylosin has effectively reduced the occurrence of liver abscesses in feedlots by 40-70% (Nagaraja & Chengappa, 1998). Tylosin has proven to effectively decrease the occurrence of liver abscesses; however, it is no longer permitted to be used as a prophylactic within the industry because it is a macrolide antibiotic.

Within human health, macrolide antibiotic use has increased greatly and are considered one of the first lines of defense for adults (Hyde et al., 2001). The efficacy of macrolide antibiotics are of great importance in human health; therefore, antimicrobial resistance (AMR) is of great concern with macrolide antibiotics as AMR greatly reduce efficacy. There are many studies with evidence that AMR increases with increased use of antibiotics with livestock (Dawson et al., 1984, Dunlop et al., 1998, Low et al., 1997). Due to concerns with AMR, the FDA mandated that a Veterinary Feed Directive (VFD) is necessary for using medically important drugs which are often referred to as those used by both humans and animals. Macrolides were among one of the classes of drugs deemed medically important (Pyatt et al., 2016). Tylosin is permitted to use as a prophylactic only in certain cases with VFD approval but not on all cattle; therefore, an alternative that can be used on all cattle to reduce the occurrence of liver abscesses is of great need.

Direct-Fed Microbials

Direct-fed microbials (DFM) have been defined by Krehbiel et al., (2003) as single or mixed cultures of live, naturally occurring microorganisms that improve digestive function of livestock when consumed. Direct-fed microbial is a broad term that can be broken down further by their modes of action as either fungal, yeast, bacterial, or a combination. All types of DFM are being investigated within the cattle industry as a means to positively influence health and performance by altering the rumen microbial biome. Some microbials are currently used in the feedlot industry in the form of a bolus, drench, or feed additive to increase performance such as average daily gain and feed efficiency. The mode of each type of these are dependent on dosage, time of administration, and frequency of administration. Fungal DFM have been used to improve performance and normalize rumen fermentation by physically breaking apart forage particles and increasing surface area for bacterial attachment. By increasing the amount of fungi within the rumen when a low-quality forage diet is fed, the overall digestibility is increased due to the fungi increasing surface area for bacterial attachment. It is not uncommon for yeast to also be administered within DFM. Yeast has many unique functions within the rumen such as oxygen regulation and buffering. Yeast may help buffer excess lactic acid production when ruminants are fed high concentrate diets (Kung et al.,2006). Unfortunately, it does not buffer enough lactic acid to prevent acidosis altogether. Yeast can remove oxygen from the surface of freshly ingested feeds and help maintain anaerobic environment within the rumen which is beneficial for obligate anaerobe bacterial species. Most of the bacterial DFM being investigated involve naturally occurring bacterium which are native to the rumen.

Bacterial DFM

Bacterial DFM can be further classified as LAB or LUB based on the mode of action of the specific DFM. Majority of studies done on bacterial DFM have targeted enhancing LUB such as *Megasphere Elsdenii, Selenomonas ruminantium, or Proprionibacterium freudenreichii* (McAllister et al., 2011). By supplementing the LUB *Megasphere elsdenii*, the overall amount of lactate that may be fermented at a given time is increased; therefore, increasing pH, improving feed efficiency, and altering VFA concentrations (Thiezen et al., 2015). *Megasphere elsdenii* DFM have also proven to reduce the amount of time necessary for transitioning cattle from low carbohydrate to high carbohydrate diets. LAB are commonly used in combination with LUB in current DFM products to increase the overall amount of propionate production. Propionate is a product of *Megasphere elsdenii* and is the only gluconeogenic VFA. Since lactate can be converted to propionate by certain LUB, lactate can be considered a precursor to gluconeogenesis as well. Lactate is beneficial within the rumen as long as there are enough LUB to keep it from accumulating.

Some DFM studies have been conducted to inhibit bacterial species. One method for reducing the amount of LAB is to introduce a population of bacteria such as *Prevotella bryantii* that compete for the same substrates (starch) as LAB (McAllister et al., 2011). By introducing competitive bacterium, the LAB are limited in production since they now have to share the substrate source amongst the introduced DFM. Some DFM produce antimicrobials known as bacteriocins which are capable of inhibiting bacteria closely related to the producing strain (McAllister et al., 2011). There is much potential to isolate and further study bacteriocins to inhibit specific bacteria.

Future Studies

Studies have proven that bacterial DFM are capable of being used as a probiotic to isolate specific bacteria within the native microbial population to significantly enhance performance, immune response, or increase rumen pH. Current DFM studies are exploring the possibility of isolating and reducing the population of liver abscess causing bacteria. One hypothesis is that if liver abscess causing bacterium are removed from the rumen, then if rumenitis occurs, there will not be any liver abscess causing bacteria to colonize in the liver; thus preventing the occurrence of abscesses. Further research on the microbial community, species interaction, and methods to manipulate microbial communities are needed to help find a DFM to reduce liver abscess occurrence.

Summary

Liver abscesses result in major economic losses to producers and packers within the beef cattle industry. One of the most effective tools for reducing the occurrence of liver abscesses, tylosin, requires a VFD due to concerns with AMR. The beef cattle industry is in need of a product of equal effectiveness that can be used on all cattle to reduce liver abscesses in cattle fed readily fermentable carbohydrates. Direct-fed microbials show potential to reduce the occurrence of liver abscesses by altering the rumen microbial biome using LAB and LUB. Currently, DFM have been used to effectively increase or inhibit specific bacteria within the rumen. DFM have potential to isolate and inhibit liver abscess causing bacteria, however, none have been found to reduce liver abscess occurrence.

Rumen Undegradable Protein in Forages

The Metabolizable Protein System

Crude protein is a combination of rumen degradable protein (RDP) and rumen undegradable protein (RUP). Rumen degradable protein is hydrolyzed in the rumen by microbes and not directly available to the animal. The RUP fraction is not degraded by microbes in the rumen and is absorbed in the gastro-intestinal tract. The CP system fails to account for protein from the microbes and endogenous protein. The metabolizable protein system accounts for rumen degradation of dietary protein and separates requirements into the needs of microorganisms in the rumen and the needs of the animal (NASEM, 2016). Metabolizable protein (MP) is the true protein digested in the small intestine and absorbed as amino acids and is calculated as true protein + digestible RUP + endogenous protein.

Protein in Crested Wheatgrass

Forages typically peak in CP at the beginning of the growing season when plants are in the vegetative state and decrease as they mature (NASEM, 2016). In forages, RDP is the larger portion of CP; RUP is typically only 5 to 36% of CP although there is some variation (Buckner et al., 2013).

Monoculture pastures of crested wheatgrass (CWG) are commonly grazed by cattle in the panhandle of Nebraska. Crested wheatgrass is a perennial cool season grass species that was introduced to Western Nebraska in the 1900’s primarily for soil conservation. Environments which receive between 8 to 20 inches of annual precipitation are ideal for CWG; however, there are more productive species to utilize for grazing if receiving more than 14 inches of annual precipitation. In short grass prairie ecosystems, like the panhandle of Nebraska, CWG generally produces 1.5 to 2 times more forage than native species (NASEM, 1996). In spring grazing systems, crested wheatgrass has been observed to vary from 6.3 to 7.2% digestible protein but decreases as it matures (Cook and Harris, 1952). Mature CWG plants are low in protein, which may limit forage digestion and body weight gain in stockers; therefore, supplementation may be beneficial for part of the grazing season (Greenwell et al., 2018).

Winter Backgrounding Systems and Development Strategies

Similar to grazing crested wheatgrass, dormant mature forages are typically low in RUP and improved gains may be observed with additional RUP supplementation (Greenwell et al., 2018). Winter backgrounding systems utilize many different management tools such as housing systems, implant technologies, or targeting different rates of supplementation.

Backgrounding Systems

Backgrounding or stocking is a phase of production that most weaned calves undergo before entering the finishing phase of beef cattle production. Traditionally, calves are backgrounded on high forage diets for an extended period of time (more than 45 days) and gain from 0.45 kg/d to 1.36 kg/d (Peel, D.S. 2003). Backgrounding systems can include grazing dormant range, crop residues, cover crops, growing forages, or feeding a total mixed ration (TMR) in a dry lot or other confinement system. A backgrounding phase can add value to weaned calves by increasing skeletal and muscle growth without additional fat, opportunities to improve animal health, and present additional marketing opportunities. With 73% of the US calf crop born before July 1

(USDA-NASS, 2022) and weaned in the fall, backgrounding systems are essential to maintain a consistent supply of feeder cattle to feedlots throughout the entire year.

Backgrounding systems can have either 1 phase or multiple phases before entering the feeder cattle market. In a single-phase backgrounding system, fall weaned calves are backgrounded through the winter on either dormant forage (range, crop residue, etc.) or in a drylot system before being sold in the spring as a short yearling (calves almost 1 year of age) into the feeder cattle market. A common two-phase backgrounding system involves weaning spring born calves in the fall, background through the winter then turned out to growing pasture in the late spring for summer grazing and market during the late summer as long yearlings (well over 1 year of age) into the feeder cattle market. Not all producers can utilize both drylot and/or winter graze backgrounding systems. Those who are capable of either system must consider economics and cattle performance within each system when selecting. Taylor et al. (2008), found that backgrounding cattle grazing winter range supplemented with dried distillers grains solubles cost less than backgrounding cattle in a drylot system. With grazing land value increasing by more than 10% in the last year and pasture rental rates increasing by 6 to 8% in 2021 (Jansen and Stokes, 2022), summer grazing backgrounding system may not have as strong of an economic advantage over a drylot system due to increased costs of grazing.

Performance during each backgrounding phase can have a large impact on animal performance and carcass characteristics during subsequent phases of production. Strategies such as targeting a specific rate of gain, the use of hormonal implants, and/or the use of feed additives can all be used to manipulate animal performance during backgrounding phases.

Rate of Gain During Winter Backgrounding

Whether a producer winter backgrounds calves in a drylot system or in a dormant grazing system, the rate of gain can be improved by increasing the amount of energy and metabolizable protein available to the animal beyond their maintenance requirements. Differentiating between energy and protein responses is a challenge due to the potential to increase microbial production with energy supplementation and not being able to determine whether additional MP is from microbial residue or protein supplementation (Griffin et al., 2012). Distillers grains with solubles is often used in backgrounding systems because it is high in protein, has more than 130% the energy value of corn when fed at 15% of a forage-based diet (Loy et al., 2008; Ahern et al., 2015), and can be delivered in a variety of forms: total mixed ration, pellet, or range cube. Additionally, supplementing distillers to grazing cattle has been reported to reduce forage intake without having a reduction in animal performance. Klopfenstein et al., (2007) found that each 0.45 kg of distillers grains supplemented to grazing cattle decreased forage intake by 0.2 kg.

Rate at which a calf gains during the winter backgrounding phase can influence performance in subsequent phases of production. High rate of gain (i.e., 0.9 kg/d) during the winter backgrounding phase have been observed to enter the summer grazing and finishing phases with greater body weight (Folmer et al., 2008; Gillespie-Lewis et al., 2015). Calves wintered at a lower rate of gain (i.e., 0.49 kg/d) often have greater ADG during the summer phase commonly known as compensatory gain: an accelerated and/or more efficient growth that commonly follows a period of growth restriction (Bohman et al., 1955). Compensatory gain values often range from 19% to 88% with a mean of 53% (Klopfenstein et al., 1999). Cattle winter backgrounded with a high rate of gain will maintain greater body weight into the finishing period unless cattle backgrounded at low rate of gain achieve 100% or greater compensation (Gillespie-Lewis (2015).

Rate of gain during winter backgrounding has also been documented to influence finishing performance. Up to 80% of increased gains achieved during the winter phase are maintained into the finishing period and result in heavier final body weights (Jordon et al., 2000; Downs et al., 1998). Gillespie-Lewis (2015) explains that unless restricted cattle gain at a level greater than their non-compensating counterparts while in the feedlot, they will finish with a lower final body weight regardless of their compensatory gain in the summer phase. However, a study by Folmer er al. (2008) observed that calves winter backgrounded at a high rate of gain (0.9 kg/d) achieved similar final body weight as calves winter backgrounded at a lower rate of gain (0.75 kg/d). Supplementing cattle at a high rate of gain in the winter backgrounding phase is a logical decision if the estimated profit from each additional kilogram at the time of selling is greater than the additional cost of feed needed to achieve it. Before making winter supplementation decisions, consider marketing strategies, cost of supplement (including delivery), and feeding methods.

Supplementation delivery strategies

Supplementing calves on pastures can be done either by hand delivery (HD) or by self-feeders (SF). Traditional HD methods include range cubes, pellets, or an unprocessed product which can be delivered on the ground or to a bunk. When HD methods are used, it is important to deliver supplement on clean surface and as uniformly as possible to try to minimize waste while achieving as similar intakes between animals as possible. Self-feeders such as creep feeders allow animals to visit a feeder as they choose. A benefit of a SF is that bulk feed can be stored in one feeding location which reduces the input cost associated with frequent feed delivery. However, attaining uniform intakes within a group of cattle is difficult as some choose not to visit a feeder where others may frequent the feeder often. A study conducted by Williams et al., (2017) utilized a Super SmartFeed SF which concluded that SF significantly increased variability of supplement intake and reduce supplement conversion efficiency despite ADG having no difference between HD and SF methods. The Super SmartFeed SF made by C-Lock inc. was designed with solar powered capabilities and dispenses a set amount of feed for each animal and monitors individual intakes based off the individual animal's radio-frequency identification tag and onboard scale system. The Super SmartFeed SF has made it possible to record individual animal intakes and limit the amount of supplement each animal can consume each day.

Supplementation delivery methods for grazing cattle can be challenging and costly but must be considered when choosing a backgrounding system, especially if more energy or protein is needed to achieve greater daily gains than what the native forage can provide.

Implant Technologies

An implant is a group of pellets comprised of either estrogens (estradiol, estradiol benzoate, and zeranol), androgens (testosterone propionate and trenbolone acetate), progesterone, or a combination (NASEM, 2016). Estradiol, progesterone, and testosterone are naturally occurring steroid hormones, whereas trenbolone acetate (TBA) is an androgenic steroid and zeranol is a fungal compound not commonly found in animals. Responses of implanting on performance and carcass quality vary with implant type (Duckett et al., 1998).

For cattle, implants are to be placed subcutaneously within the middle third of the ear. The active ingredients within the implant are then released and absorbed by the animal throughout a period of time. The type and concentration of compounds within an implant and the rate at which they are released can vary between implant products. When an implant releases its compounds there is an initial spike in hormone activity within the animal and then a slow descent over time. Once the hormone activity descends below a certain threshold, the positive response in animal performance can no longer be detected. Reimplanting may be beneficial when the improved performance either falls below a desired threshold or can no longer be detected. When reimplanting with the same dose as the previously used implant, the response is less or not different for the second implant (Selk, 1997; Hilscher et al., 2016). Therefore, when implanting cattle more than once, using implants with increasing potency in succession allows for the greatest animal lifetime gain (up to 68 kg) while maintaining or slightly improving postweaning feed conversion when compared to that of non-implanted cattle (Mader et al., 1998). In general, implants that are lower in concentration are utilized in phases of production with younger, lighter calves and implants that are higher in concentration are utilized in the later phases of production which involve more mature, heavier cattle. Growth promoting implants have been approved for use in the beef cattle industry by the Food and Drug Administration (FDA) for 55 years. Today, the FDA approves the use of implants in all phases of beef production which include suckling calves, grazing cattle, and finishing cattle. The FDA does not approve the use of growth promoting implants in cattle used for reproductive purposes.

No other management tool offers beef producers a greater return on investment than growth-promoting implants (Mader, 1998). Implants positively affect growth rate, feed efficiency, and lean tissue accretion in all phases of beef production. In suckling calves, implants have shown to improve ADG up to 6% greater than those not implanted (Selk, 1997). A study by Kuhl (1997), found that implants increased ADG in yearlings by 12 - 16%. Other studies have documented improvements in ADG up to 25% greater for yearlings administered an implant than those not implanted (Paisley, et al., 1999). In the finishing phase, implanting feedlot steers improves ADG, feed efficiency, and hot carcass weight by 18, 8, and 4%, respectively, when compared with non-implanted steers (Duckett et al., 1996). Cattle on feed for longer days may benefit from a second or even third implant during the finishing phase. Reimplanting cattle can improve feed efficiency and HCW up to 13.5 and 7% (Duckett and Andrae, 2001).

When managed correctly, implants positively affect performance in all phases of beef production without affecting performance in subsequent phases. Studies have shown that implanting suckling calves do not affect subsequent feedlot ADG or marbling scores (Schaneman and Pritchard, 1998). Kunkle et al. (1980) reported no effects on ADG during subsequent phases of performance when implanting suckling steers and the weight gained from implants during each production phase was additive. Likewise, many studies have concluded that implants administered during the backgrounding phase had no effect on subsequent feedlot ADG or feed efficiency (George et al., 2000; Paisley et al., 1998.)

and additional weight gain observed from implanting is additive throughout all phases of beef production and often maintained through finishing.

Although implants improve ADG, feed efficiency, and HCW, there can be some negative effects associated with implants if cattle are managed similar to non-implanted cattle. It may be worth considering different management strategies for implanted and non-implanted cattle when making decisions such as days on feed or diet composition. For example, a single estrogenic or estrogenic-androgenic implant has been observed to reduce marbling score by 4% and increase ribeye area by 3-4% (Duckett and Andrae, 2001). Reimplanting with an estrogenic or estrogenic-androgenic implant can further reduce marbling score beyond that of a single implant (Roeber et. al., 2000). If implanted cattle are fed more days on feed and finished to a similar backfat thickness as non-implanted cattle, than the negative effect on marbling score can be overcome while achieving a greater hot carcass weight with improved feed efficiency. Special diet considerations should also be made for implanted cattle. Growing cattle grazing low quality forage and gaining 0.28 kg/d have demonstrated a positive response to an implant (Paisley et al., 1998). However, a greater response to implants can be expected when stocker cattle are on a higher plane of nutrition (Gill et al., 1986, Duckett and Andrae, 2001: Kuhl 1997 and Paisley et al., 1999). Guiroy et al., (2002) indicate that implant response is due to a combination of a reduced proportion of the DMI required for maintenance, reduced energy content of gain, and efficiency of use of absorbed energy. Therefore, the value of delivering additional nutrients may be greater for implanted cattle than non-implanted cattle.

Conclusion

Beef cattle production systems continue to improve with the addition of new technologies while continuing to study and utilize current ones. Feeding probiotic direct-fed microbials show potential to effectively reduce liver abscess occurrence as an alternative to tylosin, but further studies are needed (Bartenslager et al., 2021). Continuing to determine feed value standards such as RUP of crested wheatgrass will help producers and nutritionists with management decisions in the beef cattle industry. Evaluating a combination of management tools throughout the entire production system can help producers select which combination of technologies or management tools can benefit the goals of the operation best.

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Figures

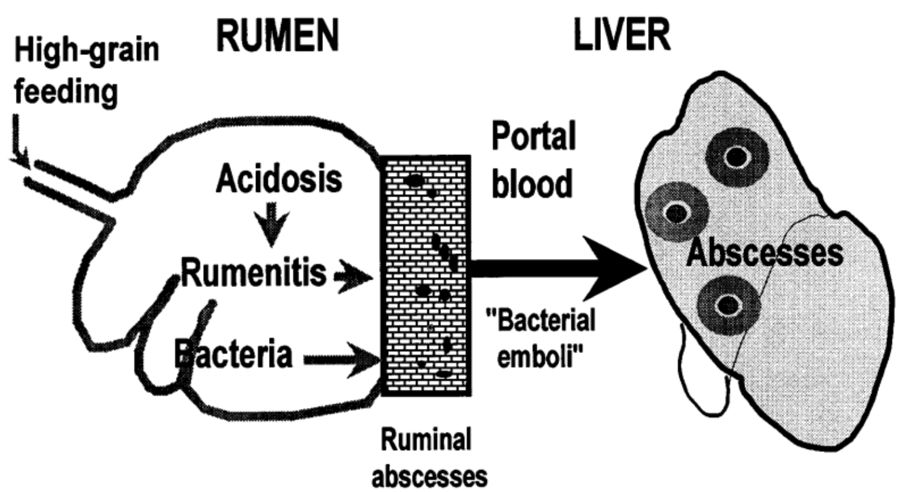

Figure 1.1 Liver abscess formation from rapidly fermentable diets (Nagaraja and Chengappa, 1998)

CHAPTER 2 - IMPACT OF A NATURAL FEED ADDITIVE USING DIRECT FED MICROBES ON FINISHING BEEF CATTLE PERFORMANCE AND LIVER ABSCESS RATE

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Abstract

A feedlot study was conducted comparing the effects of a direct-fed microbial feed additive (DFM) to no feed additive (CON) on performance and liver abscess rates in finishing beef cattle. The study utilized 60 crossbred steers (initial BW 274 kg ± 2.23) individually fed using a Calan gate system. Steers were housed in separate pens by treatment to avoid DFM cross-contamination, with pen (barn of 30 steers) assigned randomly to each treatment. Cattle were fed a diet consisting of 15% corn silage, 36.5% high moisture corn, 24.5% dry rolled corn, 20% modified distillers grains, and 4% supplement for 189 days. The DFM counts were estimated using cell cytometry and was top dressed at a concentration of approximately 81 billion bacterial cells/head/day. The DFM additive used in this study was developed to reduce the abundance of *Fusobacterium necrophorum* and *Streptococcus bovis* in the rumen. No effect of treatment on hot carcass weight (HCW), average daily gain (ADG), dry matter intake (DMI), feed efficiency (G:F), or carcass traits (Table 1.1) were observed. No significant difference in the occurrence of liver abscesses between treatment groups were observed with 4 steers having abscessed livers in the CON group and 3 steers in the DFM group.

Additionally, there were no differences in the severity of liver abscesses; all observed liver abscesses received the score of A. The DFM utilized in this study did not significantly affect performance, liver abscess rate, or the severity of liver abscesses in finishing beef cattle.

Introduction

Liver abscesses are an economic liability to the producer and are reported to decrease cattle performance as much as 11% in daily gains and up to 9.7% in feed efficiency (Brink et al., 1990). Currently, the most effective method to control liver abscesses in beef cattle is feeding tylosin, a medicated feed additive. Tylosin was available over the counter until August 29, 2016, when the application was voluntarily withdrawn and the label was changed to require veterinary oversight. Today, tylosin can be fed to cattle with approval from a veterinarian in the form of a veterinary feed directive (VFD). Veterinarian oversight has become mandatory to several antibiotics used in animal feeds to decrease the risk of increasing antibiotic resistance. The VFD works like a prescription (except that it is governed at the federal level and not the state); a licensed veterinarian must authorize the use of the drug on an animal and the owner/caretaker is allowed to obtain and administer the drug as specified by the label and FDA guidelines. Obtaining a VFD requires additional time, cost, and labor for a feedlot; things that may be limiting constraints on a feedlot as it is. An effective alternative for liver abscess prevention that does not require a VFD or feeding an antibiotic is of great interest.

Liver abscesses occur because of rumenitis from ruminal acidosis allowing microbes to escape the rumen, travel to the liver, and colonize (abscess). Direct fed microbials are a potential solution to prevent liver abscesses because they can manipulate the microbial ecosystem within the rumen. Furthermore, DFM may be used to alter specific populations of microbes within the rumen to reduce the risk of acidosis (Krehbiel et al., 2003) or reduce the population of microbes that colonize on the liver before they have a chance to escape via portal blood. Currently, there are DFM products commercially available to finishing beef cattle that do not require a VFD and effectively alter the microbial ecosystem to support a healthy rumen pH.

The DFM feed additive used in this study was specifically developed to target and reduce the population of the liver abscess causing *Fusobacterium necrophorum* and the major lactic acid producing bacteria *Streptococcus bovis* within the rumen. This DFM is found naturally in cattle, where it was isolated from, and has been validated in laboratory cultures. The objective of this study was to determine the effect of this specific DFM on finishing beef cattle performance, liver abscess occurrence, and severity of liver abscesses derived from ruminal acidosis.

Materials and Methods

All procedures using animals were approved by the University of Nebraska-Lincoln Institute of Animal Care and Use Committee (IACUC).

A finishing study was conducted from November 27, 2019, to June 2, 2020 (189 DOF) at the Eastern Nebraska Research and Extension Center, utilizing 60 crossbred steers (initial BW 274 kg ± 2.23). Steers were individually fed in 2 pens (2 barns of 30 steers) using a Calan gate system. Steers were trained to the Calan gate system prior to trial initiation. To avoid DFM contamination from social housing systems, barn was assigned randomly to DFM treatment. Based on past performance studies, barn does not impact performance. Steers were assigned at random to 1 of 2 treatments consisting of a control diet (CON) without direct fed microbials and a diet with direct fed microbials (DFM). The CON treatment is designed to represent the effect from the diet when no means of liver abscess prevention are used.

Diet

Both CON and DFM treatments received the same finishing diet consisting of high moisture corn, dry rolled corn, modified distillers grains plus solubles, 15% corn silage, and supplement (Table 2.1). No tylosin was fed to either treatment. High moisture corn was processed through a roller mill before ensiling at 70% dry matter to maximize starch availability and digestion rate which increases the potential for acidosis in this diet. Cattle were fed this diet for the duration of the trial, 189 days.

The finisher diet was fed on Day 1 of the study at 1.8% of BW on a dry matter basis. Steers were adapted to ad libitum intakes by increasing dry matter offered by 0.23 kg (DM) from day 2 of the study until ad libitum intake by individual animal was attained (approximately 20 days). Bunks were cleaned weekly with orts being collected, weighed, sub sampled, then dried in a forced air oven at 60˚C for 48-hours to correct for dry matter intake.

Processing and Harvest

On day 0 (trial initiation), cattle were implanted with 80 mg trenbolone acetate and 16 mg estradiol (Revalor-IS; Merck Animal Health, Madison, NJ) and re-implanted with 200 mg trenbolone acetate and 20 mg of estradiol (Revalor 200; Merck Animal Health, Madison, NJ) on day 100 (3/6/20). Initial body weights were based on three consecutive day weights (Days -2, -1, and 0) measured after 5 days of feeding a common diet to equalize gut-fill (Watson et al., 2013). Interim weights were collected and collars for the Calan gates were adjusted on days 57 (1/23/20), 100 (re-implant), and 148 (4/23/20). Final body weights were collected prior to shipping on day 188 (6/2/20).

Steers were shipped to Greater Omaha for harvest where carcass data and liver scores were recorded. Hot carcass weight and liver scores were collected the day of harvest. Longissimus muscle (LM) area, USDA marbling score, and 12th rib fat thickness (BF) were recorded following a 48-hour chill. Carcass-adjusted performance was calculated using final body weight, based on hot carcass weight (HCW) divided by a common dressing percentage of 63%. Quality grade was determined using marbling scores.

DFM

A cocktail mixture of *Bacillus pumilus* (*B. pumilus)* and *Bacillus licheniformis* (*B. licheniformis*) bacterial species were top dressed in the feed at 81 billion bacterial cells/head/day by spray application. Bacterial cells were isolated, cultured, and confirmed to be the correct strain using 16S rRNA sequencing.

The cocktail DFM was grown as two separate isolates then combined prior to storage. Large batch growth for harvesting *B. pumilus* was grown in 1L volumes on Brain Heart Infusion (BHI) media at 37$^{\circ C}$ and shaking at 150 rpm for 48 hours. Large batch growth for harvesting *B. licheniformis* was grown similar to *B. pumilus* with the exception of only growing for 24 hours. At the end of growth, Invitrogen's Live/Dead Assay (Life Technologies Corporation Eugene, Oregon) was used to estimate bacterial cell concentrations in the medium using flow cytometry. Flow cytometry was performed at the UNL Flow Cytometry Facility. Isolates were mixed together with 20% sterile glycerol solution for storage at -20$^{\circ C}$. Cultures were measured into individual tubes prior to cold storage so each tube could be administered to one animal at 81 billion cells/head/day. All DFM was cultured and stored prior to trial initiation. Prior to feeding, individual cultures were thawed at 4$^{\circ C}$ overnight. After topdressing the contents, tubes were rinsed with ddH_2O which was also poured in the corresponding bunk to ensure all DFM was removed from the tube.

B. pumilus and *B. licheniformis* bacterial species were used because they have shown to inhibit *S. Bovis* and *F. necrophorum* bacterial species, have characteristics that allow them to remain viable at the time of administration, and are Generally Recognized as Safe (GRAS) by the FDA.

Statistical Analysis

Data were analyzed using the PROC Mixed procedure of SAS evaluating the individual animal as the experimental unit. Steers were stratified by weight so no block was used. The statistical model directly compares DFM and CON treatments to determine any significant differences. Liver abscesses were analyzed as a binomial variable since all liver abscesses received the same score and cattle either had an abscessed liver or they did not. One steer in the DFM treatment was removed from the study due to lameness issues and one steer was removed from CON treatment due to mortality derived from an abomasum hemorrhage. Final calculations do not include the dead or removed steers. Treatment differences were declared significant for all statistical analysis at $P \leq 0.05$.

Results and Discussion

Liver abscess incidences were low, with only 4 out of 29 (13.8%) observed for CON and 3 out of 29 (10.3%) steers fed DFM; all abscessed livers received the score of A (0 severe cases). Abscess rates were low overall despite not feeding any additives and a diet with high-moisture corn (readily fermentable starch) and little forage (Table 2.1). The 13.8% prevalence for the CON with no method of treatment was low compared to industry but not uncommon. When no method is used to prevent liver abscesses, a 45% abscess rate is often observed (Brown and Lawrence, 2010); however, prevalence can be close to 0% with no means of prevention as well. In 2017, a similar diet was used for a feedlot study comparing a natural feed additive to Tylan or nothing on liver abscess prevalence and receiving and finishing performance (Wilson et al., 2018). Wilson observed a 21% liver abscess rate for cattle that did not receive any tylosin. The diet used in Wilson's study was 66% concentrate (26.4% DRC, 39.6% HMC), 25% corn byproduct (WDGS), 5% roughage (Wheat straw), and 4% supplement (0.25% being urea); similarly, the diet for this study was 68.5% concentrate (36.5% HMC, 26.5% DRC, and 7.5% grain from corn silage), 20% corn byproduct (MDGS), 7.5% roughage (corn silage), and 4% supplement (0.5% being urea). Despite Wilson's trial being 2.5% lower in concentrates, there was a 7% greater prevalence in liver abscesses. Although these two diets are not identical, their composition (concentrate and forage inclusion) are similar enough to indicate that the lower-than-expected liver abscess rate observed in this study is not due to the diet alone. It is important to point out that Wilson's study was conducted in an open lot confinement with continuous bunks whereas this DFM study was conducted in a Calan-gate system under roof with individually fed animals. In both studies cattle were fed the finishing diet ad libitum. It was concluded by Ferris et al., (2006) that DMI is not affected by using a Calan-gate feeding system, therefore, it is also unlikely that the lower prevalence in abscess rate is due to the Calan-gate system vs. conventional bunks in open lot housing.

Throughout the feeding period, there were no significant differences ($P \geq 0.51$) detected in final BW, DMI, ADG, or G:F (Table 2.2). Similarly, there were no significant differences between treatments ($P \geq 0.21$) in HCW, marbling, LM area, 12th rib fat, or liver abscesses. The literature suggests that mild and moderate liver abscesses have no or limited effects on animal performance (Brown and Lawrence, 2010) but severe liver abscesses may reduce ADG by 0.06 to 0.20 kg (Brink et al., 1990; Fox et al., 2009; Rezac et al., 2014.). It does not appear that performance or DMI were affected by the few mild cases of liver abscesses; however, no conclusion from comparison can be drawn since the groups were equally affected and are not significantly different. In other words, liver abscesses could have influenced both treatments equally thus making them appear as if there were no effect since there wouldn't be any difference.

Bartenslager et al. (2021), collected rumen samples from all steers throughout this study and reported a significant decrease in *F. necrophorum* abundance (measured using real-time PCR analysis on rumen samples) in cattle administered *B. pumilus* during the first 89 days of the 189-day feeding trial when compared to the no DFM control. The DFM used in this study was able to manipulate the microbiome and decrease *F. necrophorum,* during the first 89 days of the trial, however, it did not affect overall performance, liver abscess prevalence, or severity. Further studies (with greater liver abscess rate in the control group) may be necessary to definitively conclude the effectiveness of this DFM. The performance data indicate that cattle are capable of relatively low liver abscess prevalence while consuming high concentrate diets with no means of liver abscess prevention, although it is not very common.

Conclusion

Feeding this specific DFM at 1 billion bacterial cells/steer daily to finishing beef cattle did not significantly affect performance, carcass characteristics, liver abscess rate, or the severity of liver abscesses despite reducing *F. necrophorum* during the first 89 days. This study reaffirms that the challenges of isolating and administering a viable DFM to cattle on a finishing ration can be achieved without negatively affecting performance.

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Tables

Table 2.1 Diet composition of feed delivered to steers during the finishing period.

Ingredient	% Diet DM[1]
High-moisture corn	36.5
Dry-rolled corn	24.5
Modified distillers grains plus solubles	20.0
Corn Silage	15.0
Supplement[2]	
Limestone	1.64
Fine Ground Corn	1.40
Urea	0.50
Salt	0.30
Tallow	0.10
Beef Trace Minerals Premix	0.05
Vitamin A-D-E Premix	0.015

[1] Diet DM: 65.81%

[2] Supplement fed at 4% of dietary DM for all treatments

Table 2.2 Performance and carcass characteristics of beef steers fed a finishing diet with a novel direct fed microbial

	Treatments[1]			
Item	CON	DFM	SEM	*P*-value
Carcass-Adjusted Performance				
Initial BW, kg	274	274	2.229	0.93
Final BW, kg[2]	588	585	7.5	0.76
DMI, kg/d	9.7	9.5	0.162	0.51
ADG, kg	1.71	1.69	0.035	0.76
G:F	0.1768	0.1782	0.003	0.72
Carcass Characteristics				
HCW, kg	371	368	4.72	0.76
Marbling[3]	465	448	20.35	0.57
LM area, cm^2	89.03	83.87	2.71	0.21
12^{th} rib fat, in	1.45	1.35	0.74	0.28
Liver Abscesses, %[4]	13.79	10.34	-	-

[1] Treatments included control and DFM (top dressed)
[2] Calculated from HCW divided by a common dressing percentage (63%).
[3] Marbling score 400 = small, 500 = modest, etc.
[4] Calculated as a percentage of total animals for that treatment; lame and dead animals removed.

CHAPTER 3 - RUMEN UNDEGRADABLE PROTEIN CONTENT OF CRESTED WHEATGRASS

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Abstract

An experiment evaluated the forage value of crested wheatgrass (CWG) harvested from Western Nebraska over a two-year period (2019-2020). Two large pastures, comprised of 95% CWG, were divided into 13 paddocks (34.4 ha, 3 paddocks and 42.5 ha, 10 paddocks). Yearlings rotationally grazed the pastures at 4.2 hectares/head. Within each pasture, two paddocks were assigned at random for sampling during the grazing season. Forage samples were collected twice each month from two random locations within assigned paddocks by hand clipping forage within a $0.25m^2$ quadrant at ground level. For each year, samples were composited by pasture and month. Samples from 2019 (n = 10) were harvested in May, June, July, August, and September while 2020 samples (n = 8) were harvested in May, June, July, and August but not September due to drought conditions. In vitro and in situ mobile bag analyses were conducted to evaluate forage quality (in vitro dry matter disappearance; IVDMD, % DM and in vitro organic matter disappearance; IVOMD, % of OM) and protein composition (crude protein, CP, % DM; rumen undegradable protein content, RUP, % CP and % DM; rumen undegradable protein digestibility, RUPdig., % RUP). Orthogonal contrasts analyzed changes in forage quality over time. Forage quality decreased over the growing season in 2019 and averaged 54.0% IVDMD, 60.4% IVOMD, 9.5% CP in May and decreased to 37.0%, 43.3%, and 6.3% respectively by September (Quad. $P \leq 0.02$). No significant differences in forage quality ($P \geq 0.53$) between months were detected for samples collected in 2020 averaging 43.1% IVDMD and 46.8% IVOMD. In 2020, CP decreased from 12.1% in May to 5.3% in September (Cub. $P < 0.05$). Rumen undegradable protein (% DM) increased linearly from 0.80% to 1.09% over the growing season in 2019 ($P < 0.01$) and tended to increase quadratically in 2020 from 1.03% in May to 1.12% in July ($P = 0.06$). No change in RUPdig were detected throughout the growing season for either year.

In both years, CP decreased while RUP content, % CP increased throughout the growing season. For all samples, digestible RUP, % DM was less than 0.5%.

Key Words

Crested Wheatgrass, In Vitro Dry Matter Disappearance, Rumen Undegradable Protein

Introduction

Monoculture pastures of crested wheatgrass [CWG; *Agropyron cristatum (L.) Gaertn.*] are commonly grazed by cattle in arid sections of the western United States such as those found in the panhandle of Nebraska. This non-native species was introduced to the region during the 1900s to re-establish grasslands that had previously been plowed for farming. Crested wheatgrass was an ideal candidate to reclaim the short grass prairies of Western Nebraska because of its drought tolerance, fibrous root systems, competitiveness, seedling vigor, and low maintenance characteristics. Additionally, CWG is palatable to livestock, can withstand heavy grazing pressure (> 65% utilization), and generally produce 1.5 to 2 times more forage than native species in short grass prairies (Ogle, 2006).

Currently, it is recommended by the NRCS to provide supplemental protein for cattle grazing monoculture pastures of mature CWG. Cook and Harris, (1968) concluded that CWG produces highly digestible nutrients in the vegetative stage, but mature plants may not have enough protein to satisfy the maintenance requirements for cattle at all stages of growth. Crude protein can range from 18% to 4% of DM throughout the growing season (Ogle, 2006). A study conducted by Greenwell et al., (2018) observed improvements in ending BW and ADG for cattle supplemented with 2 different protein sources (field peas or a blend of 70.8% corn, 24% corn condensed distillers solubles, and 5.2% urea) while grazing CWG. Cattle grazing CWG and supplemented at 0.5% of BW with the blend of corn, condensed distillers solubles, and urea had 34 kg greater ending BW and 0.3 kg greater ADG than cattle not supplemented. Additionally, cattle supplemented with whole, unprocessed field peas at 0.5% of BW had a 20kg improvement in ending BW and 0.18kg greater ADG than calves not supplemented when grazing CWG. This indicates that cattle grazing CWG may benefit from additional protein throughout the grazing season.

Although additional protein supplementation may improve the performance of growing cattle, it is unclear as to how much protein is available to the cattle from CWG alone. Crude protein is a combination of rumen degradable protein (RDP) and RUP. Rumen degradable protein is hydrolyzed in the rumen by microbes and not directly available to the animal; RUP is not hydrolyzed by the microbes in the rumen and is directly available to the animal in the gastro-intestinal tract (NASEM, 2016). As forages mature, the ratio of RDP:RUP and digestibility of CP change; therefore, CP alone does not accurately represent the amount of protein available to the animal throughout the grazing season (Buckner et al., 2013). Knowing the amount and type of protein available to cattle grazing CWG can help producers make supplementation decisions throughout the grazing period. This study evaluated CWG to document RUP content, RUP digestibility, and total tract protein digestibility throughout the grazing season.

Materials and Methods

All procedures using animals were approved by the University of Nebraska-Lincoln Institute of Animal Care and Use Committee (IACUC). A 2-year study (2019 and 2020) was conducted at the university of Nebraska's High Plains Agricultural Lab (HPAL) located near Sidney, Nebraska. Each year, yearlings were stocked continuously throughout the grazing season at 4.2 hectares per head on all paddocks. The yearlings were part of a trial conducted by Wheeler et al. (2023) investigating two different supplementation strategies throughout the grazing season. The same two ruminally and duodenally fistulated steers were used for both the in vitro and in situ procedures. Steers received a limit fed diet, twice daily, consisting of 70% Smooth Bromegrass hay, 23% dried distillers grains plus solubles, 6% dry rolled corn, and 1% supplement for both analyses.

Sample collection

Two large monoculture pastures of CWG were divided into 13 paddocks (34.4 ha, 3 paddocks and 42.5 ha, 10 paddocks). Within each pasture, two paddocks were assigned at random for sampling (Pasture 1 = paddocks 2 + 4; Pasture 2 = paddocks 8 + 10). Forage samples were collected twice each month from two random locations within the assigned paddocks by hand clipping forage within a $0.25m^2$ quadrant at ground level. Due to the two pastures being in separate locations, forage samples from paddocks were composited by pasture and month (Table 3.1). Samples from 2019 (n = 10) were harvested in May, June, July, August, and September while 2020 samples (n = 8) were harvested in May, June, July, and August due to drought conditions. Local precipitation from May 1st to September 30th was 552.7 mm for 2019 and 150.1 mm for 2020 with a 10-yr average precipitation of 350.0 mm. In 2020, cattle were removed in August due to the lack of available forage. Samples were frozen at -4˚C and shipped to Lincoln, Nebraska where they were freeze dried prior to lab analysis.

In Vitro

A modified in vitro method (Tilley and Terry, 1963) was used for IVDMD with the inclusion of 1 g/L of urea to the McDougall’s buffer to reduce variation among donor animals and their diets (Nelson et al., 1972, Engels and van der Merwe, 1967; Weiss, 1994). Samples were ground to a 1mm particle size using a Wiley Mill (Thomas

Scientific, Swedesboro, NJ) then composited by month and pasture. Half a gram of each sample was placed in 1 test tube and analyzed in triplicate. Additionally, five feed standards with known forage values were included in each run to use as a common regression to adjust and compare data between separate IVDMD runs (Geisert et. al., 2007). There were two different in vitro runs for all samples. Each test tube with sample received 50 ml inoculum and flushed with CO_2 before being capped with a rubber stopper and placed in a 39$^{\circ C}$ warm water bath for 48 hours. Samples were gently swirled every 12 hours. Inoculum consisted of 1g/L urea and a 1:1 mixture of McDougall's buffer and filtered rumen fluid (Weiss, 1994). Rumen fluid was collected from the donor steers previously described. The 48-hour in vitro incubation was followed by a 24-hour pepsin incubation which simulated abomasal digestion by adding 6 ml 20% HCl and 2 ml 5% pepsin to each sample. Remaining residue was filtered via suction using Whatman 541 filter papers before being dried in a 100$^{\circ C}$ forced air oven for more than 6 hours and weighed immediately after. Filter papers with samples were then placed in crucibles and incinerated. The weight of the remaining ash was used to calculate the in vitro organic matter digestibility.

In Situ - mobile bag assay

The in-situ procedure used in this study was modified from Vanzant et al. (1998). Freeze dried CWG samples were ground to a 2 mm particle size using a Wiley Mill (Thomas Scientific, Swedesboro, NJ) then composited by month and pasture. For each composited sample, 1.25 grams were weighed into labeled Ankom R510 Dacron bags (Ankom Technologies) with a pore size of 50µm (5cm x 10 cm). Dacron bags were labeled and weighed before the sample was added and heat sealed. All Dacron bags were incubated in the rumen for either 20 or 30 hours. Haugen et al. (2006) reported that ideal rumen incubation is equal to 75% of total mean retention time to obtain accurate RUP values using the in-situ technique. In situ rumen incubation times were determined using the following equation : ((1/ K_p) + 10 hours) x 0.75 (Ellis et al., 1999; Mass et al., 1999). Passage rate was derived from the following equation: K_p = (0.07 x IVDMD (%)) – 0.20 (Klopfenstein et al., 2001).

There were 16 replicates for each sample (2019 n = 160, 2020 n = 128) half of which were assigned to each steer (Figure 3.1). Replicates assigned to each steer were further sorted with 4 Dacron bags labeled as “R” for rumen incubation only and the remaining 4 bags labeled as “D” for rumen and duodenal incubation. Half of the “R” and “D” bags were placed in one mesh lingerie bag and the other half in another mesh lingerie bag. Mesh bags were labeled by year and incubation time point (2019 – 20-hour, 2020 – 20-hour, 2019 – 30-hour, 2020 – 30-hour). Four mesh bags containing less than 50 Dacron bags each were weighted and placed in the ventral sac of the rumen of each steer. For each steer, 30-hour mesh bags were inserted at 8 am and 20-hour bags at 6 pm with all of the bags being removed at 2 pm the following day. Bags from each steer were kept separate and machine rinsed for 5 cycles consisting of a 1-minute agitation and a 2-minute spin (Whittet et al., 2003). After washing, rumen only samples were refluxed to remove any microbial attachment using neutral detergent solution (Mass et al., 1999) in an Ankom Fiber Analyzer 200 (Ankom, Fairport, NY). Samples were then dried in a 60$^{\circ C}$ forced air oven for more than 24 hours, weighed, and set aside for nitrogen analysis. Rumen only samples were used to measure the RUP content: RUP, % DM = ((Residue N * Residue weight) *6.25)/original sample DM in.

After being washed, duodenal samples were kept separate (by steer) for an abomasum digestion simulation by incubating the Dacron bags in a pepsin HCL solution (1 g pepsin per L and 0.01 N HCl) maintained at 37 $^{\circ C}$ for 3 hours. Upon completion of the simulated abomasum digestion, bags were sorted once more and froze at -4 ˚C. Half of the 20 and 30 hour "D" bags that were rumen incubated in steer 1 were inserted into the duodenal cannula of steer 2 and vice versa. Dacron bags were removed from the freezer to thaw 12 hours prior to duodenal insertion. Samples were placed in the duodenum via open "T" duodenal cannula one at a time every 5 minutes starting at 8am. No more than 18 bags were inserted per animal each day. Bags were recovered in the manure within 24 hours after insertion and placed in the freezer. At the end of the collection period, bags were thawed, rinsed (following rinsing procedures previously described), refluxed (as described for the rumen only samples), dried in a 60$^{\circ C}$ forced air oven for more than 24 hours, and weighed. All incubated samples were then shipped to Ward Laboratories to be tested for nitrogen content using the combustion method.

Statistics

The mixed procedure of SAS 9.4 was used to analyze all data. Orthogonal contrasts were used to analyze changes in forage quality over time. Due to precipitation, data were analyzed by year with month and pasture as fixed effects for IVDMD and CP. Steer was a random effect for RUP and RUPdig data with pasture, month, and rumen incubation time as fixed effects.

Results and Discussion

There was no interaction between month and incubation time for any variables measured in either year. Crested Wheatgrass samples were analyzed for forage quality

(IVDMD and IVOMD) and protein composition (CP, RUP content, RUP digestibility, and digestible RUP; Table 3.2 and Table 3.3). In both years, CP decreased with a quadratic effect ($P \leq 0.02$; Figure 3.3) and RUP as % of CP increased ($P < 0.01$) throughout the grazing season. Crude protein content was greatest in May (2019, 9.5%; 2020, 12.1%) and lowest in August (2019, 6.2%; 2020 5.3%). RUP content as % of CP was lowest in May (2019, 8.8%; 2020, 8.7%) and greatest later in the grazing season (September 2019, 17.7%; August 2020, 20.7%). Rumen undegradable protein digestibility as % RUP was not significantly different throughout the grazing season for each year (2019, $P = 0.18$; 2020, $P = 0.68$;). Digestible RUP was less than 0.50% of DM for all samples collected.

Year 1

In 2019, CP decreased throughout the grazing season, and RUP content as % DM increased. This indicates that the composition of CP is changing with RUP replacing RDP (as a % of CP) at a greater rate than CP is decreasing. CP decreased with a quadratic effect ($P < 0.01$) from 9.5% DM in May to 6.3% in September with August having the lowest at 6.2%. The RUP content as % DM and digestible RUP as % DM increased linearly ($P < 0.01$) from May to September. The lowest RUP content as % DM was observed in May (0.8%) and the greatest in September (1.1%; Figure 3.4). The lowest amount of digestible RUP as % DM was observed in May (0.33%) and the greatest in September (0.53%). The RUP digestibility as % RUP did not significantly change throughout the grazing season ($P < 0.18$); therefore, the observed increase in digestible RUP as % DM was influenced by the increase in RUP content. Forage quality was the greatest in May (IVDMD = 54.0% DM) and decreased with a quadratic effect ($P < 0.01$)

throughout the grazing season with the lowest quality observed in September (IVDMD = 37.0% DM).

Year 2

In 2020, CP decreased throughout the grazing season with a quadratic effect ($P < 0.02$) from 12.1% DM in May to 5.3% DM in August. Unlike 2019, IVDMD, RUP content as % DM, and digestible RUP as % DM did not significantly change throughout the grazing season. Although it wasn't statistically analyzed, CP was 2.6%, 1.9%, and 0.2% greater in May, June, and July of 2020 than 2019. Furthermore, RUP content as % DM was greater in 2020 than 2019 for months May, June, July, and August by 0.2%, 0.2%, 0.3%, and 0.1% of DM respectively. Digestible RUP was the greatest in August of 2020 with 0.40% of DM.

Discussion

Crested wheatgrass monoculture pastures are a great resource for livestock in semi-arid environments because they generally produce 1.2 - 2x more forage than native species found in short grass prairie ecosystems (Ogle, 2006). Currently, there are limited data evaluating the type of protein available within CWG; however, previous studies indicate that yearlings have improved ADG and EBW from additional RUP or a combination of RUP and RDP supplementation while grazing CWG (Greenwell et al., 2018). Supplementing protein is an added cost to the producer and may not always result in improved performance. Knowing the type and amount of protein available in CWG allows future research, nutritionists, and producers to target specific amount and type of protein so improvements in performance can be made in an economical manner.

By design, yearlings were continuously stocked throughout the grazing season to match the grazing practices of the region. Grazing has been shown to decrease forage quality over a grazing period (Titlow et al., 2012). Forage samples collected for this study were likely defoliated by livestock multiple times. As a result, forage values observed in this study represent stands of CWG throughout the growing season as cattle are actively grazing. Further studies evaluating protein content of CWG may benefit by including an un-grazed control group to establish a standard protein content and measure the effects on forage value and soil conservation from grazing throughout the year.

Forage samples were clipped to ground height in a $0.25m^2$ quadrat. These samples likely have more stem (lower quality plant matter) than what the cattle select for when using proper stocking rates in continuous grazing systems. Grazing selectivity can be accounted for by collecting forage samples using cattle with an esophageal fistula. A study conducted by Rao et al. (1973) found that forages collected from esophageal cannulated cattle grazing native bluestem pastures were on average 2.64% (DM) higher in CP, 6% lower in acid detergent fiber (ADF), 2.6% higher in IVDMD, and 3.2% higher IVOMD than hand clipped forage samples. Similarly, Guthrie et al., (1968) reported a 3.8% (DM) greater CP, a 5% lower ADF value, and 1.6% lower lignin content for Bermuda grass samples collected via esophageal fistulates rather than hand clipping methods; thus, indicating that the diet selected by cattle is greater in protein content and is of greater quality than that of the average biomass available on the pasture. The hand clip sampling method represents the composition of all forage biomass available for grazing; esophageal fistula sampling methods are preferred for pasture evaluation work (Guthrie et al., 1968) because they only include plant matter that is selected by the animal. The forage quality and protein values gathered from this evaluation represent the composition of CWG that is available throughout the grazing season; the composition of the diet (CWG) selected by the cattle is expected to be slightly greater in CP, lower in ADF, and greater in IVOMD.

Development of CWG is 2-3 weeks ahead of native grasses, can be grazed about 6 weeks prior to that of native rangeland (Vogel et al., 1993), and best utilized in early spring because of a sharp decline in nutrients occurring from May through July (Hart et al., 1983). The data collected in this study agrees with previous data that forage quality declines from May through September; however, it is unknown when CWG reached its highest forage quality during this study because no samples were collected before forage quality peaked. Although quality is greatest in the early spring, very little biomass is actually available which make grazing early in the spring irrelevant.

Precipitation data were recorded from a weather station located at HPAL during the grazing season from May through September (Figure 3.2). In the last 10 years, the average precipitation from May to September was 350 mm (13.8 in). In 2019, precipitation was recorded above the 10-year average with 553 mm (21.8 in). In 2020, precipitation was below the 10-year average with 150 mm (5.9 in) recorded. For both years, May received more rainfall than the rest of the months. Only one month received over 100 mm in 2020 and four of the five months in 2019 received more than 100 mm.

Crested Wheatgrass has been suggested to be an ideal species for reclamation in areas receiving 8 to 20 inches of annual precipitation (Ogle, 2006). The data from this study reflect years receiving both above and below ideal precipitation for CWG; therefore, our data represent a range of values (between years) rather than an average of values across years. Crested Wheatgrass had numerically greater crude protein content, RUP digestibility, and digestible RUP values during May, June, and July for 2020 (below average precipitation) than 2019 (above average precipitation). This suggests that CWG receiving below average precipitation may have a greater concentration of protein than that of CWG receiving above average precipitation during the growing season. Likewise, Sheaffer et.al. (1992) observed increased CP content for smooth bromegrass, reed canarygrass, orchardgrass, and timothy when in drought conditions compared to a control. This potential improvement in protein may be a result of delayed maturity for the CWG in 2020.

Implications

Overall, crude protein decreased throughout the growing season while RUP % CP increased. The RUP content of CWG may range from 0.8% to as high as 1.21% of DM throughout the grazing season. RUP digestibility is less than 50% of RUP resulting in digestible RUP being less than 0.5% of DM. These data can be used to more accurately estimate the protein being supplied to cattle grazing from CWG alone. By understanding the protein supplied from CWG, producers can more accurately predict the amount and type of protein to supplement to cattle grazing CWG throughout the summer.

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Tables

Table 3.1 Rumen undegradable protein content of Crested Wheatgrass: sample composite

	2019		2020	
Sample	Date	Paddocks[1]	Date	Paddocks[1]
1	5/30	2 + 4	5/22	2 + 4
2	6/12 + 6/26	2 + 4	6/2 + 6/16	2 + 4
3	7/9 + 7/25	2 + 4	7/1	2 + 4
4	8/7 + 8/23	2 + 4	7/28 + 8/10	2 + 4
5	9/3 + 9/16	2 + 4	5/22	8 + 10
6	5/30	8 + 10	6/2 + 6/16	8 + 10
7	6/12 + 6/26	8 + 10	7/1	8 + 10
8	7/9 + 7/25	8 + 10	7/28 + 8/10	8 + 10
9	8/7 + 8/23	8 + 10		
10	9/3 + 9/16	8 + 10		

[1]Paddocks 2 + 4 were assigned at random to represent pasture 1 and paddocks 8 + 10 for pasture 2.

Table 3.2 Crested wheatgrass through the 2019 grazing season at Sidney, Nebraska

							Orthogonal Contrasts[7]			Main Effect	Interaction[8]
Item	May	June	July	August	September	SEM	Linear	Quadratic	Cubic	Month	Month x Time
CP, % DM[1]	9.5	7.7	6.6	6.2	6.3	0.10	<0.01	<0.01	0.35	<0.01	
RUP, % CP[2]	8.8	12.0	13.9	16.2	17.7	1.00	<0.01	<0.01	0.87	<0.01	0.75
RUP, % DM[3]	0.80	0.90	0.93	0.98	1.09	0.06	<0.01	0.33	0.23	<0.01	0.53
RUP dig., %[4]	39.9	43.3	42.3	45.3	46.6	5.72	0.02	0.45	0.21	0.18	0.35
Dig RUP, % DM[5]	0.40	0.43	0.42	0.45	0.49	0.03	0.02	0.94	0.45		
IVDMD, % DM[6]	54.0	52.1	45.6	41.9	37.0	0.01	<0.01	0.02	0.35		

[1] CP, % DM – Crude protein as a percent of total dry matter
[2] RUP, %CP – rumen undegradable protein as a percent of crude protein
[3] RUP, % DM – rumen undegradable protein as a percent of total dry matter
[4] RUP dig, % – rumen undegradable protein digestibility
[5] Dig RUP, % DM – digestible rumen undegradable protein as a percent of total dry matter (RUP as % of DM that is digested by cattle)
[6] IVDMD, % DM – In vitro dry matter disappearance as a percent of total dry matter
[7] Orthogonal Contrasts – *P*-values describing changes over time
[8] Interaction between month and rumen incubation time for samples (20-hour or 30-hour incubation period)

Table 3.3 Crested wheatgrass through the 2020 grazing season at Sidney, Nebraska

						Orthogonal Contrasts[7]			Main Effect	Interaction[8]
Item	May	June	July	August	SEM	Linear	Quadratic	Cubic	Month	Month x Time
CP, % DM[1]	12.1	9.6	6.8	5.3	0.10	<0.01	0.02	0.05	<0.01	
RUP, % CP[2]	8.7	11.9	17.8	20.7	0.90	<0.01	0.92	0.19	<0.01	0.83
RUP, % DM[3]	1.03	1.14	1.21	1.06	0.06	0.58	0.06	0.50	0.24	0.62
RUP dig, % CP[4]	35.4	36.1	38.0	39.8	5.42	0.25	0.85	0.90	0.68	0.97
Dig RUP, % DM[5]	0.37	0.36	0.38	0.40	0.04	0.49	0.73	0.86		
IVDMD, % DM[6]	41.8	46.2	41.7	42.8	0.02	0.91	0.54	0.26		

[1] CP, % DM – Crude protein as a percent of total dry matter
[2] RUP, %CP – rumen undegradable protein as a percent of crude protein
[3] RUP, % DM – rumen undegradable protein as a percent of total dry matter
[4] RUP dig, % – rumen undegradable protein digestibility
[5] Dig RUP, % DM – digestible rumen undegradable protein as a percent of total dry matter (RUP as % of DM that is digested by cattle)
[6] IVDMD, % DM – In vitro dry matter disappearance as a percent of total dry matter
[7] Orthogonal Contrasts – *P*-values describing changes over time
[8] Interaction between month and rumen incubation time for samples (20-hour or 30-hour incubation period)

Figures

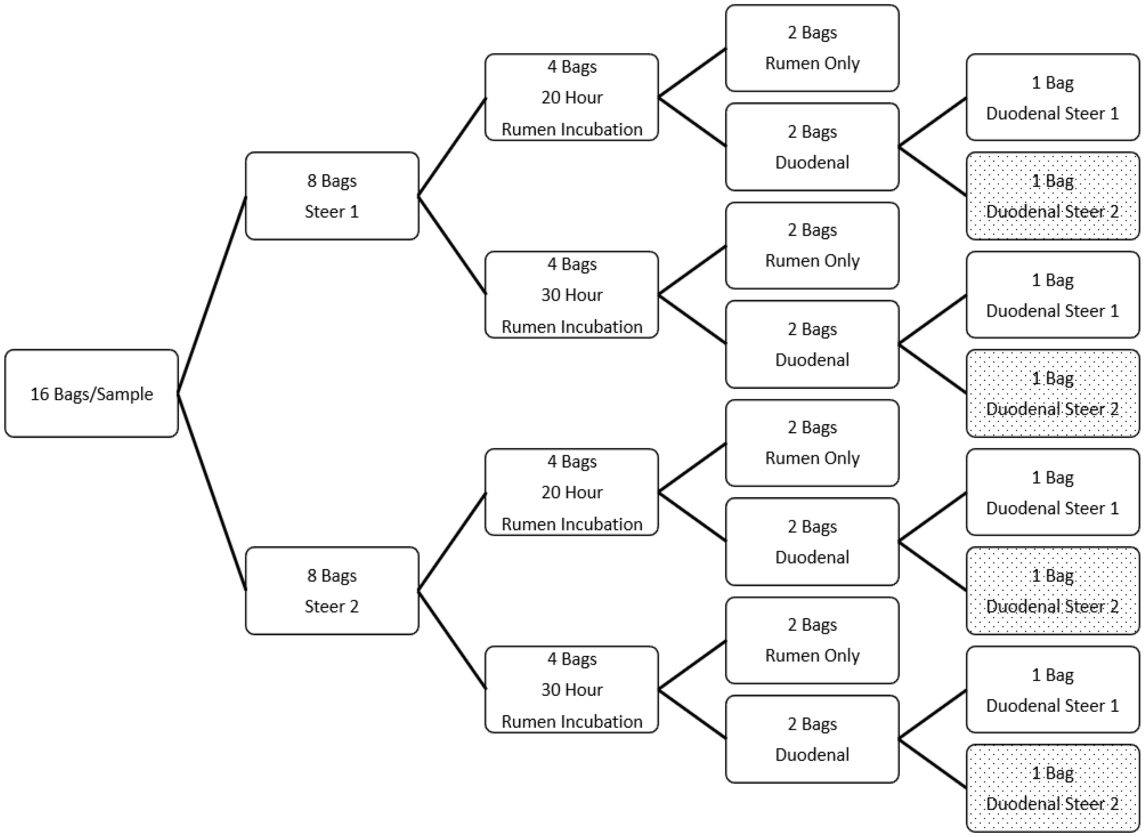

Figure 3.1 Stratification of 1 sample for in situ mobile bag assay

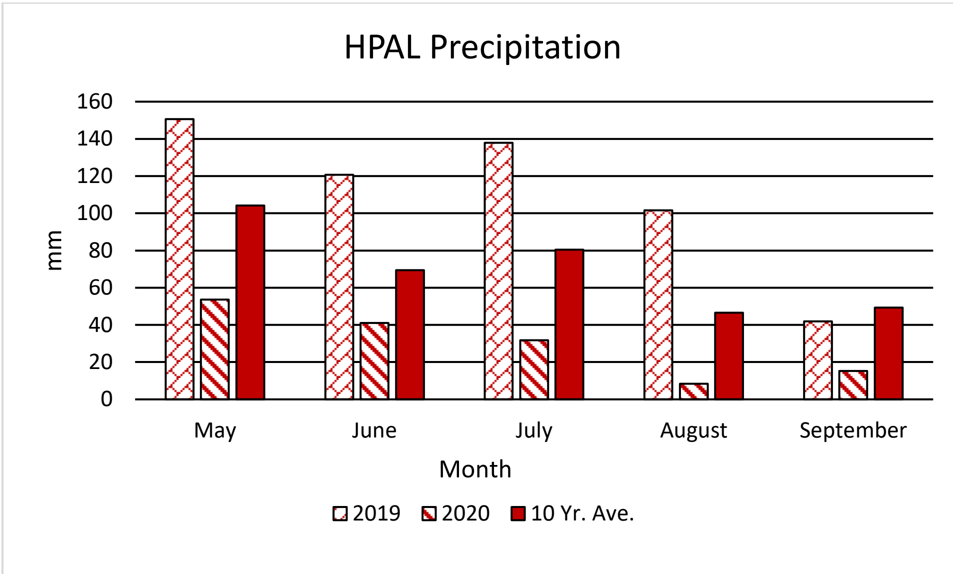

Figure 3.2 Precipitation recorded at the High Plains Agriculture Lab near Sidney, NE

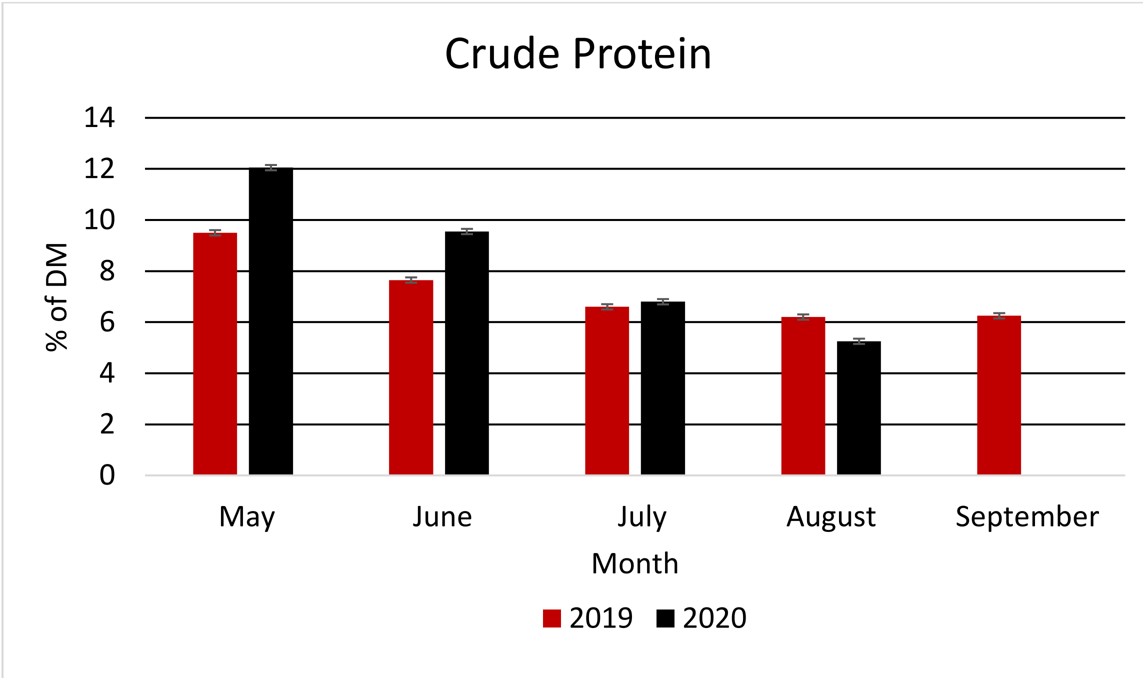

Figure 3.3 Crude protein of crested wheatgrass throughout the growing season

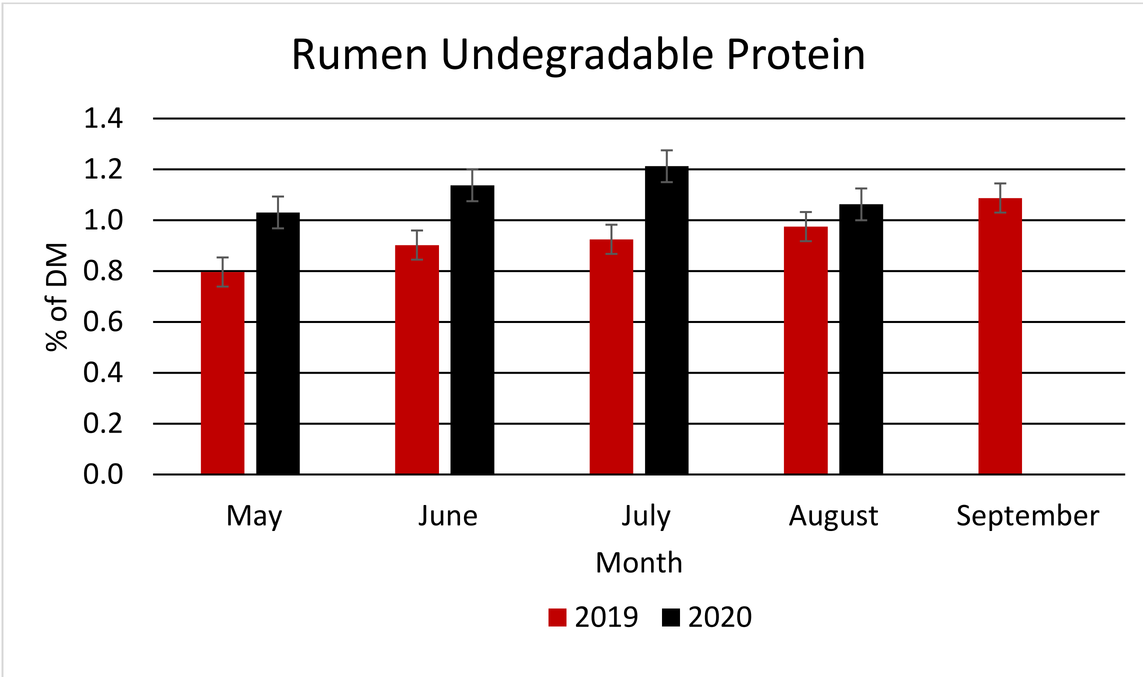

Figure 3.4 Rumen undegradable protein of crested wheatgrass throughout the growing season

CHAPTER 4 - INTERACTION OF BACKGROUNDING SYSTEM, RATE OF GAIN, AND IMPLANTING STRATEGY ON THE PERFORMANCE OF WEANED STEERS AND HEIFERS

Kelton C. Adair, J. Travis Mulliniks, Jacki A. Musgrave, and James C. MacDonald

Abstract

Two experiments were conducted at Gudmundsen Sandhills Laboratory near Whitman, NE utilizing 117 (Initial BW = 185 kg, SD = 34) crossbred steers and heifers to determine the interaction of backgrounding rate of gain and implant strategy on animal performance, compensatory gain, and carcass characteristics in two different winter backgrounding systems. During the winter backgrounding phase, calves were stratified by body weight, blocked by sex, and allocated at random to one of two experiments (Experiment 1, Dry lot; Experiment 2, grazing dormant sandhills meadow). In both experiments, calves were assigned at random to one of four treatments applied during winter backgrounding with factors including rate of gain (LOW: 0.45 or HIGH: 0.90 kg/day) and a growth implant containing 25.7 mg estradiol [IMP: Compudose implant (Elanco animal Health)] or no implant (NO IMP). Both experiments had a 119-day winter backgrounding phase before being combined and treated equally during summer backgrounding (133 days) and finishing (139 days). During the winter backgrounding phase of Exp. 1, calves wintered at HIGH had greater EBW, ADG, and G:F than LOW

calves ($P < 0.01$) and the use of a growth implant tended to increase ending BW, ADG, and DMI at both rates of gain ($P = 0.07$). Calves winter backgrounded at HIGH entered the summer grazing phase with heavier BW and ended with heavier BW than LOW despite having a lower ADG ($P < 0.01$). In the summer grazing phase, drylot calves in the HIGH IMP treatment resulted in the greatest EBW ($P < 0.04$). LOW supplementation, without an implant, improved summer backgrounding ADG ($P = 0.05$) while achieving similar carcass adjusted final BW and HCW as those wintered at HIGH with an implant. Implanting during winter backgrounding increased finishing DMI ($P = 0.06$). In Exp. 2, additional supplement yielded increased winter and summer EBW and ADG ($P <0.10$). Administering an implant to calves grazing dormant meadows during the winter backgrounding phase with variable levels of supplement intake had no effect on winter EBW and ADG, Summer EBW and ADG, or finishing ADG, carcass adjusted final BW, HCW, DMI, or G:F ($P > 0.16$).

Introduction

In beef production systems, it is common to wean calves in the fall and background them through the winter and summer before entering the finishing period. Backgrounding systems allow for multiple marketing opportunities, more evenly distribute the feeder cattle supply for feedlots, and provide additional animal management opportunities to influence health and performance. Management practices during the winter backgrounding phase can affect performance during subsequent phases of production. Strategies such as supplementation, implants, or backgrounding systems are all used in a variety of combinations by producers to achieve their production goals. An analysis of 6 backgrounding studies observed a 35 kg increase in final body weight

(FBW) for calves supplemented at a high (0.90 kg/d) rate of gain over those supplemented at a low (0.45 kg/d) rate of gain during the winter backgrounding phase (Gillespie-Lewis et al., 2015). The effects of supplementing calves at different rate of gain during winter backgrounding has been well studied (Gillespie-Lewis et al., 2015; Folmer et al., 2008; Jordon et al., 2000; Downs et al., 1998); however, the interaction of rate of gain with other production strategies such as implants should be further investigated. Although implants improve ADG in beef cattle at each phase of production, it is not well understood how implants administered during the winter backgrounding phase may interact with varying levels of supplementation and affect cattle performance during subsequent phases of production. Furthermore, implants and rate of gain interaction are of interest because diets that limit average daily gain (LOW) reduce the animal’s response to the implant (Peel, 2003). The objective of this study is to determine how the interaction of implant strategy and supplementation level (applied during the winter backgrounding phase) may affect the performance of weaned steers and heifers throughout subsequent phases of production.

Materials and Methods

A three-phase backgrounding system research trial was conducted at the Gudmundsen Sandhills laboratory (GSL) near Whitman, NE. Winter backgrounding, summer grazing, and finishing phases lasted 112, 126, and 139 days respectively. One hundred seventeen weaned calves (Initial BW = 185 kg, SD = 34) were stratified by body weight (BW) and blocked by sex when assigned at random to one of eight treatment groups (Figure 4.1) with factors consisting of wintering system (DRYLOT or RANGE), two rates of gain (LOW targeted 0.45 kg/d and HIGH targeted 0.90 kg/d), and implant strategy [IMP: 25.7 mg estradiol (Compudose; Elanco Animal Health; Greenfield, IN) or NO IMP]. Treatments were applied on day 0 of the winter phase; cattle were combined and managed the same throughout summer backgrounding and finishing phases. During the winter backgrounding phase, cattle assigned to winter graze had variable supplement intakes and did not achieve two different rates of gain (HIGH and LOW). Therefore, the study was divided into two experiments (Figure 4.2) with Exp. 1 evaluating the interaction of implant and rate of gain in a drylot backgrounding system and Exp. 2 being a regression of supplement intake on average daily gain and ending body weight.

All cattle used in this study were born and raised at GSL with an average calving date of May 16, 2020, fence line weaned in early December, and held in a drylot with ad libitum grass hay for 30 days before trial initiation. Calves were limit fed a common diet for 5 days prior to collecting initial body weight (BW) on days -2, -1, and 0.

Exp. 1: Drylot backgrounding

On day 0 of the winter backgrounding phase, calves assigned to drylot were weighed, processed, then shipped to the West Central Research Extension and Education Center (WCREEC) at North Platte, where they were stratified by rate of gain then gate sorted into 1 of 3 pens for a total of 6 pens (3 LOW and 3 HIGH) with 10 head/pen (5 pens with 10 head and 1 pen with 9 head). To achieve the desired rate of gain, two separate diets (LOW and HIGH; Table 4.1) were delivered to corresponding pens twice a day in an ad libitum bunk management system. Growsafe feed bunks (Vytelle, Calgary, AB.) were used to record daily dry matter intake (DMI) of individual animals for the 112-day feeding period. Cattle were limit fed for 5 days at 2% of BW with a diet of 50% alfalfa hay and 50% Sweet Bran (Cargill Corn Milling, Blair, NE) and then weighed for 3 consecutive days. On the third weigh day, cattle were withheld from feed, processed for the summer phase, and shipped to GSL to begin the summer grazing phase.

Exp. 2: Winter Range Backgrounding

On January 8, 2021 (day 0 of the winter backgrounding phase), calves assigned to winter range were processed and turned out onto dormant sandhills meadows. For the first 52 days, calves grazed separate paddocks within the same meadow and were supplemented as 2 separate groups (1 paddock for LOW and 1 paddock for HIGH treatment groups) in feed bunks. Dried distillers grains plus solubles (DDGS) were supplemented daily as a pellet to the LOW and HIGH groups at 1.0 kg/head and 1.9 kg/head respectively to achieve an estimated 0.45 kg and 0.90 kg ADG. On day 53, calves were combined onto one meadow and introduced to the Super Smart Feeder; an automated creep feeder that records daily intakes and dispenses feed supplements to individual animals based on their RFID ear tag. The Super Smart feeder was programmed to dispense the correct supplement to each animal according to their assigned treatment. For the remaining 59 days of the 112-day winter backgrounding phase, calves were supplemented as individual animals. Calves grazed a 63-ha meadow pasture until April 1st and then moved to an adjacent 66-ha meadow from April 1st to May 1st when they were moved into a holding pen and fed a common diet for 5 days before collecting BW for three consecutive days. Performance calculations were adjusted to account for gain that occurred during the limit feeding period by subtracting 0.45 kg from ending BW for each day of limit feeding.

Summer grazing

Cattle from Exp. 1 and Exp. 2 were combined and turned out for the summer grazing phase on the final weigh day of the winter backgrounding phase (May 7, 2021). Ending body weights for the winter backgrounding phase are the same as the initial body weights for the summer grazing phase. Both experiments remain comingled for the remainder of the study. For summer background processing, all cattle received an implant [200 mg testosterone propionate USP, 20 mg estradiol benzoate, and 29 mg tylosin tartrate (Component E-H) or 200 mg progesterone USP and 20 mg estradiol benzoate and 29 mg tylosin tartrate (Component E-S)], treated for internal/external parasites [6 mL subcutaneous (Cydectin; Bayer Animal Health, Germany)], and two insecticide cattle ear tags [XP 820 ear tags (Y-Tex; Cody, Wyoming)]. Drylot calves were immediately comingled with the winter range calves once they arrived back to GSL and turned out onto sub-irrigated sandhill meadow. Cattle rotationally grazed sub-irrigated meadows for the 126-day grazing period which was determined by forage availability. Non-native cool-season grasses dominate Sandhills meadows, in association with relatively few native warm-season grasses, forbs, sedges, and rushes. Among the main cool-season grasses are the non-native quackgrass (Elymus repens [L.] Gould), timothy (*Phleum pratense* L.), Kentucky bluegrass (*Poa pratensis* L.), and native reed canarygrass (*Phalaris arundinacea* L.). The plant community is also comprised of non-native legumes such as red clover (*Trifolium pratense* L.) and white clover (*T. repens* L.) (Schacht et al. 2000). Cattle were continuously stocked at 0.29 hectares/yearling throughout the grazing season. On September 10, 2021 (day 127 of the summer grazing phase), cattle were removed from the meadow and limit fed a common diet at 2% of BW for 5 days before collecting ending BW for 3 consecutive days. On the third weigh day, cattle were held off feed, processed for the finishing phase, and shipped to the WCREEC at North Platte. Performance calculations were adjusted to account for gain that occurred during the limit feeding period by subtracting 0.45 kg from ending BW for each day of limit feeding. Compensatory gain was calculated as the difference in BW between HIGH and LOW at the beginning of summer backgrounding minus the difference in BW at the end of the summer backgrounding divided by the difference in BW at the beginning of summer backgrounding. For example, the NO IMP treatment: [(Initial BW HIGH - Initial BW LOW) - (Ending BW HIGH - Ending BW LOW)]/(Initial BW HIGH - Initial BW LOW). [(254 - 244) - (362 - 358)] / (254 - 244) = 0.60 or 60%.

Finishing

Cattle entered the feedlot on the final weigh day of the summer grazing phase (September 17, 2021). Ending BW for the summer grazing phase and initial BW for the finishing phase are the same. Prior to shipping from GSL, all cattle received a growth promoting implant containing 200 mg trenbolone acetate, 20 mg estradiol USP, and 29 mg tylosin tartrate (Component TE-200; Elanco Animal Health) at processing. Cattle were sorted off the truck to 1 of 8 partially covered pens which contain 2 GrowSafe (Vytelle) feed bunks per pen. A 4-diet feeding program was used starting on the day of arrival to transition cattle from a forage-based diet to the grain-based finishing ration in 32 days: Sweet Bran and supplement were held constant at 40% DM inclusion while DRC increased with each new transition diet replacing meadow hay proportionally until reaching 48% DRC (Table 4.3). The finisher ration was fed to all cattle for 106 days with the inclusion of an ionophore (Rumensin-90: Elanco Animal Health) at 413 milligrams per head per day and tylosin phosphate (Tylan -40: Elanco Animal Health) at 90 milligrams per head daily. Feed was delivered once a day via Roto-Mix horizontal mixer truck throughout the finishing period. GrowSafe feed bunks were utilized to calculate individual intake from day 34 to day 109 of the finishing period. Due to cattle throwing feed out of the GrowSafe feed bunks, all 8 pens of cattle were moved to 1 large open lot pen on day 110 of the finishing period where they were fed for the remainder of the trial in a conventional continuous concrete feed bunk. The average dry matter intake (DMI) of each animal recorded during the GrowSafe period was applied for the entire finishing period for each animal. On day 139 (2/2/22), all cattle were held off feed and shipped to Tyson in Lexington, NE for harvest. Harvest projections were determined from historical data of previous calf crops and performance from this same herd. Final BW were calculated by dividing hot carcass weight (HCW) by a common dressing percent of 63%. Hot carcass weight was collected following harvest and a 48-hour chill period.

Statistical Analyses

Experiment 1 was analyzed as a 2x2 factorial design with winter rate of gain (LOW: 0.45 kg or HIGH: 0.90 kg ADG) and implant strategy (IMP or NO IMP; Figure 4.1). An ANOVA model was used for the winter performance data and ANCOVA models were used for summer and finishing performance data with initial BW from the winter phase being the covariate. The initial BW of treatment groups were used as a regression to account for initial group differences after winter backgrounding to calculate summer ending BW and ADG as well as carcass adjusted final BW, HCW, finishing ADG, DMI, G:F and carcass quality characteristics. All models were blocked by sex and included the main effects and interaction of winter rate of gain x implant strategy.

Experiment 2 analyzed winter and summer EBW and ADG as well as finishing carcass adjusted final BW, HCW, ADG, DMI, and G:F as a regression of supplement intake during the winter grazing phase. This approach was necessary because actual supplement intake was variable compared to the assigned intake of each calf. Each performance measure was tested individually for quadratic or linear interaction of implant and winter supplement intake as well as quadratic or linear main effects. Performance estimates (Table 4.9) were found by estimating the response variable mean at the targeted supplement intakes (1.0 and 1.9 kg) using the regression line. Individual animal was the experimental unit in both analyses. Data were analyzed using the Glimmix procedure of SAS 9.4 with significance declared at a $P < 0.10$.

Results and Discussion

Overall, there was little morbidity and mortality. Two steers died throughout the entirety of the trial: 1 assigned to Exp 1 died during the finishing phase and 1 assigned to Exp 2 was euthanized during the summer grazing phase due to a lameness issue. The length of the winter and summer phases were determined on grass availability. If green up was later than usual, the winter phase could be extended in a dry lot but not in a range system. Likewise, if green up occurs earlier in the year, then the winter range calves may have some advantage with improved forage quality relative to the dormant range.

Exp 1: Drylot

Winter Phase

No significant interactions between implant and rate of gain were observed ($P \geq 0.27$); therefore, main effects are presented. By design, there was no difference in initial BW ($P > 0.53$) between treatment groups (Table 4.4). Rate of gain was different between the treatments with HIGH achieving 0.80 kg/day and LOW gaining 0.54 kg/day (P < 0.01) without having a difference in DMI (P = 0.51), which demonstrates that two distinct rates of gain at a similar level of intake in an ad libitum bunk management system were achieved. Calves winter backgrounded in a drylot system and fed HIGH had 30 kg greater ending BW, 0.26 kg greater ADG, and a 26 percent improvement in feed efficiency (P < 0.01) over calves fed LOW. The difference in ending BW, ADG, and G:F response between HIGH and LOW is a result of the difference of net energy available for gain after maintenance requirements are satisfied by the diets (Table 4.1). The use of a growth promoting implant increased ending BW, ADG, and DMI within each rate of gain (P = 0.07). Implanting in the winter backgrounding phase improved ending BW for calves fed HIGH by 12 kg and calves fed LOW by 9 kg. A 14% improvement in ADG is typical for calves administered a long-acting estrogenic implant over those not implanted (Kuhl, 1997). As a percentage, implants improved ADG similarly for HIGH and LOW treatments (16 and 14% respectively); however, implants improved ADG numerically greater for HIGH than LOW (0.12 and LOW 0.07 kg respectively). Previous studies have demonstrated that implants elicit a greater response for stocker cattle when fed to a higher plane of nutrition (Duckett and Andrae, 2001; Gill et al., 1986.; Kuhl 1997). In this study, cattle fed at LOW rate of gain also had a positive response from an implant. This study indicates that positive responses to implanting may be realized in cattle fed at LOW plane of nutrition, but a numerically greater response is observed when cattle are fed HIGH plane of nutrition. Dry matter intake may be the primary driver for the gain response observed within LOW. At LOW rate of gain, IMP increased DMI by 41% (from 4.3 to 6.1 kg/day) but only improved DMI by 7% (from 5.4 to 5.8 kg/day) for HIGH. By IMP increasing DMI within LOW, the total nutrients consumed by each calf was also increased thus allowing for the hypothesis that the calves were able to achieve a higher plane of nutrition than the LOW NO IMP control without having a change in diet composition.

If a producer intends to sell calves after winter backgrounding in a drylot system, these data suggest feeding cattle to gain at least 0.74 kg/day (actual rate of gain for HIGH) to benefit the most from the implant strategy.

Summer Grazing

During summer grazing, an interaction between IMP and rate of gain was detected for ending BW (*P* = 0.04) and ADG (*P* = 0.05; Table 4.5). Calves fed to gain HIGH during the winter backgrounding phase and administered a growth promoting implant resulted in an additional 16 kg in BW at the end of the summer grazing phase compared to other treatments (*P* = 0.04). When calves were winter backgrounded at LOW rate of gain with no implant, calves tended to gain 0.11 kg/day more than any other treatment during summer grazing (LOW NO IMP = 0.88; LOW IMP = 0.78; HIGH NO IMP = 0.70; HIGH IMP = 0.73 kg/day; *P* = 0.05). It is important to note that both treatments wintered at LOW exhibited compensatory gain; however, LOW NO IMP treatment compensated 60% of the HIGH NO IMP during the summer grazing season and LOW IMP compensated only 16% of the HIGH IMP treatment. Compensatory gain values often range from 18% to 100% (Jordon et al., 2000) although compensation does not typically reach the latter. The length that cattle are on a restricted intake can influence compensation; longer restriction periods may reduce compensatory gain (Klopfenstein et. al., 1999). Klopfenstein et. al., (1999) summarized multiple compensatory gain studies with growing cattle grazing corn residues with no implants and found that full season grazing (~4 months) after >100 days of restricted intake gives 50 to 60% compensation on average which align with the compensation observed with the LOW NO IMP group in this study. Calves fed LOW with IMP had 44% less compensation than those fed LOW with NO IMP. This difference is likely due to the LOW IMP calves having a greater DMI ($P = 0.07$), thus being less restricted (more energy available beyond maintenance = greater NEg; Table 4.2) during the winter backgrounding phase than LOW NO IMP calves and having less weight to compensate for during the summer phase.

Calves winter backgrounded at HIGH rate of gain entered the summer backgrounding phase with heavier BW and ended with heavier BW than LOW despite having a lower ADG ($P < 0.01$) throughout the summer. Gillespie-Lewis et al., (2015) similarly observed increased winter gains resulting in greater initial BW in the summer grazing phase maintained through summer backgrounding with greater ending BW as well. Calves wintered at HIGH maintained 73% of the body weight advantage over steers wintered at LOW through summer grazing. Similarly, Downs et al., (1998) found that steers winter backgrounded at 0.77 kg/day maintained approximately 80% of the weight advantage over steers wintered at 0.32 kg/day during summer grazing. Implanting calves at a LOW rate of gain during the winter phase did not benefit calves intended for summer grazing (9 kg advantage for IMP at end of winter backgrounding but -6 kg advantage after summer backgrounding); however, 100% of the gains from winter implant were maintained through the summer phase when calves were wintered at a HIGH rate of gain (20 kg advantage for IMP at end of winter backgrounding and 26 kg advantage after summer backgrounding).

When observing net gain within each phase (Table 4.7), an interaction between IMP and ROG was observed for summer gain, background gain (net gain from winter + summer phases), and total gain (winter + summer + finishing phases; $P < 0.09$). In the summer phase, cattle in LOW NO IMP treatment gained 14 kg more than all other treatments due to compensatory gain ($P = 0.05$). The HIGH IMP treatment group resulted in the greatest net gain as a long yearling system with 16 kg more than any other treatment ($P = 0.04$) and had a net gain of 11 kg more total gain throughout the entire system than any other treatment ($P = 0.08$) but was not different from LOW NO IMP treatment. As expected, HIGH rate of gain had a greater net gain (30 kg) during the winter backgrounding phase than LOW but less gain (15 kg) during the summer backgrounding phase due to compensatory gains in the LOW treatments ($P = 0.01$). The HIGH rate of gain had greater net gain (15 kg) than LOW when evaluating overall backgrounding gain ($P = 0.01$). Implant improved net gain during the winter backgrounding phase by 13 and 8 kg for HIGH and LOW treatment groups ($P = 0.07$).

Based on performance, the results from this study suggest wintering calves at a high rate of gain (0.86 kg/d or better) with 25.7 mg estradiol [Compudose (Elanco animal Health)] to achieve the greatest ending BW. The treatment with the second greatest performance response was achieved when targeting a low rate of gain (0.50 kg/d) with no implant because it resulted in similar ending BW as HIGH NO IMP and LOW IMP without incurring the added cost of an implant or additional feed costs. If the additional feed cost incurred from additional ingredients needed to go from LOW to HIGH rate of gain is greater than the value of selling an additional 26 kg per head (- the cost per implant) then LOW NO IMP would be the economical choice over HIGH IMP at the end of the summer backgrounding phase.

Finishing

Winter implant and rate of gain interaction was observed for initial BW, ending BW, and HCW of the finishing period ($P < 0.08$; Table 4.6). Cattle winter backgrounded at HIGH with an implant entered the finishing phase with 16 kg more BW than all other treatments and had a greater ending BW and HCW than HIGH NO IMP and LOW IMP treatments ($P < 0.09$).

Cattle winter backgrounded at HIGH rate of gain entered the finishing phase with greater BW than LOW ($P < 0.01$); however, ending BW and HCW was not different ($P > 0.54$) between the two rates of gain. Cattle fed to achieve 0.45 kg ADG during the winter phase were more efficient in the finishing period than HIGH ($P = 0.09$). Rate of gain during the winter backgrounding phase did not influence ($P > 0.25$) ending BW, HCW, ADG, DMI, REA, marbling, or backfat in the finishing phase. Implanting during winter backgrounding increased DMI by 0.54 kg/day (75 kg per head for the entire finishing phase) during the finishing phase ($P = 0.06$) but did not influence any other parameters measured ($P > 0.17$).

In this study, the performance advantages from implant or rate of gain applied during the winter backgrounding phase were maintained up until the finishing phase. By the end of the finishing phase, feeding at a high rate of gain with an implant resulted in greater EBW and HCW than LOW IMP and HIGH NO IMP treatments but not different than calves winter backgrounded at LOW NO IMP. Winter rate of gain or implant treatment alone did not influence carcass adjusted final BW, HCW, or ADG. In other words, the body weight gains from implant or rate of gain treatments during the winter phase were not maintained through finishing. These findings contradict some backgrounding studies where body weight gains from treatments applied during winter backgrounding were maintained and had additive effects through all phases of beef production (Duckett and Andrae., 2001; Paisley et al., 1999; Gillespie-Lewis et al., 2015; Jordon et al., 2000). However, some backgrounding studies have reported performance advantages from the winter backgrounding phase being maintained only through the summer grazing phase but not finishing (Downs et al., 1998). Similar to this study, Downs et al., (1998) reported compensatory gain during summer grazing but the calves wintered at high were able to maintain 80% of the weight advantage to the end of summer grazing. In this study, calves that were wintered at HIGH or LOW rates of gain followed by grazing sandhills meadow exhibited no significant difference in final BW, finishing ADG, DMI, and G:F, when finished at an estimated common backfat thickness. Although backfat was not significantly different in this grazing study, implanted cattle had numerically greater backfat thickness which suggests that the implanted cattle could have had less days on feed while still having no significant difference in backfat to what was observed by Downs et. al., 1998. The findings from both of these studies suggest that gain advantages from the winter period are not always maintained through the finishing period but are maintained through summer grazing.

Based on the results from this study, retaining ownership of cattle after winter backgrounding in a drylot system and summer grazing with 200 mg testosterone propionate USP, 20 mg estradiol benzoate, and 29 mg tylosin tartrate [Component E-H (Elanco Animal Health)] or 200 mg progesterone USP and 20 mg estradiol benzoate and

29 mg tylosin tartrate [Component E-S (Elanco Animal Health)], should winter background calves at a low rate of gain with no implant. Since there was no significant difference in finishing performance at the same days on feed, a logical decision is to choose the least cost backgrounding system. In this case, the cheapest backgrounding system (LOW NO IMP) happens to be the system which develops cattle that convert feed to body weight the most efficiently during the finishing phase. Some studies have shown that low input grazing systems may be more economical than high input drylot systems when animals are retained through the finishing phase (Mathis et al., 2008, Taylor et al., 2008).

Exp 2: Winter Graze

There were no quadratic or linear interactions between supplement intake and implant ($P > 0.15$). In the winter grazing phase, calves were supplemented with dried distillers grains solubles (DDGS) for 52 days as two separate groups and 60 days as individual animal using a Super SmartFeed self-feeder, thus a 112-day winter backgrounding phase. Calves were supplemented as two separate groups on a cross fenced meadow for 52 days because the self-feeder was not available on day 1 of the trial. When supplemented as groups, one group was supplemented DDGS at 1.9 kg/head daily and the other at 1.0 kg/head daily to target 0.9 kg/day ADG (HIGH) and 0.45 kg/day ADG (LOW). Once the self-feeder was placed on the meadow, cattle were combined and supplemented DDGS as individual animal. The Super SmartFeed self-feeder is an automated creep feeder that dispenses feed to individual animals by reading the RFID tag located in the ear of each animal. Feed is dispensed using a chain drag system that estimates the amount fed using an algorithm considering physical feed characteristics, run time, and chain speed. This feeder is programmed to dispense only a portion of the daily allotment of feed at each visit by the animal and will not deliver any amount beyond the daily allotment for each animal. Calves assigned to HIGH or LOW were allowed up to 1.9 or 1.0 kg DDGS daily from the Super SmartFeeder. However, average supplement intake of calves on the self-feeder varied between 0 to 1.57 kg/day (Figure 4.3). A study conducted by Williams et al., (2017) utilized a similar Super SmartFeed self-feeder which concluded that self-feeders significantly increase variability of supplement intake and reduce supplement conversion efficiency despite ADG having no difference between hand delivery methods and self-feeding methods. Similarly, the calves in this study had a large variation in supplement intake during the 60-day period with the self-feeder. Due to the variation of actual intake, the targeted rates of gain (HIGH and LOW) were not significantly different from one another; therefore, means were estimated from a regression of total winter supplement intake (Figure 4.4). Total winter supplement intake was calculated for each individual animal as:

(Estimated daily intake during group housing + measured intake from Super SmartFeed)

112-Day winter backgrounding phase

Each performance variable was regressed, over total supplement intake and tested individually for quadratic and linear interactions (variable of interest x supplement intake). Having no interactions, each variable was fitted to a linear model with its own regression to create estimates using “at” statements within SAS. The regression lines used for estimates of the main effect of winter rate of gain assumed 0.75 kg and 1.65 kg DDGS intake daily. The regression lines used for estimates of the main effect of implant assumed the average supplement intake of 0.99 kg DDGS daily. As an example, winter ending body weight and ADG are regressed over daily supplement intake (Figure 4.5 and Figure 4.6). Calves that consumed 0 kg supplement were kept in the dataset (LOW, 4 head; HIGH, 2 head).

There were no significant differences between initial BW at the beginning of the trial (Table 4.8; P = 0.99). Additional supplement intake (from 0.75 to 1.65 kg) during the winter phase improved EBW and ADG during the winter and summer backgrounding phases (P <0.10). Carcass adjusted FBW and HCW (P = 0.13) tended to be greater when additional supplement was consumed in the winter backgrounding phase. Finishing DMI and feed efficiency did not differ for calves that consumed 0.75 or 1.65 kg of supplement daily in the winter backgrounding phase. For the main effects of implant, there were no differences in initial BW or ending BW between NO IMP and IMP treatments during the winter backgrounding (Table 4.9; P > 0.68). Performance in subsequent phases of production was not influenced by an implant during winter backgrounding: in the summer grazing phase, no difference between treatments were observed for ending BW or ADG (P > 0.25) and within the finishing phase, carcass adjusted final BW, HCW, ADG, DMI, and G:F were not significantly different between treatments (P > 0.36). Despite the variation with intakes and calf ADG during the winter phase, the lack of growth hormone implant response was surprising for the winter phase or subsequent phases. The lack of implant response may not be due to the variation in ADG. In fact, Paisley et al. (1998) was able to detect a significant implant response in calves grazing dormant tallgrass prairie and gaining as little as 0.30 kg/day. Furthermore, a greater response to implants can be expected when stocker cattle are on a higher plane of nutrition (Duckett and Andrae, 2001; Gill et al., 1986.; Kuhl et al. 1997). With the calves from this study gaining at least 0.53 kg/day during winter backgrounding, it is not likely that ADG was limiting the ability of the implant to respond. More observations could help increase power and therefore increase the capability of detecting significant differences. Based on the results of this winter grazing system, implanting calves while grazing dormant sandhills meadow during a winter backgrounding phase does not result in increased daily gains.

Conclusion

In the drylot winter backgrounding system, 73% and 100% percent of the body weight advantages from backgrounding at a HIGH rate of gain and implanting was maintained up until the finishing phase. Winter backgrounding calves at a HIGH rate of gain with an implant improved EBW and ADG during the summer backgrounding phase and resulted in the greatest carcass adjusted FBW and HCW ($P < 0.9$). Winter backgrounding calves at LOW with NO IMP resulted in the most efficient calves during the summer backgrounding phase ($P = 0.05$). Feeding calves to gain HIGH during the winter backgrounding phase resulted in greater EBW, ADG, and G:F after winter backgrounding and the greatest EBW after summer backgrounding ($P < 0.01$). Implanting calves in a drylot winter backgrounding system improved EBW, ADG, and DMI during winter backgrounding and DMI during the finishing phase ($P < 0.08$).

In a dormant range winter backgrounding system, additional distillers grains consumed increased EBW and ADG during the winter and summer backgrounding phases ($P < 0.01$). Implanting calves winter backgrounding on dormant sandhills meadow did not affect performance in any phase of production ($P > 0.16$). Winter rate of gain and implant treatments had no effect on finishing ADG, REA, Marbling, and backfat regardless of the backgrounding system.

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Tables

Table 4.1 Drylot winter backgrounding diet evaluation (% DM)

Ingredient	LOW[1]	HIGH[2]
Sweet Bran[3]	25	20
Meadow Hay[4]	67	56
DDGS[5]	0	17
Supplement[6]	8	7
	100%	100%
TDN, % DM[7]	63	67
ME, Mcal/kg	0.466	0.500
NEm, Mcal/kg	0.284	0.313
NEg, Mcal/kg	0.161	0.188
CP, % DM	12.84	16.02

[1]Fed ad libitum to target ROG of 0.45 kg/d
[2]Fed ad libitum to target ROG of 0.90 kg/d
[3]Cargill wet corn gluten feed product
[4]Meadow hay harvested from Gudmundsen Sandhills Laboratory
[5]Dried Distillers Grains Solubles
[6] Supplement formulated to supply Rumensin-90 at 30 g/ton DM (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)
[7] Calculations based on 2016 NASEM values for feed components

Table 4.2 Nutrient requirements for 250 kg growing calf[1]

Targeted ADG, kg	NEm, Mcal/d	NEg, Mcal/d	MP, g/d[2]
0.45	4.5	1.30	184
0.90	4.5	2.83	321

[1]Nutrient requirements based off Table 20-1 of the 2016 Nutrient Requirements of Beef Cattle
[2]MP required for gain

Table 4.3 Transition from forage-based diet to a grain-based diet on long yearlings (% DM)

	Step1	Step 2	Step 3	Finisher
DOF[1]	18	7	7	106
DRC[2]	20	30	41	48
Meadow Hay[3]	35	25	14	7
Sweet Bran	40	40	40	40
Supplement[4]	5	5	5	5

[1]Days on feed
[2]Dry rolled corn
[3]Meadow hay harvested from GSL
[4]Supplement formulated to supply Tylan-40 at 90 mg/animal daily and Rumensin-90 at 30 g/ton DM (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)

Table 4.4 Winter backgrounding in a dry lot system at 2 rates of gain with or without an implant

ROG[1]	LOW		HIGH			*P*-value		
Implant[2]	NO IMP	IMP	NO IMP	IMP	SEM	IMP	ROG	IMP x ROG
DOF[3]	112	112	112	112				
Initial BW, kg	174	175	173	182	10	0.53	0.65	0.60
Ending BW, kg	244	253	272	284	15	0.07	<0.01	0.67
ADG, kg[4]	0.50	0.57	0.74	0.86	0.06	0.07	<0.01	0.67
DMI, kg[5]	4.3	6.1	5.4	5.8	0.7	0.07	0.51	0.27
G:F	0.1163	0.0934	0.1370	0.1483	0.01	0.78	<0.01	0.30

[1]Rate of gain – LOW targeted a 0.45 kg ADG and HIGH targeted a 0.90 kg ADG during the winter backgrounding period
[2]Compudose [25.7 mg estradiol (Elanco animal Health; 2500 Innovation Way, Greenfield, IN 46140)]
[3]Days on feed
[4]Average daily gain
[5]Dry matter intake measured using GrowSafe feed bunk systems (Vytelle, llc.; Calgary, AB Canada)
[6]G:F calculated as ADG/DMI

Table 4.5 Summer grazing performance of long yearlings winter backgrounded in a drylot system at 2 rates of gain with or without an implant

ROG[1]	LOW		HIGH			*P*-value		
Winter Implant[2]	NO IMP	IMP	NO IMP	IMP	SEM	IMP	ROG	IMP x ROG
DOF[3]	126	126	126	126				
Initial BW, kg	244	253	272	284	6.8	0.07	<0.01	0.67
Ending BW, kg	358[b]	352[b]	362[b]	378[a]	6.4	0.33	<0.01	0.04
ADG, kg[4]	0.88[a]	0.78[b]	0.70[b]	0.73[b]	0.04	0.22	<0.01	0.05
Compensation, %[5]	60	16	-	-				

[a-b]Means in a row without a common superscript differ ($P < 0.10$)

[1]Rate of gain – LOW targeted a 0.45 kg ADG and HIGH targeted a 0.90 kg ADG during the winter backgrounding period

[2]25.7 mg estradiol [Compudose (Elanco animal Health; 2500 Innovation Way, Greenfield, IN 46140)] was administered during winter backgrounding phase; all cattle received either 200 mg testosterone propionate USP, 20 mg estradiol benzoate, and 29 mg tylosin tartrate [Component E-H (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] or 200 mg progesterone USP and 20 mg estradiol benzoate and 29 mg tylosin tartrate [Component E-S (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] during summer backgrounding

[3]Days on feed

[4]Average daily gain

[5]Compensation calculation: (Difference of Initial BW between IMP or NO IMP treatments- Difference in ending BW)/difference in initial BW of IMP or NO IMP treatment

Table 4.6 Finishing performance of long yearlings winter backgrounded in a drylot system at 2 rates of gain with or without an implant and summer grazed on sandhills meadow

ROG[1]	LOW		HIGH			*P*-value		
Winter Implant[2]	NO IMP	IMP	NO IMP	IMP	SEM	IMP	ROG	IMP x ROG
DOF[3]	139	139	139	139				
Initial BW, kg	358[b]	352[b]	362[b]	378[a]	3	0.33	<0.01	0.04
Ending BW, kg[4]	607[ab]	595[b]	594[b]	618[a]	12	0.54	0.61	0.08
HCW, kg[5]	382[ab]	375[b]	375[b]	389[a]	8	0.54	0.60	0.08
ADG, kg[6]	1.79	1.75	1.66	1.73	0.07	0.93	0.25	0.43
DMI, kg[7]	12.2	12.7	12.2	12.7	0.4	0.06	0.95	0.97
G:F[8]	0.1471	0.1376	0.1352	0.1360	0.0048	0.17	0.09	0.31
REA, cm^2 [9]	98.3	96.3	97.2	98.5	2.3	0.83	0.78	0.38
Marbling[10]	479	507	496	498	24	0.44	0.85	0.51
Backfat, cm	1.16	1.23	1.23	1.26	0.10	0.55	0.55	0.82

[a-b]Means in a row without a common superscript differ ($P < 0.10$)
[1]Rate of gain – LOW targeted a 0.45 kg ADG and HIGH targeted a 0.90 kg ADG during the winter backgrounding period
[2]25.7 mg estradiol [Compudose (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] was administered during winter backgrounding phase; all cattle received either 200 mg testosterone propionate USP, 20 mg estradiol benzoate, and 29 mg tylosin tartrate [Component E-H (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] or 200 mg progesterone USP and 20 mg estradiol benzoate and 29 mg tylosin tartrate [Component E-S (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] during summer backgrounding, and 200 mg TBA, 20 mg estradiol USP, and 29 mg tylosin tartrate [Component TE-200 (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] during the finishing phase
[3]Days on feed
[4]Final BW calculated as HCW/a common dressing percent (63%)
[5]Hot carcass weight measured following harvest and a 48-hour chill
[6]Average daily gain
[7]Dry matter intake measured using GrowSafe feed bunks (Vytelle, llc.; Calgary, AB Canada)
[8]Feed efficiency calculated as ADG/DMI
[9] Ribeye area measured as square centimeters
[10]Marbling score 300 = slight, 400 = small, 500 modest, etc.

Table 4.7 Net gain of steer and heifer calves winter backgrounded in a drylot system at 2 rates of gain with or without an implant, summer grazed on sandhills sub irrigated meadow, and finished on a common diet

	LOW				HIGH				*P*-value		
	NO IMP		IMP[1]		NO IMP		IMP	SEM	IMP	ROG	IMP* ROG
Winter Gain, kg[2]	70		78		99		102	7	0.07	<0.01	0.67
IMP diff[3]		8→				3→					
ROG diff[4]				26→							
Summer Gain, kg[5]	114^{a}		100^{b}		90^{b}		94^{b}	5	0.23	<0.01	0.05
IMP diff		←14				4→					
ROG diff				←15							
Finishing Gain, kg[6]	249		243		232		240	10	0.93	0.24	0.42
IMP diff		←6				8→					
ROG diff				←10							
Background Gain, kg[7]	172^{b}		166^{b}		176^{b}		192^{a}	6	0.33	<0.01	0.04
IMP diff		←6				16→					
ROG diff				15→							
Total Gain, kg	421^{ab}		409^{b}		408^{b}		432^{a}	12	0.54	0.61	0.08
IMP diff		←12				24→					
ROG diff				5→							

[ab]Means in a row without a common superscript differ ($P < 0.10$)
[1] 25.7 mg estradiol [Compudose (Elanco animal Health; 2500 Innovation Way, Greenfield, IN 46140)] administered during winter backgrounding phase
[2] Gain from calves backgrounded for 112 days in a drylot system being fed ad libitum two diets to achieve 0.45 or 0.90 kg ADG
[3] Difference between implant treatments
[4] Difference between calves winter backgrounded at two rates of gain (LOW, 0.45 kg/d and HIGH, 0.90 kg/d)
[5] Gain of yearlings during the summer backgrounding phase grazing sandhills sub irrigated meadow for 126 days after receiving either 200 mg testosterone propionate USP, 20 mg estradiol benzoate, and 29 mg tylosin tartrate [Component E-H (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)] or 200 mg progesterone USP and 20 mg estradiol benzoate and 29 mg tylosin tartrate [Component E-S (Elanco Animal Health; 2500 Innovation Way, Greenfield, IN 46140)]
[6] Gain of cattle fed a common diet during the 139 day finishing phase
[7] Backgrounding Gain = Winter gain + Summer Gain

Table 4.8 Main effect of winter rate of gain for growing and finishing performance of calves winter backgrounded on dormant sandhills meadow at variable supplement intake

	Treatments[1,2,3]			
	0.75	1.65	SEM	*P*-value
Initial BW, kg	172	171	7.1	0.99
Winter EBW, kg[4]	232	248	6.9	<0.01
Summer EBW, kg[5]	344	355	8.71	0.08
Carc. Adj. FBW, kg[6,7]	564	577	12.4	0.13
Winter ADG, kg	0.12	0.66	0.02	<0.01
Summer ADG, kg	0.87	0.83	0.03	0.09
Finishing ADG, kg	1.59	1.60	0.05	0.63
HCW, kg[8]	356	364	8.56	0.13
DMI, kg[9]	12.2	12.5	0.33	0.24
G:F[10]	0.1302	0.1276	0.002	0.56

[1] Treatments targeted 1.0 and 1.9 kg/day supplement intake to achieve 0.45 and 0.9 kg ADG; however, actual supplement intakes were clustered around 0.75 kg and 1.65 kg daily with the average at 1.32 kg
[2] Actual supplement intake varied from the targeted intake and treatments were not different; therefore, means were estimated from a regression of actual supplement intake
[3] Calves that consumed 0 kg supplement were kept in the dataset; LOW had 4 head that consumed 0 kg supplement and HIGH had 2 head
[4] Winter backgrounding period lasted 112 days
[5] Summer backgrounding period lasted 126 days
[6] Finishing phase lasted 139 days
[7] Carcass adjusted final body weight was calculated as HCW divided by a common dressing percentage of 63%
[8] Hot carcass weight recorded after a 48-hour chill following harvest
[9] Dry matter intake during finishing phase measured using the GrowSafe feed bunks by Vytelle
[10] Feed efficiency calculated as ADG/DMI

Table 4.9 Main effect of winter implant for growing and finishing performance of calves winter backgrounded on dormant sandhills meadow with variable supplement intake

	Treatments[1]			
	No Implant	Implant[2]	SEM	*P*-value
Initial BW, kg	172	172	6.38	0.92
Winter EBW, kg[3]	234	238	6.66	0.68
Summer EBW, kg[4]	347	347	7.83	0.96
Carc. Adj. FBW, kg[5,6]	571	565	11.16	0.63
Winter ADG, kg	0.53	0.57	0.02	0.16
Summer ADG, kg	0.88	0.85	0.02	0.26
Finishing ADG, kg	1.61	1.57	0.04	0.39
HCW, kg[7]	360	356	7.03	0.63
DMI, kg[8]	12.4	12.1	0.27	0.36
G:F[9]	0.1288	0.13	0.0016	0.85

[1] Main effect of implant tested at the average supplement intake of 0.99 kg per animal daily
[2] Compudose implant (25.7 mg estradiol, Elanco Animal Health)
[3] Winter backgrounding period lasted 112 days
[4] Summer backgrounding period lasted 126 days
[5] Finishing phase lasted 139 days
[6] Carcass adjusted final body weight was calculated as HCW divided by a common dressing percentage of 63%
[7] Hot carcass weight recorded after a 48-hour chill following harvest
[8] Dry matter intake measured using the GrowSafe feed bunks by Vytelle
[9] Feed efficiency calculated as ADG/DMI

Figures

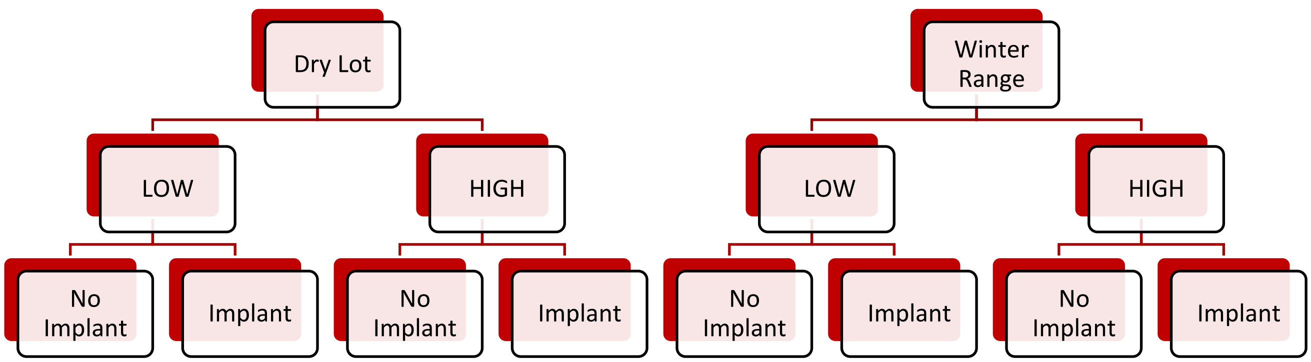

Figure 4.1 Treatment design of winter backgrounding experiments

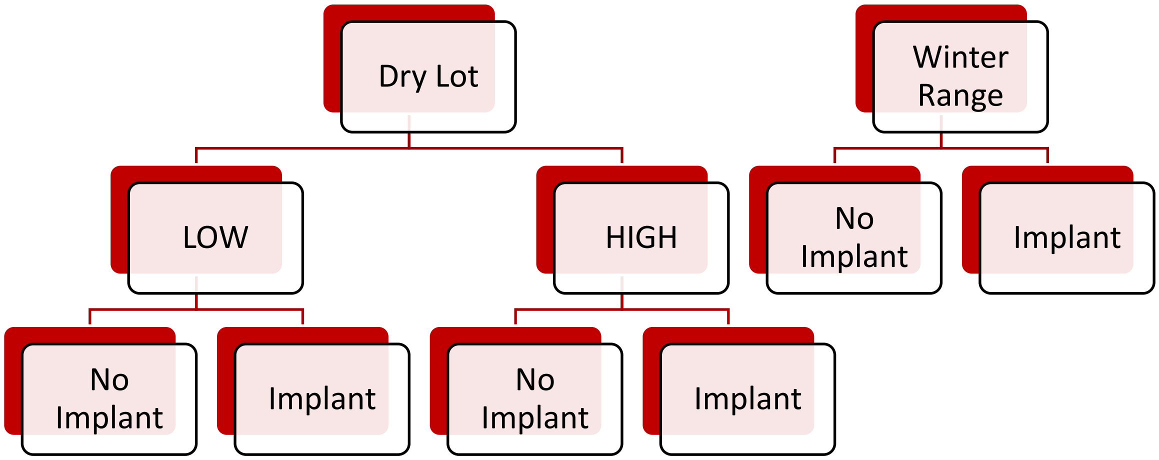

Figure 4.2 Treatment design: Experiment 1 - Drylot as a 2x2 factorial design and Experiment 2 - Winter grazing analysis of implant response as a direct regression of DDGS supplement intake

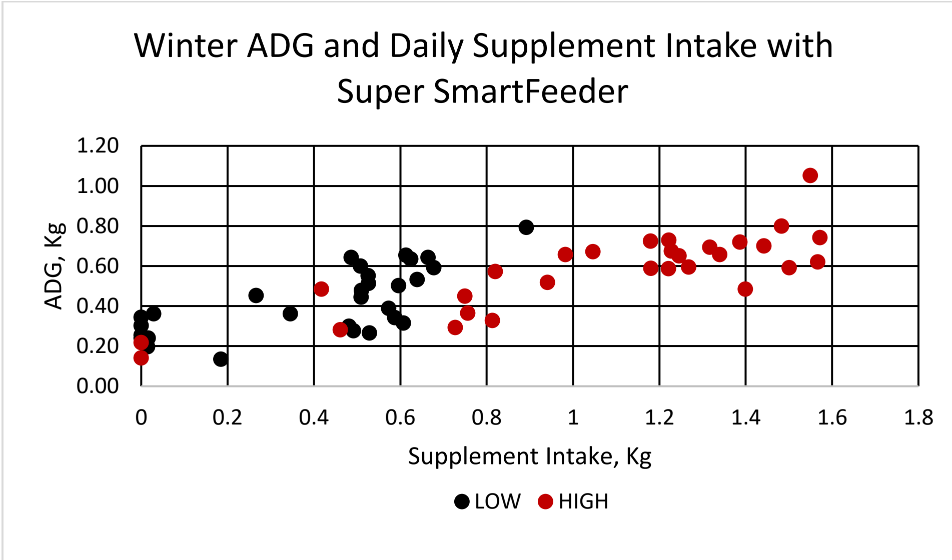

Figure 4.3 DDGS Supplement intake of calves winter backgrounded on sandhills meadow with a Super SmartFeed self-feeder for 60 days

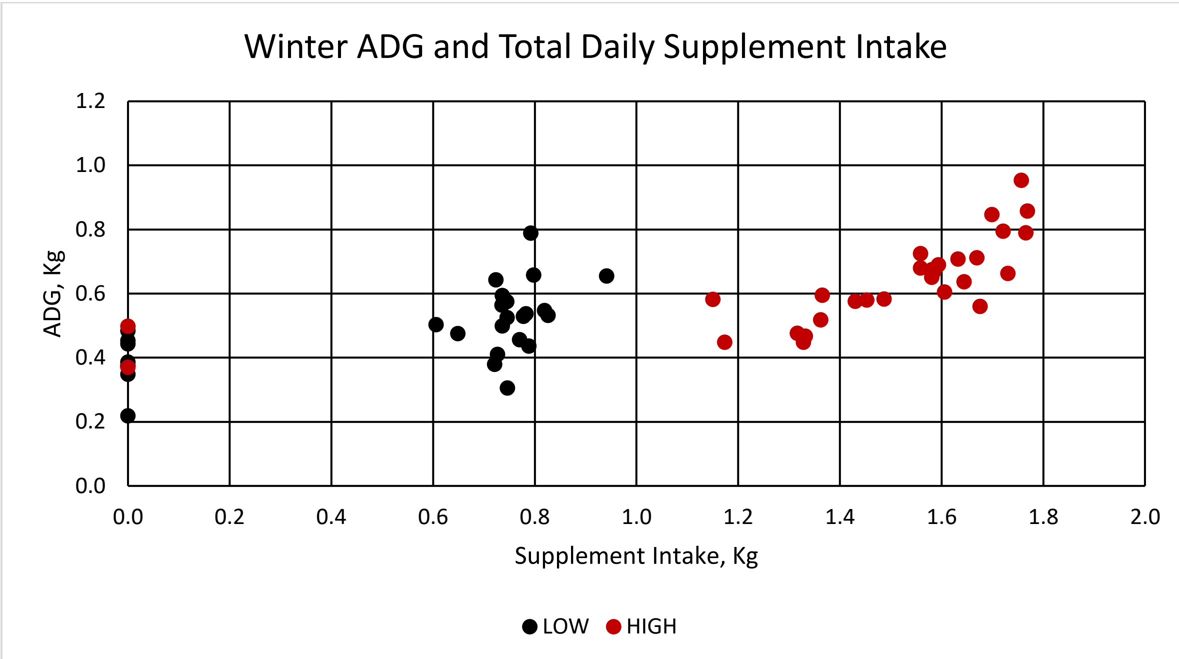

Figure 4.4 DDGS supplement of calves winter backgrounded on sandhills meadow while supplemented in bunks as 2 groups for 52 days and as individual animal for 60 days in a Super SmartFeed self-feeder at 2 supplement levels

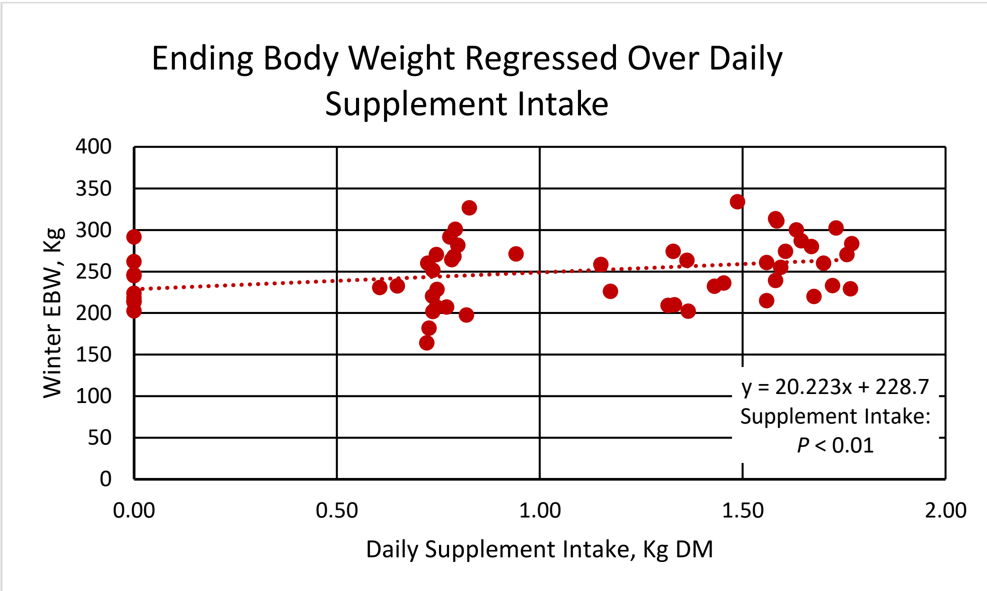

Figure 4.5 Winter ending body weight of calves winter backgrounded on winter sandhills meadows regressed over daily DDGS supplement intake

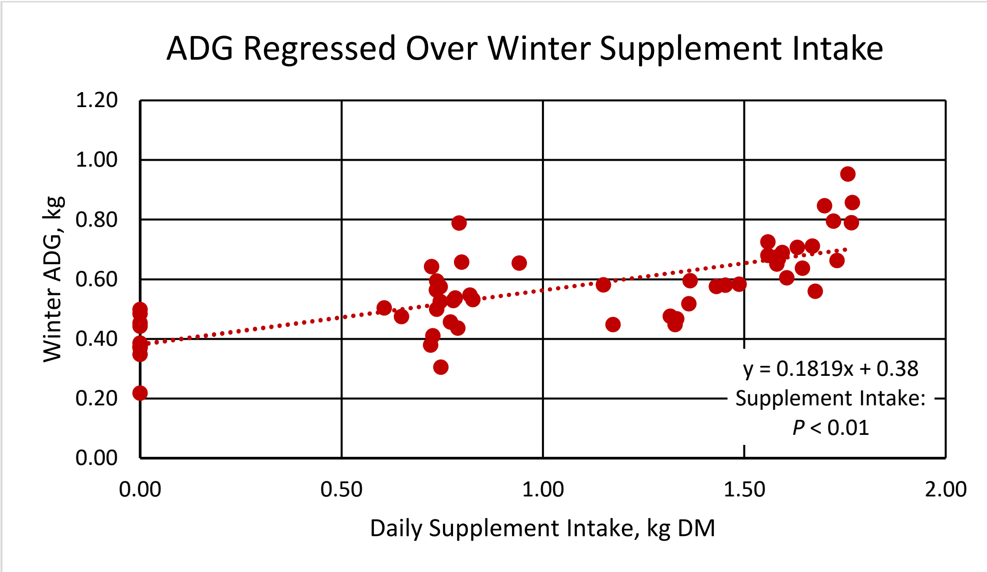

Figure 4.6 Winter average daily gain of calves winter backgrounded on winter sandhills meadows regressed over daily DDGS supplement intake